DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

49 CFR Parts 531, 533, 536, and 537

[NHTSA–2021–0053]

RIN 2127–AM34

Corporate Average Fuel Economy Standards for Model Years 2024–2026 Passenger Cars and Light Trucks

AGENCY: National Highway Traffic Safety Administration (NHTSA), Department of Transportation (DOT).

ACTION: Notice of proposed rulemaking.

SUMMARY: NHTSA, on behalf of the Department of Transportation, is proposing revised fuel economy standards for passenger cars and light trucks for model years 2024–2026. On January 20, 2021, President Biden signed an Executive order (E.O.) entitled, ''Protecting Public Health and the Environment and Restoring Science To Tackle the Climate Crisis.'' In it, the President directed that ''The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks'' (hereafter, ''the 2020 final rule'') be immediately reviewed for consistency with our Nation's abiding commitment to empower our workers and communities; promote and protect our public health and the environment; and conserve our national treasures and monuments, places that secure our national memory. President Biden further directed that the 2020 final rule be reviewed at once and that (in this case) the Secretary of Transportation consider ''suspending, revising, or rescinding'' it, via a new proposal, by July 2021. Because of the President's direction in the E.O., NHTSA reexamined the 2020 final rule under its authority to set corporate average fuel economy (CAFE) standards. In doing so, NHTSA tentatively concluded that the fuel economy standards set in 2020 should be revised so that they increase at a rate of 8 percent year over year for each model year from 2024 through 2026, for both passenger cars and light trucks. This responds to the agency's statutory mandate to improve energy conservation. This proposal also makes certain minor changes to fuel economy reporting requirements.

DATES: *Comments:* Comments are requested on or before October 26, 2021. In compliance with the Paperwork Reduction Act, NHTSA is also seeking comment on a revision to an existing information collection. For additional information, see the Paperwork Reduction Act Section under Section IX, 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 October 26, 2021. See the **SUPPLEMENTARY INFORMATION** section on ''Public Participation,'' below, for more information about written comments.

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

ADDRESSES: You may send comments, identified by Docket No. NHTSA–2021–0053, by any of the following methods:

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

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 particular information collection, select ''Currently under Review—Open for Public Comment'' or use the search function. NHTSA requests that comments sent to the OMB also be sent to the NHTSA rulemaking docket identified in the heading of this document.

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

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

FOR FURTHER INFORMATION CONTACT: Rebecca Schade, NHTSA Office of Chief Counsel, National Highway Traffic Safety Administration, 1200 New Jersey Avenue SE, Washington, DC 20590; email: *rebecca.schade@dot.gov.*

SUPPLEMENTARY INFORMATION:

Does this action apply to me?

This action 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:

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[1] ''Passenger car'' and ''light truck'' are defined in 49 CFR part 523.

Category	NAICS Codes[A]	Examples of potentially regulated entities
Industry	335111 336112	Motor Vehicle Manufacturers.
Industry	811111 811112 811198 423110	Commercial Importers of Vehicles and Vehicle Components.
Industry	335312 336312 336399 811198	Alternative Fuel Vehicle 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 person listed in **FOR FURTHER INFORMATION CONTACT.**

I. Executive Summary

NHTSA, on behalf of the Department of Transportation, is proposing to amend standards regulating corporate average fuel economy (CAFE) for passenger cars and light trucks for model years (MYs) 2024–2026. This proposal responds to NHTSA's statutory obligation to set maximum feasible CAFE standards to improve energy conservation, and to President Biden's directive in Executive Order 13990 of January 20, 2021 that ''The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks'', 2020 final rule or 2020 CAFE rule (85 FR 24174 (April 30, 2020)), be immediately reviewed for consistency with our Nation's abiding commitment to promote and protect our public health and the environment, among other things. NHTSA undertook that review immediately, and this proposal is the result of that process.

The proposed amended CAFE standards would increase in stringency from MY 2023 levels by 8 percent per year, for both passenger cars and light trucks over MYs 2024–2026. NHTSA tentatively concludes that this level is maximum feasible for these model years, as discussed in more detail in Section VI, and seeks comment on that conclusion. The proposal considers a range of regulatory alternatives, consistent with NHTSA's obligations under the National Environmental Policy Act (NEPA) and Executive Order 12866. While E.O. 13990 directed the review of CAFE standards for MYs 2021–2026, statutory lead time requirements mean that the soonest model year that can currently be amended in the CAFE program is MY 2024. The proposed standards would remain vehicle footprint-based, like the CAFE standards in effect since MY 2011. Recognizing that many readers think about CAFE standards in terms of the miles per gallon (mpg) values that the standards are projected to eventually require, NHTSA currently projects that the proposed standards would require, on an average industry fleet-wide basis, roughly 48 mpg in MY 2026. NHTSA notes both that real-world fuel economy is generally 20–30 percent lower than the estimated required CAFE level stated above, and also that the actual CAFE standards are the footprint target curves for passenger cars and light trucks, meaning that ultimate fleet-wide levels will vary depending on the mix of vehicles that industry produces for sale in those model years. Table I–1 shows the incremental differences in stringency levels for passenger cars and light trucks, by regulatory alternative, in the model years subject to regulation.

Table I-1 – Incremental Stringency Levels (mpg above Baseline) for Passenger Cars and Light Trucks, by Regulatory Alternative

Model Year	Alternative 0 (Baseline/No Action)	Alternative 1	Alternative 2	Alternative 3
Passenger cars				
2024	-	3.9	3.3	4.3
2025	-	4.9	6.8	9.2
2026	-	5.9	10.8	14.7
Light trucks				
2024	-	3.5	2.2	3.0
2025	-	4.2	4.7	6.4
2026	-	5.1	7.6	10.4
Total				
2024	-	3.7	2.6	3.5
2025	-	4.5	5.5	7.5
2026	-	5.3	8.7	11.9

This proposal is significantly different from the conclusion that NHTSA reached in the 2020 final rule, but this is because important facts have changed, and because NHTSA has reconsidered how to balance the relevant statutory considerations in light of those facts. NHTSA tentatively concludes that significantly more stringent standards are maximum feasible. Contrary to the 2020 final rule, NHTSA recognizes that the need of the United States to conserve energy must include serious consideration of the energy security risks of continuing to consume oil, which more stringent fuel economy standards can reduce. Reducing our Nation's climate impacts can also benefit our national security. Additionally, at least part of the automobile industry appears increasingly convinced that improving fuel economy and reducing greenhouse gas (GHG) emissions is a growth market for them, and that the market rewards investment in advanced technology. Nearly all auto manufacturers have announced forthcoming new higher fuel-economy and electric vehicle models, and five major manufacturers voluntarily bound themselves to stricter GHG requirements than set forth by NHTSA and the Environmental Protection Agency (EPA) in 2020 through contractual agreements with the State of California, which will result in their achieving fuel economy levels well above the standards set forth in the 2020 final rule. These companies are sophisticated, for-profit enterprises. If they are taking these steps, NHTSA can be more confident than the agency was in 2020 that the market is getting ready to make the leap to significantly higher fuel economy. The California Framework and the clear planning by industry to migrate toward more advanced fuel economy technologies are evidence of the practicability of more stringent standards. Moreover, more stringent CAFE standards will help to encourage industry to continue improving the fuel economy of all vehicles, rather than simply producing a few electric vehicles, such that all Americans can benefit from higher fuel economy and save money on fuel. NHTSA cannot consider the fuel economy of dedicated alternative fuel vehicles like battery electric vehicles when determining maximum feasible standards, but the fact that industry increasingly appears to believe that there is a market for these vehicles is broader evidence of market (and consumer) interest in fuel economy, which is relevant to NHTSA's determination of whether more stringent standards would be economically practicable. For all of these reasons, NHTSA tentatively concludes that standards that increase at 8 percent per year are maximum feasible.

This proposal is also different from the 2020 final rule in that it is issued by NHTSA alone, and EPA has issued a separate proposal. The primary reason for this is the difference in statutory authority—EPA does not have the same lead time requirements as NHTSA and is thus able to amend MY 2023 in addition to MYs 2024–2026. An important consequence of this is that EPA's proposed rate of stringency increase, after taking a big leap in MY 2023, looks slower than NHTSA's over the same time period. NHTSA emphasizes, however, that the proposed standards are what NHTSA believes best fulfills our statutory directive of energy conservation, and in the context of the EPA standards, the analysis we have done is tackling the core question of whether compliance with both standards should be achievable with the same vehicle fleet, after manufacturers fully understand the requirements from both proposals. The differences in what the two agencies' standards require become smaller each year, until alignment is achieved. While NHTSA recognizes that the last several CAFE standard rulemakings have been issued jointly with EPA, and that issuing separate proposals represents a change in approach, the agencies worked together to avoid inconsistencies and to create proposals that would continue to allow manufacturers to build a single fleet of vehicles to meet both agencies' proposed standards. Additionally, and importantly, NHTSA has also considered and accounted for California's Zero Emission Vehicle (ZEV) program (and its adoption by a number of other states) in developing the baseline for this proposal, and has accounted for the aforementioned ''Framework Agreements'' between California and BMW, Ford, Honda, Volkswagen of America (VWA), and Volvo, which are national-level GHG standards to which these companies committed for several model years.

A number of other improvements and updates have been made to the analysis since the 2020 final rule. Table I–2 summarizes these, and they are discussed in much more detail below and in the documents accompanying this preamble.

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Table I-2 – Key Analytical Updates from 2020 Final Rule

Key Updates
In all regulatory alternatives, account for the Zero Emission Vehicle (ZEV) mandates applicable in California and the States that have adopted them.
In all regulatory alternatives, account for some vehicle manufacturers' (BMW, Ford, Honda, VWA, and Volvo) voluntary commitments to the State of California to continued annual nation-wide reductions of vehicle greenhouse gas emissions through model year (MY) 2026, with greater rates of electrification than would have been required under the 2020 final rule.
In all regulatory alternatives, account for manufacturers' responses to both CAFE (alternatives) and baseline carbon dioxide standards jointly (rather than only separately).
Procedures to ensure that modeled technology application and production volumes are the same across all regulatory alternatives in the earliest model years.
Procedures to focus application of the Energy Policy and Conservation Act's (EPCA) "standard setting constraints" (i.e., regarding the consideration of compliance credits and additional dedicated alternative fueled vehicles) more precisely to only those model years for which NHTSA is proposing or finalizing new standards.
More accurate accounting for compliance treatment of flex-fuel vehicles (FFVs) and plug-in hybrid electric vehicles (PHEVs).
Include CAFE civil penalties in the "effective cost" metric used when simulating manufacturers' potential application of fuel-saving technologies.
COVID adjustment to vehicle miles traveled (VMT) model inputs (per Federal Highway Administration estimate of 2020 national VMT).
Embed Federal Highway Administration's VMT model in CAFE Model (dynamic model).
Criteria pollutant health effects reported separately for refining and electricity generation.
New procedures to estimate the impacts and corresponding monetized damages of highway vehicle crashes that do not result in fatalities, now based on historical data and future trend models that reflect the impacts of advanced crash avoidance technologies.
Social cost of carbon and damage costs for methane and nitrous oxide (interim guidance February 19, 2021).
Fuel and electricity prices using Energy Information Administration's Annual Energy Outlook 2021.
Analysis fleet updated to MY 2020.
Updated large scale simulation using Argonne National Laboratory's Autonomie model.
Inclusion of 400- and 500-mile battery electric vehicles (BEVs).
Updated battery and battery management unit size and costs using BatPaC version 4.0 (October 2020).
Updated hybrid electric vehicles, PHEV, and BEV electric machine and battery sizing.
Inclusion of high compression ratio (HCR) engines with cylinder deactivation.
Expanded turbo-downsizing to include reducing low-powered 4-cylinder naturally aspirated engines to 3-cylinder turbocharged engines.
Updated 10-speed automatic transmission efficiency characteristics based on benchmarking data from Southwest Research Institute.
Updated cold start offset assumptions using MY 2020 compliance data.
Updated mass regression analysis values for engines and electric motors.
More accurate accounting for off-cycle incremental costs relative to MY 2020 baseline fleet.
Updated fuel cell vehicle technology inputs.

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NHTSA estimates that this proposal could reduce average undiscounted fuel outlays over the lifetimes of MY 2029 vehicles by about $1,280, while increasing the average cost of those vehicles by about $960 over the baseline described above. With the social cost of carbon (SCC) discounted at 2.5 percent and other benefits and costs discounted at 3 percent, for the three affected model years NHTSA finds $65.8 billion in benefits attributable to the proposed standards and $37.4 billion in proposed costs so that present net benefits could be $28.4 billion.[2] Applied to the entire fleet for MYs 1981–2029, NHTSA estimates $120 billion in costs and $121

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[2] As discussed in Section III.G.2.b), NHTSA has discounted the SCC at 2.5% when other benefits and costs are discounted at 3% but seeks comment on this approach.

billion in benefits attributable to the proposed standards, such that the present value of aggregate net benefits to society could be $1 billion. Like any analysis of this magnitude attempting to forecast future effects of current policies, significant uncertainty exists about many key inputs. Changes in the price of fuel or in the social cost of carbon could dramatically change benefits, for example, and readers should expect that the eventual final rule will reflect any updates made to those (and many other) values that occur between now and then. It is also worth stressing that NHTSA's statutory authority requires that its standards be maximum feasible, taking into account four statutory factors. While NHTSA's estimates of costs and benefits are important considerations, it is the maximum feasible analysis that controls the setting of CAFE standards.

Like many other types of regulations, CAFE standards apply only to new vehicles. The costs attributable to new CAFE standards are thus ''front-loaded,'' because they result primarily from the application of fuel-saving technology to new vehicles. On the other hand, the impact of new CAFE standards on fuel consumption and greenhouse gases—and the associated benefits to society—occur over an extended time, as drivers buy, use, and eventually scrap these new vehicles. By accounting for many model years and extending well into the future (2050), our analysis accounts for these differing patterns in impacts, benefits, and costs. Our analysis also accounts for the potential that, by changing new vehicle prices and fuel economy levels, CAFE standards could indirectly impact the operation of vehicles produced before or after the model years (2024–2026) for which we are proposing new CAFE standards. This means that some of the proposal's impacts and corresponding benefits and costs are actually attributable to indirect impacts on vehicles produced before and after model years 2024–2026.

The bulk of our analysis considers a ''model year'' (MY) perspective that considers the lifetime impacts attributable to all vehicles produced prior to model year 2030, accounting for the operation of these vehicles over their entire useful lives (with some model year 2029 vehicles estimated to be in service as late as 2068). This approach emphasizes the role of model years 2024–2026, while accounting for the potential that it may take manufacturers a few additional years to produce fleets fully responsive to the proposed MY 2026 standards, and for the potential that the proposal could induce some changes in the operation of vehicles produced prior to MY 2024.

Our analysis also considers a ''calendar year'' (CY) perspective that includes the annual impacts attributable to all vehicles estimated to be in service in each calendar year for which our analysis includes a representation of the entire registered light-duty fleet. For this NPRM, this calendar year perspective covers each of calendar years 2021–2050, with differential impacts accruing as early as model year 2023. Compared to the ''model year'' perspective, this calendar year perspective emphasizes model years of vehicles produced in the longer term, beyond those model years for which standards are currently being proposed. Table I–3 summarizes estimates of selected physical impacts viewed from each of these two perspectives, as well as corresponding estimates of the present values of cumulative benefits, costs, and net benefits.

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Table I-3 – Selected Cumulative Impacts - Model and Calendar Year Perspectives

	Alt. 1	Alt. 2	Alt. 3
Avoided Gasoline Consumption (b. gal)			
MYs 1981-2029	30	50	75
CYs 2023-2050	105	205	290
Additional Electricity Consumption (TWh)			
MYs 1981-2029	90	275	395
CYs 2023-2050	395	1,150	1,690
CO$_2$ Emissions (mmt)			
MYs 1981-2029	295	465	665
CYs 2023-2050	1,055	1,845	2,615
Benefits ($b, 3% Discount Rate)			
MYs 1981-2029	83	121	173
CYs 2023-2050	267	434	607
Costs ($b, 3% Discount Rate)			
MYs 1981-2029	66	121	176
CYs 2023-2050	186	334	475
Net Benefits ($b, 3% Discount Rate)			
MYs 1981-2029	16	0	-3
CYs 2023-2050	81	100	132
Benefits ($b, 7% Discount Rate)			
MYs 1981-2029	52	76	108
CYs 2023-2050	145	236	332
Costs ($b, 7% Discount Rate)			
MYs 1981-2029	49	91	133
CYs 2023-2050	109	199	286
Net Benefits ($b, 7% Discount Rate)			
MYs 1981-2029	2	-15	-25
CYs 2023-2050	36	37	46

Finally, for purposes of comparing the benefits and costs of new CAFE standards to the benefits and costs of other Federal regulations, policies, and programs, we have computed "annualized" benefits and costs. These are the annual averages of the cumulative benefits and costs over the covered model or calendar years, after expressing these in present value terms.

Table I-4 – Estimated Costs, Benefits, and Net Benefits Across MYs 1981-2029 (billions of dollars), Total Fleet for Alternative 1

	Totals		Annualized	
	3% Discount Rate	**7% Discount Rate**	**3% Discount Rate**	**7% Discount Rate**
Costs	66.5	49.3	2.61	3.58
Benefits	82.6	51.6	3.24	3.75
Net Benefits	16.1	2.3	0.63	0.17

Table I-5 – Estimated Costs, Benefits, and Net Benefits Across MYs 1981-2029 (billions of dollars), Total Fleet for Alternative 2

	Totals		Annualized	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
Costs	121.1	90.7	4.75	6.59
Benefits	121.4	75.6	4.76	5.49
Net Benefits	0.3	-15.1	0.01	-1.10

Table I-6 – Estimated Costs, Benefits, and Net Benefits Across MYs 1981-2029 (billions of dollars), Total Fleet for Alternative 3

	Totals		Annualized	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
Costs	176.3	132.8	6.91	9.65
Benefits	172.9	107.6	6.78	7.82
Net Benefits	-3.4	-25.2	-0.13	-1.83

Table I-7 – Estimated Costs, Benefits, and Net Benefits Across Calendar Years 2021-2050 (billions of dollars), Total Fleet for Alternative 1

	Totals		Annualized	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
Costs	185.7	108.9	9.47	8.77
Benefits	266.6	145.2	13.60	11.70
Net Benefits	81.0	36.4	4.13	2.93

Table I-8 – Estimated Costs, Benefits, and Net Benefits Across Calendar Years 2021-2050 (billions of dollars), Total Fleet for Alternative 2

	Totals		Annualized	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
Costs	333.6	198.9	17.02	16.03
Benefits	433.6	236.0	22.12	19.02
Net Benefits	100.0	37.1	5.10	2.99

Table I-9 – Estimated Costs, Benefits, and Net Benefits Across Calendar Years 2021-2050 (billions of dollars), Total Fleet for Alternative 3

	Totals		Annualized	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
Costs	474.8	285.8	24.22	23.03
Benefits	606.5	331.7	30.94	26.73
Net Benefits	131.7	45.9	6.72	3.70

As discussed in detail below, the monetized estimated costs and benefits of this proposal are relevant and important to the agency's tentative conclusion, but they are not the whole of the conclusion.

Additionally, although NHTSA is prohibited from considering the availability of certain flexibilities in making our determination about the levels of CAFE standards that would be maximum feasible, manufacturers have a variety of flexibilities available to them to reduce their compliance burden. Table I–10 through Table I–13 below summarizes available compliance flexibilities. NHTSA seeks comment on whether to retain non-statutory flexibilities for the final rule.

Table I-10 – Statutory Flexibilities for Over-compliance with Standards

Regulatory Item	NHTSA	
	Authority	**Current Program**
Credit Earning	49 U.S.C. 32903(a)	Denominated in tenths of a mpg
Credit "Carry-forward"	49 U.S.C. 32903(a)(2)	5 MYs into the future
Credit "Carryback" (AKA "deficit carry-forward")*	49 U.S.C. 32903(a)(1)	3 MYs into the past
Credit Transfer	49 U.S.C. 32903(g)	Up to 2 mpg per fleet; transferred credits may not be used to meet minimum domestic passenger car standard (MDPCS)
Credit Trade*	49 U.S.C. 32903(f)	Unlimited quantity; traded credits may not be used to meet MDPCS

*NHTSA did not expressly model credit carryback, and credit trades were only modeled for credits that existed at the beginning of the modeling simulation. All other credits in this table were modeled.

Table I-11 – Current and Proposed Flexibilities that Address Gaps in Compliance Test Procedures

Regulatory Item	NHTSA	
	Authority	**Current and *Proposed* Program**
Air conditioning efficiency	49 U.S.C. 32904	Allows manufacturers to earn "fuel consumption improvement values" (FCIVs) equivalent to EPA credits starting in MY 2017
Off-cycle	49 U.S.C. 32904	Allows manufacturers to earn "fuel consumption improvement values" (FCIVs) equivalent to EPA credits starting in MY 2017 *For MY 2020 and beyond, NHTSA proposes to implement CAFE provisions equivalent to the EPA proposed changes*

Table I-12 – Incentives that Encourage Application of Technologies

Regulatory Item	NHTSA	
	Authority	***Proposed* Program**
Full-size pickup trucks with HEV or overperforming target*	49 U.S.C. 32904	Allows manufacturers to earn FCIVs equivalent to EPA credits for MYs 2017-2021 *NHTSA proposes to reinstate incentives for strong hybrid OR overperforming target by 20% for MYs 2022-2025*

*These credits were not modeled for the NPRM analysis.

Table I-13 – Incentives that Encourage Alternative Fuel Vehicles

Regulatory Item	NHTSA	
	Authority	**Current Program**
Dedicated alternative fuel vehicle	49 U.S.C. 32905(a) and (c)	Fuel economy calculated assuming gallon of liquid or gallon equivalent gaseous alt fuel = 0.15 gallons of gasoline; for EVs petroleum equivalency factor
Dual-fueled vehicles	49 U.S.C. 32905(b), (d), and (e); 32906(a)	Fuel economy calculated using 50% operation on alt fuel and 50% on gasoline through MY 2019. Starting with MY 2020, NHTSA uses the Society of Automotive Engineers (SAE) defined "Utility Factor" methodology to account for actual potential use, and "F-factor" for FFV; NHTSA will continue to incorporate the 0.15 incentive factor

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NHTSA recognizes that the lead time for this proposal is shorter than past rulemakings have provided, and that the economy and the country are in the process of recovering from a global pandemic and the resulting economic distress. At the same time, NHTSA also recognizes that at least parts of the industry are nonetheless stepping up their product offerings and releasing more and more high fuel-economy vehicle models, and many companies did not deviate significantly from product plans established in response to the standards set forth in the 2012 final rule (77 FR 62624, Oct. 15, 2012) and confirmed by EPA in its January 2017 Final Determination. With these considerations in mind, NHTSA is proposing to amend the CAFE standards for MYs 2024–2026. NHTSA, like any other Federal agency, is afforded an opportunity to reconsider prior views and, when warranted, to adopt new positions. Indeed, as a matter of good governance, agencies *should* revisit their positions when appropriate, especially to ensure that their actions and regulations reflect legally sound interpretations of the agency's authority and remain consistent with the agency's views and practices. As a matter of law, ''an Agency is entitled to change its interpretation of a statute.'' [3] Nonetheless, ''[w]hen an Agency adopts a materially changed interpretation of a statute, it must in addition provide a 'reasoned analysis' supporting its decision to revise its interpretation.'' [4] The analysis presented in this preamble and in the accompanying Technical Support Document (TSD), Preliminary Regulatory Impact Analysis (PRIA), Supplemental Environmental Impact Statement (SEIS), CAFE Model documentation, and extensive rulemaking docket fully supports the proposed decision and revised balancing of the statutory factors for MYs 2024–2026 standards. NHTSA seeks comment on the entirety of the rulemaking record.

II. Introduction

In this notice of proposed rulemaking (NPRM), NHTSA is proposing to revise CAFE standards for model years (MYs) 2024–2026. On January 20, 2021, the President signed Executive Order (E.O.) 13990, ''Protecting Public Health and the Environment and Restoring Science To Tackle the Climate Crisis.'' [5] In it, the President directed that ''The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks'' (hereafter, ''the 2020 final rule''), 85 FR 24174 (April 30, 2020), must be immediately reviewed for consistency with our Nation's abiding commitment to empower our workers and communities; promote and protect our public health and the environment; and conserve our national treasures and monuments, places that secure our national memory. E.O. 13990 states expressly that the Administration prioritizes listening to the science, improving public health and protecting the environment, reducing greenhouse gas emissions, and improving environmental justice while creating well-paying union jobs. The E.O. thus directs that the 2020 final rule be reviewed at once and that (in this case) the Secretary of Transportation consider ''suspending, revising, or rescinding'' it, via an NPRM, by July 2021.[6]

Section 32902(g)(1) of Title 49, United States Code allows the Secretary (by delegation to NHTSA) to prescribe regulations amending an average fuel economy standard prescribed under 49 U.S.C. 32902(a), like those prescribed in the 2020 final rule, if the amended standard meets the requirements of 32902(a). The Secretary's authority to set fuel economy standards is delegated to NHTSA at 49 CFR 1.95(a); therefore, in this NPRM, NHTSA proposes revised fuel economy standards for MYs 2024–2026. Section 32902(g)(2) states that when the amendment makes an average fuel economy standard more stringent, it must be prescribed at least 18 months before the beginning of the model year to which the amendment applies. NHTSA generally calculates the 18-month lead time requirement as April of the calendar year prior to the start of the model year. Thus, 18 months before MY 2023 would be April 2021, because MY 2023 begins in September 2022. Because of this lead time requirement, NHTSA is not proposing to amend the CAFE standards for MYs 2021–2023, even though the 2020 final rule also covered those model years. For purposes of the CAFE program, the 2020 final rule's standards for MYs 2021–2023 will remain in effect.

For the MYs for which there *is* statutory lead time to amend the standards, however, NHTSA is proposing amendments to the currently applicable fuel economy standards. Although only one year has passed since the 2020 final rule, the agency believes it is reasonable and appropriate to revisit the CAFE standards for MYs 2024–2026. In particular, the agency has further considered the serious adverse effects on energy conservation that the standards finalized in 2020 would cause

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[3] Phoenix Hydro Corp. v. FERC, 775 F.2d 1187, 1191 (D.C. Cir. 1985).

[4] Alabama Educ. Ass'n v. Chao, 455 F.3d 386, 392 (D.C. Cir. 2006) (quoting Motor Vehicle Mfrs. Ass'n of U.S., Inc. v. State Farm Mut. Auto. Ins. Co., 463 U.S. 29, 57 (1983)); *see also* Encino Motorcars, LLC v. Navarro, 136 S.Ct. 2117, 2125 (2016) (''Agencies are free to change their existing policies as long as they provide a reasoned explanation for the change.'') (citations omitted).

[5] 86 FR 7037 (Jan. 25, 2021).

[6] *Id.,* Sec. 2(a)(ii).

as compared to the proposed standards. The need of the U.S. to conserve energy is greater than understood in the 2020 final rule. In addition, standards that are more stringent than those that were finalized in 2020 appear economically practicable. Nearly all auto manufacturers have announced forthcoming new advanced technology vehicle models with higher fuel economy, making strong public commitments that mirror those of the Administration. Five major manufacturers voluntarily bound themselves to stricter national-level GHG requirements as part of the California Framework agreement. Meanwhile, certain facts on the ground remain similar to what was before NHTSA in the prior analysis—gas prices still remain relatively low in the U.S., for example, and while light-duty vehicle sales fell sharply in MY 2020, the vehicles that *did* sell tended to be, on average, larger, heavier, and more powerful, all factors that increase fuel consumption. However, the renewed focus on addressing energy conservation and the industry's apparent ability to meet more stringent standards show that a rebalancing of the EPCA factors, and the proposal of more stringent standards, is appropriate for model years 2024–2026.

The following sections introduce the proposal in more detail.

A. What is NHTSA proposing?

NHTSA is proposing to set CAFE standards for passenger cars and light trucks manufactured for sale in the United States in MYs 2024–2026. Passenger cars are generally sedans, station wagons, and two-wheel drive crossovers and sport utility vehicles (CUVs and SUVs), while light trucks are generally four-wheel drive vehicles, larger/heavier two-wheel drive sport utility vehicles, pickups, minivans, and passenger/cargo vans.[7] The proposed standards would increase at 8 percent per year for both cars and trucks, and are represented by regulatory Alternative 2 in the agency's analysis. The proposed standards would be defined by a mathematical equation that represents a constrained linear function relating vehicle footprint to fuel economy targets for both cars and trucks; vehicle footprint is roughly measured as the rectangle that is made by the four points where the vehicle's tires touch the ground. Generally, passenger cars will have more stringent targets than light trucks regardless of footprint, and smaller vehicles will have more stringent targets than larger vehicles. 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.

The proposed target curves[8] for passenger cars and light trucks are as follows; curves for MYs 2020–2023 are included in Figure II–1 and Figure II–2 for context.

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[7] ''Passenger car'' and ''light truck'' are defined at 49 CFR part 523.

[8] NHTSA underscores that the equations and coefficients defining the curves are what the agency is proposing, and not the mpg numbers that the agency currently estimates could result from manufacturers complying with the curves. Because the estimated mpg numbers are an *effect* of the proposed curves, they are presented in the following section.

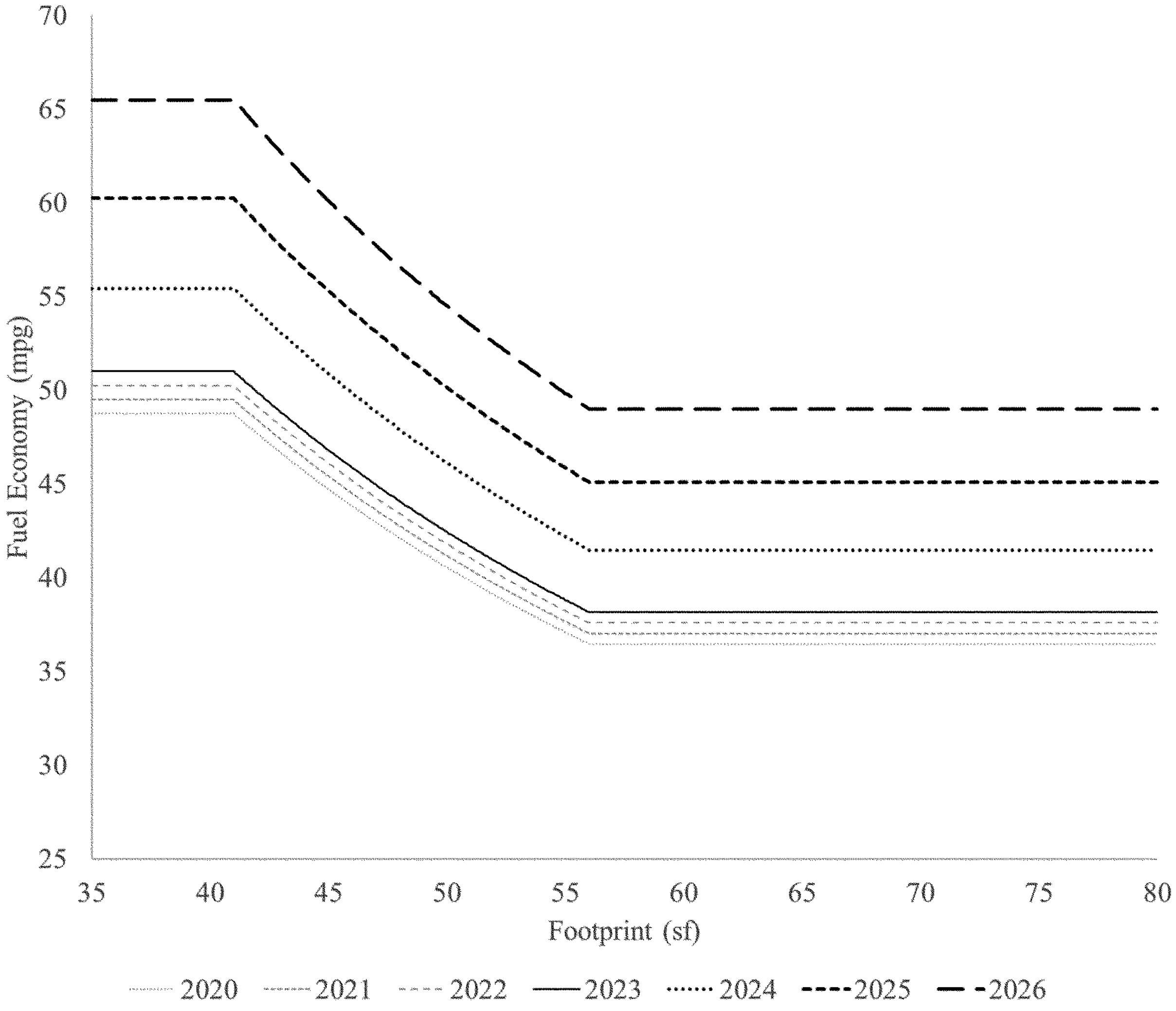

Figure II-1 – Passenger Car Fuel Economy, Proposed Target Curves

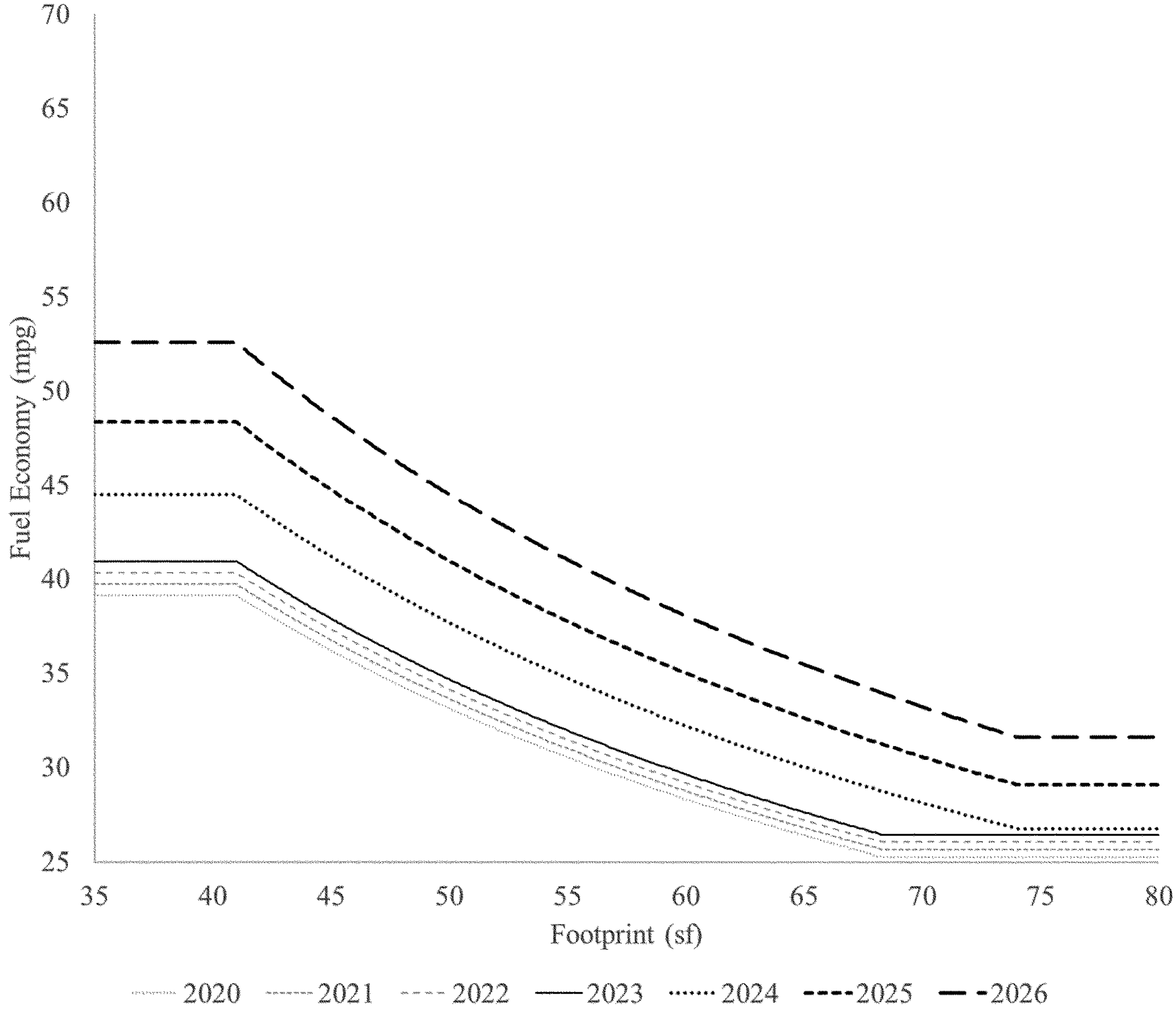

Figure II-2 – Light Truck Fuel Economy, Proposed Target Curves

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NHTSA is also proposing to amend the minimum domestic passenger car CAFE standards for MYs 2024–2026. The provision at 49 U.S.C. 32902(b)(4) requires NHTSA to project the minimum standard when it promulgates passenger car standards for a model year, so it is appropriate to revisit the minimum standards at this time. NHTSA is proposing to retain the 1.9 percent offset used in the 2020 final rule, such that the minimum domestic passenger car standard would be as shown in Table II–1.

Table II-1 – Proposed Minimum Domestic Passenger Car Standards

2024	2025	2026
44.4 mpg	48.2 mpg	52.4 mpg

The next section describes some of the effects that NHTSA estimates would follow from this proposal, including how the curves shown above translate to estimated average mile per gallon requirements for the industry.

B. What does NHTSA estimate the effects of proposing this would be?

As for past CAFE rulemakings, NHTSA has used the CAFE Model to estimate the effects of proposed CAFE standards, and of other regulatory alternatives under consideration. Some inputs to the CAFE Model are derived from other models, such as Argonne National Laboratory's ''Autonomie'' vehicle simulation tool and Argonne's Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) fuel-cycle emissions analysis model, the U.S. Energy Information Administration's (EIA's) National Energy Modeling System (NEMS), and EPA's Motor Vehicle Emission Simulator (MOVES) vehicle emissions model. Especially given the scope of the

NHTSA's analysis (through model years 2050, with driving of model year 2029 vehicles accounted for through calendar year 2068), these inputs involve a multitude of uncertainties. For example, a set of inputs with significant uncertainty could include future population and economic growth, future gasoline and electricity prices, future petroleum market characteristics (*e.g.,* imports and exports), future battery costs, manufacturers' future responses to standards and fuel prices, buyers' future responses to changes in vehicle prices and fuel economy levels, and future emission rates for ''upstream'' processes (*e.g.,* refining, finished fuel transportation, electricity generation). Considering that all of this is uncertain from a 2021 vantage point, NHTSA underscores that all results of this analysis are, in turn, uncertain, and simply represent the agency's best estimates based on the information currently before us.

NHTSA estimates that this proposal would increase the eventual[9] average of manufacturers' CAFE requirements to about 48 mpg by 2026 rather than, under the No-Action Alternative (*i.e.,* the baseline standards issued in 2020), about 40 mpg. For passenger cars, the average in 2026 is estimated to reach about 58 mpg, and for light trucks, about 42. This compares with 47 mpg and 34 mpg for cars and trucks, respectively, under the No-Action Alternative.

Table II-2 – Estimated Average of CAFE Levels (mpg) Required Under Proposal

Fleet	2024	2025	2026	2027	2028	2029
Passenger Cars	49	53	58	58	58	58
Light Trucks	35	38	42	42	42	42
Overall Fleet	41	44	48	48	48	48

Because manufacturers do not comply exactly with each standard in each model year, but rather focus their compliance efforts when and where it is most cost-effective to do so, ''estimated achieved'' fuel economy levels differ somewhat from ''estimated required'' levels for each fleet, for each year. NHTSA estimates that the industry-wide average fuel economy achieved in MY 2029 could increase from about 44 mpg under the No-Action Alternative to about 49 mpg under the proposal.

Table II-3 – Estimated Average of CAFE Levels (mpg) Achieved Under Proposal

Fleet	2024	2025	2026	2027	2028	2029
Passenger Cars	54	57	60	61	61	61
Light Trucks	37	38	40	41	41	41
Overall Fleet	43	45	48	48	49	49

As discussed above, NHTSA's analysis—unlike its previous CAFE analyses—estimates manufacturers' potential responses to the combined effect of CAFE standards and separate CO_2 standards (including agreements some manufacturers have reached with California), ZEV mandates, and fuel prices. Together, the aforementioned regulatory programs are more binding than any single program considered in isolation, and this analysis, like past analyses, shows some estimated overcompliance with the proposed CAFE standards, albeit by much less than what was shown in the NPRM that preceded the 2020 final rule, and any overcompliance is highly manufacturer-dependent.

Expressed as equivalent required and achieved average CO_2 levels (using 8887 grams of CO_2 per gallon of gasoline vehicle certification fuel), the above CAFE levels appear as shown in Table II–4 and Table II–5.

Table II-4 – Estimated Average of CAFE Levels Required Under Proposal (as Equivalent Gram per Mile CO_2 Levels)

Fleet	2024	2025	2026	2027	2028	2029
Passenger Cars	181	166	153	153	153	153
Light Trucks	253	233	214	214	214	214
Overall Fleet	219	201	185	185	185	184

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[9] Here, ''eventual'' means by MY 2029, after most of the fleet will have been redesigned under the MY 2026 standards. NHTSA allows the CAFE Model to continue working out compliance solutions for the regulated model years for three model years after the last regulated model year, in recognition of the fact that manufacturers do not comply perfectly with CAFE standards in each model year.

Table II-5 – Estimated Average of CAFE Levels Achieved Under Proposal (as Equivalent Gram per Mile CO_2 Levels)

Fleet	2024	2025	2026	2027	2028	2029
Passenger Cars	165	156	149	147	145	145
Light Trucks	243	234	221	218	216	215
Overall Fleet	206	197	187	184	182	181

Average requirements and achieved CAFE levels would ultimately depend on manufacturers' and consumers' responses to standards, technology developments, economic conditions, fuel prices, and other factors.

NHTSA estimates that over the lives of vehicles produced prior to MY 2030, the proposal would save about 50 billion gallons of gasoline and increase electricity consumption (as the percentage of electric vehicles increases over time) by about 275 terawatts (TWh), compared to levels of gasoline and electricity consumption NHTSA projects would occur under the baseline standards (*i.e.,* the No-Action Alternative).

Table II-6 – Estimated Changes in Energy Consumption vs. No-Action Alternative

Energy Source	Change in Consumption
Gasoline	-50 billion gallons
Electricity	+275 TWh

NHTSA's analysis also estimates total annual consumption of fuel by the entire on-road fleet from calendar year 2020 through calendar year 2050. On this basis, gasoline and electricity consumption by the U.S. light-duty vehicle fleet evolves as shown in Figure II–3 and Figure II–4, each of which shows projections for the No-Action Alternative (Alternative 0, *i.e.,* the baseline), Alternative 1, Alternative 2 (the proposal), and Alternative 3.

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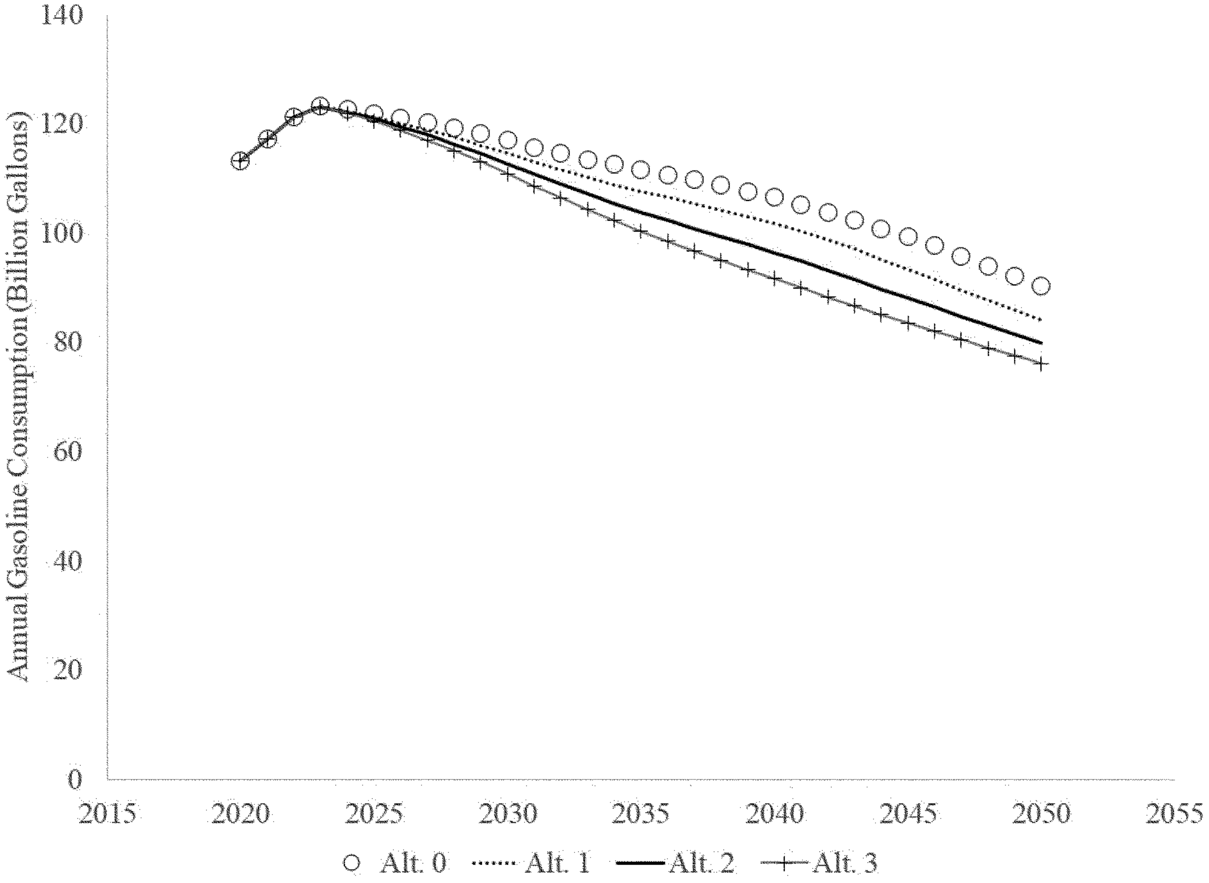

Figure II-3 – Estimated Annual Gasoline Consumption by Light-Duty On-Road Fleet

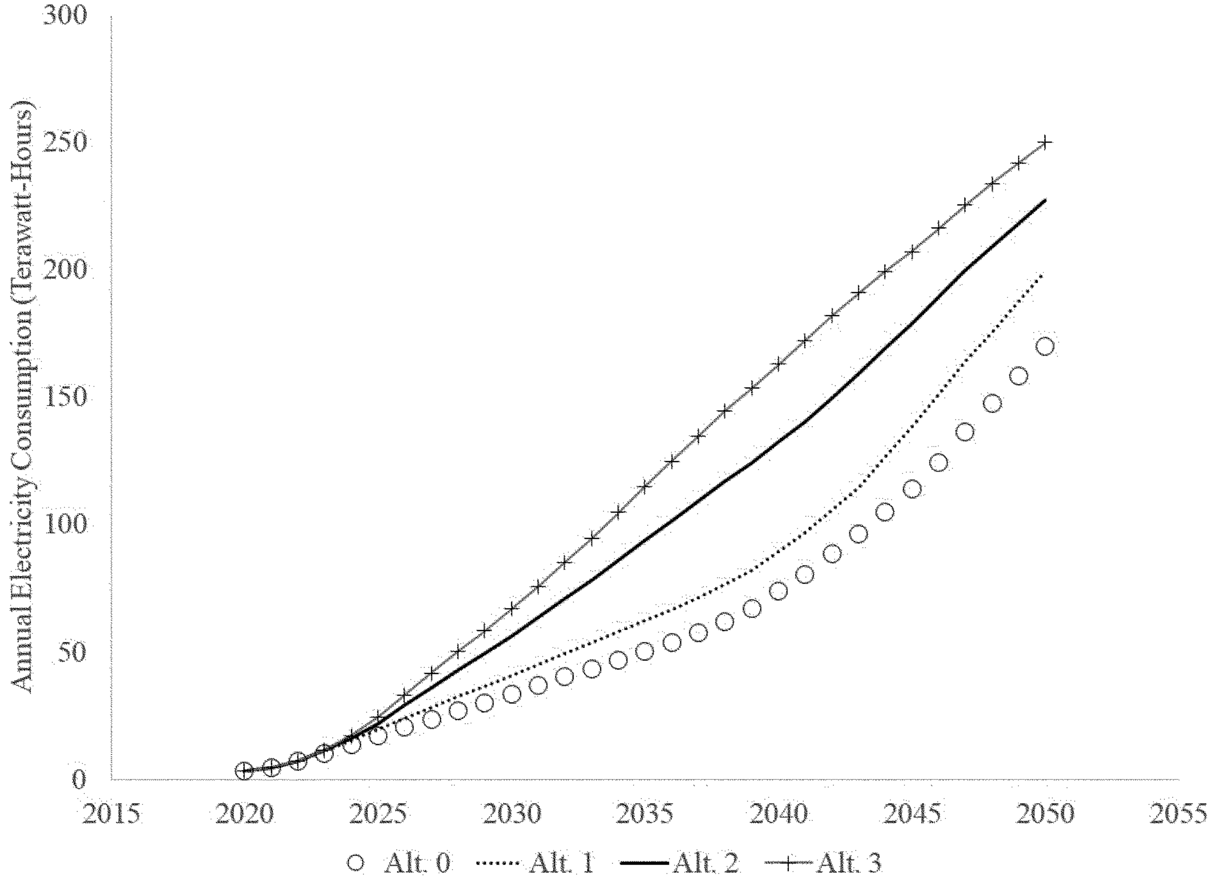

Figure II-4 – Estimated Electricity Consumption by Light-Duty On-Road Fleet

Accounting for emissions from both vehicles and upstream energy sector processes (*e.g.*, petroleum refining and electricity generation), NHTSA estimates that the proposal would reduce greenhouse gas emissions by about 465 million metric tons of carbon dioxide (CO_2), about 500 thousand metric tons of methane (CH_4), and about 12 thousand tons of nitrous oxide (N_2O).

Table II-7 – Estimated Changes in Greenhouse Gas Emissions (Metric Tons) vs. No-Action Alternative

Greenhouse Gas	Change in Emissions
Carbon Dioxide (CO_2)	-465 million tons
Methane (CH_4)	-500 thousand tons
Nitrous Oxide (N_2O)	-12 thousand tons

As for fuel consumption, NHTSA's analysis also estimates annual emissions attributable to the entire on-road fleet from calendar year 2020 through calendar year 2050. Also accounting for both vehicles and upstream processes, NHTSA estimates that CO_2 emissions could evolve over time as shown in Figure II–5, which accounts for both emissions from both vehicles and upstream processes.

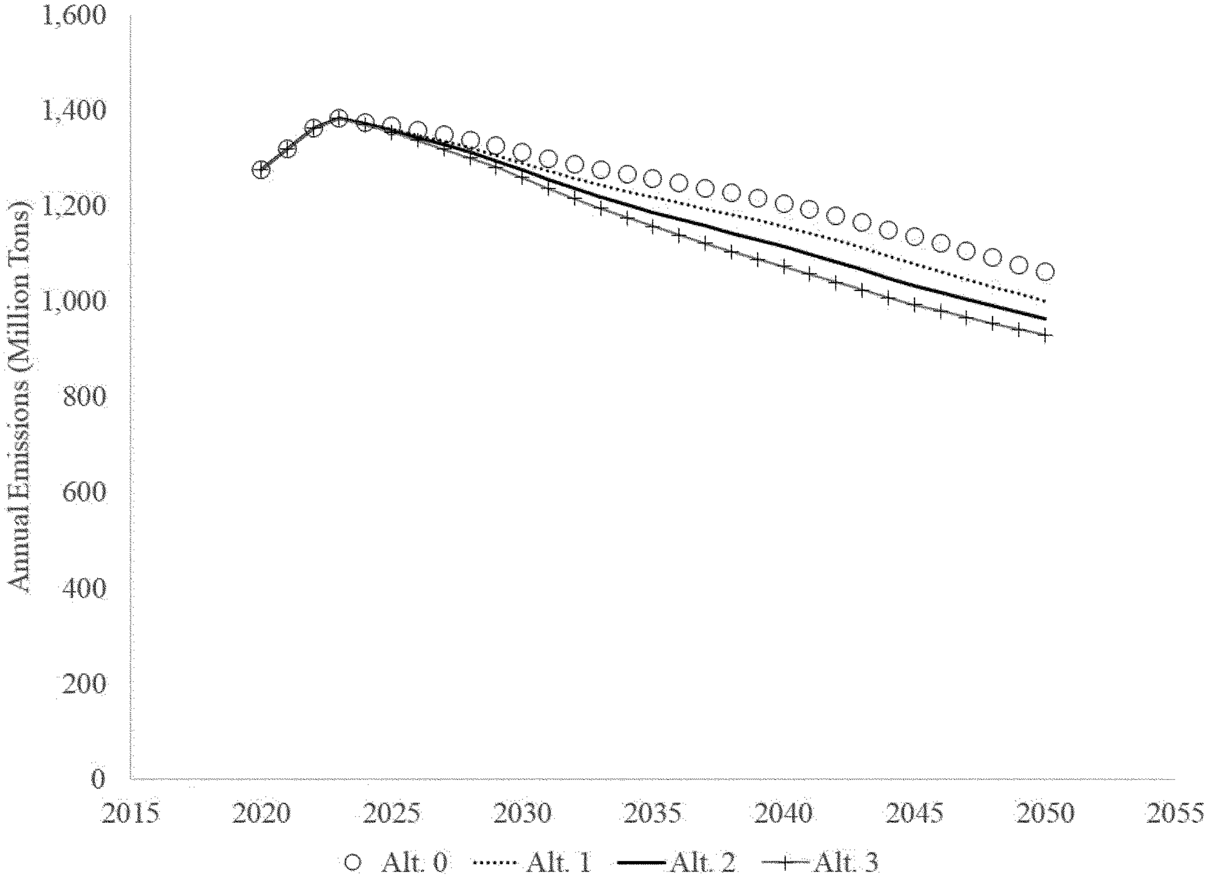

Figure II-5 – Estimated Annual CO_2 Emissions Attributable to Light-Duty On-Road Fleet

Estimated emissions of methane and nitrous oxides follow similar trends. As discussed in the TSD, PRIA, and this NPRM, NHTSA has performed two types of supporting analysis. This NPRM and PRIA focus on the "standard setting" analysis, which sets aside the potential that manufacturers could respond to standards by using compliance credits or introducing new alternative fuel vehicle (including BEVs) models during the "decision years" (for this NPRM, 2024, 2025, and 2026). The accompanying SEIS focuses on an "unconstrained" analysis, which does not set aside these potential manufacturer actions. The SEIS presents much more information regarding projected GHG emissions, as well as model-based estimates of corresponding impacts on several measures of global climate change.

Also accounting for vehicular and upstream emissions, NHTSA has estimated annual emissions of most criteria pollutants (*i.e.,* pollutants for which EPA has issued National Ambient Air Quality Standards). NHTSA estimates that under each regulatory alternative, annual emissions of carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxide (NO_X), and fine particulate matter ($PM_{2.5}$) attributable to the light-duty on-road fleet will decline dramatically between 2020 and 2050, and that emissions in any given year could be very nearly the same under each regulatory alternative. For example, Figure II–6 shows NHTSA's estimate of future NO_X emissions under each alternative.

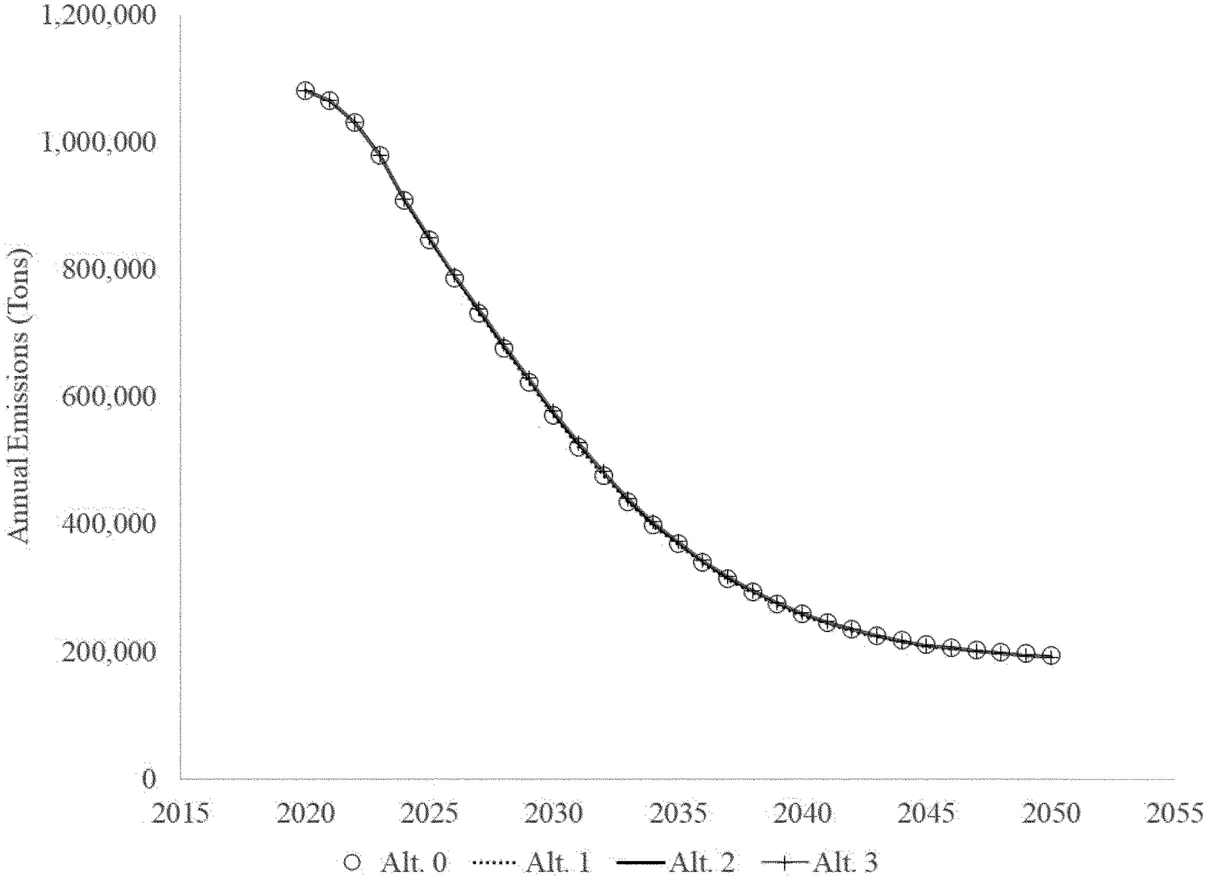

Figure II-6 – Estimated Annual NO$_X$ Emissions Attributable to Light-Duty On-Road Fleet

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On the other hand, as discussed in the PRIA and SEIS, NHTSA projects that annual SO_2 emissions attributable to the light-duty on-road fleet could increase modestly under the action alternatives, because, as discussed above, NHTSA projects that each of the action alternatives could lead to greater use of electricity (for PHEVs and BEVs). The adoption of actions—such as actions prompted by President Biden's Executive order directing agencies to develop a Federal Clean Electricity and Vehicle Procurement Strategy—to reduce electricity generation emission rates beyond projections underlying NHTSA's analysis (discussed in the TSD) could dramatically reduce SO_2 emissions under all regulatory alternatives considered here.[10]

For the "standard setting" analysis, the PRIA accompanying this NPRM provides additional detail regarding projected criteria pollutant emissions and health effects, as well as the inclusion of these impacts in this benefit-cost analysis. For the "unconstrained" or "EIS" type of analysis, the SEIS accompanying this NPRM presents much more information regarding projected criteria pollutant emissions, as well as model-based estimates of corresponding impacts on several measures of urban air quality and public health. As mentioned above, these estimates of criteria pollutant emissions are based on a complex analysis involving interacting simulation techniques and a myriad of input estimates and assumptions. Especially extending well past 2040, the analysis involves a multitude of uncertainties. Therefore, actual criteria pollutant emissions could ultimately be different from NHTSA's current estimates.

To illustrate the effectiveness of the technology added in response to this proposal, Table II–8 presents NHTSA's estimates for increased vehicle cost and lifetime fuel expenditures if we assumed the behavioral response to the lower cost of driving were zero.[11] These numbers are presented in lieu of NHTSA's primary estimate of lifetime fuel savings, which would give an incomplete picture of technological effectiveness because the analysis accounts for consumers' behavioral response to the lower cost-per-mile of driving a more fuel-efficient vehicle.

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[10] *https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/,* accessed June 17, 2021.

[11] While this comparison illustrates the effectiveness of the technology added in response to this proposal, it does not represent a full consumer welfare analysis, which would account for drivers' likely response to the lower cost-per-mile of driving, as well as a variety of other benefits and costs they will experience. The agency's complete analysis of the proposal's likely impacts on passenger car and light truck buyers appears in the PRIA, Appendix I, Table A–23–1.

Table II-8 – Estimated Impact on Average MY 2029 Vehicle Costs vs. No-Action Alternative[12]

Consumer Impact	Dollar Value
Price Increase	$960
Lifetime Fuel Savings	$1,280

With the SCC discounted at 2.5% and other benefits and costs discounted at 3%, NHTSA estimates that costs and benefits could be approximately $120 billion and $121 billion, respectively, such that the present value of aggregate net benefits to society could be somewhat less than $1 billion. With the social cost of carbon (SCC) discounted at 3% and other benefits and costs discounted at 7%, NHTSA estimates approximately $90 billion in costs and $76 billion in benefits could be attributable to vehicles produced prior to MY 2030 over the course of their lives, such that the present value of aggregate net costs to society could be approximately $15 billion.[13]

Table II-9 – Present Value of Estimated Benefits and Costs vs. No-Action Alternative for MYs through 2029

	3% Discount Rate (2.5% for SCC)	7% Discount Rate (3% for SCC)
Benefits	$121b	$76b
Costs	$121b	$91b
Net Benefits	<$1b	-$15b

Model results can be viewed many different ways, and NHTSA's rulemaking considers both ''model year'' and ''calendar year'' perspectives. The ''model year'' perspective, above, considers vehicles projected to be produced in some range of model years, and accounts for impacts, benefits, and costs attributable to these vehicles from the present (from the model year's perspective, 2020) until they are projected to be scrapped. The bulk of NHTSA's analysis considers vehicles produced prior to model year 2030, accounting for the estimated indirect impacts new standards could have on the remaining operation of vehicles already in service. This perspective emphasizes impacts on those model years nearest to those (2024–2026) for which NHTSA is proposing new standards. NHTSA's analysis also presents some results focused only on model years 2024–2026, setting aside the estimated indirect impacts on earlier model years, and the impacts estimated to occur during model years 2027–2029, as some manufacturers and products ''catch up'' to the standards.

Another way to present the benefits and costs of the proposal is the ''calendar year'' perspective shown in Table II–10, which is similar to how EPA presents benefits and costs in its proposal for GHG standards for MYs 2023–2026. The calendar year perspective considers all vehicles projected to be in service in each of some range of future calendar years. NHTSA's presentation of results from this perspective considers calendar years 2020–2050, because the model's representation of the full on-road fleet extends through 2050. Unlike the model year perspective, this perspective includes vehicles projected produced during model years 2030–2050. This perspective emphasizes longer-term impacts that could accrue if standards were to continue without change. Table II–10 shows costs and benefits for MYs 2023–2026 while Table II–9 shows costs and benefits through MY 2029.

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[12] Assumes no rebound effect.

[13] NHTSA interprets the 2021 IWG draft guidance as indicating that a 2.5% discount rate for the SCC is consistent with discounting near-term benefits and costs of the proposal at the OMB-recommended consumption discount rate of 3%. For the OMB-recommended discount rate of 7%, NHTSA concluded that a 3% discount rate for the SCC was reasonable given that the IWG draft guidance suggested that the appropriate discount rate for the SCC was likely lower than 3%. NHTSA refers readers specifically to pp. 16–17 of that guidance, available at *https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf?source=email.*

Table II-10 – Estimates of Benefits and Costs of the Preferred Alternative for Model Years 2023 through 2026, 3% Discount Rate

MY	Cost	Benefit	Net Benefits
	Present Values		
2023	$5.6	$3.5	-$2.1
2024	$8.9	$13.6	$4.7
2025	$10.7	$21.2	$10.5
2026	$12.2	$27.5	$15.3
Sum	$37.4	$65.8	$28.4

Though based on the exact same model results, these two perspectives provide considerably different views of estimated costs and benefits. Because technology costs account for a large share of overall estimated costs, and are also projected to decline over time (as manufacturers gain more experience with new technologies), costs tend to be ‘‘front loaded’’—occurring early in a vehicle’s life and tending to be higher in earlier model years than in later model years. Conversely, because social benefits of standards occur as vehicles are driven, and because both fuel prices and the social cost of CO_2 emissions are projected to increase in the future, benefits tend to be ‘‘back loaded.’’ As a result, estimates of future fuel savings, CO_2 reductions, and net social benefits are higher under the calendar year perspective than under the model year perspective. On the other hand, with longer-term impacts playing a greater role, the calendar year perspective is more subject to uncertainties regarding, for example, future technology costs and fuel prices.

Even though NHTSA and EPA estimate benefits, costs, and net benefits using similar methodologies and achieve similar results, different approaches to accounting may give the false appearance of significant divergences. Table II–10 above presents NHTSA’s results using comparable accounting to EPA’s preamble Table 5. EPA also presents cost and benefit information in its RIA over calendar years 2021 through 2050. The numbers most comparable to those presented in EPA’s RIA are those NHTSA developed to complete its Supplemental Environmental Impact Statement (SEIS) using an identical accounting approach. This is because the statutory limitations constraining NHTSA’s standard setting analysis, such as those in 49 U.S.C. 32902(h) prohibiting consideration of full vehicle electrification during the rulemaking timeframe, or consideration of the trading or transferring of overcompliance credits, do not similarly apply to its EIS analysis.[14] NHTSA’s EIS analysis estimates $312 billion in costs, $443 billion in benefits, and $132 billion in net benefits using a 3% discount rate over calendar years 2021 through 2050.[15] NHTSA describes its cost and benefit accounting approach in Section V of this preamble.

C. Why does NHTSA tentatively believe the proposal would be maximum feasible, and how and why is this tentative conclusion different from the 2020 final rule?

NHTSA’s tentative conclusion, after consideration of the factors described below and information in the administrative record for this action, is that 8 percent increases in stringency for MYs 2024–2026 (Alternative 2 of this analysis) are maximum feasible. The Department of Transportation is deeply committed to working aggressively to improve energy conservation and reduce security risks associated with energy use, and higher standards appear increasingly likely to be economically practicable given almost-daily announcements by major automakers about forthcoming new high-fuel-economy vehicle models, as described in more detail below. Despite only one year having passed since the 2020 final rule, enough has changed in the U.S. and the world that revisiting the CAFE standards for MYs 2024–2026, and raising their stringency considerably, is both appropriate and reasonable.

The 2020 final rule set CAFE standards that increased at 1.5 percent per year for cars and trucks for MYs 2021–2026, in large part because it prioritized industry concerns and reducing vehicle purchase costs to consumers and manufacturers. This proposed rule acknowledges the priority of energy conservation, consistent with NHTSA’s statutory authority. Moreover, NHTSA is also legally required to consider the environmental implications of this action under NEPA, and while the 2020 final rule did undertake a NEPA analysis, it did not prioritize the environmental considerations aspects of the statutory need of the U.S. to conserve energy.

NHTSA recognizes that the amount of lead time available before MY 2024 is less than what was provided in the 2012 rule. As will be discussed further in Section VI, NHTSA believes that the evidence suggests that the proposed standards are still economically practicable.

We note further that while this proposal is different from the 2020 final rule (and also from the 2012 final rule), NHTSA, like any other Federal agency, is afforded an opportunity to reconsider prior views and, when warranted, to adopt new positions. Indeed, as a matter of good governance, agencies *should* revisit their positions when appropriate, especially to ensure that their actions and regulations reflect legally sound interpretations of the agency’s authority and remain consistent with the agency’s views and practices. As a matter of law, ‘‘an Agency is entitled to change its interpretation of a statute.’’ [16] Nonetheless, ‘‘[w]hen an Agency adopts a materially changed interpretation of a statute, it must in addition provide a ‘reasoned analysis’ supporting its decision to revise its interpretation.’’ [17]

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[14] As the EIS analysis contains information that NHTSA is statutorily prevented from considering, the agency does not rely on this analysis in regulatory decision-making.

[15] *See* PRIA Chapter 6.5 for more information regarding NHTSA’s estimates of annual benefits and costs using NHTSA’s standard setting analysis. *See* Tables B–7–25 through B–7–30 in Appendix II of the PRIA for a more detailed breakdown of NHTSA’s EIS analysis.

[16] Phoenix Hydro Corp. v. FERC, 775 F.2d 1187, 1191 (D.C. Cir. 1985).

[17] Alabama Educ. Ass’n v. Chao, 455 F.3d 386, 392 (D.C. Cir. 2006) (quoting Motor Vehicle Mfrs. Ass’n of U.S., Inc. v. State Farm Mut. Auto. Ins. Co.,

Continued

This preamble and the accompanying TSD and PRIA all provide extensive detail on the agency's updated analysis, and Section VI contains the agency's explanation of how the agency has considered that analysis and other relevant information in tentatively determining that the proposed CAFE standards are maximum feasible for MYs 2024–2026 passenger cars and light trucks.

D. How is this proposal consistent with EPA's proposal and with California's programs?

The NHTSA and EPA proposals remain coordinated despite being issued as separate regulatory actions. Because NHTSA and EPA are regulating the exact same vehicles and manufacturer will use the same technologies to meet both sets of standards, NHTSA and EPA coordinated during the development of each agency's independent proposal to revise the standards set forth in the 2020 final rule. The NHTSA-proposed CAFE and EPA-proposed CO_2 standards for MY 2026 represent roughly equivalent levels of stringency and may serve as a coordinated starting point for subsequent standards. While the proposed CAFE and CO_2 standards for MYs 2024–2025 are different, this is largely due to the difference in the ''start year'' for the revised regulations—EPA is proposing to revise standards for MY 2023, while EPCA's lead time requirements, which do not apply to EPA, prevent NHTSA from proposing revised standards until MY 2024. In order to set standards for MY 2023, EPA intends to issue its final rule by December 31, 2021, whereas NHTSA has until April 2022 to finalize standards for MY 2024. The difference in timing makes separate rulemaking actions reasonable and prudent. The specific differences in what the two agencies' standards require become smaller each year, until alignment is achieved. The agencies still have coordinated closely to minimize inconsistency between the programs and will continue to do so through the final rule stage.

While NHTSA's and EPA's programs differ in certain other respects, like programmatic flexibilities, those differences are not new in this proposal. Some parts of the programs are harmonized, and others differ, often as a result of statute. Since NHTSA and EPA began regulating together under President Obama, differences in programmatic flexibilities have meant that manufacturers have had (and will have) to plan their compliance strategies considering both the CAFE standards and the GHG standards and assure that they are in compliance with both, while still building a single fleet of vehicles to accomplish that goal. NHTSA is proposing CAFE standards that increase at 8 percent per year over MYs 2024–2026 because that is what NHTSA has tentatively concluded is maximum feasible in those model years, under the EPCA factors, and is confident that industry would still be able to build a single fleet of vehicles to meet both the NHTSA and EPA standards. Auto manufacturers are extremely sophisticated companies, well-able to manage complex compliance strategies that account for multiple regulatory programs concurrently. If different agencies' standards are more binding for some companies in certain years, this does not mean that manufacturers must build *multiple* fleets of vehicles, simply that they will have to be more strategic about *how* they build their fleet.

NHTSA has also considered and accounted for California's ZEV mandate (and its adoption by a number of other states) in developing the baseline for this proposal, and has also accounted for the Framework Agreements between California, BMW, Ford, Honda, VWA, and Volvo. NHTSA believes that it is reasonable to include ZEV in the baseline for this proposal regardless of whether California receives a waiver of preemption under the Clean Air Act (CAA) because, according to California, industry overcompliance with the ZEV mandate has been extensive, which indicates that whether or not a waiver exists, many companies intend to produce ZEVs in volumes comparable to what a ZEV mandate would require. Because no decision has yet been made on a CAA waiver for California, and because modeling a sub-national fleet is not currently an analytical option for NHTSA, NHTSA has not expressly accounted for California GHG standards in the analysis for this proposal, although we seek comment on whether and how to account for them in the final rule. Chapter 6 of the accompanying PRIA shows the estimated effects of all of these programs simultaneously.

III. Technical Foundation for NPRM Analysis

A. Why does NHTSA conduct this analysis?

NHTSA is proposing to establish revised CAFE standards for passenger cars and light trucks produced for model years (MYs) 2024–2026. NHTSA's review of the existing standards is consistent with Executive Order 13990, Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis, signed on January 20, 2021, directing the review of the 2020 final rule that established CAFE standards for MYs 2021–2026 and the consideration of whether to suspend, revise, or rescind that action by July 2021.[18] NHTSA establishes CAFE standards under the Energy Policy and Conservation Act, as amended, and this proposal is undertaken pursuant to that authority. This proposal would require CAFE stringency for both passenger cars and light trucks to increase at a rate of 8 percent per year annually from MY 2024 through MY 2026. NHTSA estimates that over the useful lives of vehicles produced prior to MY 2030, the proposal would save about 50 billion gallons of gasoline and increase electricity consumption by about 275 TWh. Accounting for emissions from both vehicles and upstream energy sector processes (*e.g.,* petroleum refining and electricity generation), NHTSA estimates that the proposal would reduce greenhouse gas emissions by about 465 million metric tons of carbon dioxide (CO_2), about 500 thousand tons metric tons of methane (CH_4), and about 12 thousand tons of nitrous oxide (N_2O).

When NHTSA promulgates new regulations, it generally presents an analysis that estimates the impacts of such regulations, and the impacts of other regulatory alternatives. These analyses derive from statutes such as the Administrative Procedure Act (APA) and National Environmental Policy Act (NEPA), from Executive orders (such as Executive Order 12866 and 13653), and from other administrative guidance (*e.g.,* Office of Management Budget Circular A–4). For CAFE, the Energy Policy and Conservation Act (EPCA), as amended by the Energy Independence and Security Act (EISA), contains a variety of provisions that require NHTSA to consider certain compliance elements in certain ways and avoid considering other things, in determining maximum feasible CAFE standards. Collectively, capturing all of these requirements and guidance elements analytically means that, at least for CAFE, NHTSA presents an analysis that spans a meaningful range of regulatory alternatives, that quantifies a range of technological, economic, and environmental impacts, and that does so in a manner that accounts for EPCA's express requirements for the CAFE program

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463 U.S. 29, 57 (1983)); *see also* Encino Motorcars, LLC v. Navarro, 136 S.Ct. 2117, 2125 (2016) (''Agencies are free to change their existing policies as long as they provide a reasoned explanation for the change.'') (citations omitted).

[18] 86 FR 7037 (Jan. 25, 2021).

(*e.g.,* passenger cars and light trucks are regulated separately, and the standard for each fleet must be set at the maximum feasible level in each model year).

NHTSA's decision regarding the proposed standards is thus supported by extensive analysis of potential impacts of the regulatory alternatives under consideration. Along with this preamble, a Technical Support Document (TSD), a Preliminary Regulatory Impact Analysis (PRIA), and a Supplemental Environmental Impact Statement (SEIS), together provide an extensive and detailed enumeration of related methods, estimates, assumptions, and results. NHTSA's analysis has been constructed specifically to reflect various aspects of governing law applicable to CAFE standards and has been expanded and improved in response to comments received to the prior rulemaking and based on additional work conducted over the last year. Further improvements may be made based on comments received to this proposal, the 2021 NAS Report,[19] and other additional work generally previewed in these rulemaking documents. The analysis for this proposal aided NHTSA in implementing its statutory obligations, including the weighing of various considerations, by reasonably informing decision-makers about the estimated effects of choosing different regulatory alternatives.

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

NHTSA uses the CAFE Compliance and Effects Modeling System (usually shortened to the ''CAFE Model'') to estimate manufacturers' potential responses to new CAFE and CO_2 standards and to estimate various impacts of those responses. DOT's Volpe National Transportation Systems Center (often simply referred to as the ''Volpe Center'') develops, maintains, and applies the model for NHTSA. NHTSA has used the CAFE Model to perform analyses supporting every CAFE rulemaking since 2001. The 2016 rulemaking regarding heavy-duty pickup and van fuel consumption and CO_2 emissions also used the CAFE Model for analysis (81 FR 73478, October 25, 2016).

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

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[19] National Academies of Sciences, Engineering, and Medicine (NASEM), 2021. *Assessment of Technologies for Improving Fuel Economy of Light-Duty Vehicles—2025–2035,* Washington, DC: The National Academies Press (hereafter, ''2021 NAS Report''). *Available at https://www.nationalacademies.org/our-work/assessment-of-technologies-for-improving-fuel-economy-of-light-duty-vehicles-phase-3* and for hard-copy review at DOT headquarters.

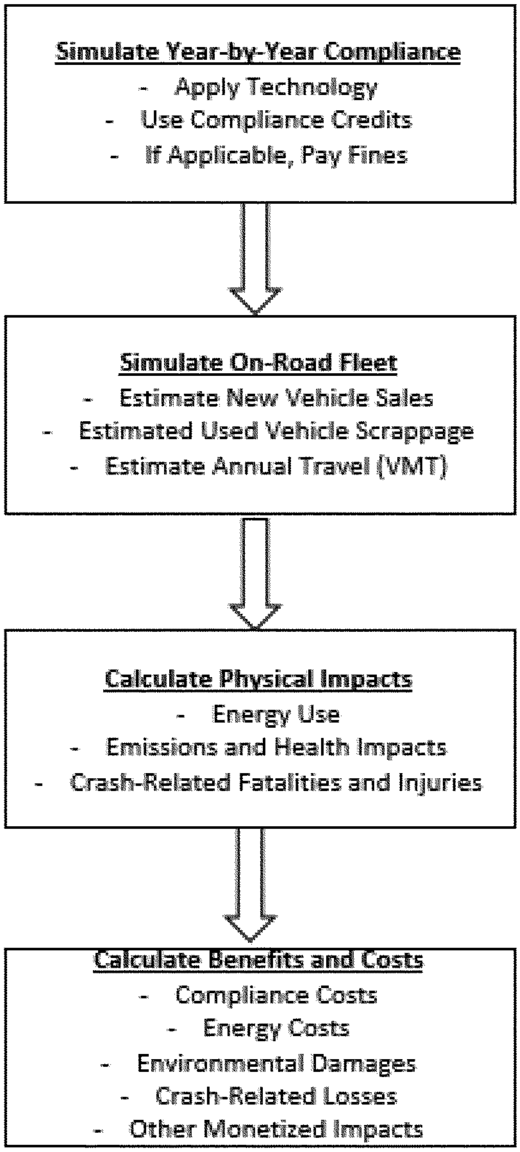

Figure III-1 – CAFE Model Procedures and Logical Flow

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More specifically, the model may be characterized as an integrated system of models. For example, one model estimates manufacturers' responses, another estimates resultant changes in total vehicle sales, and still another estimates resultant changes in fleet turnover (*i.e.,* scrappage). Additionally, and importantly, the model does not determine the form or stringency of the standards. Instead, the model applies inputs specifying the form and stringency of standards to be analyzed and produces outputs showing the impacts of manufacturers working to meet those standards, which become the basis for comparing between 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 truck regulatory classes, and stringency of the CAFE standards for each model year to be analyzed. For example, a regulatory scenario may define CAFE standards that increase in stringency by 8 percent per year for 3 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[20] initial forecast of the vehicle models offered for sale during the simulation period. The compliance simulation then attempts to bring each manufacturer into compliance with the standards[21] defined by the regulatory scenario contained within an input file developed by the user.

Estimating impacts involves calculating resultant changes in new vehicle costs, estimating a variety of costs (*e.g.,* for fuel) and effects (*e.g.,* CO_2 emissions from fuel combustion) occurring as vehicles are driven over their lifetimes before eventually being

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[20] 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 file that contains the forecast used for this proposal is available on NHTSA's website.

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

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 passenger cars and light trucks. Both basic analytical elements involve the application of many analytical inputs. Many of these inputs are developed *outside* of the model and not *by* the model. For example, the model *applies* fuel prices; it does not *estimate* fuel prices.

NHTSA also uses EPA's MOVES model to estimate ''tailpipe'' (a.k.a. ''vehicle'' or ''downstream'') emission factors for criteria pollutants,[22] and uses four Department of Energy (DOE) and DOE-sponsored models to develop inputs to the CAFE Model, including three developed and maintained by DOE's Argonne National Laboratory. The agency uses the DOE Energy Information Administration's (EIA's) National Energy Modeling System (NEMS) to estimate fuel prices,[23] 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.[24] DOT also sponsored DOE/Argonne to use Argonne's Autonomie full-vehicle modeling and simulation system to estimate the fuel economy impacts for roughly a million combinations of technologies and vehicle types.[25] [26] The TSD and PRIA describe details of the agency's use of these models. In addition, as discussed in the SEIS accompanying this NPRM, DOT relied on a range of climate models to estimate impacts on climate, air quality, and public health. The SEIS discusses and describes the use of these models.

To prepare for analysis supporting this proposal, DOT has refined and expanded the CAFE Model through ongoing development. Examples of such changes, some informed by past external comments, made since early 2020 include:

- Inclusion of 400- and 500-mile BEVs;
- Inclusion of high compression ratio (HCR) engines with cylinder deactivation;
- Accounting for manufacturers' responses to both CAFE and CO_2 standards jointly (rather than only separately)
- Accounting for the ZEV mandates applicable in California and the ''Section 177'' states;
- Accounting for some vehicle manufacturers' (BMW, Ford, Honda, VW, and Volvo) voluntary agreement with the State of California to continued annual national-level reductions of vehicle greenhouse gas emissions through MY 2026, with greater rates of electrification than would have been required under the 2020 Federal final rule;[27]
  - ○ Inclusion of CAFE civil penalties in the ''effective cost'' metric used when simulating manufacturers' potential application of fuel-saving technologies;
  - ○ Refined procedures to estimate health effects and corresponding monetized damages attributable to criteria pollutant emissions;
  - ○ New procedures to estimate the impacts and corresponding monetized damages of highway vehicle crashes that do not result in fatalities;
  - ○ Procedures to ensure that modeled technology application and production volumes are the same across all regulatory alternatives in the earliest model years; and
  - ○ Procedures to more precisely focus application of EPCA's ''standard setting constraints'' (*i.e.,* regarding the consideration of compliance credits and additional dedicated alternative fueled vehicles) to only those model years for which NHTSA is proposing or finalizing new standards.

These changes reflect DOT's long-standing commitment to ongoing refinement of its approach to estimating the potential impacts of new CAFE standards.

NHTSA underscores that this analysis exercises the CAFE Model in a manner that explicitly accounts for the fact that in producing a single fleet of vehicles for sale in the United States, manufacturers face the *combination* of CAFE standards, EPA CO_2 standards, and ZEV mandates, and for five manufacturers, the voluntary agreement with California to more stringent CO_2 reduction requirements (also applicable to these manufacturers' total production for the U.S. market) through model year 2026. These regulations and contracts have important structural and other differences that affect the strategy a manufacturer could use to comply with each of the above.

As explained, the analysis is designed to reflect a number of statutory and regulatory requirements applicable to CAFE and tailpipe CO_2 standard-setting. EPCA contains a number of requirements governing the scope and nature of CAFE standard setting. Among these, some have been in place since EPCA was first signed into law in 1975, and some were added in 2007, when Congress passed EISA and amended EPCA. EPCA/EISA requirements regarding the technical characteristics of CAFE standards and the analysis thereof include, but are not limited to, the following, and the analysis reflects these requirements as summarized:

Corporate Average Standards: The provision at 49 U.S.C. 32902 requires standards that apply to the average fuel economy levels achieved by each corporation's fleets of vehicles produced for sale in the U.S.[28] The CAFE Model calculates the CAFE and CO_2 levels of each manufacturer's fleets based on estimated production volumes and characteristics, including fuel economy levels, of distinct vehicle models that could be produced for sale in the U.S.

Separate Standards for Passenger Cars and Light Trucks: The provision at 49 U.S.C. 32902 requires the Secretary of Transportation to set CAFE standards separately for passenger cars and light trucks. The CAFE Model accounts separately for passenger cars and light trucks when it analyzes CAFE or CO_2 standards, including differentiated standards and compliance.

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[22] *See https://www.epa.gov/moves.* This proposal uses version MOVES3, available at *https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves.*

[23] *See https://www.eia.gov/outlooks/aeo/info_nems_archive.php.* This proposal uses fuel prices estimated using the Annual Energy Outlook (AEO) 2021 version of NEMS (*see https://www.eia.gov/outlooks/aeo/pdf/02%20AEO2021%20Petroleum.pdf*).

[24] Information regarding GREET is available at *https://greet.es.anl.gov/index.php.* This NPRM uses the 2020 version of GREET.

[25] 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/batpac-model-software.*

[26] 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-suite-applications/propulsion-systems/gt-power-engine-simulation-software.*

[27] For more information on the Framework Agreements for Clean Cars, including the specific agreements signed by individual manufacturers, *see https://ww2.arb.ca.gov/news/framework-agreements-clean-cars.*

[28] This differs from safety standards and traditional emissions standards, which apply separately to each vehicle. For example, every vehicle produced for sale in the U.S. must, on its own, meet all applicable Federal motor vehicle safety standards (FMVSS), but no vehicle produced for sale must, on its own, meet Federal fuel economy standards. Rather, each manufacturer is required to produce a mix of vehicles that, taken together, achieve an average fuel economy level no less than the applicable minimum level.

Attribute-Based Standards: The provision at 49 U.S.C. 32902 requires the Secretary of Transportation to define CAFE standards as mathematical functions expressed in terms of one or more vehicle attributes related to fuel economy. This means that for a given manufacturer's fleet of vehicles produced for sale in the U.S. 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, and the mix and attributes of vehicles in the manufacturer's fleet. The CAFE Model accounts for such functions and vehicle attributes explicitly.

Separately Defined Standards for Each Model Year: The provision at 49 U.S.C. 32902 requires the Secretary to set CAFE standards (separately for passenger cars and light trucks[29]) 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.[30]

Separate Compliance for Domestic and Imported Passenger Car Fleets: The provision at 49 U.S.C. 32904 requires the EPA Administrator to determine CAFE compliance separately for each manufacturers' fleets of domestic passenger cars and imported passenger cars, which manufacturers must consider as they decide how to improve the fuel economy of their passenger car fleets. The CAFE Model accounts explicitly for this requirement when simulating manufacturers' potential responses to CAFE standards, and combines any given manufacturer's domestic and imported cars into a single fleet when simulating that manufacturer's potential response to CO_2 standards (because EPA does not have separate standards for domestic and imported passenger cars).

Minimum CAFE Standards for Domestic Passenger Car Fleets: The provision at 49 U.S.C. 32902 requires that domestic passenger car fleets meet a minimum standard, which is calculated as 92 percent of the industry-wide average level required under the applicable attribute-based CAFE standard, as projected by the Secretary at the time the standard is promulgated. The CAFE Model accounts explicitly for this requirement for CAFE standards and sets this requirement aside for CO_2 standards.

Civil Penalties for Noncompliance: The provision at 49 U.S.C. 32912 (and implementing regulations) prescribes a rate (in dollars per tenth of a mpg) at which the Secretary is to levy civil penalties if a manufacturer fails to comply with a CAFE standard for a given fleet in a given model year, after considering available credits. Some manufacturers have historically demonstrated a willingness to pay civil penalties rather than achieving full numerical compliance across all fleets. The CAFE Model calculates civil penalties for CAFE shortfalls and provides means to estimate that a manufacturer might stop adding fuel-saving technologies once continuing to do so would be effectively more ''expensive'' (after accounting for fuel prices and buyers' willingness to pay for fuel economy) than paying civil penalties. The CAFE Model does not allow civil penalty payment as an option for CO_2 standards.

Dual-Fueled and Dedicated Alternative Fuel Vehicles: For purposes of calculating CAFE levels used to determine compliance, 49 U.S.C. 32905 and 32906 specify methods for calculating the fuel economy levels of vehicles operating on alternative fuels to gasoline or diesel through MY 2020. After MY 2020, methods for calculating alternative fuel vehicle (AFV) fuel economy are governed by regulation. The CAFE Model is able to account for these requirements explicitly for each vehicle model. However, 49 U.S.C. 32902 prohibits consideration of the fuel economy of dedicated alternative fuel vehicle (AFV) models when NHTSA determines what levels of CAFE standards are maximum feasible. The CAFE Model therefore has an option to be run in a manner that excludes the additional application of dedicated AFV technologies in model years for which maximum feasible standards are under consideration. As allowed under NEPA for analysis appearing in EISs informing decisions regarding CAFE standards, the CAFE Model can also be run without this analytical constraint. The CAFE Model does account for dual- and alternative fuel vehicles when simulating manufacturers' potential responses to CO_2 standards. For natural gas vehicles, both dedicated and dual-fueled, EPA has a multiplier of 2.0 for model years 2022–2026.[31]

ZEV Mandates: The CAFE Model can simulate manufacturers' compliance with ZEV mandates applicable in California and ''Section 177''[32] states. The approach involves identifying specific vehicle model/configurations that could be replaced with PHEVs or BEVs, and immediately making these changes in each model year, before beginning to consider the potential that other technologies could be applied toward compliance with CAFE or CO_2 standards.

Creation and Use of Compliance Credits: The provision at 49 U.S.C. 32903 provides that manufacturers may earn CAFE ''credits'' by achieving a CAFE 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'' and ''carried back'' between model years, transferred between regulated classes (domestic passenger cars, imported passenger cars, and light trucks), and traded between manufacturers. However, credit use is also subject to specific statutory limits. For example, CAFE compliance credits can be carried forward a maximum of five model years and carried back a maximum of three model years. Also, EPCA/EISA caps the amount of credit that can be transferred between passenger car and light truck fleets and prohibits manufacturers from applying traded or transferred credits to offset a failure to achieve the applicable minimum standard for domestic passenger cars. The CAFE Model explicitly simulates manufacturers' potential use of credits carried forward from prior model years or transferred from other fleets.[33] The provision at 49

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[29] 49 U.S.C. chapter 329 uses the term ''non-passenger automobiles,'' while NHTSA uses the term ''light trucks'' in its CAFE regulations. The terms' meanings are identical.

[30] For example, a new engine first applied to given vehicle model/configuration in model year 2020 will most likely be ''carried forward'' to model year 2021 of that same vehicle model/configuration, in order to reflect the fact that manufacturers do not apply brand-new engines to a given vehicle model every single year. The CAFE Model is designed to account for these real-world factors.

[31] While EPA is proposing changes to this and other flexibility provisions in its separate NPRM, for purposes of this NPRM, the CAFE Model only reflects the current EPA regulatory flexibilities.

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

[33] The CAFE Model does not explicitly simulate the potential that manufacturers would carry CAFE or CO_2 credits back (*i.e.,* borrow) from future model years, or acquire and use CAFE compliance credits from other manufacturers. At the same time, because EPA has currently elected not to limit credit trading, the CAFE Model can be exercised in a manner that simulates unlimited (a.k.a. ''perfect'') CO_2 compliance credit trading throughout the industry (or, potentially, within discrete trading ''blocs''). NHTSA believes there is significant uncertainty in how manufacturers may choose to employ these particular flexibilities in the future: For example, while it is reasonably foreseeable that a manufacturer who over-complies in one year may ''coast'' through several subsequent years relying on those credits rather than continuing to make technology improvements, it is harder to assume with confidence that manufacturers will rely on

U.S.C. 32902 prohibits consideration of manufacturers' potential application of CAFE compliance credits when setting maximum feasible CAFE standards. The CAFE Model can be operated in a manner that excludes the application of CAFE credits for a given model year under consideration for standard setting. For modeling CO_2 standards, the CAFE Model does not limit transfers. Insofar as the CAFE Model can be exercised in a manner that simulates trading of CO_2 compliance credits, such simulations treat trading as unlimited.[34]

Statutory Basis for Stringency: The provision at 49 U.S.C. 32902 requires the Secretary to set CAFE standards at the maximum feasible levels, considering technological feasibility, economic practicability, the need of the United States to conserve energy, and the impact of other motor vehicle standards of the Government. EPCA/EISA authorizes the Secretary to interpret these factors, and as the Department's interpretation has evolved, NHTSA has continued to expand and refine its qualitative and quantitative analysis to account for these statutory factors. For example, one of the ways that economic practicability considerations are incorporated into the analysis is through the technology effectiveness determinations: The Autonomie simulations reflect the agency's judgment that it would not be economically practicable for a manufacturer to ''split'' an engine shared among many vehicle model/configurations into myriad versions each optimized to a single vehicle model/configuration.

National Environmental Policy Act: In addition, NEPA requires the Secretary to issue an EIS that documents the estimated impacts of regulatory alternatives under consideration. The SEIS accompanying this NPRM documents changes in emission inventories as estimated using the CAFE Model, but also documents corresponding estimates—based on the application of other models documented in the SEIS, of impacts on the global climate, on tropospheric air quality, and on human health.

Other Aspects of Compliance: Beyond these statutory requirements applicable to DOT and/or EPA are a number of specific technical characteristics of CAFE and/or CO_2 regulations that are also relevant to the construction of this analysis. For example, EPA has defined procedures for calculating average CO_2 levels, and has revised procedures for calculating CAFE levels, to reflect manufacturers' application of ''off-cycle'' technologies that increase fuel economy (and reduce CO_2 emissions). Although too little information is available to account for these provisions explicitly in the same way that the agency has accounted for other technologies, the CAFE Model does include and makes use of inputs reflecting the agency's expectations regarding the extent to which manufacturers may earn such credits, along with estimates of corresponding costs. Similarly, the CAFE Model includes and makes use of inputs regarding credits EPA has elected to allow manufacturers to earn toward CO_2 levels (not CAFE) based on the use of air conditioner refrigerants with lower global warming potential (GWP), or on the application of technologies to reduce refrigerant leakage. In addition, the CAFE Model accounts for EPA ''multipliers'' for certain alternative fueled vehicles, based on current regulatory provisions or on alternative approaches. Although these are examples of regulatory provisions that arise from the exercise of discretion rather than specific statutory mandate, they can materially impact outcomes.

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

A number of assumptions have been updated since the 2020 final rule for this proposal. While NHTSA would have made these updates as a matter of course, we note that that the COVID–19 pandemic has been profoundly disruptive, including in ways directly material to major analytical inputs such as fuel prices, gross domestic product (GDP), vehicle production and sales, and highway travel. As discussed below, NHTSA has updated its ''analysis fleet'' from a model year 2017 reference to a model year 2020 reference, updated estimates of manufacturers' compliance credit ''holdings,'' updated fuel price projections to reflect the U.S. Energy Information Administration's (EIA's) 2021 Annual Energy Outlook (AEO), updated projections of GDP and related macroeconomic measures, and updated projections of future highway travel. In addition, through Executive Order 13990, President Biden has required the formation of an Interagency Working Group (IWG) on the Social Cost of Greenhouse Gases and charged this body with updating estimates of the social costs of carbon, nitrous oxide, and methane. As discussed in the TSD, NHTSA has applied the IWG's interim guidance, which contains cost estimates (per ton of emissions) considerably greater than those applied in the analysis supporting the 2020 SAFE rule. These and other updated analytical inputs are discussed in detail in the TSD. NHTSA seeks comment on the above discussion.

B. What is NHTSA analyzing?

As in the CAFE and CO_2 rulemakings in 2010, 2012, and 2020, NHTSA is proposing to set attribute-based CAFE standards defined by a mathematical function of vehicle footprint, which has observable correlation with fuel economy. 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.[35] Thus, the proposed standards (and regulatory alternatives) 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. Chapter 1.2.3 of the TSD discusses in detail NHTSA's continued

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future technology investments to offset prior-year shortfalls, or whether/how manufacturers will trade credits with market competitors rather than making their own technology investments. Historically, carry-back and trading have been much less utilized than carry-forward, for a variety of reasons including higher risk and preference not to 'pay competitors to make fuel economy improvements we should be making' (to paraphrase one manufacturer), although NHTSA recognizes that carry-back and trading are used more frequently when standards increase in stringency more rapidly. Given the uncertainty just discussed, and given also the fact that the agency has yet to resolve some of the analytical challenges associated with simulating use of these flexibilities, the agency considers borrowing and trading to involve sufficient risk that it is prudent to support this proposal with analysis that sets aside the potential that manufacturers could come to depend widely on borrowing and trading. While compliance costs in real life may be somewhat different from what is modeled today as a result of this analytical decision, that is broadly true no matter what, and the agency does not believe that the difference would be so great that it would change the policy outcome. Furthermore, a manufacturer employing a trading strategy would presumably do so because it represents a lower-cost compliance option. Thus, the estimates derived from this modeling approach are likely to be conservative in this respect, with real-world compliance costs possibly being lower.

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

[35] 49 U.S.C. 32902(a)(3)(A).

reliance on footprint as the relevant attribute in this proposal.

Under the footprint-based standards, the function defines a fuel economy performance target for each unique footprint combination within a car or truck model type. Using the functions, each manufacturer thus will have a CAFE average standard for each year that is almost certainly unique to each of its fleets,[36] based upon the footprints and production volumes of the vehicle models produced by that manufacturer. A manufacturer will have separate footprint-based standards for cars and for trucks, consistent with 49 U.S.C. 32902(b)'s direction that NHTSA must set separate standards for cars and for trucks. The functions are mostly sloped, so that generally, larger vehicles (*i.e.,* vehicles with larger footprints) will be subject to lower mpg targets than smaller vehicles. This is because, generally speaking, smaller vehicles are more capable of achieving higher levels of fuel economy, mostly because they tend not to have to work as hard (and therefore require as much energy) to perform their driving task. Although a manufacturer's fleet average standards could be estimated throughout the model year based on the projected production volume of its vehicle fleet (and are estimated as part of EPA's certification process), the standards with which the manufacturer must comply are determined by its final model year 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.[37]

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

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

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

Where:

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

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

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

c is the slope (in gallons per mile 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.

For the preferred alternative, this equation is represented graphically as the curves in Figure III–2.

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

[37] 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).

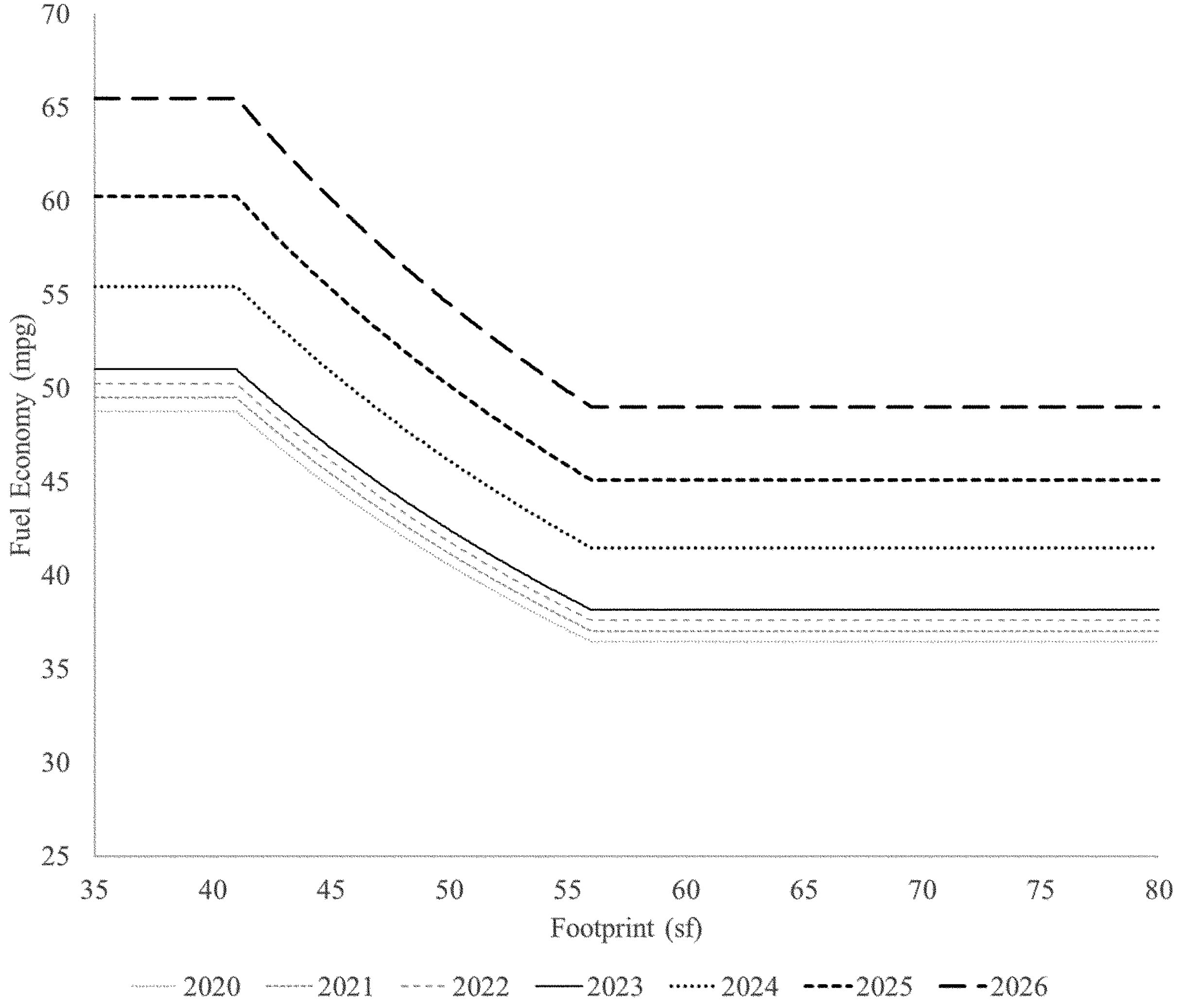

Figure III-2 – Preferred Alternative, Fuel Economy Target Curves, Passenger Cars

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

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

Equation III-2 – Light Truck Fuel Economy Target Curve

Where:

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

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

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

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

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

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

For the preferred alternative, this equation is represented graphically as the curves in Figure III–3.

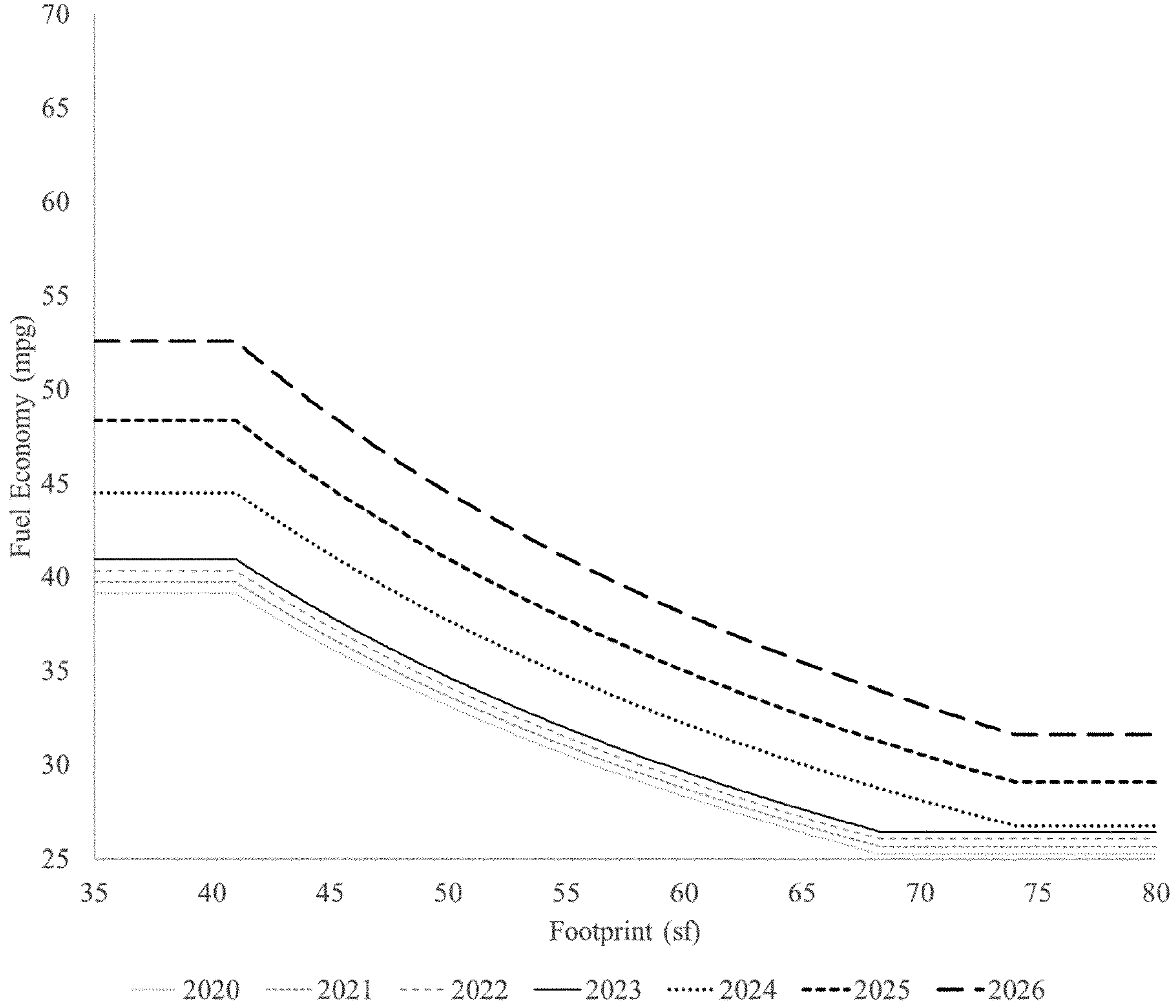

Figure III-3 – Preferred Alternative, Fuel Economy Target Curves, Light Trucks

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Although the general model of the target function equation is the same for each vehicle category (passenger cars and light trucks) and each model year, the parameters of the function equation differ for cars and trucks. The actual parameters for both the preferred alternative and the other regulatory alternatives are presented in Section IV.B of this preamble.

As has been the case since NHTSA began establishing attribute-based standards, no vehicle need meet the specific applicable fuel economy target, because compliance with CAFE standards is determined based on corporate average fuel economy. In this respect, CAFE standards are unlike, for example, Federal Motor Vehicle Safety Standards (FMVSS) and certain vehicle criteria pollutant emissions standards where each car must meet the requirements. CAFE standards apply to the average fuel economy levels achieved by manufacturers' entire fleets of vehicles produced for sale in the U.S. Safety standards apply on a vehicle-by-vehicle basis, such that every single vehicle produced for sale in the U.S. must, on its own, comply with minimum FMVSS. When first mandating CAFE standards in the 1970s, Congress specified a more flexible averaging-based approach that allows some vehicles to ''under comply'' (*i.e.,* fall short of the overall flat standard, or fall short of their target under attribute-based standards) as long as a manufacturer's overall fleet is in compliance.

The required CAFE level applicable to a given 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 III–3.

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

Equation III-3 – Calculation for Required CAFE Level

Where:

$CAFE_{required}$ is the CAFE level the fleet is required to achieve,
i refers to specific vehicle model/configurations in the fleet,
$PRODUCTION_i$ is the number of model configuration i produced for sale in the U.S., and
$TARGET_{FE,I}$ is the fuel economy target (as defined above) for model configuration i.

Chapter 1 of the TSD describes the use of attribute-based standards, generally, and explains the specific decision, in past rules and for the current rule, to continue to use vehicle footprint as the attribute over which to vary stringency. That chapter also discusses the policy in selecting the specific mathematical function; the methodologies used to develop the current attribute-based standards; and methodologies previously used to reconsider the mathematical function for CAFE standards. NHTSA refers readers to the TSD for a full discussion of these topics.

While Chapter 1 of the TSD explains why the proposed standards for MYs 2024–2026 continue to be footprint-based, the question has arisen periodically of whether NHTSA should instead consider multi-attribute standards, such as those that also depend on weight, torque, power, towing capability, and/or off-road capability. To date, every time NHTSA has considered options for which attribute(s) to select, the agency has concluded that a properly-designed footprint-based approach provides the best means of achieving the basic policy goals (*i.e.,* by increasing the likelihood of improved fuel economy across the entire fleet of vehicles; by reducing disparities between manufacturers' compliance burdens; and by reducing incentives for manufacturers to respond to standards in ways that could compromise overall highway safety) involved in applying an attribute-based standard. At the same time, footprint-based standards need also to be structured in a way that furthers the energy and environmental policy goals of EPCA without creating inappropriate incentives to increase vehicle size in ways that could increase fuel consumption or compromise safety. That said, as NHTSA moves forward with the CAFE program, and continues to refine our understanding of the light-duty vehicle market and trends in vehicle and highway safety, NHTSA will also continue to revisit whether other approaches (or other ways of applying the same basic approaches) could foreseeably provide better means of achieving policy goals.

For example, in the 2021 NAS Report, the committee recommended that if Congress does not act to remove the prohibition at 49 U.S.C. 32902(h) on considering the fuel economy of dedicated alternative fuel vehicles (like BEVs) in determining maximum feasible CAFE standards, then NHTSA should account for the fuel economy benefits of ZEVs by ''setting the standard as a function of a second attribute in addition to footprint—for example, the expected market share of ZEVs in the total U.S. fleet of new light-duty vehicles—such that the standards increase as the share of ZEVs in the total U.S. fleet increases.'' [38] DOE seconded this suggestion in its comments during interagency review of this proposal. Chapter 1 of the TSD contains an examination of this suggestion, and NHTSA seeks comment on whether and how NHTSA might consider adding electrification as an attribute on which to base CAFE standards.

Changes in the market that have occurred since NHTSA last examined the appropriateness of the footprint curves have been, for the most part, consistent with the trends that the agency identified in 2018. For the most part, the fleet has continued to grow somewhat in vehicle size, as vehicle manufacturers have continued over the past several years to reduce their offerings of smaller footprint vehicles and increase their sales of larger footprint vehicles and continue to sell many small to mid-size crossovers and SUVs, some of which are classified as passenger cars and some of which are light trucks. Although this trend has had the effect of reducing the achieved fuel economy of the fleet (and thus increasing its carbon dioxide emissions) as compared to if vehicles had instead remained the same size or gotten smaller, NHTSA does not believe that there have been sufficiently major changes in the relationship between footprint and fuel economy over the last three years to warrant a detailed re-examination of that relationship as part of this proposal. Moreover, changes to the footprint curves can significantly affect manufacturers' ability to comply. Given the available lead time between now and the beginning of MY 2024, NHTSA believes it is unlikely any potential benefit of changing the shape of the footprint curves (when we are already proposing to change standard stringency) would outweigh the costs of doing so.

NHTSA seeks comment on the choice of footprint as the attribute on which the proposed standards are based, and particularly seeks comment on the 2021 NAS report recommendation described above. If commenters wish to provide comments on possible changes to the attribute(s) on which fuel economy standards should be based, including approaches for considering vehicle electrification in ways that would further a zero emissions fleet as discussed in Chapter 1 of the TSD, NHTSA would appreciate commenters including a discussion of the timeframe in which those changes should be made—for example, whether and how much lead time would be preferable for making such changes, particularly recognizing the available lead time for MY 2024. NHTSA also seeks comment on whether, to the extent that vehicle upsizing trends and fuel economy curves are causally related instead of correlated, it is the curve shape versus the choice of footprint that creates this relationship (or, alternatively, whether the relationship if any derives from vehicle classification). Again, if commenters wish to provide comments on possible changes to the curve shapes, NHTSA would appreciate commenters including a discussion of the timeframe in which those changes should be made.

NHTSA seeks comment on the discussion above and in the TSD.

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[38] National Academies of Sciences, Engineering, and Medicine, 2021. *Assessment of Technologies for Improving Fuel Economy of Light-Duty Vehicles—2025–2035,* Washington, DC: The National Academies Press (hereafter, ''2021 NAS Report''), at Summary Recommendation 5. *Available at https://www.nationalacademies.org/our-work/assessment-of-technologies-for-improving-fuel-economy-of-light-duty-vehicles-phase-3* and for hard-copy review at DOT headquarters.

C. What inputs does the compliance analysis require?

The CAFE Model applies various technologies to different vehicle models in each manufacturer's product line to simulate how each manufacturer might make progress toward compliance with the specified standard. Subject to a variety of user-controlled constraints, the model applies technologies based on their relative cost-effectiveness, as determined by several input assumptions regarding the cost and effectiveness of each technology, the cost of compliance (determined by the change in CAFE or CO_2 credits, CAFE-related civil penalties, or value of CO_2 credits, depending on the compliance program being evaluated), and the value of avoided fuel expenses. For a given manufacturer, the compliance simulation algorithm applies technologies either until the manufacturer runs out of cost-effective technologies,[39] until the manufacturer exhausts all available technologies, or, if the manufacturer is assumed to be willing to pay civil penalties or acquire credits from another manufacturer, until paying civil penalties or purchasing credits becomes more cost-effective than increasing vehicle fuel economy. At this stage, the system assigns an incurred technology cost and updated fuel economy to each vehicle model, as well as any civil penalties incurred/credits purchased by each manufacturer. This compliance simulation process is repeated for each model year included in the study period (through model year 2050 in this analysis).

At the conclusion of the compliance simulation for a given regulatory scenario the system transitions between compliance simulation and effects calculations. This is the point where the system produces a full representation of the registered light-duty vehicle population in the United States. The CAFE Model then uses this fleet to generate estimates of the following (for each model year and calendar year included in the analysis): Lifetime travel, fuel consumption, carbon dioxide and criteria pollutant emissions, the magnitude of various economic externalities related to vehicular travel (*e.g.,* congestion and noise), and energy consumption (*e.g.,* the economic costs of short-term increases in petroleum prices, or social damages associated with GHG emissions). The system then uses these estimates to measure the benefits and costs associated with each regulatory alternative (relative to the no-action alternative).

To perform this analysis, the CAFE Model uses millions of data points contained in several input files that have been populated by engineers, economists, and safety and environmental program analysts at both NHTSA and the DOT's Volpe National Transportations Systems Center (Volpe). In addition, some of the input data comes from modeling and simulation analysis performed by experts at Argonne National Laboratory using their Autonomie full vehicle simulation model and BatPaC battery cost model. Other inputs are derived from other models, such as the U.S. Energy Information Administration's (EIA's) National Energy Modeling System (NEMS), Argonne's "GREET" fuel-cycle emissions analysis model, and U.S. EPA's "MOVES" vehicle emissions analysis model. As NHTSA and Volpe are both organizations within DOT, we use DOT throughout these sections to refer to the collaborative work performed for this analysis.

This section and Section III.D describe the inputs that the compliance simulation requires, including an in-depth discussion of the technologies used in the analysis, how they are defined in the CAFE Model, how they are characterized on vehicles that already exist in the market, how they can be applied to realistically simulate manufacturer's decisions, their effectiveness, and their cost. The inputs and analyses for the effects calculations, including economic, safety, and environmental effects, are discussed later in Sections III.C through III.H. NHTSA seeks comment on the following discussion.

1. Overview of Inputs to the Analysis

As discussed above, the current analysis involves estimating four major swaths of effects. First, the analysis estimates how the application of various combinations of technologies could impact vehicles' costs and fuel economy levels (and CO_2 emission rates). Second, the analysis estimates how vehicle manufacturers might respond to standards by adding fuel-saving technologies to new vehicles. Third, the analysis estimates how changes in new vehicles might impact vehicle sales and operation. Finally, the analysis estimates how the combination of these changes might impact national-scale energy consumption, emissions, highway safety, and public health.

There are several CAFE Model input files important to the discussion these first two steps, and these input files are discussed in detail later in this section and in Section III.D. The Market Data file contains the detailed description of the vehicle models and model configurations each manufacturer produces for sale in the U.S. The file also contains a range of other inputs that, though not specific to individual vehicle models, may be specific to individual manufacturers. The Technologies file identifies about six dozen technologies to be included in the analysis, indicates when and how widely each technology can be applied to specific types of vehicles, provides most of the inputs involved in estimating what costs will be incurred, and provides some of the inputs involved in estimating impacts on vehicle fuel consumption and weight.

The CAFE Model also makes use of databases of estimates of fuel consumption impacts and, as applicable, battery costs for different combinations of fuel saving technologies.[40] These databases are termed the FE1 and FE2 Adjustments databases (the main database and the database specific to plug-in hybrid electric vehicles, applicable to those vehicles' operation on electricity) and the Battery Costs database. DOT developed these databases using a large set of full vehicle and accompanying battery cost model simulations developed by Argonne National Laboratory. The Argonne simulation outputs, battery costs, and other reference materials are also discussed in the following sections.[41]

The following discussion in this section and in Section III.D expands on the inputs used in the compliance analysis. Further detail is included in Chapters 2 and 3 of the TSD accompanying this proposal, and all input values relevant to the compliance analysis can be seen in the Market Data, Technologies, fuel consumption and battery cost database files, and Argonne

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[39] Generally, the model considers a technology cost-effective if it pays for itself in fuel savings within 30 months. Depending on the settings applied, the model can continue to apply technologies that are *not* cost-effective rather than choosing other compliance options; if it does so, it will apply those additional technologies in order of cost-effectiveness (*i.e.,* most cost-effective first).

[40] To be used as files provided separately from the model and loaded every time the model is executed, these databases are prohibitively large, spanning more than a million records and more than half a gigabyte. To conserve memory and speed model operation, DOT has integrated the databases into the CAFE Model executable file. When the model is run, however, the databases are extracted and placed in an accessible location on the user's disk drive.

[41] The Argonne workbooks included in the docket for this proposal include ten databases that contain the outputs of the Autonomie full vehicle simulations, two summary workbooks of assumptions used for the full vehicle simulations, a data dictionary, and the lookup tables for battery costs generated using the BatPaC battery cost model.

summary files included in the docket for this proposal. As previously mentioned, other model input files underlie the effects analysis, and these are discussed in detail in Sections III.C through III.H. NHTSA seeks comment on the above discussion.

2. The Market Data File

The Market Data file contains the detailed description of the vehicle models and model configurations each manufacturer produces for sale in the U.S. This snapshot of the recent light duty vehicle market, termed the analysis fleet, or baseline fleet, is the starting point for the evaluation of different stringency levels for future fuel economy standards. The analysis fleet provides a reference from which to project how manufacturers could apply additional technologies to vehicles to cost-effectively improve vehicle fuel economy, in response to regulatory action and market conditions.[42] For this analysis, the MY 2020 light duty fleet was selected as the baseline for further evaluation of the effects of different fuel economy standards. The Market Data file also contains a range of other inputs that, though not specific to individual vehicle models, may be specific to individual manufacturers.

The Market Data file is an Excel spreadsheet that contains five worksheets. Three worksheets, the Vehicles worksheet, Engines worksheet, and Transmissions worksheet, characterize the baseline fleet for this analysis. The three worksheets contain a characterization of every vehicle sold in MY 2020 and their relevant technology content, including the engines and transmissions that a manufacturer uses in its vehicle platforms and how those technologies are shared across platforms. In addition, the Vehicles worksheet includes baseline economic and safety inputs linked to each vehicle that allow the CAFE Model to estimate economic and safety impacts resulting from any simulated compliance pathway. The remaining two worksheets, the Manufacturers worksheet and Credits and Adjustments worksheet, include baseline compliance positions for each manufacturer, including each manufacturer's starting CAFE credit banks and whether the manufacturer is willing to pay civil penalties for noncompliance with CAFE standards, among other inputs.

New inputs have been added for this analysis in the Vehicles worksheet and Manufacturers worksheet. The new inputs indicate which vehicles a manufacturer may reasonably be expected to convert to a zero emissions vehicle (ZEV) at first redesign opportunity, to comply with several States' ZEV program provisions. The new inputs also indicate if a manufacturer has entered into an agreement with California to achieve more stringent CO_2 emissions reductions targets than those promulgated in the 2020 final rule.

The following sections discuss how we built the Market Data file, including characterizing vehicles sold in MY 2020 and their technology content, and baseline safety, economic, and manufacturer compliance positions. A detailed discussion of the Market Data file development process is in TSD Chapter 2.2. NHTSA seeks comment on the below discussion and the agency's approach to developing the Market Data file for this proposal.

(a) Characterizing Vehicles and Their Technology Content

The Market Data file integrates information from many sources, including manufacturer compliance submissions, publicly available information, and confidential business information. At times, DOT must populate inputs using analyst judgment, either because information is still incomplete or confidential, or because the information does not yet exist.[43] For this analysis DOT uses mid-model year 2020 compliance data as the basis of the analysis fleet. The compliance data is supplemented for each vehicle nameplate with manufacturer specification sheets, usually from the manufacturer media website, or from online marketing brochures.[44] For additional information about how specification sheets inform MY 2020 vehicle technology assignments, see the technology specific assignments sections in Section III.D.

DOT uses the mid-model year 2020 compliance data to create a row on the Vehicles worksheet in the Market Data file for each vehicle (or vehicle variant[45]) that lists a certification fuel economy, sales volume, regulatory class, and footprint. DOT identifies which combination of modeled technologies reasonably represents the fuel saving technologies already on each vehicle, and assigns those technologies to each vehicle, either on the Vehicles worksheet, the Engines worksheet, or the Transmissions worksheet. The fuel saving technologies considered in this analysis are listed in Table III–1.

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[42] The CAFE Model does not generate compliance paths a manufacturer should, must, or will deploy. It is intended as a tool to demonstrate a compliance pathway a manufacturer *could* choose. It is almost certain all manufacturers will make compliance choices differing from those projected by the CAFE Model.

[43] Forward looking refresh/redesign cycles are one example of when analyst judgement is necessary.

[44] The catalogue of reference specification sheets (broken down by manufacturer, by nameplate) used to populate information in the market data file is available in the docket.

[45] The market data file often includes a few rows for vehicles that may have identical certification fuel economies, regulatory classes, and footprints (with compliance sales volumes divided out among rows), because other pieces of information used in the CAFE Model may be dissimilar. For instance, in the reference materials used to create the Market Data file, for a nameplate curb weight may vary by trim level (with premium trim levels often weighing more on account of additional equipment on the vehicle), or a manufacturer may provide consumers the option to purchase a larger fuel tank size for their vehicle. These pieces of information may not impact the observed compliance position directly, but curb weight (in relation to other vehicle attributes) is important to assess mass reduction technology already used on the vehicle, and fuel tank size is directly relevant to saving time at the gas pump, which the CAFE Model uses when calculating the value of avoided time spent refueling.

Table III-1 – Fuel Saving Technologies that the CAFE Model May Apply

Technology Name	Abbreviation	Market Data File Worksheet	Technology Group
Electric Power Steering	EPS	Vehicles	Additional technologies
Improved Accessory Devices	IACC	Vehicles	Additional technologies
Start-Stop system	12VSS	Vehicles	Electrification
Belt Integrated Starter Generator	BISG	Vehicles	Electrification
Strong Hybrid Electric Vehicle, Parallel	SHEVP2	Vehicles	Electrification
Strong Hybrid Electric Vehicle, Power Split with Atkinson Engine	SHEVPS	Vehicles	Electrification
Strong Hybrid Electric Vehicle, Parallel with HCR0 Engine (Alternative path for Turbo Engine Vehicles)	P2HCR0	Vehicles	Electrification
Strong Hybrid Electric Vehicle, Parallel with HCR1 Engine (Alternative path for Turbo Engine Vehicles)	P2HCR1	Vehicles	Electrification
Strong Hybrid Electric Vehicle, Parallel with HCR1D Engine (Alternative path for Turbo Engine Vehicles)	P2HCR1D	Vehicles	Electrification

Technology Name	Abbreviation	Market Data File Worksheet	Technology Group
Strong Hybrid Electric Vehicle, Parallel with HCR2 Engine (Alternative path for Turbo Engine Vehicles)	P2HCR2	Vehicles	Electrification
Plug-in Hybrid Vehicle with Atkinson Engine and 20 miles of electric range	PHEV20	Vehicles	Electrification
Plug-in Hybrid Vehicle with Atkinson Engine and 50 miles of electric range	PHEV50	Vehicles	Electrification
Plug-in Hybrid Vehicle with TURBO1 Engine and 20 miles of electric range	PHEV20T	Vehicles	Electrification
Plug-in Hybrid Vehicle with TURBO1 Engine and 50 miles of electric range	PHEV50T	Vehicles	Electrification
Plug-in Hybrid Vehicle with Atkinson Engine and 20 miles of electric range (Alternative path for Turbo Engine Vehicles)	PHEV20H	Vehicles	Electrification
Plug-in Hybrid Vehicle with Atkinson Engine and 50 miles of electric range (Alternative path for Turbo Engine Vehicles)	PHEV50H	Vehicles	Electrification
Battery Electric Vehicle with 200 miles of range	BEV200	Vehicles	Electrification
Battery Electric Vehicle with 300 miles of range	BEV300	Vehicles	Electrification
Battery Electric Vehicle with 400 miles of range	BEV400	Vehicles	Electrification
Battery Electric Vehicle with 500 miles of range	BEV500	Vehicles	Electrification
Fuel Cell Vehicle	FCV	Vehicles	Electrification
Low Drag Brakes	LDB	Vehicles	Additional technologies
Secondary Axle Disconnect	SAX	Vehicles	Additional technologies
Baseline Tire Rolling Resistance	ROLL0	Vehicles	Rolling Resistance
Tire Rolling Resistance, 10% Improvement	ROLL10	Vehicles	Rolling Resistance
Tire Rolling Resistance, 20% Improvement	ROLL20	Vehicles	Rolling Resistance
Baseline Aerodynamic Drag Technology	AERO0	Vehicles	Aerodynamic Drag
Aerodynamic Drag, 5% Drag Coefficient Reduction	AERO5	Vehicles	Aerodynamic Drag
Aerodynamic Drag, 10% Drag Coefficient Reduction	AERO10	Vehicles	Aerodynamic Drag
Aerodynamic Drag, 15% Drag Coefficient Reduction	AERO15	Vehicles	Aerodynamic Drag
Aerodynamic Drag, 20% Drag Coefficient Reduction	AERO20	Vehicles	Aerodynamic Drag
Baseline Mass Reduction Technology	MR0	Vehicles	Mass Reduction
Mass Reduction – 5.0% of Glider	MR1	Vehicles	Mass Reduction
Mass Reduction – 7.5% of Glider	MR2	Vehicles	Mass Reduction
Mass Reduction – 10.0% of Glider	MR3	Vehicles	Mass Reduction
Mass Reduction – 15.0% of Glider	MR4	Vehicles	Mass Reduction
Mass Reduction – 20.0% of Glider	MR5	Vehicles	Mass Reduction

Technology Name	Abbreviation	Market Data File Worksheet	Technology Group
Mass Reduction – 28.2% of Glider	MR6	Vehicles	Mass Reduction
Single Overhead Cam	SOHC	Engines	Basic Engines
Dual Overhead Cam	DOHC	Engines	Basic Engines
Engine Friction Reduction	EFR	Engines	Engine Improvements
Variable Valve Timing	VVT	Engines	Basic Engines
Variable Valve Lift	VVL	Engines	Basic Engines
Stoichiometric Gasoline Direct Injection	SGDI	Engines	Basic Engines
Cylinder Deactivation	DEAC	Engines	Basic Engines
Turbocharged Engine	TURBO1	Engines	Advanced Engines
Advanced Turbocharged Engine	TURBO2	Engines	Advanced Engines
Turbocharged Engine with Cooled Exhaust Gas Recirculation	CEGR1	Engines	Advanced Engines
Advanced Cylinder Deactivation	ADEAC	Engines	Advanced Engines
High Compression Ratio Engine (Atkinson Cycle)	HCR0	Engines	Advanced Engines
Advanced High Compression Ratio Engine (Atkinson Cycle)	HCR1	Engines	Advanced Engines
Advanced High Compression Ratio Engine (Atkinson Cycle) with Cylinder Deactivation	HCR1D	Engines	Advanced Engines
EPA, 2016 Vintage Characterization High Compression Ratio Engine (Atkinson Cycle), with Cylinder Deactivation	HCR2	Engines	Advanced Engines
Variable Compression Ratio Engine	VCR	Engines	Advanced Engines
Variable Turbo Geometry Engine	VTG	Engines	Advanced Engines
Variable Turbo Geometry Engine with eBooster	VTGE	Engines	Advanced Engines
Turbocharged Engine with Cylinder Deactivation	TURBOD	Engines	Advanced Engines
Turbocharged Engine with Advanced Cylinder Deactivation	TURBOAD	Engines	Advanced Engines
Advanced Diesel Engine	ADSL	Engines	Advanced Engines
Advanced Diesel Engine with Improvements	DSLI	Engines	Advanced Engines
Advanced Diesel Engine with Improvements and Advanced Cylinder Deactivation	DSLIAD	Engines	Advanced Engines
Compressed Natural Gas Engine	CNG	Engines	Advanced Engines

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For additional information on the characterization of these technologies (including the cost, prevalence in the 2020 fleet, effectiveness estimates, and considerations for their adoption) see the appropriate technology section in Section III.D or TSD Chapter 3.

DOT also assigns each vehicle a technology class. The CAFE Model uses the technology class (and engine class, discussed below) in the Market Data file to reference the most relevant technology costs for each vehicle, and fuel saving technology combinations. We assign each vehicle in the fleet a technology class using a two-step algorithm that takes into account key characteristics of vehicles in the fleet compared to the baseline characteristics of each technology class.[46] As discussed further in Section III.C.4.b), there are ten technology classes used in the CAFE analysis that span five vehicle types and two performance variants. The

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[46] Baseline 0 to 60 mph accelerations times are assumed for each technology class as part of the Autonomie full vehicle simulations. DOT calculates class baseline curb weights and footprints by averaging the curb weights and footprints of vehicles within each technology class as assigned in previous analyses.

technology class algorithm and assignment process is discussed in more detail in TSD Chapter 2.4.2.

We also assign each vehicle an engine technology class so that the CAFE Model can reference the powertrain costs in the Technologies file that most reasonably align with the observed vehicle. DOT assigns engine technology classes for all vehicles, including electric vehicles. If an electric powertrain replaces and internal combustion engine, the electric motor specifications may be different (and hence costs may be different) depending on the capabilities of the internal combustion engine it is replacing, and the costs in the technologies file (on the engine tab) account for the power output and capability of the gasoline or electric drivetrain.

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 simulates part sharing by implementing shared engines, shared transmissions, and shared mass reduction platforms. Vehicles sharing a part (as recognized in the CAFE Model), will adopt fuel saving technologies affecting that part together. To account for parts sharing across products, vehicle model/configurations that share engines are assigned the same engine code,[47] vehicle model/configurations that share transmissions have the same transmission code, and vehicles that adopt mass reduction technologies together share the same platform. For more information about engine codes, transmission codes, and mass reduction platforms see TSD Chapter 3.

Manufacturers often introduce fuel saving technologies at a major redesign of their product or adopt technologies at minor refreshes in between major product redesigns. To support the CAFE Model accounting for new fuel saving technology introduction as it relates to product lifecycle, the Market Data file includes a projection of redesign and refresh years for each vehicle. DOT projects future redesign years and refresh years based on the historical cadence of that vehicle's product lifecycle. For new nameplates, DOT considers the manufacturer's treatment of product lifecycles for past products in similar market segments. When considering year-by-year analysis of standards, the sizing of redesign and refresh intervals will affect projected compliance pathways and how quickly manufacturers can respond to standards. TSD Chapter 2.2.1.7 includes additional information about the product design cycles assumed for this proposal based on historical manufacturer product design cycles.

The Market Data file also includes information about air conditioning (A/C) and off-cycle technologies, but the information is not currently broken out at a row level, vehicle by vehicle.[48] Instead, historical data (and forecast projections, which are used for analysis regardless of regulatory scenario) are listed by manufacturer, by fleet on the Credits and Adjustments worksheet of the Market Data file. Section III.D.8 shows model inputs specifying estimated adjustments (all in grams/mile) for improvements to air conditioner efficiency and other off-cycle energy consumption, and for reduced leakage of air conditioner refrigerants with high global warming potential (GWP). DOT estimated future values based on an expectation that manufacturers already relying heavily on these adjustments would continue do so, and that other manufacturers would, over time, also approach the limits on adjustments allowed for such improvements.

(b) Characterizing Baseline Safety, Economic, and Compliance Positions

In addition to characterizing vehicles and their technology content, the Market Data file contains a range of other inputs that, though not specific to individual vehicle models, may be specific to individual manufacturers, or that characterize baseline safety or economic information.

First, the CAFE Model considers the potential safety effect of mass reduction technologies and crash compatibility of different vehicle types. Mass reduction technologies lower the vehicle's curb weight, which may improve crash compatibility and safety, or not, depending on the type of vehicle. DOT assigns each vehicle in the Market Data file a safety class that best aligns with the mass-size-safety analysis. This analysis is discussed in more detail in Section III.H of this proposal and TSD Chapter 7.

The CAFE Model also includes procedures to consider the direct labor impacts of manufacturer's response to CAFE regulations, considering the assembly location of vehicles, engines, and transmissions, the percent U.S. content (that reflects percent U.S. and Canada content),[49] and the dealership employment associated with new vehicle sales. The Market Data file therefore includes baseline labor information, by vehicle. Sales volumes also influence total estimated direct labor projections in the analysis.

We hold the percent U.S. content constant for each vehicle row for the duration of the analysis. In practice, this may not be the case. Changes to trade policy and tariff policy may affect percent U.S. content in the future. Also, some technologies may be more or less likely to be produced in the U.S., and if that is the case, their adoption could affect future U.S. content. NHTSA does not have data at this time to support varying the percent U.S. content.

We also hold the labor hours projected in the Market Data file per unit transacted at dealerships, per unit produced for final assembly, per unit produced for engine assembly, and per unit produced for transmission assembly constant for the duration of the analysis, and project that the origin of these activities to remain unchanged. In practice, it is reasonable to expect that plants could move locations, or engine and transmission technologies are replaced by another fuel saving technology (like electric motors and fixed gear boxes) that could require a meaningfully different amount of assembly labor hours. NHTSA does not have data at this time to support varying labor hours projected in the Market Data file, but we will continue to explore methods to estimate the direct labor impacts of manufacturer's responses to CAFE standards in future analyses.

As observed from Table III–2, manufacturers employ U.S. labor with varying intensity. In many cases, vehicles certifying in the light truck (LT) regulatory class have a larger percent U.S. content than vehicles certifying in the passenger car (PC) regulatory class.

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[47] Engines (or transmissions) may not be exactly identical, as specifications or vehicle integration features may be different. However, the architectures are similar enough that it is likely the powertrain systems share research and development (R&D), tooling, and production resources in a meaningful way.

[48] Regulatory provisions regarding off-cycle technologies are new, and manufacturers have only recently begun including related detailed information in compliance reporting data. For this analysis, though, such information was not sufficiently complete to support a detailed representation of the application of off-cycle technology to specific vehicle model/configurations in the MY 2020 fleet.

[49] Percent U.S. content was informed by the 2020 Part 583 American Automobile Labeling Act Reports, appearing on NHTSA's website.

Table III-2 – Sales Weighted Percent U.S. Content by Manufacturer, by Regulatory Class

Manufacturer	PC	LT	Total MY 2020 Sales Weighted Percent U.S. Content	Portion of Vehicles Assembled in the U.S.	Portion of Engines Assembled in the U.S.	Portion of Transmissions Assembled in the U.S.
BMW	7.1%	29.3%	15.4%	42.4%	0.0%	0.0%
Daimler	19.1%	36.2%	28.1%	41.2%	39.8%	0.0%
Fiat Chrysler Automobiles (FCA)	47.7%	52.9%	52.2%	68.0%	41.3%	45.7%
Ford	35.2%	47.5%	44.2%	83.4%	32.9%	88.5%
General Motors (GM)	39.8%	47.0%	44.7%	68.3%	69.8%	86.1%
Honda	55.8%	61.7%	58.3%	74.9%	85.9%	58.6%
Hyundai Kia-H	21.8%	0.0%	19.4%	46.0%	46.0%	34.3%
Hyundai Kia-K	12.8%	33.3%	20.7%	38.4%	17.2%	37.8%
JLR	2.6%	6.3%	6.2%	0.0%	0.0%	31.7%
Mazda	1.1%	1.1%	1.1%	0.0%	0.0%	0.0%
Mitsubishi	0.0%	0.3%	0.2%	0.0%	0.0%	0.0%
Nissan	29.0%	32.6%	30.1%	49.9%	47.5%	0.0%
Subaru	35.5%	22.9%	25.6%	53.2%	0.0%	0.0%
Tesla[50]	50.6%	50.0%	50.6%	100.0%	100.0%	100.0%
Toyota	35.2%	42.7%	38.7%	42.4%	46.0%	19.4%
Volvo	10.2%	1.1%	3.4%	12.4%	0.0%	0.0%
VWA	10.3%	8.8%	9.4%	13.5%	0.0%	0.0%
TOTAL	32.4%	41.2%	37.4%	57.1%	44.1%	44.1%

Next, manufacturers may over-comply with CAFE standards and bank so-called over compliance credits. As discussed further in Section III.C.7, manufacturers may use these credits later, sell them to other manufacturers, or let them expire. The CAFE Model does not explicitly trade credits between and among manufacturers, but staff have adjusted starting credit banks in the Market Data file to reflect trades that are likely to happen when the simulation begins (in MY 2020). Considering information manufacturers have reported regarding compliance credits, and considering recent manufacturers' compliance positions, DOT estimates manufacturers' potential use of compliance credits in earlier MYs. This aligns to an extent that represents how manufacturers could deplete their credit banks rather than producing high volume vehicles with fuel saving technologies in earlier MYs. This also avoids the unrealistic application of technologies for manufacturers in early analysis years that typically rely on credits. For a complete discussion about how this data is collected and assigned in the Market Data file, see TSD Chapter 2.2.2.3.

The Market Data file also includes assumptions about a vehicle manufacturer's preferences towards civil penalty payments. EPCA requires that if a manufacturer does not achieve compliance with a CAFE standard in a given model year and cannot apply credits sufficient to cover the compliance shortfall, the manufacturer must pay civil penalties (*i.e.,* fines) to the Federal Government. If inputs indicate that a manufacturer treats civil penalty payment as an economic choice (*i.e.,* one to be taken if doing so would be economically preferable to applying further technology toward compliance), the CAFE Model, when evaluating the manufacturer's response to CAFE standards in a given model year, will apply fuel-saving technology only up to the point beyond which doing so would be more expensive (after subtracting the value of avoided fuel outlays) than paying civil penalties.

For this analysis, DOT exercises the CAFE Model with inputs treating all manufacturers as treating civil penalty

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[50] Tesla does not have internal combustion engines, or multi-speed transmissions, even though they are identified as producing engine and transmission systems in the United States in the Market Data file.

payment as an economic choice through model year 2023. While DOT expects that only manufacturers with some history of paying civil penalties would actually treat civil penalty payment as an acceptable option, the CAFE Model does not currently simulate compliance credit trading between manufacturers, and DOT expects that this treatment of civil penalty payment will serve as a reasonable proxy for compliance credit purchases some manufacturers might actually make through model year 2023. These input assumptions for model years through 2023 reduce the potential that the model will overestimate technology application in the model years leading up to those for which the agency is proposing new standards. As in past CAFE rulemaking analyses (except that supporting the 2020 final rule), DOT has treated manufacturers with some history of civil penalty payment (*i.e.,* BMW, Daimler, FCA, Jaguar-Land Rover, Volvo, and Volkswagen) as continuing to treat civil penalty payment as an acceptable option beyond model year 2023, but has treated all other manufacturers as unwilling to do so beyond model year 2023.

Next, the CAFE Model uses an ''effective cost'' metric to evaluate options to apply specific technologies to specific engines, transmissions, and vehicle model configurations. Expressed on a $/gallon basis, the analysis computes this metric by subtracting the estimated values of avoided fuel outlays and civil penalties from the corresponding technology costs, and then dividing the result by the quantity of avoided fuel consumption. The analysis computes the value of fuel outlays over a ''payback period'' representing the manufacturer's expectation that the market will be willing to pay for some portion of fuel savings achieved through higher fuel economy. Once the model has applied enough technology to a manufacturer's fleet to achieve compliance with CAFE standards (and CO_2 standards and ZEV mandates) in a given model year, the model will apply any further fuel economy improvements estimated to produce a negative effective cost (*i.e.,* any technology applications for which avoided fuel outlays during the payback period are larger than the corresponding technology costs). As discussed above in Section III.A and below in Section III.C, DOT anticipates that manufacturers are likely to act as if the market is willing to pay for avoided fuel outlays expected during the first 30 months of vehicle operation.

We seek comment on whether this expectation is appropriate, or whether some other amount of time should be used. If commenters believe a different amount of time should be used for the payback assumption, it would be most helpful if commenters could define the amount of time, provide an explanation of why that amount of time is preferable, provide any data or information on which the amount of time is based, and provide any discussion of how changing this assumption would interact with other elements in the analysis.

In addition, the Market Data file includes two new sets of inputs for this analysis. In 2020, five vehicle manufacturers reached a voluntary commitment with the state of California to improve the fuel economy of their future nationwide fleets above levels required by the 2020 final rule. For this analysis, compliance with this agreement is in the baseline case for designated manufacturers. The Market Data file contains inputs indicating whether each manufacturer has committed to exceed Federal requirements per this agreement.

Finally, when considering other standards that may affect fuel economy compliance pathways, DOT includes projected zero emissions vehicles (ZEV) that would be required for manufacturers to meet standards in California and Section 177 States, per the waiver granted under the Clean Air Act. To support the inclusion of the ZEV program in the analysis, DOT identifies specific vehicle model/configurations that could adopt BEV technology in response to the ZEV program, independent of CAFE standards, at the first redesign opportunity. These ZEVs are identified in the Market Data file as future BEV200s, BEV300s, or BEV400s. Not all announced BEV nameplates appear in the MY 2020 Market Data file; in these cases, in consultation with CARB, DOT used the volume from a comparable vehicle in the manufacturer's Market Data file portfolio as a proxy. The Market Data file also includes information about the portion of each manufacturer's sales that occur in California and Section 177 states, which is helpful for determining how many ZEV credits each manufacturer will need to generate in the future to comply with the ZEV program with their own portfolio in the rulemaking timeframe. These new procedures are described in detail below and in TSD Chapter 2.3.

3. Simulating the Zero Emissions Vehicle Program

California's Zero Emissions Vehicle (ZEV) program is one part of a program of coordinated standards that the California Air Resources Board (CARB) has enacted to control emissions of criteria pollutants and greenhouse gas emissions from vehicles. The program began in 1990, within the low-emission vehicle (LEV) regulation,[51] and has since expanded to include eleven other states.[52] These states may be referred to as Section 177 states, in reference to Section 177 of the Clean Air Act's grant of authority to allow these states to adopt California's air quality standards,[53] but it is important to note that not all Section 177 states have adopted the ZEV program component.[54] In the following discussion of the incorporation of the ZEV program into the CAFE Model, any reference to the Section 177 states refers to those states that have adopted California's ZEV program requirements.

To account for the ZEV program, and particularly as other states have recently adopted California's ZEV standards, DOT includes the main provisions of the ZEV program in the CAFE Model's analysis of compliance pathways. As explained below, incorporating the ZEV program into the model includes converting vehicles that have been identified as potential ZEV candidates into battery-electric vehicles (BEVs) at the first redesign opportunity, so that a manufacturer's fleet meets calculated ZEV credit requirements. Since ZEV program compliance pathways happen independently from the adoption of fuel saving technology in response to increasing CAFE standards, the ZEV program is considered in the baseline of the analysis, and in all other regulatory alternatives.

Through its ZEV program, California requires that all manufacturers that sell cars within the state meet ZEV credit standards. The current credit requirements are calculated based on manufacturers' California sales volumes. Manufacturers primarily earn ZEV credits through the production of BEVs, fuel cell vehicles (FCVs), and

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[51] California Air Resource Board (CARB), Zero-Emission Vehicle Program. California Air Resources Board. Accessed April 12, 2021. *https://ww2.arb.ca.gov/our-work/programs/zero-emission-vehicle-program/about.*

[52] At the time of writing, the Section 177 states that have adopted the ZEV program are Colorado, Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, Vermont, and Washington. *See* Vermont Department of Environmental Conservation, Zero Emission Vehicles. Accessed April 12, 2021. *https://dec.vermont.gov/air-quality/mobile-sources/zev#:~:text=To%20date%2C%2012%20states%20have,ZEVs%20over%20the%20next%20decade.*

[53] Section 177 of the Clean Air Act allows other states to adopt California's air quality standards.

[54] At the time of writing, Delaware and Pennsylvania are the two states that have adopted the LEV standards, but not the ZEV portion.

transitional zero-emissions vehicles (TZEVs), which are vehicles with partial electrification, namely plug-in hybrids (PHEVs). Total credits are calculated by multiplying the credit value each ZEV receives by the vehicle's volume.

The ZEV and PHEV/TZEV credit value per vehicle is calculated based on the vehicle's range; ZEVs may earn up to 4 credits each and PHEVs with a US06 all-electric range capability of 10 mi or higher receive an additional 0.2 credits on top of the credits received based on all-electric range.[55] The maximum PHEV credit amount available per vehicle is 1.10.[56] Note however that CARB only allows intermediate-volume manufacturers to meet their ZEV credit requirements through PHEV production.[57]

DOT's method for simulating the ZEV program involves several steps; first, DOT calculates an approximate ZEV credit target for each manufacturer based on the manufacturer's national sales volumes, share of sales in Section 177 states, and the CARB credit requirements. Next, DOT identifies a general pathway to compliance that involves accounting for manufacturers' potential use of ZEV overcompliance credits or other credit mechanisms, and the likelihood that manufacturers would choose to comply with the requirements with BEVs rather than PHEVs or other types of compliant vehicles, in addition to other factors. For this analysis, as discussed further below, DOT consulted with CARB to determine reasonable assumptions for this compliance pathway. Finally, DOT identifies vehicles in the MY 2020 analysis fleet that manufacturers could reasonably adapt to comply with the ZEV standards at the first opportunity for vehicle redesign, based on publicly announced product plans and other information. Each of these steps is discussed in turn, below, and a more detailed description of DOT's simulation of the ZEV program is included in TSD Chapter 2.3.

The CAFE Model is designed to present outcomes at a national scale, so the ZEV analysis considers the Section 177 states as a group as opposed to estimating each state's ZEV credit requirements individually. To capture the appropriate volumes subject to the ZEV requirement, DOT calculates each manufacturer's total market share in Section 177 states. DOT also calculates the overall market share of ZEVs in Section 177 states, in order to estimate as closely as possible the number of predicted ZEVs we expect all manufacturers to sell in those states. These shares are then used to scale down national-level information in the CAFE Model to ensure that we represent only Section 177 states in the final calculation of ZEV credits that we project each manufacturer to earn in future years.

DOT uses model year 2019 National Vehicle Population Profile (NVPP) from IHS Markit—Polk to calculate these percentages.[58] These data include vehicle characteristics such as powertrain, fuel type, manufacturer, nameplate, and trim level, as well as the state in which each vehicle is sold, which allows staff to identify the different types of ZEVs manufacturers sell in the Section 177 state group. DOT may make use of future Polk data in updating the analysis for the final rule and may include other states that join the ZEV program after the publication of this proposal, if necessary.

We calculate sales volumes for the ZEV credit requirement based on each manufacturer's future assumed market share in Section 177 states. DOT decided to carry each manufacturer's ZEV market shares forward to future years, after examination of past market share data from model year 2016, from the 2017 version of the NVPP.[59] Comparison of these data to the 2020 version showed that manufacturers' market shares remain fairly constant in terms of geographic distribution. Therefore, we determined that it was reasonable to carry forward the recently calculated market shares to future years.

We calculate total credits required for ZEV compliance by multiplying the percentages from CARB's ZEV requirement schedule by the Section 177 state volumes. CARB's credit percentage requirement schedule for the years covered in this analysis begins at 9.5% in 2020 and ramps up in increments to 22% by 2025.[60] Note that the requirements do not currently change after 2025.[61]

We generate national sales volume predictions for future years using the Compliance Report, a CAFE Model output file that includes simulated sales by manufacturer, fleet, and model year. We use a Compliance Report that corresponds to the baseline scenario of 1.5% per year increases in standards for both passenger car and light truck fleets. The resulting national sales volume predictions by manufacturer are then multiplied by each manufacturer's total market share in the Section 177 states to capture the appropriate volumes in the ZEV credits calculation. Required credits by manufacturer, per year, are determined by multiplying the Section 177 state volumes by CARB's ZEV credit percentage requirement. These required credits are subsequently added to the CAFE Model inputs as targets for manufacturer compliance with ZEV standards in the CAFE baseline.

The estimated ZEV credit requirements serve as a target for simulating ZEV compliance in the baseline. To achieve this, DOT determines a modeling philosophy for ZEV pathways, reviews various sources for information regarding upcoming ZEV programs, and inserts those programs into the analysis fleet inputs. As manufacturers can meet ZEV standards in a variety of different ways, using various technology combinations, the analysis must include certain simplifying assumptions in choosing ZEV pathways. We made these assumptions in conjunction with guidance from CARB staff. The following sections discuss the approach used to simulate a pathway to ZEV program compliance in this analysis.

First, DOT targeted 2025 compliance, as opposed to assuming manufacturers would perfectly comply with their credit requirements in each year prior to 2025. This simplifying assumption was made upon review of past history of ZEV credit transfers, existing ZEV credit banks, and redesign schedules. DOT focused on integrating ZEV technology throughout that timeline with the target of meeting 2025 obligations; thus, some manufacturers are estimated to over-comply or under-comply, depending on their individual situations, in the years 2021–2024.

Second, DOT determined that the most reasonable way to model ZEV compliance would be to allow under-compliance in certain cases and assume that some manufacturers would not meet their ZEV obligation on their own in 2025. Instead, these manufacturers were assumed to prefer to purchase credits from another manufacturer with a credit surplus. Reviews of past ZEV credit transfers between manufacturers informed the decision to make this

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[55] US06 is one of the drive cycles used to test fuel economy and all-electric range, specifically for the simulation of aggressive driving. *See* Dynamometer Drive Schedules | Vehicle and Fuel Emissions Testing | U.S. EPA for more information, as well as Section III.C.4 and Section III.D.3.d).

[56] 13 CCR 1962.2(c)(3).

[57] 13 CCR 1962.2(c)(3).

[58] National Vehicle Population Profile (NVPP) 2020, IHS Markit—Polk. At the time of the analysis, model year 2019 data from the NVPP contained the most current estimate of market shares by manufacturer, and best represented the registered vehicle population on January 1, 2020.

[59] National Vehicle Population Profile (NVPP) 2017, IHS Markit—Polk.

[60] *See* 13 CCR 1962.2(b). The percentage credit requirements are as follows: 9.5% in 2020, 12% in 2021, 14.5% in 2022, 17% in 2023, 19.5% in 2024, and 22% in 2025 and onward.

[61] 13 CCR 1962.2(b).

simplifying assumption.[62] CARB advised that for these manufacturers, the CAFE Model should still project that each manufacturer meet approximately 80% of their ZEV requirements with technology included in their own portfolio. Manufacturers that were observed to have generated many ZEV credits in the past or had announced major upcoming BEV initiatives were projected to meet 100% of their ZEV requirements on their own, without purchasing ZEV credits from other manufacturers.[63]

Third, DOT agreed that manufacturers would meet their ZEV credit requirements in 2025 though the production of BEVs. As discussed above, manufacturers may choose to build PHEVs or FCVs to earn some portion of their required ZEV credits. However, DOT projected that manufacturers would rely on BEVs to meet their credit requirements, based on reviews of press releases and industry news, as well as discussion with CARB. Since nearly all manufacturers have announced some plans to produce BEVs at a scale meaningful to future ZEV requirements, DOT agreed that this was a reasonable assumption.[64] Furthermore, as CARB only allows intermediate-volume manufacturers to meet their ZEV credit requirements through the production of PHEVs, and the volume status of these few manufacturers could change over the years, assuming BEV production for ZEV compliance is the most straightforward path.

Fourth, to account for the new BEV programs announced by some manufacturers, DOT identified vehicles in the 2020 fleet that closely matched the upcoming BEVs, by regulatory class, market segment, and redesign schedule. DOT made an effort to distribute ZEV candidate vehicles by CAFE regulatory class (light truck, passenger car), by manufacturer, in a manner consistent with the 2020 manufacturer fleet mix. Since passenger car and light truck mixes by manufacturer could change in response to the CAFE policy alternative under consideration, this effort was deemed necessary in order to avoid redistributing the fleet mix in an unrealistic manner. However, there were some exceptions to this assumption, as some manufacturers are already closer to meeting their ZEV obligation through 2025 with BEVs currently produced, and some manufacturers underperform their compliance targets more so in one fleet than another. In these cases, DOT deviated from keeping the LT/PC mix of BEVs evenly distributed across the manufacturer's portfolio.[65]

DOT then identified future ZEV programs that could plausibly contribute towards the ZEV requirements for each manufacturer by 2025. To obtain this information, DOT examined various sources, including trade press releases, industry announcements, and investor reports. In many cases, these BEV programs are in addition to programs already in production.[66] Some manufacturers have not yet released details of future electric vehicle programs at the time of writing, but have indicated goals of reaching certain percentages of electric vehicles in their portfolios by a specified year. In these cases, DOT reviewed the manufacturer's current fleet characteristics as well as the aspirational information in press releases and other news in order to make reasonable assumptions about the vehicle segment and range of those future BEVs. DOT may reassign some manufacturer's ZEV programs in the analysis fleet for the final rule based on stakeholder comments or other public information releases that occur in time for the final rule analysis.

Overall, analysts assumed that manufacturers would lean towards producing BEV300s rather than BEV200s, based on the information reviewed and an initial conversation with CARB.[67] Phase-in caps were also considered, especially for BEV200, with the understanding that the CAFE Model will always pick BEV200 before BEV300 or BEV400, until the quantity of BEV200s is exhausted. See Section III.D.3.c) for details regarding BEV phase-in caps.

BEVs, especially BEVs with smaller battery packs and less range, are less likely to meet all the performance needs of traditional pickup truck owners today. However, new markets for BEVs may emerge, potentially in the form of electric delivery trucks and some light-duty electric truck applications in state and local government. The extent to which BEVs will be used in these and other new markets is difficult to project. DOT did identify certain trucks as upcoming BEVs for ZEV compliance, and these BEVs were expected to have higher ranges, due to the specific performance needs associated with these vehicles. Outside of the ZEV inputs described here, the CAFE Model does not handle the application of BEV technology with any special considerations as to whether the vehicle is a pickup truck or not. Comments from manufacturers are solicited on this issue.

Finally, in order to simulate manufacturers' compliance with their particular ZEV credits target, 142 rows in the analysis fleet were identified as substitutes for future ZEV programs. As discussed above, the analysis fleet summarizes the roughly 13.6 million light-duty vehicles produced and sold in the United States in the 2020 model year with more than 3,500 rows, each reflecting information for one vehicle type observed. Each row includes the vehicle's nameplate and trim level, the sales volume, engine, transmission, drive configuration, regulatory class, projected redesign schedule, and fuel saving technologies, among other attributes.

As the goal of the ZEV analysis is to simulate compliance with the ZEV program in the baseline, and the analysis fleet only contains vehicles produced during model year 2020, DOT identified existing models in the analysis fleet that shared certain characteristics with upcoming BEVs. DOT also focused on identifying substitute vehicles with redesign years similar to the future BEV's introduction year. The sales volumes of those existing models, as predicted for 2025, were then used to simulate production of the upcoming BEVs. DOT identified a combination of rows that would meet the ZEV target, could contribute productively towards CAFE program obligations (by manufacturer and by fleet), and would introduce BEVs in each manufacturer's portfolio in a way that reasonably aligned with projections and announcements. DOT tagged each of these rows with information in the Market Data file, instructing the CAFE Model to apply the specified BEV technology to the row at the first redesign year, regardless of the scenario or type of CAFE or GHG simulation.

The CAFE Model does not optimize compliance with the ZEV mandate; it relies upon the inputs described in this section in order to estimate each

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[62] *See https://ww2.arb.ca.gov/our/work/programs/advanced-clean-cars-program/zev-program-zero-emission-vehicle-credit-balances* for past credit balances and transfer information.

[63] The following manufacturers were assumed to meet 100% ZEV compliance: Ford, General Motors, Hyundai, Kia, Jaguar Land Rover, and Volkswagen Automotive. Tesla was also assumed to meet 100% of its required standards, but the analyst team did not need to add additional ZEV substitutes to the baseline for this manufacturer.

[64] *See* TSD Chapter 2.3 for a list of potential BEV programs recently announced by manufacturers.

[65] The GM light truck and passenger car distribution is one such example.

[66] Examples of BEV programs already in production include the Nissan Leaf and the Chevrolet Bolt.

[67] BEV300s are 300-mile range battery-electric vehicles. *See* Section III.D.3.b) for further information regarding electrification fleet assignments.

manufacturer's resulting ZEV credits. The resulting amount of ZEV credits earned by manufacturer for each model year can be found in the CAFE Model's Compliance file.

Not all ZEV-qualifying vehicles in the U.S. earn ZEV credits, as they are not all sold in states that have adopted ZEV regulations. In order to reflect this in the CAFE Model, which only estimates sales volumes at the national level, the percentages calculated for each manufacturer are used to scale down the national-level volumes. Multiplying national-level ZEV sales volumes by these percentages ensures that only the ZEVs sold in Section 177 states count towards the ZEV credit targets of each manufacturer.[68] See Section 5.8 of the CAFE Model Documentation for a detailed description of how the model applied these ZEV technologies and any changes made to the model's programming for the incorporation of the ZEV program into the baseline.

As discussed above, DOT made an effort to distribute the newly identified ZEV candidates between CAFE regulatory classes (light truck and passenger car) in a manner consistent with the proportions seen in the 2020 analysis fleet, by manufacturer. As mentioned previously, there were a few exceptions to this assumption in cases where manufacturers' regulatory class distribution of current or planned ZEV programs clearly differed from their regulatory class distribution as a whole.

In some instances, the regulatory distribution of flagged ZEV candidates leaned towards a higher portion of PCs. The reasoning behind this differs in each case, but there is an observed pattern in the 2020 analysis fleet of fewer BEVs being light trucks, especially pickups. The 2020 analysis fleet contains no BEV pickups in the light truck segment. The slow emergence of electric pickups could be linked to the specific performance needs associated with pickup trucks. However, the market for BEVs may emerge in unexpected ways that are difficult to project. Examples of this include anticipated electric delivery trucks and light-duty electric trucks used by state and local governments. Due to these considerations, DOT tagged some trucks as BEVs for ZEV, and expected that these would generally be of higher ranges.

TSD Chapter 2.3 includes more information about the process we use to simulate ZEV program compliance in this analysis.

4. Technology Effectiveness Values

The next input we use to simulate manufacturers' decision-making processes for the year-by-year application of technologies to specific vehicles are estimates of how effective each technology would be at reducing fuel consumption. For this analysis, we use full-vehicle modeling and simulation to estimate the fuel economy improvements manufacturers could make to a fleet of vehicles, considering the vehicles' technical specifications and how combinations of technologies interact. Full-vehicle modeling and simulation uses physics-based models to predict how combinations of technologies perform as a full system under defined conditions. We use full vehicle simulations performed in Autonomie, a physics-based full-vehicle modeling and simulation software developed and maintained by the U.S. Department of Energy's Argonne National Laboratory.[69]

A model is a mathematical representation of a system, and simulation is the behavior of that mathematical representation over time. In this analysis, the model is a mathematical representation of an entire vehicle,[70] including its individual components such as the engine and transmission, overall vehicle characteristics such as mass and aerodynamic drag, and the environmental conditions, such as ambient temperature and barometric pressure. We simulate the model's behavior over test cycles, including the 2-cycle laboratory compliance tests (or 2-cycle tests),[71] to determine how the individual components interact.

Using full-vehicle modeling and simulation to estimate technology efficiency improvements has two primary advantages over using single or limited point estimates. An analysis using single or limited point estimates may assume that, for example, one fuel economy-improving technology with an effectiveness value of 5 percent by itself and another technology with an effectiveness value of 10 percent by itself, when applied together achieve an additive 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 versus pickup truck) and the way in which the technology interacts with other technologies on the vehicle, as different technologies may provide different incremental levels of fuel economy improvement if implemented alone or in combination with other technologies. Any oversimplification of these complex interactions leads to less accurate and often overestimated effectiveness estimates.

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

An important feature of this analysis is that the incremental effectiveness of each technology and combinations of technologies should be accurate and relative to a consistent baseline vehicle. For this analysis, the baseline absolute fuel economy value for each vehicle in the analysis fleet is based on CAFE compliance data for each make and model.[72] The absolute fuel economy values of the full vehicle simulations are

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[68] The single exception to this assumption is Mazda, as Mazda has not yet produced any ZEV-qualifying vehicles at the time of writing. Thus, the percentage of ZEVs sold in Section 177 states cannot be calculated from existing data. However, Mazda has indicated its intention to produce ZEV-qualifying vehicles in the future, so DOT assumed that 100% of future ZEVs would be sold in Section 177 states for the purposes of estimating ZEV credits in the CAFE Model.

[69] Islam, E. S., A. Moawad, N. Kim, R. Vijayagopal, and A. Rousseau. *A Detailed Vehicle Simulation Process to Support CAFE Standards for the MY 2024–2026 Analysis.* ANL/ESD–21/9 [hereinafter Autonomie model documentation].

[70] Each full vehicle model in this analysis is composed of sub-models, which is why the full vehicle model could also be referred to as a full system model, composed of sub-system models.

[71] EPA's compliance test cycles are used to measure the fuel economy of a vehicle. For readers unfamiliar with this process, it is like running a car on a treadmill following a program—or more specifically, two programs. The ''programs'' are the ''urban cycle,'' or Federal Test Procedure (abbreviated as ''FTP''), and the ''highway cycle,'' or Highway Fuel Economy Test (abbreviated as ''HFET'' or ''HWFET''), and they have not changed substantively since 1975. Each cycle is a designated speed trace (of vehicle speed versus time) that all certified vehicles must follow during testing. The FTP is meant roughly to simulate stop and go city driving, and the HFET is meant roughly to simulate steady flowing highway driving at about 50 mph.

[72] *See* Section III.C.2 for further discussion of CAFE compliance data in the Market Data file.

used only to determine incremental effectiveness and are never used directly to assign an absolute fuel economy value to any vehicle model or configuration. For subsequent technology changes, we apply the incremental effectiveness values of one or more technologies to the baseline fuel economy value to determine the absolute fuel economy achieved for applying the technology change.

As an example, if a Ford F–150 2-wheel drive crew cab and short bed in the analysis fleet has a fuel economy value of 30 mpg for CAFE compliance, 30 mpg will be considered the reference absolute fuel economy value. A similar full vehicle model node in the Autonomie simulation may begin with an average fuel economy value of 32 mpg, and with incremental addition of a specific technology X its fuel economy improves to 35 mpg, a 9.3 percent improvement. In this example, the incremental fuel economy improvement (9.3 percent) from technology X would be applied to the F–150's 30 mpg absolute value.

We determine the incremental effectiveness of technologies as applied to the thousands of unique vehicle and technology combinations in the analysis fleet. Although, as mentioned above, full-vehicle modeling and simulation reduces the work and time required to assess the impact of moving a vehicle from one technology state to another, it would be impractical—if not impossible—to build a unique vehicle model for every individual vehicle in the analysis fleet. Therefore, as discussed in the following sections, the Autonomie analysis relies on ten vehicle technology class models that are representative of large portions of the analysis fleet vehicles. The vehicle technology classes ensure that key vehicle characteristics are reasonably represented in the full vehicle models. The next sections discuss the details of the technology effectiveness analysis input specifications and assumptions. NHTSA seeks comment on the following discussion.

(a) Full Vehicle Modeling and Simulation

As discussed above, for this analysis we use Argonne's full vehicle modeling tool, Autonomie, to build vehicle models with different technology combinations and simulate the performance of those models over regulatory test cycles. The difference in the simulated performance between full vehicle models, with differing technology combination, is used to determine effectiveness values. We consider over 50 individual technologies as inputs to the Autonomie modeling.[73] These inputs consist of engine technologies, transmission technologies, powertrain electrification, lightweighting, aerodynamic improvements, and tire rolling resistance improvements. Section III.D broadly discusses each of the technology groupings definitions, inputs, and assumptions. A deeper discussion of the Autonomie modeled subsystems, and how inputs feed the sub models resulting in outputs, is contained in the Autonomie model documentation that accompanies this analysis. The 50 individual technologies, when considered with the ten vehicle technology classes, result in over 1.1 million individual vehicle technology combination models. For additional discussion on the full vehicle modeling used in this analysis see TSD Chapter 2.

While Argonne built full-vehicle models and ran simulations for many combinations of technologies, it did not simulate literally every single vehicle model/configuration in the analysis fleet. Not only would it be impractical to assemble the requisite detailed information specific to each vehicle/model configuration, much of which would likely only be provided on a confidential basis, doing so would increase the scale of the simulation effort by orders of magnitude. Instead, Argonne simulated ten different vehicle types, corresponding to the five ‘‘technology classes'' generally used in CAFE analysis over the past several rulemakings, each with two performance levels and corresponding vehicle technical specifications (*e.g.,* small car, small performance car, pickup truck, performance pickup truck, etc.).

Technology classes are a means of specifying common technology input assumptions for vehicles that share similar characteristics. Because each vehicle technology class has unique characteristics, the effectiveness of technologies and combinations of technologies is different for each technology class. Conducting Autonomie simulations uniquely for each technology class provides a specific set of simulations and effectiveness data for each technology class. In this analysis the technology classes are compact cars, midsize cars, small SUVs, large SUVs, and pickup trucks. In addition, for each vehicle class there are two levels of performance attributes (for a total of 10 technology classes). The high performance and low performance vehicles classifications allow for better diversity in estimating technology effectiveness across the fleet.

For additional discussion on the development of the vehicle technology classes used in this analysis and the attributes used to characterize each vehicle technology class, see TSD Chapter 2.4 and the Autonomie model documentation.

Before any simulation is initiated in Autonomie, Argonne must ‘‘build'' a vehicle by assigning reference technologies and initial attributes to the components of the vehicle model representing each technology class. The reference technologies are baseline technologies that represent the first step on each technology pathway used in the analysis. For example, a compact car is built by assigning it a baseline engine (DOHC, VVT, port fuel injection (PFI)), a baseline transmission (AT5), a baseline level of aerodynamic improvement (AERO0), a baseline level of rolling resistance improvement (ROLL0), a baseline level of mass reduction technology (MR0), and corresponding attributes from the Argonne vehicle assumptions database like individual component weights. A baseline vehicle will have a unique starting point for the simulation and a unique set of assigned inputs and attributes, based on its technology class. Argonne collected over a hundred baseline vehicle attributes to build the baseline vehicle for each technology class. In addition, to account for the weight of different engine sizes, like 4-cylinder versus 8-cylinder or turbocharged versus naturally aspirated engines, Argonne developed a relationship curve between peak power and engine weight based on the A2Mac1 benchmarking data. Argonne uses the developed relationship to estimate mass for all engines. For additional discussion on the development and optimization of the baseline vehicle models and the baseline attributes used in this analysis see TSD Chapter 2.4 and the Autonomie model documentation.

The next step in the process is to run a powertrain sizing algorithm that ensures the built vehicle meets or exceeds defined performance metrics, including low-speed acceleration (time required to accelerate from 0–60 mph), high-speed passing acceleration (time required to accelerate from 50–80 mph), gradeability (the ability of the vehicle to maintain constant 65 miles per hour speed on a six percent upgrade), and towing capacity. Together, these performance criteria are widely used by the automotive industry as metrics to quantify vehicle performance attributes

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[73] *See* Autonomie model documentation; ANL—All Assumptions_Summary_NPRM_022021.xlsx; ANL—Data Dictionary_January 2021.xlsx.

that consumers observe and that are important for vehicle utility and customer satisfaction.

As with conventional vehicle models, electrified vehicle models were also built from the ground up. For MY 2020, the U.S. market has an expanded number of available hybrid and electric vehicle models. To capture improvements for electrified vehicles for this analysis, DOT applied a mass regression analysis process that considers electric motor weight versus electric motor power (similar to the regression analysis for internal combustion engine weights) for vehicle models that have adopted electric motors. Benchmarking data for hybrid and electric vehicles from the A2Mac1 database were analyzed to develop a regression curve of electric motor peak power versus electric motor weight.[74]

We maintain performance neutrality in the full vehicle simulations by resizing engines, electric machines, and hybrid electric vehicle battery packs at specific incremental technology steps. To address product complexity and economies of scale, engine resizing is limited to specific incremental technology changes that would typically be associated with a major vehicle or engine redesign. This is intended to reflect manufacturers' comments to DOT on how they consider engine resizing and product complexity, and DOT's observations on industry product complexity. A detailed discussion on powertrain sizing can be found in TSD Chapter 2.4 and in the Autonomie model documentation.

After all vehicle class and technology combination models have been built, Autonomie simulates the vehicles' performance on test cycles to calculate the effectiveness improvement of adding fuel-economy-improving technologies to the vehicle. Simulating vehicles' performance using tests and procedures specified by Federal law and regulations minimizes the potential variation in determining technology effectiveness.

For vehicles with conventional powertrains and micro hybrids, Autonomie simulates the vehicles per EPA 2-cycle test procedures and guidelines.[75] For mild and full hybrid electric vehicles and FCVs, Autonomie simulates the vehicles using the same EPA 2-cycle test procedure and guidelines, and the drive cycles are repeated until the initial and final state of charge are within a SAE J1711 tolerance. For PHEVs, Autonomie simulates vehicles per similar procedures and guidelines as prescribed in SAE J1711.[76] For BEVs Autonomie simulates vehicles per similar procedures and guidelines as prescribed in SAE J1634.[77]

(b) Performance Neutrality

The purpose of the CAFE analysis is to examine the impact of technology application that can improve fuel economy. When the fuel economy-improving technology is applied, often the manufacturer must choose how the technology will affect the vehicle. The advantages of the new technology can either be completely applied to improving fuel economy or be used to increase vehicle performance while maintaining the existing fuel economy, or some mix of the two effects. Historically, vehicle performance has improved over the years as more technology is applied to the fleet. The average horsepower is the highest that it has ever been; all vehicle types have improved horsepower by at least 42 percent compared to the 1978 model year, and pickup trucks have improved by 48 percent.[78] Fuel economy has also improved, but the horsepower and acceleration trends show that not 100 percent of technological improvements have been applied to fuel savings. While future trends are uncertain, the past trends suggest vehicle performance is unlikely to *decrease,* as it seems reasonable to assume that customers will, at a minimum, demand vehicles that offer the same utility as today's fleet.

For this rulemaking analysis, DOT analyzed technology pathways manufacturers could use for compliance that attempt to maintain vehicle attributes, utility, and performance. Using this approach allows DOT to assess the costs and benefits of potential standards under a scenario where consumers continue to get the similar vehicle attributes and features, other than changes in fuel economy. The purpose of constraining vehicle attributes is to simplify the analysis and reduce variance in other attributes that consumers may value across the analyzed regulatory alternatives. This allows for a streamlined accounting of costs and benefits by not requiring the values of other vehicle attributes that trade off with fuel economy.

To confirm minimal differences in performance metrics across regulatory alternatives, DOT analyzed the sales-weighted average 0–60 mph acceleration performance of the entire simulated vehicle fleet for MYs 2020 and 2029. The analysis compared performance under the baseline standards and preferred alternative. This analysis identified that the analysis fleet under no action standards in MY 2029 had a 0.77 percent worse 0–60 mph acceleration time than under the preferred alternative, indicating there is minimal difference in performance between the alternatives. This assessment shows that for this analysis, the performance difference is minimal across regulatory alternatives and across the simulated model years, which allows for fair, direct comparison among the alternatives. Further details about this assessment can be found in TSD Chapter 2.4.5.

(c) Implementation in the CAFE Model

The CAFE Model uses two elements of information from the large amount of data generated by the Autonomie simulation runs: Battery costs, and fuel consumption on the city and highway cycles. DOT combines the fuel economy information from the two cycles to produce a composite fuel economy for each vehicle, and for each fuel used in dual fuel vehicles. The fuel economy information for each simulation run is converted into a single value for use in the CAFE Model.

In addition to the technologies in the Autonomie simulation, the CAFE Model also incorporated a handful of technologies not explicitly simulated in Autonomie. These technologies' performance either could not be captured on the 2-cycle test, or there was no robust data usable as an input for full-vehicle modeling and simulation. The specific technologies are discussed in the individual technology sections below and in TSD Chapter 3. To calculate fuel economy improvements attributable to these additional technologies, estimates of fuel consumption improvement factors were developed and scale multiplicatively when applied together. See TSD Chapter 3 for a complete discussion on how these factors were developed. The Autonomie-simulated results and additional technologies are combined, forming a single dataset used by the CAFE Model.

Each line in the CAFE Model dataset represents a unique combination of technologies. DOT organizes the records using a unique technology state vector,

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[74] *See* Autonomie model documentation, Chapter 5.2.10 Electric Machines System Weight.

[75] 40 CFR part 600.

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

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

[78] ''The 2020 EPA Automotive Trends Report, Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975,'' EPA–420–R–21–003, January 2021 [hereinafter 2020 EPA Automotive Trends Report].

or technology key (tech key), that describes the technology content associated with each unique record. The modeled 2-cycle fuel economy (miles per gallon) of each combination is converted into fuel consumption (gallons per mile) and then normalized relative to a baseline tech key. The improvement factors used by the model are a given combination's fuel consumption improvement relative to the baseline tech key in its technology class.

The tech key format was developed by recognizing that most of the technology pathways are unrelated and are only logically linked to designate the direction in which technologies are allowed to progress. As a result, it is possible to condense the paths into groups based on the specific technology. These groups are used to define the technology vector, or tech key. The following technology groups defined the tech key: Engine cam configuration (CONFIG), VVT engine technology (VVT), VVL engine technology (VVL), SGDI engine technology (SGDI), DEAC engine technology (DEAC), non-basic engine technologies (ADVENG), transmission technologies (TRANS), electrification and hybridization (ELEC), low rolling resistance tires (ROLL), aerodynamic improvements (AERO), mass reduction levels (MR), EFR engine technology (EFR), electric accessory improvement technologies (ELECACC), LDB technology (LDB), and SAX technology (SAX). This summarizes to a tech key with the following fields: CONFIG; VVT; VVL; SGDI; DEAC; ADVENG; TRANS; ELEC; ROLL; AERO; MR; EFR; ELECACC; LDB; SAX. It should be noted that some of the fields may be blank for some tech key combinations. These fields will be left visible for the examples below, but blank fields may be omitted from tech keys shown elsewhere in the documentation.

As an example, a technology state vector describing a vehicle with a SOHC engine, variable valve timing (only), a 6-speed automatic transmission, a belt-integrated starter generator, rolling resistance (level 1), aerodynamic improvements (level 2), mass reduction (level 1), electric power steering, and low drag brakes, would be specified as ''SOHC; VVT; ; ; ; ; AT6; BISG; ROLL10; AERO20; MR1; ; EPS; LDB ; .'' [79]

Once a vehicle is assigned (or mapped) to an appropriate tech key, adding a new technology to the vehicle simply represents progress from a previous tech key to a new tech key. The previous tech key refers to the technologies that are currently in use on a vehicle. The new tech key is determined, in the simulation, by adding a new technology to the combination represented by the previous state vector while simultaneously removing any technologies that are superseded by the newly added one.

For example, start with a vehicle with the tech key: SOHC; VVT; AT6; BISG; ROLL10; AERO20; MR1; EPS; LDB. Assume the simulation is evaluating PHEV20 as a candidate technology for application on this vehicle. The new tech key for this vehicle is computed by removing SOHC, VVT, AT6, and BISG technologies from the previous state vector,[80] and adding PHEV20, resulting a tech key that looks like this: PHEV20; ROLL10; AERO20; MR1; EPS; LDB.

From here, the simulation obtains a fuel economy improvement factor for the new combination of technologies and applies that factor to the fuel economy of a vehicle in the analysis fleet. The resulting improvement is applied to the original compliance fuel economy value for a discrete vehicle in the MY 2020 analysis fleet.

5. Defining Technology Adoption in the Rulemaking Timeframe

As discussed in Section III.C.2, starting with a fixed analysis fleet (for this analysis, the model year 2020 fleet indicated in manufacturers' early CAFE compliance data), the CAFE Model estimates ways each manufacturer could potentially apply specific fuel-saving technologies to specific vehicle model/configurations in response to, among other things (such as fuel prices), CAFE standards, CO_2 standards, commitments some manufacturers have made to CARB's ''Framework Agreement'', and ZEV mandates imposed by California and several other States. The CAFE Model follows a year-by-year approach to simulating manufacturers' potential decisions to apply technology, accounting for multiyear planning within the context of estimated schedules for future vehicle redesigns and refreshes during which significant technology changes may most practicably be implemented.

The modeled technology adoption for each manufacturer under each regulatory alternative depends on this representation of multiyear planning, and on a range of other factors represented by other model characteristics and inputs, such as the logical progression of technologies defined by the model's technology pathways; the technologies already present in the analysis fleet; inputs directing the model to ''skip'' specific technologies for specific vehicle model/configurations in the analysis fleet (*e.g.,* because secondary axle disconnect cannot be applied to 2-wheel-drive vehicles, and because manufacturers already heavily invested in engine turbocharging and downsizing are unlikely to abandon this approach in favor of using high compression ratios); inputs defining the sharing of engines, transmissions, and vehicle platforms in the analysis fleet; the model's logical approach to preserving this sharing; inputs defining each regulatory alternative's specific requirements; inputs defining expected future fuel prices, annual mileage accumulation, and valuation of avoided fuel consumption; and inputs defining the estimated efficacy and future cost (accounting for projected future ''learning'' effects) of included technologies; inputs controlling the maximum pace the simulation is to ''phase in'' each technology; and inputs further defining the availability of each technology to specific technology classes.

Two of these inputs—the ''phase-in cap'' and the ''phase-in start year''—apply to the manufacturer's entire estimated production and, for each technology, define a share of production in each model year that, once exceeded, will stop the model from further applying that technology to that manufacturer's fleet in that model year. The influence of these inputs varies with regulatory stringency and other model inputs. For example, setting the inputs to allow immediate 100% penetration of a technology will not guarantee any application of the technology if stringency increases are low and the technology is not at all cost effective. Also, even if these are set to allow only very slow adoption of a technology, other model aspects and inputs may nevertheless force more rapid application than these inputs, alone, would suggest (*e.g.,* because an engine technology propagates quickly due to sharing across multiple vehicles, or because BEV application must increase quickly in response to ZEV requirements). For this analysis, nearly

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[79] In the example tech key, the series of semicolons between VVT and AT6 correspond to the engine technologies which are not included as part of the combination, while the gap between MR1 and EPS corresponds to EFR and the omitted technology after LDB is SAX. The extra semicolons for omitted technologies are preserved in this example for clarity and emphasis and will not be included in future examples.

[80] For more discussion of how the CAFE Model handles technology supersession, *see* S4.5 of the CAFE Model Documentation.

all of these inputs are set at levels that do not limit the simulation at all.

As discussed below, for the most advanced engines (advanced cylinder deactivation, variable compression ratio, variable turbocharger geometry, and turbocharging with cylinder deactivation), DOT has specified phase-in caps and phase-in start years that limit the pace at which the analysis shows the technology being adopted in the rulemaking timeframe. For example, this analysis applies a 34% phase-in cap and MY 2019 phase-in start year for advanced cylinder deactivation (ADEAC), meaning that in MY 2021 (using a MY 2020 fleet, the analysis begins simulating further technology application in MY 2021), the model will stop adding ADEAC to a manufacturer's MY 2021 fleet once ADEAC reaches more than 68% penetration, because $34\% \times (2021 - 2019) = 34\% \times 2 = 68\%$.

This analysis also applies phase-in caps and corresponding start years to prevent the simulation from showing inconceivable rates of applying battery-electric vehicles (BEVs), such as showing that a manufacturer producing very few BEVs in MY 2020 could plausibly replace every product with a 300- or 400-mile BEV by MY 2025. Also, as discussed in Section III.D.4, this analysis applies phase-in caps and corresponding start years intended to ensure that the simulation's plausible application of the highest included levels of mass reduction (20% and 28.2% reductions of vehicle ''glider'' weight) do not, for example, outpace plausible supply of raw materials and development of entirely new manufacturing facilities.

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

6. Technology Costs

DOT estimates present and future costs for fuel-saving technologies taking into consideration the type of vehicle, or type of engine if 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. DMCs generally do not include the indirect costs of tools, capital equipment, financing costs, engineering, sales, administrative support or return on investment. DOT accounts for these indirect costs via a scalar markup of direct manufacturing costs (the retail price equivalent, or RPE). Finally, costs for technologies may change over time as industry streamlines design and manufacturing processes. To reflect this, DOT estimates potential cost improvements with learning effects (LE). The retail cost of equipment in any future year is estimated to be equal to the product of the DMC, RPE, and LE. Considering the retail cost of equipment, instead of merely direct manufacturing costs, is important to account for the real-world price effects of a technology, as well as market realities. Absent a Government mandate, motor vehicle manufacturers will not undertake expensive development and production efforts to implement technologies without realistic prospects of consumers being willing to pay enough for such technology to allow for the manufacturers to recover their investment.

(a) Direct Manufacturing Costs

Direct manufacturing costs (DMCs) are the component and assembly costs of the physical parts and systems that make up a complete vehicle. The analysis used 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. In the simplest cases, the agency-sponsored studies produced results that confirmed third-party industry estimates and aligned with confidential information provided by manufacturers and suppliers. In cases with a large difference between the tear-down study results and credible independent sources, DOT scrutinized the study assumptions, and sometimes revised or updated the analysis accordingly.

Due to the variety of technologies and their applications, and the cost and time required to conduct detailed tear-down analyses, the agency did not sponsor teardown studies for every technology. In addition, some fuel-saving technologies were considered that are pre-production or are sold in very small pilot volumes. For those technologies, DOT could not conduct a tear-down study to assess costs because the product is not yet in the marketplace for evaluation. In these cases, DOT relied upon third-party estimates and confidential information from suppliers and manufacturers; however, there are some common pitfalls with relying on confidential business information to estimate costs. The agency and the source may have had incongruent or incompatible definitions of ''baseline.'' 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, under no contractual obligation to DOT, may provide incomplete and/or misleading 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. The agency carefully evaluates new information in light of these common pitfalls, especially regarding emerging technologies.

While costs for fuel-saving technologies reflect the best estimates available today, technology cost estimates will likely change in the future as technologies are deployed and as production is expanded. For emerging technologies, DOT uses the best information available at the time of the analysis and will continue to update cost assumptions for any future analysis. The discussion of each category of technologies in Section III.D (*e.g.,* engines, transmissions, electrification) and corresponding TSD Chapter 3 summarizes the specific cost estimates DOT applied for this analysis.

(b) Indirect Costs (Retail Price Equivalent)

As discussed above, direct costs represent the cost associated with acquiring raw materials, fabricating parts, and assembling vehicles with the various technologies manufacturers are expected to use to meet future CAFE standards. 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. All of these items contribute to the price consumers ultimately pay for the vehicle. These components of retail prices are illustrated in Table III–3 below.

Table III-3 – Retail Price Components

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

To estimate the impact of higher vehicle prices on consumers, both direct and indirect costs must be considered. To estimate total consumer costs, DOT multiplies direct manufacturing costs by an indirect cost factor to represent the average price for fuel-saving technologies at retail.

Historically, the method most commonly used to estimate indirect costs of producing a motor vehicle has been the retail price equivalent (RPE). The RPE markup factor is based on an examination of historical financial data contained in 10–K reports filed by manufacturers with the Securities and Exchange Commission (SEC). It represents the ratio between the retail price of motor vehicles and the direct costs of all activities that manufacturers engage in.

Figure III–4 indicates that 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. This ratio has been remarkably consistent, averaging roughly 1.5 with minor variations from year to year over this period. At no point has the RPE markup exceeded 1.6 or fallen below 1.4.[81] During this time frame, the average annual increase in real direct costs was 2.5 percent, and the average annual increase in real indirect costs was also 2.5 percent. Figure III–4 illustrates the historical relationship between retail prices and direct manufacturing costs.[82]

An RPE of 1.5 does not imply that manufacturers automatically mark up each vehicle by exactly 50 percent. Rather, it means that, over time, the competitive marketplace has resulted in pricing structures that average out to this relationship across the entire industry. Prices for any individual model may be marked up at a higher or lower rate depending on market demand. The consumer who buys a popular vehicle may, in effect, subsidize the installation of a new technology in a less marketable vehicle. But, on average, over time and across the vehicle fleet, the retail price paid by consumers has risen by about $1.50 for each dollar of direct costs incurred by manufacturers.

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

[82] Rogozhin, A., Gallaher, M., & McManus, W., 2009, Automobile Industry Retail Price Equivalent and Indirect Cost Multipliers. Report by RTI International to Office of Transportation Air Quality. U.S. Environmental Protection Agency, RTI Project Number 0211577.002.004, February, Research Triangle Park, NC.

Spinney, B.C., Faigin, B., Bowie, N., & St. Kratzke, 1999, Advanced Air Bag Systems Cost, Weight, and Lead Time analysis Summary Report, Contract NO. DTNH22–96–0–12003, Task Orders—001, 003, and 005. Washington, DC, U.S. Department of Transportation.

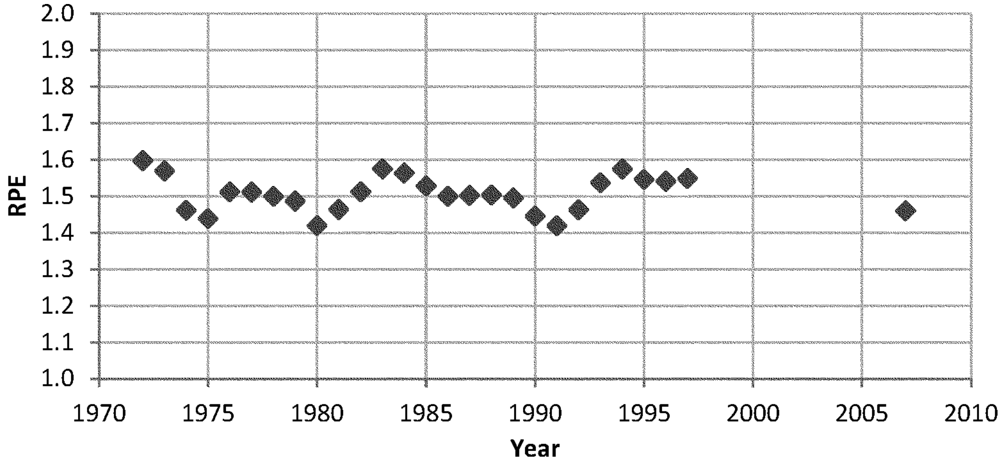

Figure III-4 – Historical Data for Retail Price Equivalent (RPE), 1972-1997 and 2007

It is also important to note that direct costs associated with any specific technology will change over time as some combination of learning and resource price changes occurs. Resource costs, such as the price of steel, can fluctuate over time and can experience real long-term trends in either direction, depending on supply and demand. However, the normal learning process generally reduces direct production costs as manufacturers refine production techniques and seek out less costly parts and materials for increasing production volumes. By contrast, this learning process does not generally influence indirect costs. The implied RPE for any given technology would thus be expected to grow over time as direct costs decline relative to indirect costs. The RPE for any given year is based on direct costs of technologies at different stages in their learning cycles, and that may have different implied RPEs than they did in previous years. 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.

The RPE has been used in all NHTSA safety and most previous CAFE rulemakings to estimate costs. In 2011, the National Academy of Sciences recommended RPEs of 1.5 for suppliers and 2.0 for in-house production be used to estimate total costs.[83] The Alliance of Automobile Manufacturers also advocates these values as appropriate markup factors for estimating costs of technology changes.[84] In their 2015 report, the National Academy of Sciences recommend 1.5 as an overall RPE markup.[85] An RPE of 2.0 has also been adopted by a coalition of environmental and research groups (Northeast States Center for a Clean Air Future (NESCCAF), International Council on Clean Transportation (ICCT), Southwest Research Institute, and TIAX–LLC) in a report on reducing heavy truck emissions, and 2.0 is recommended by the U.S. Department of Energy for estimating the cost of hybrid-electric and automotive fuel cell costs (see Vyas et al. (2000) in Table III–4 below). Table III–4 below also lists other estimates of the RPE. Note that all RPE estimates vary between 1.4 and 2.0, with most in the 1.4 to 1.7 range.

Table III–4—Alternate Estimates of the RPE[86]

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[83] Effectiveness and Impact of Corporate Average Fuel Economy Standards, Washington, DC—The National Academies Press; NRC, 2011.

[84] Communication from Chris Nevers (Alliance) to Christopher Lieske (EPA) and James Tamm (NHTSA), *http://www.regulations.gov* Docket ID Nos. NHTSA–2018–0067; EPA–HQ–OAR–2018–0283, p.143.

[85] National Research Council 2015. Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light Duty Vehicles. Washington, DC: The National Academies Press. *https://doi.org/10.17226/21744* [hereinafter 2015 NAS report].

[86] Duleep, K.G. *2008 Analysis of Technology Cost and Retail Price.* Presentation to Committee on Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy, January 25, Detroit, MI.; Jack Faucett Associates, September 4, 1985. Update of EPA's Motor Vehicle Emission Control Equipment Retail Price Equivalent (RPE) Calculation Formula. Chevy Chase, MD—Jack Faucett Associates; McKinsey & Company, October 2003. Preface to the Auto Sector Cases. *New Horizons—Multinational Company Investment in Developing Economies,* San Francisco, CA.; NRC (National Research Council), 2002. Effectiveness and Impact of Corporate Average Fuel Economy Standards, Washington, DC—The National Academies Press; NRC, 2011. Assessment of Fuel Economy Technologies for Light Duty Vehicles. Washington, DC—The National Academies Press; Cost, Effectiveness, and Deployment of Fuel Economy Technologies in Light Duty Vehicles. Washington, DC—The National Academies Press, 2015; Sierra Research, Inc., November 21, 2007, Study of Industry-Average Mark-Up Factors used to Estimate Changes in Retail Price Equivalent (RPE) for Automotive Fuel Economy and Emissions Control Systems, Sacramento, CA—Sierra Research, Inc.; Vyas, A. Santini, D., & Cuenca, R. 2000. Comparison of Indirect Cost Multipliers for Vehicle Manufacturing. Center for Transportation Research, Argonne National Laboratory, April. Argonne, Ill.

Table III-4 – Alternate Estimates of the RPE[86]

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 original equipment manufacturer (OEM), electric, and hybrid vehicles
NRC, 2002	1.4 (corrected to > by Duleep)
McKinsey and Company, 2003	1.7 based on European study
CARB, 2004	1.4 (derived using the JFA initial 1.26 value, not the corrected 1.7+ value)
Sierra Research for AAA, 2007	2.0 or >, based on Chrysler data
Duleep, 2008	1.4, 1.56, 1.7 based on integration complexity
NRC, NAS 2011	1.5 for Tier 1 supplier, 2.0 for OEM
NRC, NAS 2015	1.5 for OEM

The RPE has thus enjoyed widespread use and acceptance by a variety of governmental, academic, and industry organizations.

In past rulemakings, a second type of indirect cost multiplier has also been examined. Known as the ''Indirect Cost Multiplier'' (ICM) approach, ICMs were first examined alongside the RPE approach in the 2010 rulemaking regarding standards for MYs 2012–2016 (75 FR 25324, May 7, 2010). Both methods have been examined in subsequent rulemakings.

Consistent with the 2020 final rule, we continue to employ the RPE approach to account for indirect manufacturing costs. The RPE accounts for indirect costs like engineering, sales, and administrative support, as well as other overhead costs, business expenses, warranty costs, and return on capital considerations. A detailed discussion of indirect cost methods and the basis for our use of the RPE to reflect these costs is available in the Final Regulatory Impact Analysis (FRIA) for the 2020 final rule.[87]

(c) Stranded Capital Costs

The idea behind stranded capital is that 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.

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

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

(d) Cost Learning

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. Typically, a representation of this cost learning, or learning curves, reflects initial learning rates that are relatively high, followed by slower learning as additional improvements are made and production efficiency peaks. This eventually produces an asymptotic shape to the learning curve, as small percent decreases are applied to gradually declining cost levels. These learning curve estimates are applied to various technologies that are used to meet CAFE standards.

We estimate cost learning by considering methods established by T.P. Wright and later expanded upon by J.R. Crawford.[88] [89] 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

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[87] Final Regulatory Impact Analysis, The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Year 2021–2026 Passenger Cars and Light Trucks, USDOT, EPA, March 2020, at 354–76.

[88] Wright, T.P., Factors Affecting the Cost of Airplanes. *Journal of Aeronautical Sciences,* Vol. 3 (1936), at 124–25. Available at *http://www.uvm.edu/pdodds/research/papers/others/1936/wright1936a.pdf.*

[89] Crawford, J.R., *Learning Curve, Ship Curve, Ratios, Related Data,* Burbank, California-Lockheed Aircraft Corporation (1944).

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

As pictured in Figure III–5, Wright's learning curve shows the first unit is produced at a cost of $1,000. Initially cost per unit falls rapidly for each successive unit produced. However, as production continues, cost falls more gradually at a decreasing rate. For each doubling of cumulative production at any level, cost per unit declines 20 percent, so that 80 percent of cost is retained. The CAFE Model uses the basic approach by Wright, where cost reduction is estimated by applying a fixed percentage to the projected cumulative production of a given fuel economy technology.

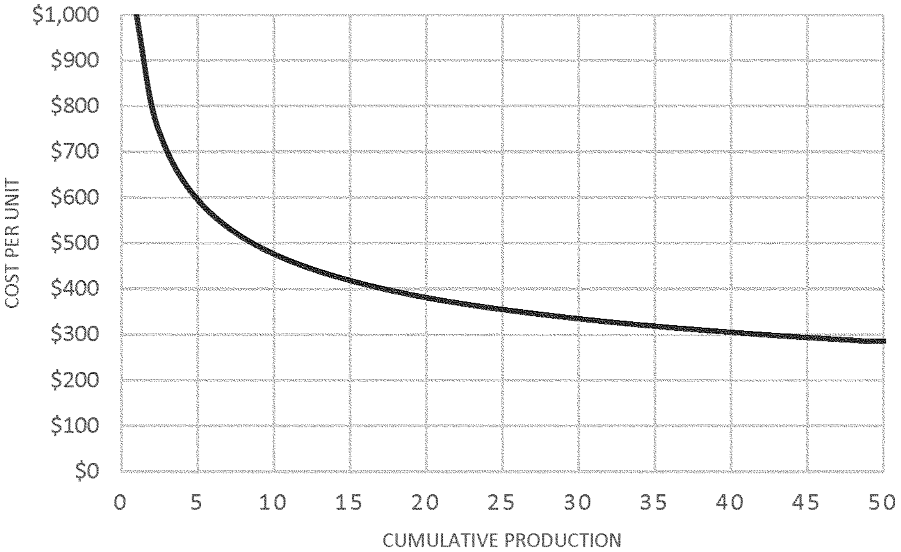

Figure III-5 – Wright's Learning Curve (Progress Ratio = 0.8)

The analysis accounts for learning effects with model year-based cost learning forecasts for each technology that reduces direct manufacturing costs over time. We evaluate the historical use of technologies, and reviews industry forecasts to estimate future volumes to develop the model year-based technology cost learning curves.

The following section discusses the development of model year-based cost learning forecasts for this analysis, including how the approach has evolved from the 2012 rulemaking for MY 2017–2025 vehicles, and how the progress ratios were developed for different technologies considered in the analysis. Finally, we discuss how these learning effects are applied in the CAFE Model.

(1) Time Versus Volume-Based Learning

For the 2012 joint CAFE and GHG rulemaking, DOT developed learning curves as a function of vehicle model year.[90] Although the concept of this methodology is derived from Wright's cumulative production volume-based learning curve, its application for CAFE technologies was more of a function of time. More than a dozen learning curve schedules were developed, varying between fast and slow learning, and assigned to each technology corresponding to its level of complexity and maturity. The schedules were applied to the base year of direct manufacturing cost and incorporate a percentage of cost reduction by model year, declining at a decreasing rate through the technology's production life. Some newer technologies experience 20 percent cost reductions for introductory model years, while mature or less complex technologies experience 0–3 percent cost reductions over a few years.

In their 2015 report to Congress, the National Academy of Sciences (NAS) recommended NHTSA should "continue to conduct and review empirical evidence for the cost reductions that occur in the automobile industry with volume, especially for large-volume technologies that will be relied on to meet the CAFE/GHG standards." [91]

In response, we incorporated statically projected cumulative volume production data of fuel economy-improving technologies, representing an improvement over the previously used time-based method. Dynamic projections of cumulative production are not feasible with current CAFE Model capabilities, so one set of projected cumulative production data for most vehicle technologies was developed for the purpose of determining cost impact. We obtained historical cumulative production data for many technologies produced and/or sold in the U.S. to establish a starting point for learning schedules. Groups of similar technologies or technologies of similar complexity may share identical learning schedules.

The slope of the learning curve, which determines the rate at which cost reductions occur, has been estimated using research from an extensive literature review and automotive cost tear-down reports (see below). The slope of the learning curve is derived from the progress ratio of manufacturing automotive and other mobile source technologies.

(2) Deriving the Progress Ratio Used in This Analysis

Learning curves vary among different types of manufactured products. Progress ratios can range from 70 to 100

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[90] 77 FR 62624 (Oct. 15, 2012).

[91] National Research Council 2015. Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles. Washington, DC: The National Academies Press. *https://doi.org/10.17226/21744.*

percent, where 100 percent indicates no learning can be achieved.[92] Learning effects tend to be greatest in operations where workers often touch the product, while effects are less substantial in operations consisting of more automated processes. As automotive manufacturing plant processes become increasingly automated, a progress ratio towards the higher end would seem more suitable. We incorporated findings from automotive cost-teardown studies with EPA's 2015 literature review of learning-related studies to estimate a progress ratio used to determine learning schedules of fuel economy-improving technologies.

EPA's literature review examined and summarized 20 studies related to learning in manufacturing industries and mobile source manufacturing.[93] The studies focused on many industries, including motor vehicles, ships, aviation, semiconductors, and environmental energy. Based on several criteria, EPA selected five studies providing quantitative analysis from the mobile source sector (progress ratio estimates from each study are summarized in Table III–5, below). Further, those studies expand on Wright's learning curve function by using cumulative output as a predictor variable, and unit cost as the response variable. As a result, EPA determined a best estimate of 84 percent as the progress ratio in mobile source industries. However, of those five studies, EPA at the time placed less weight on the Epple et al. (1991) study, because of a disruption in learning due to incomplete knowledge transfer from the first shift to introduction of a second shift at a North American truck plant. While learning may have decelerated immediately after adding a second shift, we note that unit costs continued to fall as the organization gained experience operating with both shifts. We recognize that disruptions are an essential part of the learning process and should not, in and of themselves, be discredited. For this reason, the analysis uses a re-estimated average progress ratio of 85 percent from those five studies (equally weighted).

Table III-5 – Progress Ratios from EPA's Literature Review

Author (Publication Date)	Industry	Progress Ratio (Cumulative Output Approach)
Argote et al. (1997)[94]	Trucks	85%
Benkard (2000)[95]	Aircraft (commercial)	82%
Epple et al. (1991)[96]	Trucks	90%
Epple et al. (1996)[97]	Trucks	85%
Levitt et al. (2013)[98]	Automobiles	82%

In addition to EPA's literature review, this progress ratio estimate was informed based on findings from automotive cost-teardown studies. NHTSA routinely performs evaluations of costs of previously issued Federal Motor Vehicle Safety Standards (FMVSS) for new motor vehicles and equipment. NHTSA engages contractors to perform detailed engineering "tear-down" analyses for representative samples of vehicles, to estimate how much specific FMVSS add to the weight and retail price of a vehicle. As part of the effort, the agency examines cost and production volume for automotive safety technologies. In particular, we estimated costs from multiple cost tear-down studies for technologies with actual production data from the *Cost and weight added by the Federal Motor Vehicle Safety Standards for MY 1968–2012 passenger cars and LTVs* (2017).[99]

We chose five vehicle safety technologies with sufficient data to estimate progress ratios of each, because these technologies are large-volume technologies and are used by almost all vehicle manufacturers. Table III–6 includes these five technologies and yields an average progress rate of 92 percent.

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[92] Martin, J., "What is a Learning Curve?" Management and Accounting Web, University of South Florida, available at: *https://www.maaw.info/LearningCurveSummary.htm.*

[93] *Cost Reduction through Learning in Manufacturing Industries and in the Manufacture of Mobile Sources,* United States Environmental Protection Agency (2015). Prepared by ICF International and available at *https://19january2017snapshot.epa.gov/sites/production/files/2016–11/documents/420r16018.pdf.*

[94] Argote, L., Epple, D., Rao, R. D., & Murphy, K., *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).

[95] Benkard, C. L., *Learning and Forgetting—The Dynamics of Aircraft Production*, The American Economic Review, Vol. 90(4), at 1034–54 (2000).

[96] Epple, D., Argote, L., & Devadas, R., *Organizational Learning Curves—A Method for Investigating Intra-Plant Transfer of Knowledge Acquired through Learning by Doing*, Organization Science, Vol. *2*(1), at 58–70 (1991).

[97] Epple, D., Argote, L., & Murphy, K., *An Empirical Investigation of the Microstructure of Knowledge Acquisition and Transfer through Learning by Doing*, Operations Research, Vol. 44(1), at 77–86 (1996).

[98] Levitt, S. D., List, J. A., & Syverson, C., *Toward an Understanding of Learning by Doing—Evidence from an Automobile Assembly Plant*, Journal of Political Economy, Vol. 121 (4), at 643–81 (2013).

[99] 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). Washington, DC—National Highway Traffic Safety Administration (November 2017), at 30–33.

Table III-6 – Progress Ratios Researched by NHTSA

Technology	Progress Ratio
Anti-lock Brake Systems	87%
Driver Airbags	93%
Manual 3-pt lap shoulder safety belts	96%
Adjustable Head Restraints	91%
Dual Master Cylinder	95%

For the final progress ratio used in the CAFE Model, the five progress rates from EPA's literature review and five progress rates from NHTSA's evaluation of automotive safety technologies results were averaged. This resulted in an average progress rate of approximately 89 percent. We placed equal weight on progress ratios from all 10 sources. More specifically, we placed equal weight on the *Epple et al. (1991)* study, because disruptions have more recently been recognized as an essential part in the learning process, especially in an effort to increase the rate of output.

(3) Obtaining Appropriate Baseline Years for Direct Manufacturing Costs

DOT obtained direct manufacturing costs for each fuel economy-improving technology from various sources, as discussed above. To establish a consistent basis for direct manufacturing costs in the rulemaking analysis, we adjusted each technology cost to MY 2018 dollars. For each technology, the DMC is associated with a specific model year, and sometimes a specific production volume, or cumulative production volume. The base model year is established as the MY in which direct manufacturing costs were assessed (with learning factor of 1.00). With the aforementioned data on cumulative production volume for each technology and the assumption of a 0.89 progress ratio for all automotive technologies, we can solve for an implied cost for the first unit produced. For some technologies, we used modestly different progress ratios to match detailed cost projections if available from another source (for instance, batteries for plug-in hybrids and battery electric vehicles).

This approach produces reasonable estimates for technologies already in production, and some additional steps are required to set appropriate learning rates for technologies not yet in production. Specifically, for technologies not yet in production in MY 2017, the cumulative production volume in MY 2017 is zero, because manufacturers have not yet produced the technologies. For pre-production cost estimates in previous CAFE rulemakings, we often relied on confidential business information sources to predict future costs. Many sources for pre-production cost estimates include significant learning effects, often providing cost estimates assuming high volume production, and often for a timeframe late in the first production generation or early in the second generation of the technology. Rapid doubling and re-doubling of a low cumulative volume base with Wright's learning curves can provide unrealistic cost estimates. In addition, direct manufacturing cost projections can vary depending on the initial production volume assumed. Accordingly, we carefully examined direct costs with learning, and made adjustments to the starting point for those technologies on the learning curve to better align with the assumptions used for the initial direct cost estimate.

(4) Cost Learning Applied in the CAFE Model

For this analysis, we applied learning effects to the incremental cost over the null technology state on the applicable technology tree. After this step, we calculated year-by-year incremental costs over preceding technologies on the tech tree to create the CAFE Model inputs.[100] The shift from incremental cost accounting to absolute cost accounting in recent CAFE analyses made cost inputs more transparently relatable to detailed model output, and relevant to this discussion, made it easier to apply learning curves in the course of developing inputs to the CAFE Model.

We grouped certain technologies, such as advanced engines, advanced transmissions, and non-battery electric components and assigned them to the same learning schedule. While these grouped technologies differ in operating characteristics and design, we chose to group them based on their complexity, technology integration, and economies of scale across manufacturers. The low volume of certain advanced technologies, such as hybrid and electric technologies, poses a significant issue for suppliers and prevents them from producing components needed for advanced transmissions and other technologies at more efficient high scale production. The technology groupings consider market availability, complexity of technology integration, and production volume of the technologies that can be implemented by manufacturers and suppliers. For example, technologies like ADEAC and VCR are grouped together; these technologies were not in production or were only in limited introduction in MY 2017 and are planned to be introduced in limited production by a few manufacturers. The details of these technologies are discussed in Section III.D.

In addition, we expanded model inputs to extend the explicit simulation of technology application through MY 2050. Accordingly, we updated the learning curves for each technology group to cover MYs through 2050. For MYs 2017–2032, we expect incremental improvements in all technologies, particularly in electrification technologies because of increased production volumes, labor efficiency, improved manufacturing methods, specialization, network building, and other factors. While these and other factors contribute to continual cost learning, we believe that many fuel economy-improving technologies considered in this rule will approach a flat learning level by the early 2030s. Specifically, older and less complex internal combustion engine technologies and transmissions will reach a flat learning curve sooner when compared to electrification technologies, which have more opportunity for improvement. For batteries and non-battery electrification components, we estimated a steeper learning curve that

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[100] These costs are located in the CAFE Model Technologies file.

will gradually flatten after MY 2040. For a more detailed discussion of the electrification learning curves, see Section III.D.3.

Each technology in the CAFE Model is assigned a learning schedule developed from the methodology explained previously. For example, the following chart shows learning rates for several technologies applicable to midsize sedans, demonstrating that while we estimate that such learning effects have already been almost entirely realized for engine turbocharging (a technology that has been in production for many years), we estimate that significant opportunities to reduce the cost of the greatest levels of mass reduction (*e.g.,* MR5) remain, and even greater opportunities remain to reduce the cost of batteries for HEVs, PHEVs, BEVs. In fact, for certain advanced technologies, we determined that the results predicted by the standard learning curves progress ratio was not realistic, based on unusual market price and production relationships. For these technologies, we developed specific learning estimates that may diverge from the 0.89 progress rate. As shown in Figure III–6, these technologies include: turbocharging and downsizing level 1 (TURBO1), variable turbo geometry electric (VTGE), aerodynamic drag reduction by 15 percent (AERO15), mass reduction level 5 (MR5), 20 percent improvement in low-rolling resistance tire technology (ROLL20) over the baseline, and battery integrated starter/generator (BISG).

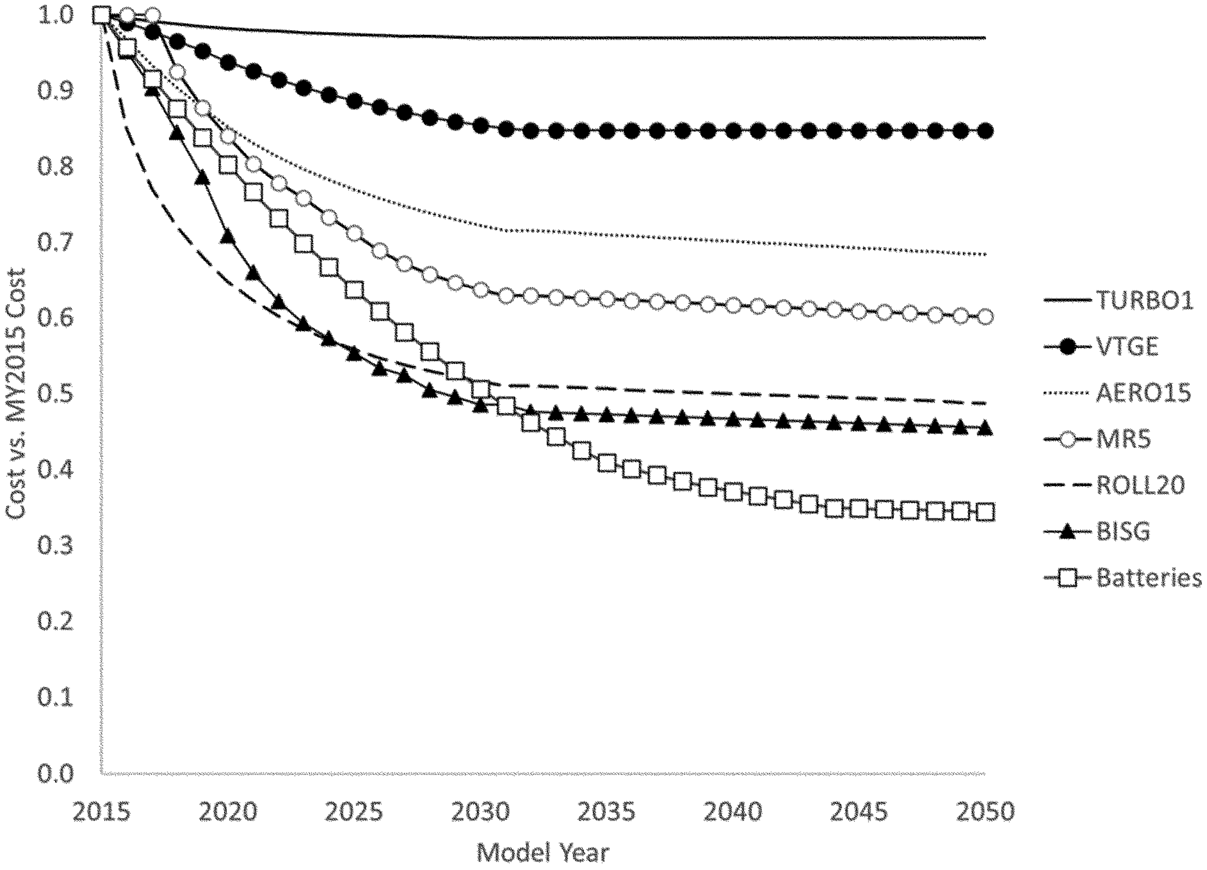

Figure III-6 – Examples of Year-by-Year Cost Learning Effects (Midsize Sedan)

(e) Cost Accounting

To facilitate specification of detailed model inputs and review of detailed model outputs, the CAFE Model continues to use absolute cost inputs relative to a known base component cost, such that the estimated cost of each technology is specified relative to a common reference point for the relevant technology pathway. For example, the cost of a 7-speed transmission is specified relative to a 5-speed transmission, as is the cost of every other transmission technology. Conversely, in some earlier versions of the CAFE Model, *incremental cost* inputs were estimated relative to the technology immediately preceding on the relevant technology pathway. For our 7-speed transmission example, the incremental cost would be relative to a 6-speed transmission. This change in the structure of cost inputs does not, by itself, change model results, but it does make the connection between these inputs and corresponding outputs more transparent. The CAFE Model Documentation accompanying our analysis presents details of the structure for model cost inputs.[101] The individual technology sections in Section III.D provide a detailed discussion of cost accounting for each technology.

7. Manufacturer's Credit Compliance Positions

This proposed rule involves a variety of provisions regarding ''credits'' and other compliance flexibilities. Some regulatory provisions allow a manufacturer to earn ''credits'' that will

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[101] CAFE Model Documentation, S4.7.

be counted toward a vehicle's rated CO_2 emissions level, or toward a fleet's rated average CO_2 or CAFE level, without reference to required levels for these average levels of performance. Such flexibilities effectively modify emissions and fuel economy test procedures or methods for calculating fleets' CAFE and average CO_2 levels. Other provisions (for CAFE, statutory provisions) allow manufacturers to earn credits by achieving CAFE or average CO_2 levels beyond required levels; these provisions may hence more appropriately be termed ''compliance credits.'' We described in the 2020 final rule how the CAFE Model simulates these compliance credit provisions for both the CAFE program and for EPA's CO_2 standards.[102] For this analysis, we modeled the no-action and action alternatives as a set of CAFE standards in place simultaneously with EPA baseline (*i.e.,* 2020 final) CO_2 standards, related CARB agreements with five manufacturers, and ZEV mandates in place in California and some other states. The modeling of CO_2 standards and standard-like contractual obligations includes our representation of applicable credit provisions.

EPCA has long provided that, by exceeding the CAFE standard applicable to a given fleet in a given model year, a manufacturer may earn corresponding ''credits'' that the same manufacturer may, within the same regulatory class, apply toward compliance in a different model year. EISA amended these provisions by providing that manufacturers may, subject to specific statutory limitations, transfer compliance credits between regulatory classes and trade compliance credits with other manufacturers. The CAA provides the EPA with broad standard-setting authority for the CO_2 program, with no specific directives regarding CO_2 standards or CO_2 compliance credits.

EPCA also specifies that NHTSA may not consider the availability of CAFE credits (for transfer, trade, or direct application) toward compliance with new standards when establishing the standards themselves.[103] Therefore, this analysis excludes model years 2024–2026 from those in which carried-forward or transferred credits can be applied for the CAFE program.

The ''unconstrained'' perspective acknowledges that these flexibilities exist as part of the program and, while not considered by NHTSA in setting standards, are nevertheless important to consider when attempting to estimate the real impact of any alternative. Under the ''unconstrained'' perspective, credits may be earned, transferred, and applied to deficits in the CAFE program throughout the full range of model years in the analysis. The Draft Supplemental Environmental Impact Statement (SEIS) accompanying this proposed rule, like the corresponding SEIS analysis, presents ''unconstrained'' modeling results. Also, because the CAA provides no direction regarding consideration of any CO_2 credit provisions, this analysis includes simulation of carried-forward and transferred CO_2 credits in all model years.

The CAFE Model, therefore, does provide means to simulate manufacturers' potential application of some compliance credits, and both the analysis of CO_2 standards and the NEPA analysis of CAFE standards do make use of this aspect of the model. On the other hand, 49 U.S.C. 32902(h) prevents NHTSA from, in its standard setting analysis, considering the potential that manufacturers could use compliance credits in model years for which the agency is establishing maximum feasible CAFE standards. Further, as discussed below, we also continue to find it appropriate for the analysis largely to refrain from simulating two of the mechanisms allowing the use of compliance credits.

The CAFE Model's approach to simulating compliance decisions accounts for the potential to earn and use CAFE credits as provided by EPCA/EISA. The model similarly accumulates and applies CO_2 credits when simulating compliance with EPA's standards. Like past versions, the current CAFE Model can simulate credit carry-forward (*i.e.,* banking) between model years and transfers between the passenger car and light truck fleets but not credit carry-back (*i.e.,* borrowing) from future model years or trading between manufacturers.

While NHTSA's ''unconstrained'' evaluation can consider the potential to carry back compliance credits from later to earlier model years, past examples of failed attempts to carry back CAFE credits (*e.g.,* a MY 2014 carry back default leading to a civil penalty payment) underscore the riskiness of such ''borrowing.'' Recent evidence indicates manufacturers are disinclined to take such risks, and we find it reasonable and prudent to refrain from attempting to simulate such ''borrowing'' in rulemaking analysis.

Like the previous version, the current CAFE Model provides a basis to specify (in model inputs) CAFE credits available from model years earlier than those being explicitly simulated. For example, with this analysis representing model years 2020–2050 explicitly, credits earned in the model year 2015 are made available for use through the model year 2020 (given the current five-year limit on carry-forward of credits). The banked credits are specific to both the model year and fleet in which they were earned.

To increase the realism with which the model transitions between the early model years (MYs 2020–2023) and the later years that are the subject of this action, we have accounted for the potential that some manufacturers might trade credits earned prior to 2020 to other manufacturers. However, the analysis refrains from simulating the potential that manufacturers might continue to trade credits during and beyond the model years covered by this action. In 2018 and 2020, the analysis included idealized cases simulating ''perfect'' (*i.e.,* wholly unrestricted) trading of CO_2 compliance credits by treating all vehicles as being produced by a single manufacturer. Even for CO_2 compliance credit trading, these scenarios were not plausible, because it is exceedingly unlikely that some pairs of manufacturers would trade compliance credits. NHTSA did not include such cases for CAFE compliance credits, because EPCA provisions (such as the minimum domestic passenger car standard requirement) make such scenarios impossible. At this time, we remain concerned that any realistic simulation of such trading would require assumptions regarding which specific pairs of manufacturers might trade compliance credits, and the evidence to date makes it clear that the credit market is far from fully ''open.''

We also remain concerned that to set standards based on an analysis that presumes the use of program flexibilities risks making the corresponding actions mandatory. Some flexibilities—credit carry-forward (banking) and transfers between fleets in particular—involve little risk because they are internal to a manufacturer and known in advance. As discussed above, credit carry-back involves significant risk because it amounts to borrowing against future improvements, standards, and production volume and mix. Similarly, credit trading also involves significant risk, because the ability of manufacturer A to acquire credits from manufacturer B depends not just on manufacturer B actually earning the expected amount of credit, but also on manufacturer B being willing to trade with manufacturer A, and on potential interest by other manufacturers. Manufacturers' compliance plans have

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[102] *See* 85 FR 24174, 24303 (April 30, 2020).

[103] 49 U.S.C. 32902(h)(3).

already evidenced cases of compliance credit trades that were planned and subsequently aborted, reinforcing our judgment that, like credit banking, credit trading involves too much risk to be included in an analysis that informs decisions about the stringency of future standards.

As discussed in the CAFE Model Documentation, the model's default logic attempts to maximize credit carry-forward—that is, to ''hold on'' to credits for as long as possible. If a manufacturer needs to cover a shortfall that occurs when insufficient opportunities exist to add technology to achieve compliance with a standard, the model will apply credits. Otherwise, the manufacturer carries forward credits until they are about to expire, at which point it will use them before adding technology that is not considered cost-effective. The model attempts to use credits that will expire within the next three years as a means to smooth out technology applications over time to avoid both compliance shortfalls and high levels of over-compliance that can result in a surplus of credits. Although it remains impossible precisely to predict the manufacturer's actual earning and use of compliance credits, and this aspect of the model may benefit from future refinement as manufacturers and regulators continue to gain experience with these provisions, this approach is generally consistent with manufacturers' observed practices.

NHTSA introduced the CAFE Public Information Center (PIC) to provide public access to a range of information regarding the CAFE program,[104] including manufacturers' credit balances. However, there is a data lag in the information presented on the CAFE PIC that may not capture credit actions across the industry for as much as several months. Furthermore, CAFE credits that are traded between manufacturers are adjusted to preserve the gallons saved that each credit represents.[105] The adjustment occurs at the time of application rather than at the time the credits are traded. This means that a manufacturer who has acquired credits through trade, but has not yet applied them, may show a credit balance that is either considerably higher or lower than the real value of the credits when they are applied. For example, a manufacturer that buys 40 million credits from Tesla may show a credit balance in excess of 40 million. However, when those credits are applied, they may be worth only 1/10 as much—making that manufacturer's true credit balance closer to 4 million than 40 million (*e.g.,* when another manufacturer uses credits acquired from Tesla, the manufacturer may only be able to offset a 1 mpg compliance shortfall, even though the credits' ''face value'' suggests the manufacturer could offset a 10 mpg compliance shortfall).

Specific inputs accounting for manufacturers' accumulated compliance credits are discussed in TSD Chapter 2.2.2.3.

In addition to the inclusion of these existing credit banks, the CAFE Model also updated its treatment of credits in the rulemaking analysis. EPCA requires that NHTSA set CAFE standards at maximum feasible levels for each model year without consideration of the program's credit mechanisms. However, as recent CAFE rulemakings have evaluated the effects of standards over longer time periods, the early actions taken by manufacturers required more nuanced representation. Accordingly, the CAFE Model now provides means to exclude the simulated application of CAFE compliance credits only from specific model years for which standards are being set (for this analysis, 2024–2026), while allowing CAFE credits to be applied in other model years.

In addition to more rigorous accounting of CAFE and CO_2 compliance credits, the model also accounts for air conditioning efficiency and off-cycle adjustments. NHTSA's program considers those adjustments in a manufacturer's compliance calculation starting in MY 2017, and specific estimates of each manufacturer's reliance on these adjustments are discussed above in Section III.C.2.a). Because air conditioning efficiency and off-cycle adjustments are not credits in NHTSA's program, but rather adjustments to compliance fuel economy, they may be included under either a ''standard setting'' or ''unconstrained'' analysis perspective.

The manner in which the CAFE Model treats the EPA and CAFE A/C efficiency and off-cycle credit programs is similar, but the model also accounts for A/C leakage (which is not part of NHTSA's program). When determining the compliance status of a manufacturer's fleet (in the case of EPA's program, PC and LT are the only fleet distinctions), the CAFE Model weighs future compliance actions against the presence of existing (and expiring) CO_2 credits resulting from over-compliance with earlier years' standards, A/C efficiency credits, A/C leakage credits, and off-cycle credits.

The model currently accounts for any off-cycle adjustments associated with technologies that are included in the set of fuel-saving technologies explicitly simulated as part of this proposal (for example, start-stop systems that reduce fuel consumption during idle or active grille shutters that improve aerodynamic drag at highway speeds) and accumulates these adjustments up to the cap. As discussed further in Section III.D.8, this analysis considers that some manufacturers may apply up to 15.0 g/mi of off-cycle credit by MY 2032. We considered the potential to model the application of off-cycle technologies explicitly. However, doing so would require data regarding which vehicle models already possess these improvements as well as the cost and expected value of applying them to other models in the future. Such data are currently too limited to support explicit modeling of these technologies and adjustments.

When establishing maximum feasible fuel economy standards, NHTSA is prohibited from considering the availability of alternatively fueled vehicles,[106] and credit provisions related to AFVs that significantly increase their fuel economy for CAFE compliance purposes. Under the ''standard setting'' perspective, these technologies (pure battery electric vehicles and fuel cell vehicles[107]) are not available in the compliance simulation to improve fuel economy. Under the ''unconstrained'' perspective, such as is documented in the SEIS, the CAFE Model considers these technologies in the same manner as other available technologies and may apply them if they represent cost-effective compliance pathways. However, under both perspectives, the analysis continues to include dedicated AFVs that could be produced in response to CAFE standards outside the model years for which standards are being set, or for other reasons (*e.g.,* ZEV mandates, as accounted for in this analysis).

EPCA also provides that CAFE levels may, subject to limitations, be adjusted upward to reflect the sale of flexible fuel vehicles (FFVs). Because these adjustments ended in model year 2020, this analysis assumes no manufacturer

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[104] CAFE Public Information Center, *https://one.nhtsa.gov/cafe_pic/cafe_pic_home.htm* (last visited May 11, 2021).

[105] CO_2 credits for EPA's program are denominated in metric tons of CO_2 rather than gram/mile compliance credits and require no adjustment when traded between manufacturers or fleets.

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

[107] Dedicated compressed natural gas (CNG) vehicles should also be excluded in this perspective but are not considered as a compliance strategy under any perspective in this analysis.

will earn FFV credits within the modeling horizon.

Also, the CAA provides no direction regarding consideration of alternative fuels, and EPA has provided that manufacturers selling PHEVs, BEVs, and FCVs may, when calculating fleet average CO_2 levels, ''count'' each unit of production as more than a single unit. The CAFE Model accounts for these ''multipliers.'' For example, under EPA's current regulation, when calculating the average CO_2 level *achieved* by its MY 2019 passenger car fleet, a manufacturer may treat each 1,000 BEVs as 2,000 BEVs. When calculating the average level *required* of this fleet, the manufacturer must use the actual production volume (in this example, 1,000 units). Similarly, the manufacturer must use the actual production volume when calculating compliance credit balances.

There were no natural gas vehicles in the baseline fleet, and the analysis did not apply natural gas technology due to cost effectiveness. The application of a 2.0 multiplier for natural gas vehicles for MYs 2024–2026 would have no impact on the analysis because given the state of natural gas vehicle refueling infrastructure, the cost to equip vehicles with natural gas tanks, the outlook for petroleum prices, and the outlook for battery prices, we have little basis to project more than an inconsequential response to this incentive in the foreseeable future.

D. Technology Pathways, Effectiveness, and Cost

Vehicle manufacturers meet increasingly more stringent fuel economy standards by applying increasing levels of fuel-economy-improving technologies to their vehicles. An appropriate characterization of the technologies available to manufacturers to meet fuel economy standards is, therefore, an important input required to assess the levels of standards that manufacturers can achieve. Like previous CAFE standards analyses, this proposal considers over 50 fuel-economy-improving technologies that manufacturers could apply to their MY 2020 fleet of vehicles to meet proposed levels of CAFE standards in MYs 2024–2026. The characterization of these technologies, the technology effectiveness values, and technology cost assumptions build on work performed by DOT, EPA, the National Academy of Sciences, and other Federal and state government agencies including the Department of Energy's Argonne National Laboratory and the California Air Resources Board.

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

Even though the analysis considers over 50 individual technologies, the fuel economy improvement from any individual technology must be considered in conjunction with the other fuel-economy-improving technologies applied to the vehicle. For example, there is an obvious fuel economy benefit that results from converting a vehicle with a traditional internal combustion engine to a battery electric vehicle; however, the benefit of the electrification technology depends on the other road load reducing technologies (*i.e.,* mass reduction, aerodynamic, and rolling resistance) on the vehicle.

Technologies added in combination to a vehicle will not result in a simply additive fuel economy improvement from each individual technology. As discussed in Section III.C.4, full vehicle modeling and simulation provides the required degree of accuracy to project how different technologies will interact in the vehicle system. For example, as discussed further in Sections III.D.1 and III.D.3, a parallel hybrid architecture powertrain improves fuel economy, in part, by allowing the internal combustion engine to spend more time operating at efficient engine speed and load conditions. This reduces the advantage of adding advanced internal combustion engine technologies, which also improve fuel economy, by broadening the range of speed and load conditions for the engine to operate at high efficiency. This redundancy in fuel savings mechanism results in a reduced effectiveness improvement when the technologies are added to each other.

The effectiveness of a technology depends on the type of vehicle the technology is being applied to. For example, applying mass reduction technology results in varying effectiveness as the absolute mass reduced is a function of the starting vehicle mass, which varies across technology classes. See Section III.D.4 for more details.

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

The baseline for cost and effectiveness values must be identified before assuming that a cost or effectiveness value could be employed for any individual technology. For example, as discussed further in Section III.D.1.d) below, this analysis uses a set of engine map models that were developed by starting with a small number of baseline engine configurations, and then, in a very systematic and controlled process, adding specific well-defined technologies to create a new map for each unique technology combination.

The following sections discuss the engine, transmission, electrification, mass reduction, aerodynamic, tire rolling resistance, and other vehicle technologies considered in this analysis. Each section discusses how we define the technology in the CAFE Model,[108] how we assigned the technology to vehicles in the MY 2020 analysis fleet used as a starting point for this analysis, any adoption features applied to the technology so the analysis better represents manufacturers' real-world decisions, the technology effectiveness values, and technology cost.

Please note that the following technology effectiveness sections provide *examples* of the *range* of effectiveness values that a technology could achieve when applied to the entire vehicle system, in conjunction with the other fuel-economy-improving technologies already on or also applied at the same time to 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 FE_1 and FE_2 Adjustments files that are integrated in the CAFE Model executable file. Similarly, the technology costs provided in each section are *examples* of absolute costs seen in specific model years (MYs 2020, 2025, and 2030 for most technologies), for specific vehicle classes. To see all absolute technology costs used in the analysis across all model years, see the Technologies file.

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

NHTSA seeks comment on the following discussion.

1. Engine Paths

For this analysis, the extensive variety of light duty vehicle internal combustion (IC) engine technologies are classified into discrete engine technology paths. These paths are used to model the most representative characteristics, costs, and performance of the fuel-economy improving technologies most likely available during the rulemaking time frame, MYs 2024–2026. Due to uncertainties in the cost and capabilities of emerging technologies, some new and pre-production technologies are not part of this analysis. We did not include technologies unlikely to be feasible in the rulemaking timeframe, technologies unlikely to be compatible with U.S. fuels, or technologies for which there was not appropriate data available to allow the simulation of effectiveness across all vehicle technology classes in this analysis.

The following sections discuss IC engine technologies considered in this analysis, general technology categories used by the CAFE Model, and how the engine technologies are assigned in the MY 2020 analysis fleet. The following sections also discuss adoption features applicable to engine technologies, engine technologies' effectiveness when combined in a full vehicle model, and the engine technologies' costs.

(a) Engine Modeling in the CAFE Model

DOT models IC engine technologies that manufacturers can use to improve fuel economy. Some engine technologies can be incorporated into existing engines with minor or moderate changes to the engines, but many engine technologies require an entirely new engine architecture.

We divide engine technologies into two categories, ''basic engine technologies'' and ''advanced engine technologies.'' ''Basic engine technologies'' refer to technologies adaptable to an existing engine with minor or moderate changes to the engine. ''Advanced engine technologies'' refer to technologies that generally require significant changes or an entirely new engine architecture. The words ''basic'' and ''advanced'' are not meant to confer any information about the level of sophistication of the technology. Many advanced engine technology definitions also include some basic engine technologies, and these basic technologies are accounted for in the costs and effectiveness values of the advance engine. Figure III–7 shows how the basic and other engines are laid out on pathways evaluated in the compliance simulation. Each engine technology is briefly described, below. It is important to note the ''Basic Engine Path'' shows that every engine starts with VVT and can add one, some, or all the technologies in the dotted box, as discussed in Section III.D.1.a)(1).

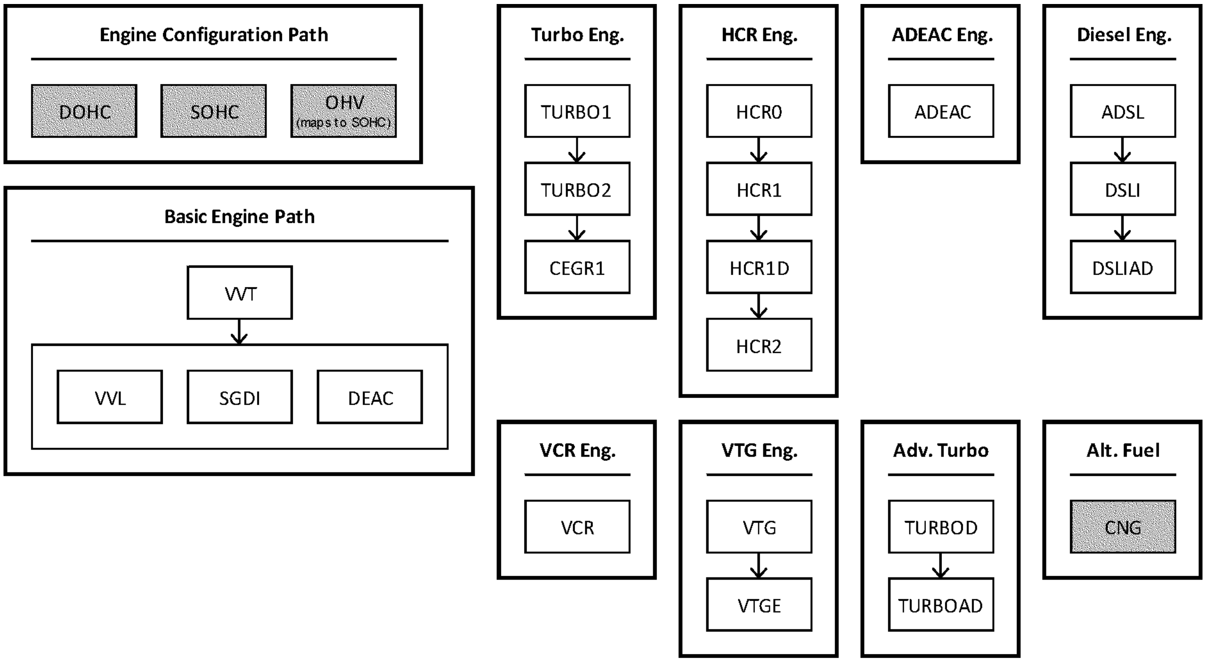

Figure III-7 – Engine Technology Paths in the CAFE Model

(1) Basic Engines

In the CAFE Model, basic engine technologies may be applied individually or in combination with other basic engine technologies. The basic engine technologies include variable valve timing (VVT), variable valve lift (VVL), stoichiometric gasoline direct injection (SGDI), and cylinder deactivation. Cylinder deactivation includes a basic level (DEAC) and an advanced level (ADEAC). DOT applies the basic engine technologies across two engine architectures: dual over-head camshaft (DOHC) engine architecture and single over-head camshaft (SOHC) engine architecture.

VVT: Variable valve timing is a family of valve-train designs that dynamically adjusts the timing of the intake valves, exhaust valves, or both, in relation to piston position. VVT can reduce pumping losses, provide increased engine torque and horsepower over a broad engine operating range, and allow unique operating modes, such as Atkinson cycle operation, to further enhance efficiency.[109] VVT is nearly universally used in the MY 2020 fleet. VVT enables more control of in-cylinder

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[109] 2015 NAS report, at 31.

air flow for exhaust scavenging and combustion relative to fixed valve timing engines. Engine parameters such as volumetric efficiency, effective compression ratio, and internal exhaust gas recirculation (iEGR) can all be enabled and accurately controlled by a VVT system.

VVL: Variable valve lift dynamically adjusts the distance a valve travels from the valve seat. The dynamic adjustment can optimize airflow over a broad range of engine operating conditions. The technology can increase effectiveness by reducing pumping losses and by affecting the fuel and air mixture motion and combustion in-cylinder.[110] VVL is less common in the MY 2020 fleet than VVT, but still prevalent. Some manufacturers have implemented a limited, discrete approach to VVL. The discrete approach allows only limited (*e.g.,* two) valve lift profiles versus allowing a continuous range of lift profiles.

SGDI: Stoichiometric gasoline direct injection sprays fuel at high pressure directly into the combustion chamber, which provides cooling of the in-cylinder charge via in-cylinder fuel vaporization to improve spark knock tolerance and enable an increase in compression ratio and/or more optimal spark timing for improved efficiency.[111] SGDI is common in the MY 2020 fleet, and the technology is used in many advanced engines as well.

DEAC: Basic cylinder deactivation disables intake and exhaust valves and turns off fuel injection for the deactivated cylinders during light load operation. DEAC is characterized by a small number of discrete operating configurations.[112] The engine runs temporarily as though it were a smaller engine, reducing pumping losses and improving efficiency. DEAC is present in the MY 2020 baseline fleet.

ADEAC: Advanced cylinder deactivation systems, also known as rolling or dynamic cylinder deactivation systems, allow a further degree of cylinder deactivation than the base DEAC. ADEAC allows the engine to vary the percentage of cylinders deactivated and the sequence in which cylinders are deactivated, essentially providing ‘‘displacement on demand’’ for low load operations. A small number of vehicles have ADEAC in the MY 2020 baseline fleet.

Section III.D.1.d) contains additional information about each basic engine technology used in this analysis, including information about the engine map models used in the full vehicle technology effectiveness modeling.

(2) Advanced Engines

DOT defines advanced engine technologies in the analysis as technologies that require significant changes in engine structure, or an entirely new engine architecture.[113] The advanced engine technologies represent the application of alternate combustion cycles or changes in the application of forced induction to the engine. Each advanced engine technology has a discrete pathway for progression to improved versions of the technology, as seen above in Figure III–7. The advanced engine technology pathways include a turbocharged pathway, a high compression ratio (Atkinson) engine pathway, a variable turbo geometry (Miller Cycle) engine pathway, a variable compression ratio pathway, and a diesel engine pathway. Although the CAFE Model includes a compressed natural gas (CNG) pathway, that technology is a baseline-only technology and was not included in the analysis; currently, there are no dedicated CNG vehicles in the MY 2020 analysis fleet.

TURBO: Forced induction engines, or turbocharged downsized engines, are characterized by technology that can create greater-than-atmospheric pressure in the engine intake manifold when higher output is needed. The raised pressure results in an increased amount of airflow into the cylinder supporting combustion, increasing the specific power of the engine. Increased specific power means the engine can generate more power per unit of cylinder volume. The higher power per cylinder volume allows the overall engine volume to be reduced, while maintaining performance. The overall engine volume decrease results in an increase in fuel efficiency by reducing parasitic loads associated with larger engine volumes.[114]

Cooled exhaust gas recirculation is also part of the advanced forced induction technology path. The basic recycling of exhaust gases using VVT is called internal EGR (iEGR) and is included as part of the performance improvements provided by the VVT basic engine technology. Cooled EGR (cEGR) is a second method for diluting the incoming air that takes exhaust gases, passes them through a heat exchanger to reduce their temperature, and then mixes them with incoming air in the intake manifold.[115] As discussed in Section III.D.1.d), many advanced engine maps include EGR.

Five levels of turbocharged engine downsizing technologies are considered in this analysis: A ‘basic’ level of turbocharged downsized technology (TURBO1), an advanced turbocharged downsized technology (TURBO2), an advanced turbocharged downsized technology with cooled exhaust gas recirculation applied (cEGR), a turbocharged downsized technology with basic cylinder deactivation applied (TURBOD), and a turbocharged downsized technology with advanced cylinder deactivation applied (TURBOAD).

HCR: Atkinson engines, or high compression ratio engines, represent a class of engines that achieve a higher level of fuel efficiency by implementing an alternate combustion cycle.[116] Historically, the Otto combustion cycle has been used by most gasoline-based spark ignition engines. Increased research into improving fuel economy has resulted in the development of alternate combustion cycles that allow for greater levels of thermal efficiency. One such alternative combustion cycle is the Atkinson cycle. Atkinson cycle operation is achieved by allowing the expansion stroke of the engine to overextend allowing the combustion products to achieve the lowest possible pressure before the exhaust stroke.[117] [118] [119]

Descriptions of Atkinson cycle engines and Atkinson mode or Atkinson-enabled engine technologies have been used interchangeably in association with high compression ratio (HCR) engines, for past rulemaking analyses. Both technologies achieve a higher thermal efficiency than traditional Otto cycle-only engines, however, the two engine types operate differently. For purposes of this analysis, Atkinson technologies can be categorized into two groups to reduce confusion: (1) Atkinson-enabled engines and (2) Atkinson engines.

Atkinson-enabled engines, or high compression ratio engines (HCR),

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[110] 2015 NAS report, at 32.

[111] 2015 NAS report, at 34.

[112] 2015 NAS report, at 33.

[113] Examples of this include but are not limited to changes in cylinder count, block geometry or combustion cycle changes.

[114] 2015 NAS report, at 34.

[115] 2015 NAS report, at 35.

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

[117] Otto cycle is a four-stroke cycle that has four piston movements over two engine revolutions for each cycle. First stroke: Intake or induction; seconds stroke: Compression; third stroke: Expansion or power stroke; and finally, fourth stroke: Exhaust.

[118] Compression ratio is the ratio of the maximum to minimum volume in the cylinder of an internal combustion engine.

[119] Expansion ratio is the ratio of maximum to minimum volume in the cylinder of an IC engine when the valves are closed (*i.e.,* the piston is traveling from top to bottom to produce work).

dynamically swing between operating closer to an Otto cycle or an Atkinson cycle based on engine loads. During high loads the engine will use the lower-efficiency, power-dense Otto cycle mode, while at low loads the engine will use the higher-efficiency, lower power-dense Atkinson cycle mode. The hybrid combustion cycle operation is used to address the low power density issues that can limit the Atkinson-only engine and allow for a wider application of the technology.

The level of efficiency improvement experienced by a vehicle employing Atkinson cycle operation is directly related to how much of the engine's operation time is spent in Atkinson mode. Vehicles that can experience operation at a high load for long portions of their operating cycle will see little to no benefit from this technology. This limitation to performance results in manufacturers typically limiting the application of this technology to vehicles with a use profile that can take advantage of the technology's behavior.

Three HCR or Atkinson-enabled engines are available in the analysis: (1) The baseline Atkinson-enabled engine (HCR0), (2) the enhanced Atkinson enabled engine (HCR1), and finally, (3) the enhanced Atkinson enabled engine with cylinder deactivation (HCR1D).

In contrast, Atkinson engines in this analysis are defined as engines that operate full-time in the Atkinson cycle. The most common method of achieving Atkinson operation is the use of late intake valve closing. This method allows backflow from the combustion chamber into the intake manifold, reducing the dynamic compression ratio, and providing a higher expansion ratio. The higher expansion ratio improves thermal efficiency but reduces power density. The low power density generally relegates these engines to hybrid vehicle (SHEVPS) applications only in this analysis. Coupling the engines to electric motors and significantly reducing road loads can compensate for the lower power density and maintain desired performance levels for the vehicle.[120] The Toyota Prius is an example of a vehicle that uses an Atkinson engine. The 2017 Toyota Prius achieved a peak thermal efficiency of 40 percent.[121]

NHTSA seeks comment on whether and how to consider ''HCR2'' in the analysis for the final rule.

VTG: The Miller cycle is another type of overexpansion combustion cycle, similar to the Atkinson cycle. The Miller cycle, however, operates in combination with a forced induction system that helps address the impacts of reduced power density during high load operating conditions. Miller cycle-enabled engines use a similar technology approach as seen in Atkinson-enabled engines to effectively create an expanded expansion stroke of the combustion cycle.

In the analysis, the baseline Miller cycle-enabled engine includes the application of a variable turbo geometry technology (VTG). The advanced Miller cycle enabled system includes the application of a 48V-based electronic boost system (VTGE). VTG technology allows the system to vary boost level based on engine operational needs. The use of a variable geometry turbocharger also supports the use of cooled exhaust gas recirculation.[122] An electronic boost system has an electric motor added to assist a turbocharger at low engine speeds. The motor assist mitigates turbocharger lag and low boost pressure at low engine speeds. The electronic assist system can provide extra boost needed to overcome the torque deficits at low engine speeds.[123]

VCR: Variable compression ratio (VCR) engines work by changing the length of the piston stroke of the engine to optimize the compression ratio and improve thermal efficiency over the full range of engine operating conditions. Engines using VCR technology are currently in production, but appear to be targeted primarily towards limited production, high performance applications. Nissan is the only manufacturer to use this technology in the MY 2020 baseline fleet. Few manufacturers and suppliers provided information about VCR technologies, and DOT reviewed several design concepts that could achieve a similar functional outcome. In addition to design concept differences, intellectual property ownership complicates the ability to define a VCR hardware system that could be widely adopted across the industry. Because of these issues, adoption of the VCR engine technology is limited to Nissan only.

ADSL: Diesel engines have several characteristics that result in superior fuel efficiency over traditional gasoline engines. These advantages include reduced pumping losses due to lack of (or greatly reduced) throttling, high pressure direct injection of fuel, a more efficient combustion cycle,[124] and a very lean air/fuel mixture relative to an equivalent-performance gasoline engine.[125] However, diesel technologies require additional enablers, such as a NOx adsorption catalyst system or a urea/ammonia selective catalytic reduction system, for control of NOx emissions.

DOT considered three levels of diesel engine technology: the baseline diesel engine technology (ADSL) is based on a standard 2.2L turbocharged diesel engine; the more advanced diesel engine (DSLI) starts with the ADSL system and incorporates a combination of low pressure and high pressure EGR, reduced parasitic loss, friction reduction, a highly-integrated exhaust catalyst with low temp light off temperatures, and closed loop combustion control; and finally the most advanced diesel system (DSLIAD) is the DSLI system with advanced cylinder deactivation technology added.

EFR: Engine friction reduction technology is a general engine improvement meant to represent future technologies that reduce the internal friction of an engine. EFR technology is not available for application until MY 2023. The future technologies do not significantly change the function or operation of the engine but reduce the energy loss due to the rotational or rubbing friction experienced in the bearings or cylinder during normal operation. These technologies can include improved surface coatings, lower-tension piston rings, roller cam followers, optimal thermal management and piston surface treatments, improved bearing design, reduced inertial loads, improved materials, or improved geometry.

(b) Engine Analysis Fleet Assignments

As a first step in assigning baseline levels of engine technologies in the analysis fleet, DOT used data for each manufacturer to determine which platforms shared engines. Within each manufacturer's fleet, DOT assigned unique identification designations (engine codes) based on configuration, technologies applied, displacement, compression ratio, and power output. DOT used power output to distinguish between engines that might have the same displacement and configuration

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[120] Toyota. ''Under the Hood of the All-new Toyota Prius.'' Oct. 13, 2015. Available at *https://global.toyota/en/detail/9827044*. Last accessed Nov. 22, 2019.

[121] Matsuo, S., Ikeda, E., Ito, Y., and Nishiura, H., ''The New Toyota Inline 4 Cylinder 1.8L ESTEC 2ZR–FXE Gasoline Engine for Hybrid Car,'' SAE Technical Paper 2016–01–0684, 2016, *https://doi.org/10.4271/2016-01-0684*.

[122] 2015 NAS report, at 116.

[123] 2015 NAS report, at 62.

[124] Diesel cycle is also a four-stroke cycle like the Otto Cycle, except in the intake stroke no fuel is injected and fuel is injected late in the compression stroke at higher pressure and temperature.

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

but significantly different horsepower ratings.

The CAFE Model identifies leaders and followers for a manufacturer's vehicles that use the same engine, indicated by sharing the same engine code. The model automatically determines which engines are leaders by using the highest sales volume row of the highest sales volume nameplate that is assigned an engine code. This leader-follower relationship allows the CAFE Model simulation to maintain engine sharing as more technology is applied to engines.

DOT accurately represents each engine using engine technologies and engine technology classes. The first step is to assign engine technologies to each engine code. Technology assignment is based on the identified characteristics of the engine being modeled, and based on technologies assigned, the engine will be aligned with an engine map model that most closely corresponds.

The engine technology classes are a second identifier used to accurately account for engine costs. The engine technology class is formatted as number of cylinders followed by the letter C, number of banks followed by the letter B, and an engine head configuration designator, which is _SOHC for single overhead cam, _ohv for overhead valve, or blank for dual overhead cam. As an example, one variant of the GMC Acadia has a naturally aspirated DOHC inline 4-cylinder engine, so DOT assigned the vehicle to the '4C1B' engine technology class and assigned the technology VVT and SGDI. Table III–7 shows examples of observed engines with their corresponding assigned engine technologies as well as engine technology classes.

Table III-7 – Examples of Observed Engines and Their Corresponding Engine Technology Class and Technology Assignments

Vehicle	Engine Observed	Engine Technology Class Assigned	Engine Technology Assigned
GMC Acadia	Naturally Aspirated DOHC Inline 4 cylinder	4C1B	VVT, SGDI
VW Arteon	Turbocharged DOHC Inline 4 cylinder	6C2B	TURBO1
Bentley Bentayga	Turbocharged DOHC W12 w/ cylinder deactivation	16C4B	TURBOD
Honda Passport	Naturally Aspirated SOHC V6	6C2B_SOHC	VVT, VVL, SGDI, DEAC
Honda Civic	Turbocharged DOHC Inline 4 cylinder	4C1B	TURBO1
Cadillac CT5	Turbocharged DOHC V6 w/ cylinder deactivation	8C2B	TURBOD
Ford Escape	Turbocharged DOHC Inline 3 cylinder	4C1B_L	TURBO1
Chevrolet Silverado	Naturally Aspirated OHV V8 w/ skip fire	8C2B_ohv	ADEAC

The cost tables for a given engine class include downsizing (to an engine architecture with fewer cylinders) when turbocharging technology is applied, and therefore, the turbocharged engines observed in the 2020 fleet (that have already been downsized) often map to an engine class with more cylinders. For instance, an observed TURBO1 V6 engine would map to an 8C2B (V8) engine class, because the turbo costs on the 8C2B engine class worksheet assume a V6 (6C2B) engine architecture. Diesel engines map to engine technology classes that match the observed cylinder count since naturally aspirated diesel engines are not found in new light duty vehicles in the U.S. market. Similarly, as indicated above, the TURBO1 I3 in the Ford Escape maps to the 4C1B_L (I4) engine class, because the turbo costs on the 4C1B_L engine class worksheet assume a I3 (3C1B) engine architecture. Some instances can be more complex, including low horsepower variants for 4-cylinder engines, and are shown in Table III–8.

For this analysis, we have allowed additional downsizing beyond what has been previously modeled. We allow enhanced downsizing because manufacturers have downsized low output naturally aspirated engines to turbo engines with smaller architectures than traditionally observed.[126] [127] [128] To capture this new level of turbo downsizing we created a new category of low output naturally aspirated engines, which is only applied to 4-cylinder engines in the MY 2020 fleet. These engines use the costing tabs in the Technologies file with the 'L' designation and are assumed to downsize to turbocharged 3-cylinder engines for costing purposes. We seek comment regarding the expected further application of this technology to larger cylinder count engines, such as 8-cylinder engines that may be turbo

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[126] Richard Truett, "GM Brining 3-Cylinder back to North America." Automotive News, December 01, 2019. *https://www.autonews.com/cars-concepts/gm-bringing-3-cylinder-back-na.*

[127] Stoklosa, Alexander, "2021 Mini Cooper Hardtop." Car and Driver, December 2, 2014. *https://www.caranddriver.com/reviews/a15109143/2014-mini-cooper-hardtop-manual-test-review/.*

[128] Leanse, Alex "2020 For Escape Options: Hybrid vs. 3-Cylinder EcoBoost vs. 4-Cylinder EcoBoost." MotorTrend, Sept 24, 2019. *https://www.motortrend.com/news/2020-ford-escape-engine-options-pros-and-cons-comparison/.*

downsized to 4-cylinder engines. We would also like comment on how to define the characteristic of an engine that may be targeted for enhanced downsizing.

Table III-8 – Examples of Engine Technology Class Assignment Logic

Observed Gasoline Engine Configuration	Observed Number of Cylinders	Horsepower	Naturally Aspirated or Turbo	Engine Technology Class Assigned
Inline	3	Any	NA	3C1B
Inline	3	Any	Turbo	4C1B_L
Inline	4	<=180	NA	4C1B_L
Inline	4	<=180	Turbo	4C1B
Boxer	4	<=180	NA	4C2B_L
Boxer	4	<=180	Turbo	4C2B
Inline	4	>180	NA	4C1B
Inline	4	>180	Turbo	6C2B
Boxer	4	>180	Turbo	6C2B
Inline	5	Any	Turbo	6C2B
W	16	Any	Turbo	16C4B

TSD Chapter 3.1.2 includes more details about baseline engine technology assignment logic, and details about the levels of engine technology penetration in the MY 2020 fleet.

(c) Engine Adoption Features

Engine adoption features are defined through a combination of (1) refresh and redesign cycles, (2) technology path logic, (3) phase-in capacity limits, and (4) SKIP logic. Figure III–7 above shows the technology paths available for engines in the CAFE Model. Engine technology development and application typically results in an engine design moving from the basic engine tree to one of the advanced engine trees. Once an engine design moves to the advanced engine tree it is not allowed to move to alternate advanced engine trees. Specific path logic, phase-in caps, and SKIP logic applied to each engine technology are discussed by engine technology, in turn.

Refresh and redesign cycles dictate when engine technology can be applied. Technologies applicable only during a platform redesign can be applied during a platform refresh if another vehicle platform that shares engine codes (uses the same engine) has already applied the technology during a redesign. For example, models of the GMC Acadia and the Cadillac XT4 use the same engine (assigned engine code 112011 in the Market Data file); if the XT4 adds a new engine technology during a redesign, then the Acadia may also add the same engine technology during the next refresh or redesign. This allows the model to maintain engine sharing relationships while also maintaining refresh and redesign schedules.[129] For engine technologies, DOHC, OHV, VVT, and CNG engine technologies are baseline only, while all other engine technologies can only be applied at a vehicle redesign.

Basic engine technologies in the CAFE Model are represented by four technologies: VVT, VVL, SGDI, and DEAC. DOT assumes that 100% of basic engine platforms use VVT as a baseline, based on wide proliferation of the technology in the U.S. fleet. The remaining three technologies, VVL, SGDI, and DEAC, can all be applied individually or in any combination of the three. An engine can jump from the basic engines path to any other engine path except the Alternative Fuel Engine Path.

Turbo downsizing allows manufacturers to maintain vehicle performance characteristics while reducing engine displacement and cylinder count. Any basic engine can adopt one of the turbo engine technologies (TURBO1, TURBO2 and CEGR1). Vehicles that have turbocharged engines in the baseline fleet will stay on the turbo engine path to prevent unrealistic engine technology change in the short timeframe considered in the rulemaking analysis. Turbo technology is a mutually exclusive technology in that it cannot be adopted for HCR, diesel, ADEAC, or CNG engines.

Non-HEV Atkinson mode engines are a collection of engines in the HCR engine pathway (HCR0, HCR1, HCR1D and HCR2). Atkinson 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. DOT expanded the availability of HCR technology compared to the 2020 final rule because of new observed applications in the market.[130] However, there are three categories of adoption features specific to the HCR engine pathway:[131]

- DOT does not allow vehicles with 405 or more horsepower to adopt HCR engines due to their prescribed duty cycle being more demanding and likely not supported by the lower power density found in HCR-based engines.[132]
- Pickup trucks and vehicles that share engines with pickup trucks are

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[129] *See* Section III.C.2.a) for more discussion on platform refresh and redesign cycles.

[130] For example, the Hyundai Palisade and Kia Telluride have a 291 hp V6 HCR1 engine. The specification sheets for these vehicles are located in the docket for this action.

[131] *See* Section III.D.1.d)(1) Engine Maps, for a discussion of why HCR2 and P2HCR2 were not used in the central analysis. ''SKIP'' logic was used to remove this engine technology from application, however as discussed below, we maintain HCR2 and P2HCR2 in the model architecture for sensitivity analysis and for future engine map model updates.

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

also excluded from receiving HCR engines; the duty cycle for these heavy vehicles, particularly when hauling cargo or towing, are likely unable to take full advantage of Atkinson cycle use, and would ultimately spend the majority of operation as an Otto cycle engine, negating the benefits of HCR technology.[133]

- HCR engine application is also restricted for some manufacturers that are heavily performance-focused and have demonstrated a significant commitment to power dense technologies such as turbocharged downsizing.[134]

NHTSA seeks comment on the appropriateness of these restrictions for the final rule.

Advanced cylinder deactivation technology (ADEAC), or dynamic cylinder deactivation (*e.g.,* Dynamic Skip Fire), can be applied to any engine with basic technology. This technology represents a naturally aspirated engine with ADEAC. Additional technology can be applied to these engines by moving to the Advanced Turbo Engine Path.

Miller cycle (VTG and VTGE) engines can be applied to any basic and turbocharged engine. VTGE technology is enabled by the use of a 48V system that presents an improvement from traditional turbocharged engines, and accordingly VTGE includes the application of a mild hybrid (BISG) system.

VCR engines can be applied to basic and turbocharged engines, but the technology is limited to Nissan and Mitsubishi.[135] VCR technology requires a complete redesign of the engine, and in the analysis fleet, only two of Nissan's models had incorporated this technology. The agency does not believe any other manufacturers will invest to develop and market this technology in their fleet in the rulemaking time frame.

Advanced turbo engines are becoming more prevalent as the technologies mature. TURBOD combines TURBO1 and DEAC technologies and represents the first advanced turbo. TURBOAD combines TURBO1 and ADEAC technologies and is the second and last level of advanced turbos. Engines from either the Turbo Engine Path or the ADEAC Engine Path can adopt these technologies.

Any basic engine technologies (VVT, VVL, SGDI, and DEAC) can adopt ADSL and DSLI engine technologies. Any basic engine and diesel engine can adopt DSLIAD technology in this analysis; however, DOT applied a phase in cap and year for this technology at 34 percent and MY 2023, respectively. In DOT's engineering judgement, this is a rather complex and costly technology to adopt and it would take significant investment for a manufacturer to develop. For more than a decade, diesel engine technologies have been used in less than one percent of the total light-duty fleet production and have been found mostly on medium and heavy-duty vehicles.

Finally, DOT allows the CAFE Model to apply EFR to any engine technology except for DSLI and DSLIAD. DSLI and DSLIAD inherently have incorporated engine friction technologies from ADSL. In addition, friction reduction technologies that apply to gasoline engines cannot necessarily be applied to diesel engines due to the higher temperature and pressure operation in diesel engines.

(d) Engine Effectiveness Modeling

Effectiveness values used for engine technologies were simulated in two ways. The value was either calculated based on the difference in full vehicle simulation results created using the Autonomie modeling tool, or effectiveness values were determined using an alternate calculation method, including analogous improvement or fuel economy improvement factors.

(1) Engine Maps

Most effectiveness values used as inputs for the CAFE Model were determined by comparing results of full vehicle simulations using the Autonomie simulation tool. For a full discussion about how Autonomie was used, see Section III.C.4 and TSD Chapter 2.4, in addition to the Autonomie model documentation. Engine map models were the primary inputs used to simulate the effects of different engine technologies in the Autonomie full vehicle simulations.

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 brake mean effective pressure (BMEP)[136] on the vertical axis. A third engine characteristic, such as brake-specific fuel consumption (BSFC),[137] 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 used in this analysis are referred to as engine map models.

The engine map models used in this analysis are representative of technologies that are currently in production or are expected to be available in the rulemaking timeframe, MYs 2024–2026. The engine map models were developed to be representative of the performance achievable across industry for a given technology and are not intended to represent the performance of a single manufacturer's specific engine. The broadly representative performance level was targeted because the same combination of technologies produced by different manufacturers will have differences in performance, due to manufacturer-specific designs for engine hardware, control software, and emissions calibration.

Accordingly, DOT expects that the engine maps developed for this analysis will differ from engine maps for manufacturers' specific engines. However, DOT intends and expects 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.

The analysis never applies absolute BSFC levels from the engine maps to any vehicle model or configuration for the rulemaking analysis. The absolute fuel economy values from the full vehicle Autonomie simulations are used only to determine incremental effectiveness for switching from one technology to another technology. The incremental effectiveness is applied to the absolute fuel economy of vehicles in the analysis fleet, which are based on CAFE compliance data. For subsequent

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[133] This is based on CBI conversation with manufacturers that currently employ HCR-based technology but saw no benefit when the technology was applied to truck platforms in their fleet.

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

[135] Nissan and Mitsubishi are strategic partners and members of the Renault-Nissan-Mitsubishi Alliance.

[136] Brake mean effective pressure is an engineering measure, independent of engine displacement, that indicates the actual work an engine performs.

[137] Brake-specific fuel consumption is the rate of fuel consumption divided by the power being produced.

technology changes, incremental effectiveness is applied 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. However, achieving this can be challenging.

For this analysis, DOT used a small number of baseline engine configurations with well-defined BSFC maps, and then, in a very systematic and controlled process, added specific well-defined technologies to create a BSFC map for each unique technology combination. This could theoretically be done through engine or vehicle testing, but testing would need to be conducted on a single engine, and each configuration would require physical parts and associated engine calibrations to assess the impact of each technology configuration, which is impractical for the rulemaking analysis because of the extensive design, prototype part fabrication, development, and laboratory resources that are required to evaluate each unique configuration. Modeling is an approach used by industry to assess an array of technologies with more limited testing. Modeling offers the opportunity to isolate the effects of individual technologies by using a single or small number of baseline engine configurations and incrementally adding technologies to those baseline configurations. This provides a consistent reference point for the BSFC maps for each technology and for combinations of technologies that enables the differences in effectiveness among technologies to be carefully identified and quantified.

The Autonomie model documentation provides a detailed discussion on how the engine map models were used as inputs to the full vehicle simulations performed using the Autonomie tool. The Autonomie model documentation contains the engine map model topographic figures, and additional engine map model data can be found in the Autonomie input files.[138]

Most of the engine map models used in this analysis were developed by IAV GmbH (IAV) Engineering. 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.[139] The primary outputs of IAV's work for this analysis are engine maps that model the operating characteristics of engines equipped with specific technologies.

The generated engine maps were validated against IAV's global database of benchmarked data, engine test data, single cylinder test data, prior modeling studies, technical studies, and information presented at conferences.[140] The effectiveness values from the simulation results were also validated against detailed engine maps produced from the Argonne engine benchmarking programs, as well as published information from industry and academia, ensuring reasonable representation of simulated engine technologies.[141] The engine map models used in this analysis and their specifications are shown in Table III–9.

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[138] *See* additional Autonomie supporting materials in docket number NHTSA–2021–0053 for this proposal.

[139] IAV Automotive Engineering, *https://www.iav.com/en/.*

[140] Friedrich, I., Pucher, H., and Offer, T., ''Automatic Model Calibration for Engine-Process Simulation with Heat-Release Prediction,'' SAE Technical Paper 2006–01–0655, 2006, *https://doi.org/10.4271/2006-01-0655.* Rezaei, R., Eckert, P., Seebode, J., and Behnk, K., ''Zero-Dimensional Modeling of Combustion and Heat Release Rate in DI Diesel Engines,'' SAE Int. J. Engines 5(3):874–885, 2012, *https://doi.org/10.4271/2012-01-1065.* Multistage Supercharging for Downsizing with Reduced Compression Ratio (2015). MTZ Rene Berndt, Rene Pohlke, Christopher Severin and Matthias Diezemann IAV GmbH. Symbiosis of Energy Recovery and Downsizing (2014). September 2014 MTZ Publication Heiko Neukirchner, Torsten Semper, Daniel Luederitz and Oliver Dingel IAV GmbH.

[141] Bottcher,. L, Grigoriadis, P. ''ANL—BSFC map prediction Engines 22–26.'' IAV (April 30, 2019). 20190430_ANL_Eng 22–26 Updated_Docket.pdf.

Table III-9 – Engine Map Models used in This Analysis

Engines	Technologies	Notes
Eng01	DOHC+VVT	Parent NA engine, Gasoline, 2.0L, 4 cyl, NA, PFI, DOHC, dual cam VVT, CR10.2
Eng02	DOHC+VVT+VVL	VVL added to Eng01
Eng03	DOHC+VVT+VVL+SGDI	SGDI added to Eng02, CR11
Eng04	DOHC+VVT+VVL+SGDI +DEAC	Cylinder deactivation added to Eng03
Eng5a	SOHC+VVT+PFI	Eng01 converted to SOHC (gasoline, 2.0L, 4cyl, NA, PFI, single cam VVT) For Reference Only
Eng5b	SOHC+VVT (level 1 Red. Friction)	Eng5a with valvetrain friction reduction (small friction reduction)
Eng6a	SOHC+VVT+VVL (level 1 Red. Friction)	Eng02 with valvetrain friction reduction (small friction reduction)
Eng7a	SOHC+VVT+VVL+SGDI (level 1 Red. Friction)	Eng03 with valvetrain friction reduction (small friction reduction), addition of VVL and SGDI
Eng8a	SOHC+VVT+VVL+SGDI +DEAC (level 1 Red. Friction)	Eng04 with valvetrain friction reduction (small friction reduction), addition of DEAC
Eng12	DOHC Turbo 1.6l 18bar	Parent Turbocharged Engine, Gasoline, 1.6L, 4 cyl, turbocharged, SGDI, DOHC, dual cam VVT, VVL Engine BMEP: 18 bar
Eng12 DEAC	DOHC Turbo 1.6l 18bar	Eng12 with DEAC applied, Engine BMEP 18bar
Eng13	DOHC Turbo 1.2l 24bar	Eng12 downsized to 1.2L, Engine BMEP 24 bar
Eng14	DOHC Turbo 1.2l 24bar + Cooled EGR	Cooled external EGR added to Eng13 Engine BMEP 24 bar
Eng17	Diesel	Diesel, 2.2L (measured on test bed)
Eng18	DOHC+VVT+SGDI	Gasoline, 2.0L, 4 cyl, NA, SGDI, DOHC, VVT
Eng19	DOHC+VVT+DEAC	Cylinder deactivation added to Eng01
Eng20	DOHC+VVT+VVL+DEAC	Cylinder deactivation added to Eng02
Eng21	DOHC+VVT+SGDI+DEAC	Cylinder deactivation added to Eng18
Eng22b	DOHC+VVT	Atkinson-enabled 2.5L DOHC, VVT, PFI, CR14
Eng24	Current SkyActiv 2.0l 93AKI	Non-HEV Atkinson mode, Gasoline, 2.0L, 4 cyl, DOHC, NA, SGDI, VVT, CR 13.1, 93 AKI
Eng25	Future SkyActiv 2.0l CEGR 93AKI+DEAC	Non-HEV Atkinson mode, Gasoline, 2.0L, 4 cyl, DOHC, NA, SGDI, VVT, cEGR, DEAC CR 14.1, 93 AKI For Reference Only
Eng26	Atkinson Cycle Engine	HEV and PHEV Atkinson Cycle Engine 1.8L
Eng23b	DOHC+VTG+VVT+VVL+SGDI +cEGR	Miller Cycle, 2.0L DOHC, VTG, SGDI, cEGR, VVT, VVL, CR12
Eng23c	DOHC+VTG+VVT+SGDI +cEGR+Eboost	Eng23b with an 48V Electronic supercharger and battery pack
Eng26a	DOHC+VCR+VVT+SGDI +Turbo+cEGR	VVT, SGDI, Turbo, cEGR, VCR CR 9-12

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Two engine map models shown in Table III–9, Eng24 and Eng25, were not developed as part of the IAV modeling effort and only Eng24 is used in this analysis. The Eng24 and Eng25 engine maps are equivalent to the ATK and ATK2 models developed for the 2016 Draft Technical Assessment Report (TAR), EPA Proposed Determination, and Final Determination.[142] The ATK1 engine model is based directly on the 2.0L 2014 Mazda SkyActiv-G (ATK) engine. The ATK2 represents an Atkinson engine concept based on the Mazda engine, adding cEGR, cylinder deactivation, and an increased compression ratio (14:1). In this analysis, Eng24 and Eng25 correspond to the HCR1 and HCR2 technologies.

The HCR2 engine map model application in this analysis follows the approach of the 2020 final rule.[143] The agency believes the use of HCR0, HCR1, and the new addition of HCR1D reasonably represents the application of Atkinson Cycle engine technologies within the current light-duty fleet and the anticipated applications of Atkinson Cycle technology in the MY 2024–2026 timeframe.

We are currently developing an updated family of HCR engine map models that will include cEGR, cylinder deactivation and a combination thereof. The new engine map models will closely align with the baseline assumptions used in the other IAV-based HCR engine map models used for the agency's analysis. The updated engine map models will likely not be available for the final rule associated with this proposal because of engine map model testing and validation requirements but will be available for future CAFE analyses. We believe the timing for including the new engine map models is reasonable, because a manufacturer that could apply this technology in response to CAFE standards is likely not do so before MY 2026, as the application of this technology will require an engine redesign. We also believe this is reasonable given manufacturer's statements that there are diminishing returns to additional conventional engine technology improvements considering vehicle electrification commitments.

NHTSA seeks comment on whether and how to change our engine maps for HCR2 in the analysis for the final rule.

(2) Analogous Engine Effectiveness Improvements and Fuel Economy Improvement Factors

For some technologies, the effectiveness for applying an incremental engine technology was determined by using the effectiveness values for applying the same engine technology to a reasonably similar base engine. An example of this can be seen in the determination of the application of SGDI to the baseline SOHC engine. Currently there is no engine map model for the SOHC+VVT+SGDI engine configuration. To create the effectiveness data required as an input to the CAFE Model, first, a pairwise comparison between technology configurations that included the DOHC+VVT engine (Eng1) and the DOHC+VVT+SGDI (Eng18) engine was conducted. Then, the results of that comparison were used to generate a data set of emulated performance values for adding the SGDI technology to the SOHC+VVT engine (Eng5b) systems.

The pairwise comparison is performed by finding the difference in fuel consumption performance between every technology configuration using the analogous base technology (*e.g.,* Eng1) and every technology configuration that only changes to the analogous technology (*e.g.,* Eng18). The individual changes in performance between all the technology configurations are then added to the same technology configurations that use the new base technology (*e.g.,* Eng5b) to create a new set of performance values for the new technology (*e.g.,* SOHC+VVT+SGDI). Table III–10 shows the engine technologies where analogous effectiveness values were used.

Table III-10 – Engine Technology Performance Values Determined by Analogous Effectiveness Values

Analogous Baseline	Analogous Technology	New Base Technology	New Technology
Eng1 DOHC+VVT	Eng18 DOHC+VVT+SGDI	Eng5b SOHC+VVT	SOHC+VVT+SGDI
Eng1 DOHC+VVT	Eng19 SOHC+VVT+DEAC	Eng5b SOHC+VVT	SOHC+VVT+DEAC
Eng1 DOHC+VVT	Eng20 DOHC+VVT+VVL+DEAC	Eng5b SOHC+VVT	SOHC+VVT+VVL+DEAC
Eng1 DOHC+VVT	Eng21 DOHC+VVT+SGDI+DEAC	Eng5b SOHC+VVT	SOHC+VVT+SGDI+DEAC
Eng12 (TURBO1)	Eng12DEAC (TURBOD)	Eng24 (HCR1)	HCR1D

DOT also developed a static fuel efficiency improvement factor to simulate applying an engine technology for some technologies where there was either no appropriate analogous technology or there were not enough data to create a full engine map model. The improvement factors were generally developed based on literature review or confidential business information (CBI) provided by stakeholders. Table III–11 provides a summary of the technology

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[142] Ellies, B., Schenk, C., and Dekraker, P., ''Benchmarking and Hardware-in-the-Loop Operation of a 2014 MAZDA SkyActiv 2.0L 13:1 Compression Ratio Engine,'' SAE Technical Paper 2016–01–1007, 2016, doi:10.4271/2016–01–1007.

[143] 85 FR 24425–27 (April 30, 2020).

effectiveness values simulated using improvement factors, and the value and rules for how the improvement factors were applied. Advanced cylinder deactivation (ADEAC, TURBOAD, DSLIAD), advanced diesel engines (DSLIA) and engine friction reduction (EFR) are the three technologies modeled using improvement factors.

The application of the advanced cylinder deactivation is responsible for three of the five technologies using an improvement factor in this analysis. The initial review of the advanced cylinder deactivation technology was based on a technical publication that used a MY 2010 SOHC VVT basic engine.[144] Additional information about the technology effectiveness came from a benchmarking analysis of pre-production 8-cylinder OHV prototype systems.[145] However, at the time of the analysis no studies of production versions of the technology were available, and the only available technology effectiveness came from existing studies, not operational information. Thus, only estimates of effect could be developed and not a full model of operation. No engine map model could be developed, and no other technology pairs were analogous.

To model the effects of advanced cylinder deactivation, an improvement factor was determined based on the information referenced above and applied across the engine technologies. The effectiveness values for naturally aspirated engines were predicted by using full vehicle simulations of a basic engine with DEAC, SGDI, VVL, and VVT, and adding 3 percent or 6 percent improvement based on engine cylinder count: 3 percent for engines with 4 cylinders or less and 6 percent for all other engines. Effectiveness values for turbocharged engines were predicted using full vehicle simulations of the TURBOD engine and adding 1.5 percent or 3 percent improvement based on engine cylinder count: 1.5 percent for engines with 4 cylinders or less and 3 percent for all other engines. For diesel engines, effectiveness values were predicted by using the DSLI effectiveness values and adding 4.5 percent or 7.5 percent improvement based on vehicle technology class: 4.5 percent improvement was applied to small and medium non-performance cars, small performance cars, and small non-performance SUVs. 7.5 percent improvement was applied to all other vehicle technology classes.

The analysis modeled advanced engine technology application to the baseline diesel engine by applying an improvement factor to the ADSL engine technology combinations. A 12.8 percent improvement factor was applied to the ADSL technology combinations to create the DSLI technology combinations. The improvement in performance was based on the application of a combination of low pressure and high pressure EGR, reduced parasitic loss, advanced friction reduction, incorporation of highly-integrated exhaust catalyst with low temp light off temperatures, and closed loop combustion control.[146] [147] [148] [149]

As discussed above, the application of the EFR technology does not simulate the application of a specific technology, but the application of an array of potential improvements to an engine. All reciprocating and rotating components in the engine are potential candidates for friction reduction, and minute improvements in several components can add up to a measurable fuel economy improvement.[150] [151] [152] [153] Because of the incremental nature of this analysis, a range of 1–2 percent improvement was identified initially, and narrowed further to a specific 1.39% improvement. The final value is likely representative of a typical value industry may be able to achieve in future years.

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[144] Wilcutts, M., Switkes, J., Shost, M., and Tripathi, A., ‘‘Design and Benefits of Dynamic Skip Fire Strategies for Cylinder Deactivated Engines,’’ SAE Int. J. Engines 6(1):278–288, 2013, available at *https://doi.org/10.4271/2013-01-0359.* Eisazadeh-Far, K. and Younkins, M., ‘‘Fuel Economy Gains through Dynamic-Skip-Fire in Spark Ignition Engines,’’ SAE Technical Paper 2016–01–0672, 2016, available at *https://doi.org/10.4271/2016-01-0672.*

[145] EPA, 2018. ‘‘Benchmarking and Characterization of a Full Continuous Cylinder Deactivation System.’’ Presented at the SAE World Congress, April 10–12, 2018. Retrieved from *https://www.regulations.gov/document?D=EPA-HQ-OAR-2018-0283-0029.*

[146] 2015 NAS report, at 104.

[147] Hatano, J., Fukushima, H., Sasaki, Y., Nishimori, K., Tabuchi, T., Ishihara, Y. ‘‘The New 1.6L 2-Stage Turbo Diesel Engine for HONDA CR–V.’’ 24th Aachen Colloquium—Automobile and Engine Technology 2015.

[148] Steinparzer, F., Nefischer, P., Hiemesch, D., Kaufmann, M., Steinmayr, T. ‘‘The New Six-Cylinder Diesel Engines from the BMW In-Line Engine Module.’’ 24th Aachen Colloquium—Automobile and Engine Technology 2015.

[149] Eder, T., Weller, R., Spengel, C., Böhm, J., Herwig, H., Sass, H. Tiessen, J., Knauel, P. ‘‘Launch of the New Engine Family at Mercedes-Benz.’’ 24th Aachen Colloquium—Automobile and Engine Technology 2015.

[150] ‘‘Polyalkylene Glycol (PAG) Based Lubricant for Light- & Medium-Duty Axles,’’ 2017 DOE Annual Merit Review. Ford Motor Company, Gangopadhyay, A., Ved, C., Jost, N. *https://energy.gov/sites/prod/files/2017/06/f34/ft023_gangopadhyay_2017_o.pdf.*

[151] ‘‘*Power-Cylinder Friction Reduction through Coatings, Surface Finish, and Design,*’’ 2017 DOE Annual Merit Review. Ford Motor Company. Gangopadhay, A. Erdemir, A. *https://energy.gov/sites/prod/files/2017/06/f34/ft050_gangopadhyay_2017_o.pdf.*

[152] ‘‘*Nissan licenses energy-efficient engine technology to HELLER,*’’ *https://newsroom.nissan-global.com/releases/170914-01-e?lang=en-US&rss&la=1&downloadUrl=%2Freleases%2F170914-01-e%2Fdownload.* Last accessed April 2018.

[153] ‘‘*Infiniti's Brilliantly Downsized V–6 Turbo Shines,*’’ *http://wardsauto.com/engines/infiniti-s-brilliantly-downsized-v-6-turbo-shines.* Last Accessed April 2018.

Table III-11 – Engine Technologies Modeled Using Efficiency Improvement Factors

Baseline Technology	Fuel Efficiency Improvement Factor	New Technology
DEAC	3% for ≤ 4 Cylinders 6% for > 4 Cylinders	ADEAC
TURBOD	1.5% for ≤ 4 Cylinders 3% for > 4Cylinders	TURBOAD
ADSL	12.8%	DSLI
DSLI	4.5% for small and medium non-performance cars and SUVs, and small performance cars; 7.5% for all other technology classes	DSLIAD
All Engine Technologies	1.39%	EFR

(3) Engine Effectiveness Values

The effectiveness values for the engine technologies, for all ten vehicle technology classes, are shown in Figure III–8. Each of the effectiveness values shown is representative of the improvements seen for upgrading only the listed engine technology for a given combination of other technologies. In other words, the range of effectiveness values seen for each specific technology (*e.g.,* TURBO1) represents the addition of the TURBO1 technology to every technology combination that could select the addition of TURBO1. See Table III–12 for several specific examples. It must be emphasized, the change in fuel consumption values between entire technology keys is used,[154] and not the individual technology effectiveness values. Using the change between whole technology keys captures the complementary or non-complementary interactions among technologies.

Table III-12 – Example of Effectiveness Calculations Shown in Figure III-8*

Tech	Vehicle Tech Class	Initial Technology Key	Fuel Consumption Initial (gal/mile)	Fuel Consumption New (gal/mile)	Effectiveness (%)
TURBO1	Medium Car	DOHC;VVT;;;;;AT8L2;SS12V;ROLL10;AERO5;MR2	0.0282	0.0248	12.15
TURBO1	Medium Car	DOHC;VVT;;;;;AT8L2;CONV;ROLL10;AERO5;MR2	0.0292	0.0254	13.13
TURBO1	Medium Car	DOHC;VVT;;;;;AT8L2;BISG;ROLL10;AERO5;MR2	0.0275	0.0237	13.80
TURBO1	Medium Car	DOHC;VVT;;;;;AT6;SS12V;ROLL10;AERO5;MR2	0.0312	0.0269	13.80

*The 'Tech' is added to the 'Initial Technology Key' replacing the existing engine technology, resulting in the new fuel consumption value. The percent effectiveness is found by determining the percent improved fuel consumption of the new value versus the initial value.[155]

Some of the advanced engine technologies have values that indicate seemingly low effectiveness. Investigation of these values shows the low effectiveness was a result of applying the advanced engines to existing SHEVP2 architectures. This effect is expected and illustrates the importance of using the full vehicle modeling to capture interactions between technologies and capture instances of both complimentary technologies and non-complimentary technologies. In this instance, the SHEVP2 powertrain improves fuel economy, in part, by allowing the engine to spend more time operating at efficient engine speed and load conditions. This reduces the advantage of adding advanced engine technologies, which also improve fuel economy, by broadening the range of speed and load conditions for the engine to operate at high efficiency. This redundancy in fuel savings mechanism results in a lower effectiveness when the technologies are added to each other.

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[154] Technology key is the unique collection of technologies that constitutes a specific vehicle, *see* Section III.C.4.c).

[155] The full data set we used to generate this example can be found in the FE_1 Improvements file.

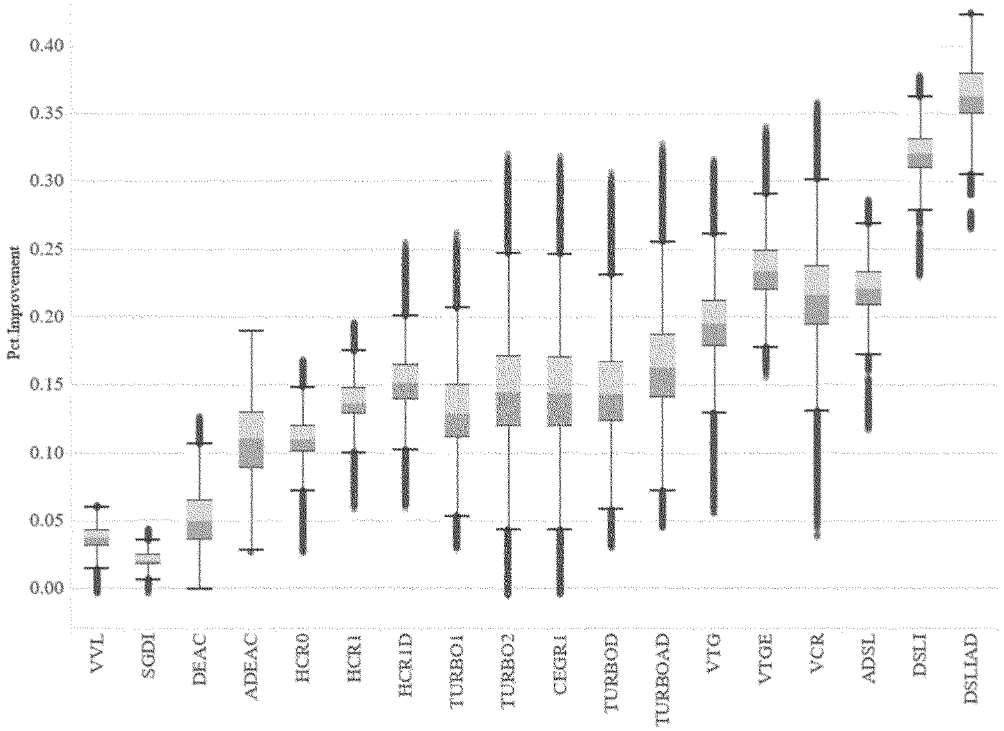

Figure III-8 – Engine Technologies Effectiveness Values for all Vehicle Technology Classes[156]

(e) Engine Costs

The CAFE Model considers both cost and effectiveness in selecting any technology changes. We have allocated considerable resources to sponsoring research to determine direct manufacturing costs (DMCs) for fuel saving technologies. As discussed in detail in TSD Chapter 3.1.5, the engine costs used in this analysis build on estimates from the 2015 NAS report, agency-funded teardown studies, and work performed by non-government organizations.[157]

Absolute costs of the engine technology are used in this analysis instead of relative costs, which were used prior to the 2020 final rule. The absolute costs are used to ensure the full cost of the IC engine is removed when electrification technologies are applied specifically for the transition to BEVs. This analysis models the cost of adoption of BEV technology by first removing the costs associated with IC powertrain systems, then applying the BEV systems costs. Relative costs can still be determined through comparison of the absolute costs for the initial technology combination and the new technology combination.

As discussed in detail in TSD Chapter 3.1.5, engine costs are assigned based on the number of cylinders in the engine and whether the engine is naturally aspirated or turbocharged and downsized. Table III–13 below shows an example of absolute costs for engine technologies in 2018$. The example costs are shown for a straight 4-cylinder DOHC engine and V-6-cylinder DOHC engine. The table shows costs declining across successive years due to the learning rate applied to each engine technology. For a full list of all absolute engine costs used in the analysis across all model years, see the Technologies file.

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[156] The box shows the inner quartile range (IQR) of the effectiveness values and whiskers extend out 1.5 × IQR. The dots outside this range show effectiveness values outside those thresholds. The data used to create this figure can be found in the FE_1 Improvements file.

[157] FEV prepared several cost analysis studies for EPA on subjects ranging from advanced 8-speed transmissions to belt alternator starters or start/stop systems. NHTSA contracted Electricore, EDAG, and Southwest Research for teardown studies evaluating mass reduction and transmissions. The 2015 NAS report also evaluated technology costs developed based on these teardown studies.

Table III-13 – Examples of Absolute Costs for Engine Technologies in 2018$ for a Straight 4-Cylinder DOHC Engine and a V-6-Cylinder DOHC Engine for Select Model Years

Technology	4C1B Costs (2018$)			6C2B Costs (2018$)		
	MY 2020	MY 2025	MY 2030	MY 2020	MY 2025	MY 2030
EFR	66.61	63.97	57.83	99.92	95.96	86.74
VVT	5,205.13	5,201.71	5,199.02	6,059.15	6,052.31	6,046.93
VVL	5,402.62	5,393.28	5,385.95	6,298.29	6,284.28	6,273.28
SGDI	5,435.72	5,425.38	5,417.27	6,347.93	6,332.43	6,320.26
DEAC	5,268.59	5,263.27	5,259.08	6,040.39	6,034.11	6,029.18
TURBO1	6,228.96	6,179.91	6,152.15	7,073.58	7,020.02	6,989.71
TURBO2	6,807.16	6,644.50	6,538.33	7,673.21	7,498.58	7,384.60
CEGR1	7,221.06	7,019.17	6,887.39	8,087.11	7,873.26	7,733.67
ADEAC	6,292.36	6,217.71	6,174.57	7,633.14	7,521.16	7,456.45
HCR0	5,819.86	5,803.73	5,801.18	6,953.63	6,928.79	6,924.86
HCR1	5,863.02	5,833.12	5,825.45	6,996.80	6,958.18	6,949.13
HCR1D	6,040.68	6,005.45	5,993.60	7,206.43	7,161.53	7,147.55
VCR	7,370.02	7,208.71	7,124.07	8,214.65	8,048.82	7,961.63
VTG	7,592.44	7,380.16	7,241.61	8,457.91	8,234.25	8,088.26
VTGE	8,892.07	8,403.54	8,097.54	9,757.54	9,257.62	8,944.19
TURBOD	6,406.61	6,352.24	6,320.30	7,251.23	7,192.35	7,157.85
TURBOAD	6,971.41	6,861.47	6,801.38	7,816.03	7,701.57	7,638.93
ADSL	9,726.31	9,459.91	9,362.48	11,384.74	11,065.55	10,948.81
DSLI	10,226.67	9,931.51	9,823.56	12,036.41	11,679.77	11,549.33
DSLIAD	10,791.47	10,440.74	10,304.64	12,883.61	12,443.61	12,270.94
CNG	11,822.52	11,612.31	11,471.76	12,676.54	12,462.91	12,319.67

2. Transmission Paths

For this analysis, DOT classified all light duty vehicle transmission technologies into discrete transmission technology paths. These paths are used to model the most representative characteristics, costs, and performance of the fuel-economy improving transmissions most likely available during the rulemaking time frame, MYs 2024–2026.

The following sections discuss how transmission technologies considered in this analysis are defined, the general technology categories used by the CAFE Model, and the transmission technologies' relative effectiveness and costs. The following sections also provide an overview of how the transmission technologies were assigned to the MY 2020 fleet, as well as the adoption features applicable to the transmission technologies.

(a) Transmission Modeling in the CAFE Model

DOT modeled two major categories of transmissions for this analysis: Automatic and manual. Automatic transmissions are characterized by automatically selecting and shifting between transmission gears for the driver during vehicle operation. Automatic transmissions are further subdivided into four subcategories: Traditional automatic transmissions (AT), dual clutch transmissions (DCT), continuously variable transmissions (CVT), and direct drive transmissions (DD).

ATs and CVTs also employ different levels of high efficiency gearbox (HEG) technology. HEG improvements for transmissions represent incremental advancement 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. DOT considered three levels of HEG improvements in this analysis, based on 2015 recommendations by the National Academy of Sciences and CBI data.[158] HEG efficiency improvements are applied to ATs and CVTs, as those transmissions inherently have higher friction and parasitic loads related to hydraulic control systems and greater component complexity, compared to MTs and DCTs. HEG technology improvements are noted in the transmission technology pathways by increasing ''levels'' of a transmission technology; for example, the baseline 8-speed automatic transmission is termed ''AT8'', while an AT8 with level 2 HEG technology is ''AT8L2'' and an AT8 with level 3 HEG technology is ''AT8L3.''

AT: Conventional planetary gear automatic transmissions are the most

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[158] 2015 NAS report, at 191.

popular transmission.[159] ATs typically contain three or four planetary gear sets that provide the various gear ratios. Gear ratios are selected by activating solenoids which engage or release multiple clutches and brakes as needed. ATs are packaged with torque converters, which provide a fluid coupling between the engine and the driveline and provide a significant increase in launch torque. When transmitting torque through this fluid coupling, energy is lost due to the churning fluid. These losses can be eliminated by engaging the torque convertor clutch to directly connect the engine and transmission (''lockup''). For the Draft TAR and 2020 final rule, EPA and DOT surveyed automatic transmissions in the market to assess trends in gear count and purported fuel economy improvements.[160] Based on that survey, and also EPA's more recent 2019 and 2020 Automotive Trends Reports,[161] DOT concluded that modeling ATs with a range of 5 to 10 gears, with three levels of HEG technology for this analysis was reasonable.

CVT: Conventional continuously variable transmissions consist of two cone-shaped pulleys, connected with a belt or chain. Moving the pulley halves allows the belt to ride inward or outward radially on each pulley, effectively changing the speed ratio between the pulleys. This ratio change is smooth and continuous, unlike the step changes of other transmission varieties.[162] DOT modeled two types of CVT systems in the analysis, the baseline CVT and a CVT with HEG technology applied.

DCT: Dual clutch transmissions, like automatic transmissions, automate shift and launch functions. DCTs use separate clutches for even-numbered and odd-numbered gears, allowing the next gear needed to be pre-selected, resulting in faster shifting. The use of multiple clutches in place of a torque converter results in lower parasitic losses than ATs.[163] Because of a history of limited appeal,[164] [165] DOT constrains application of additional DCT technology to vehicles already using DCT technology, and only models two types of DCTs in the analysis.

MT: Manual transmissions are transmissions that require direct control by the driver to operate the clutch and shift between gears. In a manual transmission, gear pairs along an output shaft and parallel layshaft are always engaged. Gears are selected via a shift lever, operated by the driver. The lever operates synchronizers, which speed match the output shaft and the selected gear before engaging the gear with the shaft. During shifting operations (and during idle), a clutch between the engine and transmission is disengaged to decouple engine output from the transmission. Automakers today offer a minimal selection of new vehicles with manual transmissions.[166] As a result of reduced market presence, DOT only included three variants of manual transmissions in the analysis.

The transmission model paths used in this analysis are shown in Figure III–9. Baseline-only technologies (MT5, AT5, AT7L2, AT9L2, and CVT) are grayed and can only be assigned as initial vehicle transmission configurations. Further details about transmission path modeling can be found in TSD Chapter 3.2.

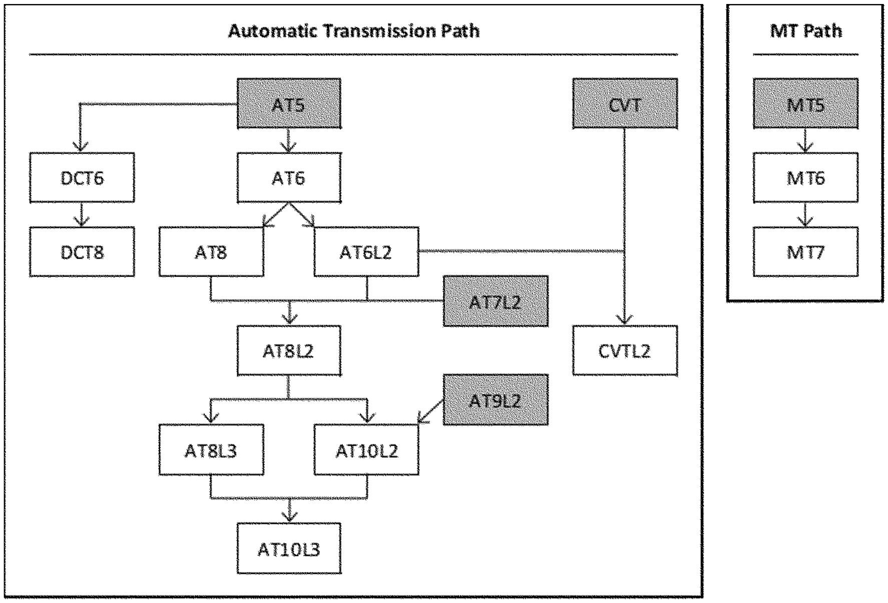

Figure III-9 – CAFE Model Pathways for Transmission Technologies

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[159] 2020 EPA Automotive Trends Report, at 57–61.

[160] Draft TAR at 5–50, 5–51; Final Regulatory Impact Analysis accompanying the 2020 final rule, at 549.

[161] The 2019 EPA Automotive Trends Report, EPA–420–R–20–006, at 59 (March 2020), *https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100YVFS.pdf* [hereinafter 2019 EPA Automotive Trends Report]; 2020 EPA Automotive Trends Report, at 57.

[162] 2015 NAS report, at 171.

[163] 2015 NAS report, at 170.

[164] 2020 EPA Automotive Trends Report, at 57.

[165] National Academies of Sciences, Engineering, and Medicine 2021. Assessment of Technologies for Improving Light-Duty Vehicle Fuel Economy 2025–2035. Washington, DC: The National Academies Press. *https://doi.org/10.17226/26092,* at 4–56 [hereinafter 2021 NAS report].

[166] 2020 EPA Automotive Trends Report, at 61.

(b) Transmission Analysis Fleet Assignments

The wide variety of transmissions on the market are classified into discrete transmission technology paths for this analysis. These paths are used to model the most representative characteristics, costs, and performance of the fuel economy-improving technologies most likely available during the rulemaking time frame.

For the 2020 analysis fleet, DOT gathered data on transmissions from manufacturer mid-model year CAFE compliance submissions and publicly available manufacturer specification sheets. These data were used to assign transmissions in the analysis fleet and determine which platforms shared transmissions.

Transmission type, number of gears, and high-efficiency gearbox (HEG) level are all specified for the baseline fleet assignment. The number of gears in the assignments for automatic and manual transmissions usually match the number of gears listed by the data sources, with some exceptions. Four-speed transmissions were not modeled in Autonomie for this analysis due to their rarity and low likelihood of being used in the future, so DOT assigned 2020 vehicles with an AT4 or MT4 to an AT5 or MT5 baseline, respectively. Some dual-clutch transmissions were also an exception; dual-clutch transmissions with seven gears were assigned to DCT6.

For automatic and continuously variable transmissions, the identification of the most appropriate transmission path model required additional steps; this is because high-efficiency gearboxes are considered in the analysis but identifying HEG level from specification sheets alone was not always straightforward. DOT conducted a review of the age of the transmission design, relative performance versus previous designs, and technologies incorporated and used the information obtained to assign an HEG level. No automatic transmissions in the MY 2020 analysis fleet were determined to be at HEG Level 3. In addition, no six-speed automatic transmissions were assigned HEG Level 2. However, DOT found all 7-speed, all 9-speed, all 10-speed, and some 8-speed automatic transmissions to be advanced transmissions operating at HEG Level 2 equivalence. Eight-speed automatic transmissions developed after MY 2017 are assigned HEG Level 2. All other transmissions are assigned to their respective transmission's baseline level. The baseline (HEG level 1) technologies available include AT6, AT8, and CVT.

DOT assigned any vehicle in the analysis fleet with a hybrid or electric powertrain a direct drive (DD) transmission. This designation is for informational purposes; if specified, the transmission will not be replaced or updated by the model.

In addition to technology type, gear count, and HEG level, transmissions are characterized in the analysis fleet by drive type and vehicle architecture. Drive types considered in the analysis include front-, rear-, all-, and four-wheel drive. The definition of drive types in the analysis does not always align with manufacturers' drive type designations; see the end of this subsection for further discussion. These characteristics, supplemented by information such as gear ratios and production locations, showed that manufacturers use transmissions that are the same or similar on multiple vehicle models. Manufacturers have told the agency they do this to control component complexity and associated costs for development, manufacturing, assembly, and service. If multiple vehicle models share technology type, gear count, drive configuration, internal gear rations, and production location, the transmissions are treated as a single group for the analysis. Vehicles in the analysis fleet with the same transmission configuration adopt additional fuel-saving transmission technology together, as described in Section III.C.2.a).

Shared transmissions are designated and tracked in the CAFE Model input files using transmission codes. Transmission codes are six-digit numbers that are assigned to each transmission and encode information about them. This information includes the manufacturer, drive configuration, transmission type, and number of gears. TSD Chapter 3.2.2 includes more information on the transmission codes designated in the MY 2020 analysis fleet.

Different transmission codes are assigned to variants of a transmission that may have appeared to be similar based on the characteristics considered in the analysis but are not mechanically identical. DOT analysts distinguish among transmission variants by comparing their internal gear ratios and production locations. For example, several Ford nameplates carry a rear-wheel drive, 10-speed automatic transmission. These nameplates comprise a wide variety of body styles and use cases, and so DOT assigned different transmission codes to these different nameplates. Because they have different transmission codes, they are not treated as ''shared'' for the purposes of the analysis and have the opportunity to adopt transmission technologies independently.

Note that when determining the drive type of a transmission, the assignment of all-wheel drive versus four-wheel drive is determined by vehicle architecture. This assignment does not necessarily match the drive type used by the manufacturer in specification sheets and marketing materials. Vehicles with a powertrain capable of providing power to all wheels and a transverse engine (front-wheel drive architecture) are assigned all-wheel drive. Vehicles with power to all four wheels and a longitudinal engine (rear-wheel drive architecture) are assigned four-wheel drive.

(c) Transmission Adoption Features

Transmission technology pathways are designed to prevent ''branch hopping''—changes in transmission type that would correspond to significant changes in transmission architecture—for vehicles that are relatively advanced on a given pathway. For example, any automatic transmission with more than five gears cannot move to a dual-clutch transmission. For a more detailed discussion of path logic applied in the analysis, including technology supersession logic and technology mutual exclusivity logic, please see CAFE Model Documentation S4.5 Technology Constraints (Supersession and Mutual Exclusivity). Additionally, the CAFE Model prevents ''branch hopping'' to prevent stranded capital associated with moving from one transmission architecture to another. Stranded capital is discussed in Section III.C.6.

Some technologies that are modeled in the analysis are not yet in production, and therefore are not assigned in the baseline fleet. Nonetheless, these technologies, which are projected to be available in the analysis timeframe, are available for future adoption. For instance, an AT10L3 is not observed in the baseline fleet, but it is plausible that manufacturers that employ AT10L2 technology may improve the efficiency of those AT10L2s in the rulemaking timeframe.

The following sections discuss specific adoption features applied to each type of transmission technology.

When electrification technologies are adopted, the transmissions associated with those technologies will supersede the existing transmission on a vehicle. The transmission technology is superseded if P2 hybrids, plug-in hybrids, or battery electric vehicle technologies are applied. For more information, see Section III.D.3.c).

The automatic transmission path precludes adoption of other transmission types once a platform progresses past an AT6. 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 were adopted after AT6 in the rulemaking timeframe.

Vehicles that did not start out with AT7L2 or AT9L2 transmissions cannot adopt those technologies in the model. The agency observed that MY 2017 vehicles with those technologies were primarily luxury performance vehicles and concluded that other vehicles would likely not adopt those technologies. DOT concluded that this was also a reasonable assumption for the MY 2020 analysis fleet because vehicles that have moved to more advanced automatic transmissions have overwhelmingly moved to 8-speed and 10-speed transmissions.[167]

CVT adoption is limited by technology path logic. CVTs cannot be adopted by vehicles that do not originate with a CVT or by vehicles with multispeed transmissions beyond AT6 in the baseline fleet. Vehicles with multispeed transmissions greater than AT6 demonstrate increased ability to operate the engine at a highly efficient speed and load. Once on the CVT path, the platform is only allowed to apply improved CVT technologies. The analysis restricts the application of CVT technology on larger vehicles because of the higher torque (load) demands of those vehicles and CVT torque limitations based on durability constraints. Additionally, this restriction is used to avoid the significant level of stranded capital.

The analysis allows vehicles in the baseline fleet that have DCTs to apply an improved DCT and allows vehicles with an AT5 to consider DCTs. Drivability and durability issues with some DCTs have resulted in a low relative adoption rate over the last decade; this is also broadly consistent with manufacturers' technology choices.[168]

Manual transmissions can only move to more advanced manual transmissions for this analysis, because other transmission types do not provide a similar driver experience (utility). Manual transmissions cannot adopt AT, CVT, or DCT technologies under any circumstance. Other transmissions cannot move to MT because manual transmissions lack automatic shifting associated with the other transmission types (utility) and in recognition of the low customer demand for manual transmissions.[169]

(d) Transmission Effectiveness Modeling

For this analysis, DOT used the Autonomie full vehicle simulation tool to model the interaction between transmissions and the full vehicle system to improve fuel economy, and how changes to the transmission subsystem influence the performance of the full vehicle system. The full vehicle simulation approach clearly defines the contribution of individual transmission technologies and separates those contributions from other technologies in the full vehicle system. The modeling approach follows the recommendations of the National Academy of Sciences in its 2015 light duty vehicle fuel economy technology report to use full vehicle modeling supported by application of collected improvements at the sub-model level.[170] See TSD Chapter 3.2.4 for more details on transmission modeling inputs and results.

The only technology effectiveness results that were not directly calculated using the Autonomie simulation results were for the AT6L2. DOT determined that the model for this specific technology was inconsistent with the other transmission models and overpredicted effectiveness results. Evaluation of the AT6L2 transmission model revealed an overestimated efficiency map was developed for the AT6L2 model. The high level of efficiency assigned to the transmission surpassed benchmarked advanced transmissions.[171] To address the issue, DOT replaced the effectiveness values of the AT6L2 model. DOT replaced the effectiveness for the AT6L2 technology with analogous effectiveness values from the AT7L2 transmission model. For additional discussion on how analogous effectiveness values are determined please see Section III.D.1.d)(2).

The effectiveness values for the transmission technologies, for all ten vehicle technology classes, are shown in Figure III–10. Each of the effectiveness values shown is representative of the improvements seen for upgrading only the listed transmission technology for a given combination of other technologies. In other words, the range of effectiveness values seen for each specific technology, *e.g.,* AT10L3, represents the addition of the AT10L3 technology to every technology combination that could select the addition of AT10L3. It must be emphasized that the graph shows the change in fuel consumption values between entire technology keys,[172] and not the individual technology effectiveness values. Using the change between whole technology keys captures the complementary or non-complementary interactions among technologies. In the graph, the box shows the inner quartile range (IQR) of the effectiveness values and whiskers extend out 1.5 × IQR. The dots outside of the whiskers show values for effectiveness that are outside these bounds.

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[167] 2020 EPA Automotive Trends Report, at 64, figure 4.18.

[168] *Ibid.*

[169] *Ibid.*

[170] 2015 NAS report, at 292.

[171] Autonomie model documentation, Chapter 5.3.4. Transmission Performance Data.

[172] Technology key is the unique collection of technologies that constitutes a specific vehicle, *see* Section III.C.4.c).

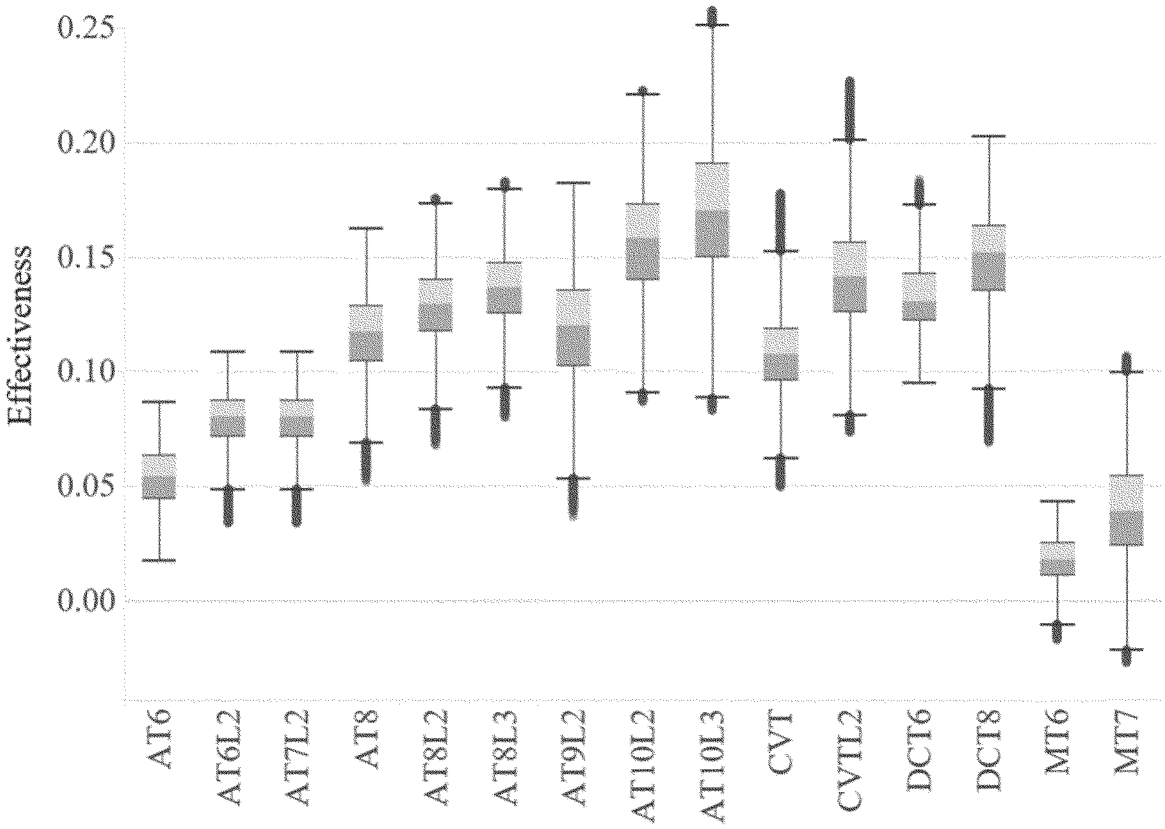

Figure III-10 – Transmission Technologies Effectiveness Values for all Vehicle Technology Classes[173]

Note that the effectiveness for the MT5, AT5 and DD technologies are not shown. The DD transmission does not have a standalone effectiveness because it is only implemented as part of electrified powertrains. The MT5 and AT5 also have no effectiveness values because both technologies are baseline technologies against which all other technologies are compared.

(e) Transmission Costs

This analysis uses transmission costs drawn from several sources, including the 2015 NAS report and NAS-cited studies. TSD Chapter 3.2.5 provides a detailed description of the cost sources used for each transmission technology. Table III–14 shows an example of absolute costs for transmission technologies in 2018$ across select model years, which demonstrates how cost learning is applied to the transmission technologies over time. Note, because transmission hardware is often shared across vehicle classes, transmission costs are the same for all vehicle classes. For a full list of all absolute transmission costs used in the analysis across all model years, see the Technologies file.

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[173] The data used to create this figure can be found the FE_1 Improvements file.

Table III-14 – Examples of Absolute Costs for Transmission Technologies in 2018$ for Select Model Years

Technology	MY 2020	MY 2025	MY 2030
MT5	1,563.97	1,563.97	1,563.97
MT6	1,928.41	1,917.08	1,910.70
MT7	2,226.75	2,100.64	2,034.88
AT5	2,085.30	2,085.30	2,085.30
AT6	2,063.19	2,063.19	2,063.19
AT6L2	2,331.44	2,303.65	2,293.25
AT7L2	2,298.63	2,276.53	2,268.26
AT8	2,195.36	2,195.18	2,195.15
AT8L2	2,442.32	2,405.33	2,391.49
AT8L3	2,649.15	2,590.74	2,568.89
AT9L2	2,546.03	2,498.29	2,480.43
AT10L2	2,546.03	2,498.29	2,480.43
AT10L3	2,753.44	2,684.21	2,658.31
DCT6	2,115.89	2,115.84	2,115.84
DCT8	2,653.91	2,653.15	2,653.02
CVT	2,332.83	2,322.63	2,315.25
CVTL2	2,518.80	2,500.94	2,488.02

3. Electrification Paths

The electric paths include a large set of technologies that share the common element of using electrical power for certain vehicle functions that were traditionally powered mechanically by engine power. Electrification technologies thus can range from electrification of specific accessories (for example, electric power steering to reduce engine loads by eliminating parasitic losses) to electrification of the entire powertrain (as in the case of a battery electric vehicle).

The following subsections discuss how each electrification technology is defined in the CAFE Model and the electrification pathways down which a vehicle can travel in the compliance simulation. The subsections also discuss how the agency assigned electrified vehicle technologies to vehicles in the MY 2020 analysis fleet, any limitations on electrification technology adoption, and the specific effectiveness and cost assumptions used in the Autonomie and CAFE Model analysis.

(a) Electrification Modeling in the CAFE Model

The CAFE Model defines the technology pathway for each type of electrification grouping in a logical progression. Whenever the CAFE Model converts a vehicle model to one of the available electrified systems, both effectiveness and costs are updated according to the specific components' modeling algorithms. Additionally, all technologies on the different electrification paths are mutually exclusive and are evaluated in parallel. For example, the model may evaluate PHEV20 technology prior to having to apply 12-volt stop-start (SS12V) or strong hybrid technology. The specific set of algorithms and rules are discussed further in the sections below, and more detailed discussions are included in the CAFE Model Documentation. The specifications for each electrification technology used in the analysis is discussed below.

The technologies that are included on the three vehicle-level paths pertaining to the electrification and electric improvements defined within the modeling system are illustrated in Figure III–11. As shown in the Electrification path, the baseline-only CONV technology is grayed out. This technology is used to denote whether a vehicle comes in with a conventional powertrain (*i.e.,* a vehicle that does not include any level of hybridization) and to allow the model to properly map to the Autonomie vehicle simulation database results. If multiple branches converge on a single technology, the subset of technologies that will be disabled from further adoption is extended only up the point of convergence.

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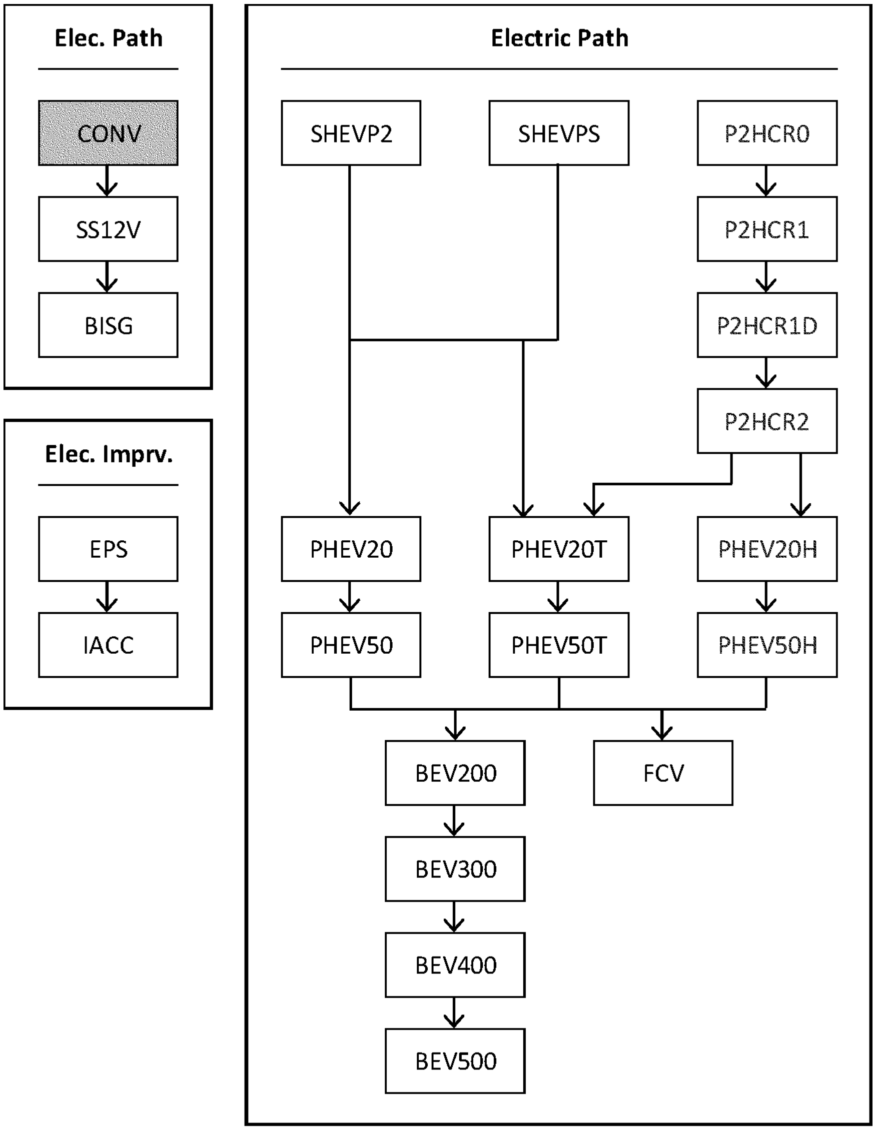

Figure III-11 – Electrification Paths in the CAFE Model

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SS12V: 12-volt stop-start (SS12V), sometimes referred to as start-stop, idle-stop, or a 12-volt micro hybrid system, is the most basic hybrid system that facilitates idle-stop capability. In this system, the integrated starter generator is coupled to the internal combustion (IC) engine. When the vehicle comes to an idle-stop the IC engine completely shuts off, and, with the help of the 12-volt battery, the engine cranks and starts again in response to throttle to move the vehicle, application or release of the brake pedal to move the vehicle. The 12-volt battery used for the start-stop system is an improved unit compared to a traditional 12-volt battery, and is capable of higher power, increased life cycle, and capable of minimizing voltage drop on restart. This technology is beneficial to reduce fuel consumption and emissions when the vehicle frequently stops, such as in city driving conditions or in stop and go traffic. 12VSS can be applied to all vehicle technology classes.

BISG: The belt integrated starter generator, sometimes referred to as a mild hybrid system or P0 hybrid, provides idle-stop capability and uses a higher voltage battery with increased energy capacity over conventional automotive batteries. These higher voltages allow the use of a smaller, more powerful and efficient electric motor/generator which replaces the standard alternator. In BISG systems, the motor/generator is coupled to the engine via belt (similar to a standard alternator). In addition, these motor/generators can assist vehicle braking and recover braking energy while the vehicle slows down (regenerative braking) and in turn can propel the vehicle at the beginning of launch, allowing the engine to be restarted later. Some limited electric assist is also provided during acceleration to improve engine efficiency. Like the micro hybrids, BISG can be applied to all vehicles in the analysis except for Engine 26a (VCR). We assume all mild hybrids are 48-volt systems with engine belt-driven motor/generators.

SHEVP2/SHEVPS: A strong hybrid vehicle is a vehicle that combines two or more propulsion systems, where one uses gasoline (or diesel), and the other captures energy from the vehicle during deceleration or braking, or from the engine and stores that energy for later used by the vehicle. This analysis evaluated the following strong hybrid systems: Hybrids with ‘‘P2’’ parallel drivetrain architectures (SHEVP2),[174] and hybrids with power-split architectures (SHEVPS). Both types provide start-stop or idle-stop functionality, regenerative braking capability, and vehicle launch assist. A SHEVPS has a higher potential for fuel economy improvement than a SHEVP2, although its cost is also higher and engine power density is lower.[175]

P2 parallel hybrids (SHEVP2) are a type of hybrid vehicle that use a transmission-integrated electric motor placed between the engine and a gearbox or CVT, with a clutch that allows decoupling of the motor/transmission from the engine. Although similar to the configuration of the crank mounted integrated starter generator (CISG) system discussed previously, a P2 hybrid is typically equipped with a larger electric motor and battery in comparison to the CISG. Disengaging the clutch allows all-electric operation and more efficient brake-energy recovery. Engaging the clutch allows coupling of the engine and electric motor and, when combined with a transmission, reduces gear-train losses relative to power-split or 2-mode hybrid systems. P2 hybrid systems typically rely on the internal combustion engine to deliver high, sustained power levels. Electric-only mode is used when power demands are low or moderate.

An important feature of the SHEVP2 system is that it can be applied in conjunction with most engine technologies. Accordingly, once a vehicle is converted to a SHEVP2 powertrain in the compliance simulation, the CAFE Model allows the vehicle to adopt the conventional engine technology that is most cost effective, regardless of relative location of the existing engine on the engine technology path. For example, a vehicle in the MY 2020 analysis fleet that starts with a TURBO2 engine could adopt a TURBO1 engine with the SHEVP2 system, if that TURBO1 engine allows the vehicle to meet fuel economy standards more cost effectively.

The power-split hybrid (SHEVPS) is a hybrid electric drive system that replaces the traditional transmission with a single planetary gear set (the power-split device) and a motor/generator. This motor/generator uses the engine either to charge the battery or to supply additional power to the drive motor. A second, more powerful motor/generator is connected to the vehicle's final drive and always turns with the wheels. The planetary gear splits engine power between the first motor/generator and the drive motor either to charge the battery or to supply power to the wheels. During vehicle launch, or when the battery state of charge (SOC) is high, the engine is turned off and the electric motor propels the vehicle.[176] During normal driving, the engine output is used both to propel the vehicle and to generate electricity. The electricity generated can be stored in the battery and/or used to drive the electric motor. During heavy acceleration, both the engine and electric motor (by consuming battery energy) work together to propel the vehicle. When braking, the electric motor acts as a generator to convert the kinetic energy of the vehicle into electricity to charge the battery.

Table III–15 below shows the configuration of conventional engines and transmissions used with strong hybrids for this analysis. The SHEVPS powertrain configuration was paired with a planetary transmission (eCVT) and Atkinson engine (Eng26). This configuration was designed to maximize efficiency at the cost of reduced towing capability and real-world acceleration performance.[177] In contrast, the SHEVP2 powertrains were paired with an advanced 8-speed automatic transmissions (AT8L2) and could be paired with most conventional engines.[178]

Table III-15 – Configuration of Strong Hybrid Architectures with Transmissions and Engines

CAFE Model Technologies	Transmission Options	Engine Options (PC/SUV)	Engine Options (LT)
SHEVPS	Planetary - eCVT	Eng 26 - Atkinson	N/A
SHEVP2[179]	AT8L2	All Engines except for VTGE and VCR	All Engines except for VTGE and VCR

PHEV: Plug-in hybrid electric vehicles are hybrid electric vehicles with the means to charge their battery packs from an outside source of electricity (usually the electric grid). These vehicles have larger battery packs with more energy storage and a greater capability to be discharged than other non-plug-in hybrid electric vehicles. PHEVs also generally use a control system that allows the battery pack to be substantially depleted under electric-only or blended mechanical/electric operation and batteries that can be cycled in charge-sustaining operation at a lower state of charge than non-plug-in hybrid electric vehicles. These vehicles generally have a greater all-electric range than typical strong HEVs. Depending on how these vehicles are operated, they can use electricity exclusively, operate like a conventional hybrid, or operate in some combination of these two modes.

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[174] Depending on the location of electric machine (motor with or without inverter), the parallel hybrid technologies are classified as P0-motor located at the primary side of the engine, P1-motor located at the flywheel side of the engine, P2-motor located between engine and transmission, P3-motor located at the transmission output, and P4-motor located on the axle.

[175] Kapadia, J., Kok, D., Jennings, M., Kuang, M. et al., ''Powersplit or Parallel—Selecting the Right Hybrid Architecture,'' SAE Int. J. Alt. Power. 6(1):2017, doi:10.4271/2017–01–1154.

[176] Autonomie model documentation, Chapter 4.13.2.

[177] Kapadia, J., D, Kok, M. Jennings, M. Kuang, B. Masterson, R. Isaacs, A. Dona. 2017. Powersplit or Parallel—Selecting the Right Hybrid Architecture. SAE International Journal of Alternative Powertrains 6 (1): 68–76. *https://doi.org/10.4271/2017-01-1154.*

[178] We did not model SHEVP2s with VTGe (Eng23c) and VCR (Eng26a).

[179] Engine 01, 02, 03, 04, 5b, 6a, 7a, 8a, 12, 12-DEAC, 13, 14, 17, 18, 19, 20, 21, 22b, 23b, 24, 24-Deac. *See* Section III.D.1 for these engine specifications.

There are four PHEV architectures included in this analysis that reflect combinations of two levels of all-electric range (AER) and two engine types. DOT selected 20 miles AER and 50 miles AER to reasonably span the various AER in the market, and their effectiveness and cost. DOT selected an Atkinson engine and a turbocharged downsized engine to span the variety of engines in the market.

PHEV20/PHEV20H and PHEV50/PHEV50H are essentially a SHEVPS with a larger battery and the ability to drive with the engine turned off. In the CAFE Model, the designation for ''H'' in PHEVxH could represent another type of engine configuration, but for this analysis DOT used the same effectiveness values as PHEV20 and PHEV50 to represent PHEV20H and PHEV50H, respectively. The PHEV20/PHEV20H represents a ''blended-type'' plug-in hybrid, which can operate in all-electric (engine off) mode only at light loads and low speeds, and must blend electric motor and engine power together to propel the vehicle at medium or high loads and speeds. The PHEV50/PHEV50H represents an extended range electric vehicle (EREV), which can travel in all-electric mode even at higher speeds and loads. Further discussion of engine sizing, batteries, and motors for these PHEVs is discussed in Section III.D.3.d).

PHEV20T and PHEV50T are 20 mile and 50 mile AER vehicles based on the SHEVP2 engine architecture. The PHEV versions of these architectures include larger batteries and motors to meet performance in charge sustaining mode at higher speeds and loads as well as similar performance and range in all electric mode in city driving, at higher speeds and loads. For this analysis, the CAFE Model considers these PHEVs to have an advanced 8-speed automatic transmission (AT8L2) and TURBO1 (Eng12) in the powertrain configuration. Further discussion of engine sizing, batteries, and motors for these PHEVs is discussed in Section III.D.3.d).

Table III–16 shows the different PHEV configurations used in this analysis.

Table III-16 – Configuration of Plug-in Hybrid Architectures with Transmissions and Engines

CAFE Model Technologies	Transmission Options	Engine Options (PC/SUV)	Engine Options (LT)
PHEV20/PHEV20H	Planetary - eCVT	Eng 26 – Atkinson Engine	N/A
PHEV20T	AT8L2	Eng 12 - TURBO1	Eng 12 - TURBO1
PHEV50/PHEV50H	Planetary - eCVT	Eng 26 - Atkinson	N/A
PHEV50T	AT8L2	Eng 12 - TURBO1	Eng 12 - TURBO1

BEV: Battery electric vehicles are equipped with all-electric drive systems powered by energy-optimized batteries charged primarily by electricity from the grid. BEVs do not have a combustion engine or traditional transmission. Instead, BEVs rely on all electric powertrains, with an advanced transmission packaged with the powertrain. The range of battery electric vehicles vary by vehicle and battery pack size.

DOT simulated BEVs with ranges of 200, 300, 400, and 500 miles in the CAFE Model. BEV range is measured pursuant to EPA test procedures and guidance.[180] The CAFE Model assumes that BEVs transmissions are unique to each vehicle (*i.e.,* the transmissions are not shared by any other vehicle) and that no further improvements are available.

A key note about the BEVs offered in this analysis is that the CAFE Model does not account for vehicle range when considering additional BEV technology adoption. That is, the CAFE Model does not have an incentive to build BEV300, 400, and 500s, because the BEV200 is just as efficient as those vehicles and counts the same toward compliance, but at a significantly lower cost because of the smaller battery. While manufacturers have been building 200-mile range BEVs, those vehicles have generally been passenger cars. Manufacturers have told DOT that greater range is important for meeting the needs of broader range of consumers and to increase consumer demand. More recently, there has been a trend towards manufacturers building higher range BEVs in the market, and manufacturers building CUV/SUV and pickup truck BEVs. To simulate the potential relationship of BEV range to consumer demand, DOT has included several adoption features for BEVs. These are discussed further in Section III.D.3.c).

Fuel cell electric vehicle (FCEV): Fuel cell electric vehicles are equipped with an all-electric drivetrain, but unlike BEVs, FCEVs do not solely rely on batteries; rather, electricity to run the FCEV electric motor is mainly generated by an onboard fuel cell system. FCEV architectures are similar to series hybrids,[181] but with the engine and generator replaced by a fuel cell. Commercially available FCEVs consume hydrogen to generate electricity for the fuel cell system, with most automakers using high pressure gaseous hydrogen storage tanks. FCEVs are currently produced in limited numbers and are available in limited geographic areas where hydrogen refueling stations are accessible. For reference, in MY 2020, only four FCV models were offered for

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[180] BEV electric ranges are determined per EPA guidance Document. ''EPA Test Procedure for Electric Vehicles and Plug-in Hybrids.'' *https://fueleconomy.gov/feg/pdfs/EPA%20test%20procedure%20for%20EVs-PHEVs-11–14–2017.pdf.* November 14, 2017. Last Accessed May 3, 2021.

[181] Series hybrid architecture is a strong hybrid that has the engine, electric motor and transmission in series. The engine in a series hybrid drives a generator that charges the battery.

sale, and since 2014 only 9,975 FCVs have been sold.[182] [183]

For this analysis, the CAFE Model simulates a FCEV with a range of 320 miles. Any type of powertrain could adopt a FCEV powertrain; however, to account for limited market penetration and unlikely increased adoption in the rulemaking timeframe, technology phase in caps were used to control how many FCEVs a manufacturer could build. The details of this concept are further discussed in Section III.D.3.c).

(b) Electrification Analysis Fleet Assignments

DOT identified electrification technologies present in the baseline fleet and used these as the starting point for the regulatory analysis. These assignments were based on manufacturer-submitted CAFE compliance information, publicly available technical specifications, marketing brochures, articles from reputable media outlets, and data from Wards Intelligence.[184]

Table III–17 gives the baseline fleet penetration rates of electrification technologies eligible to be assigned in the baseline fleet. Over half the fleet had some level of electrification, with the vast majority of these being micro hybrids. BEVs represented less than 2% of MY 2020 baseline fleet; BEV300 was the most common BEV technology, while no BEV500s were observed.

Table III-17 – Penetration Rate of Electrification Technologies in the MY 2020 Fleet

Electrification Technology	Sales Volume with this Technology	Penetration Rate in 2020 Baseline Fleet
None	5,791,220	42.61%
SS12V	6,837,257	50.30%
BISG	258,629	1.90%
SHEVP2	6,409	0.05%
SHEVPS	378,523	2.78%
PHEV20	46,393	0.34%
PHEV20T	18,943	0.14%
PHEV50	2,392	0.02%
PHEV50T	18	0.0001%
BEV200	72,123	0.53%
BEV300	145,900	1.07%
BEV400	34,000	0.25%
BEV500	0	0%
FCV	744	0.005%

Micro and mild hybrids refer to the presence of SS12V and BISG, respectively. The data sources discussed above were used to identify the presence of these technologies on vehicles in the fleet. Vehicles were assigned one of these technologies only if its presence could be confirmed with manufacturer brochures or technical specifications.

Strong hybrid technologies included SHEVPS and SHEVP2. Note that P2HCR0, P2HCR1, P2HCR1D, and P2HCR2 are not assigned in the fleet and are only available to be applied by the model. When possible, manufacturer specifications were used to identify the strong hybrid architecture type. In the absence of more sophisticated information, hybrid architecture was determined by number of motors. Hybrids with one electric motor were assigned P2, and those with two were assigned power-split (PS). DOT seeks comment on additional ways the agency could perform initial hybrid assignments based on publicly available information.

Plug-in hybrid technologies PHEV20/20T and PHEV50/50T are assigned in the baseline fleet. PHEV20H and PHEV50H are not assigned in the fleet and are only available to be applied by the model. Vehicles with an electric-only range of 40 miles or less were assigned PHEV20; those with a range above 40 miles were assigned PHEV50. They were respectively assigned PHEV20T/50T if the engine was turbocharged (*i.e.,* if it would qualify for one of technologies on the turbo engine technology pathway). DOT also had to calculate baseline fuel economy values for PHEV technologies as part of the PHEV analysis fleet assignments; that process is described in detail in TSD Chapter 3.3.2.

Fuel cell and battery electric vehicle technologies included BEV200/300/400/500 and FCV. Vehicles with all-electric powertrains that used hydrogen fuel were assigned FCV. The BEV technologies were assigned to vehicles based on range thresholds that best account for vehicles' existing range capabilities while allowing room for the model to potentially apply more advanced electrification technologies.

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[182] Argonne National Laboratory, "Light Duty Electric Drive Vehicles Monthly Sales Update." Energy Systems Division, *https://www.anl.gov/es/light-duty-electric-drive-vehicles-monthly-sales-updates.* Last Accessed May 4, 2021.

[183] *See* the MY 2020 Market Data file. The four vehicles are the Honda Clarity, Hyundai Nexo and Nexo Blue, and Toyota Mirai.

[184] "U.S. Car and Light Truck Specifications and Prices, '20 Model Year." *Wards Intelligence,* 3 Aug. 2020, *wardsintelligence.informa.com/WI964244/US-Car-and-Light-Truck-Specifications-and-Prices-20-Model-Year.*

For more detail about the electrification analysis fleet assignment process, see TSD Chapter 3.3.2.

(c) Electrification Adoption Features

Multiple types of adoption features applied to the electrification technologies. The hybrid/electric technology path logic dictated how vehicles could adopt different levels of electrification technology. Broadly speaking, more advanced levels of hybridization or electrification superseded all prior levels, with certain technologies within each level being mutually exclusive. The analysis modeled (from least to most electrified) micro hybrids, mild hybrids, strong hybrids, plug-in hybrids, and fully electric vehicles.

As discussed further below, SKIP logic—restrictions on the adoption of certain technologies—applied to plug-in (PHEV) and strong hybrid vehicles (SHEV). Some technologies on these pathways were ''skipped'' if a vehicle was high performance, required high towing capabilities as a pickup truck, or belonged to certain manufacturers who have demonstrated that their future product plans will more than likely not include the technology. The specific criteria for SKIP logic for each applicable electrification technology will be expanded on later in this section.

This section also discusses the supersession of engines and transmissions on vehicles that adopt SHEV or PHEV powertrains. To manage the complexity of the analysis, these types of hybrid powertrains were modeled with several specific engines and transmissions, rather than in multiple configurations. Therefore, the cost and effectiveness values SHEV and PHEV technologies take into account these specific engines and transmissions.

Finally, phase-in caps limited the adoption rates of battery electric (BEV) and fuel cell vehicles (FCV). These phase-in caps were set by DOT, taking into account current market share, scalability, and reasonable consumer adoption rates of each technology. TSD Chapter 3.3.3 discusses the electrification phase-in caps and the reasoning behind them in detail.

The only adoption feature applicable to micro and mild hybrid technologies was path logic. The pathway consists of a linear progression starting with a conventional powertrain with no electrification at all, which is superseded by SS12V, which in turn is superseded by BISG. Vehicles could only adopt micro and mild hybrid technology if the vehicle did not already have a more advanced level of electrification.

The adoption features applied to strong hybrid technologies included path logic, powertrain substitution, and vehicle class restrictions. Per the defined technology pathways, SHEVPS, SHEVP2, and the P2HCR technologies were considered mutually exclusive. In other words, when the model applies one of these technologies, the others are immediately disabled from future application. However, all vehicles on the strong hybrid pathways could still advance to one or more of the plug-in hybrid technologies.

When the model applied any strong hybrid technology to a vehicle, the transmission technology on the vehicle was superseded. Regardless of the transmission originally present, P2 hybrids adopt an 8-speed automatic transmission (AT8L2), and PS hybrids adopt a continuously variable transmission (eCVT).

When the model applies the SHEVP2 technology, the model can consider various engine options to pair with the SHEVP2 architecture according to existing engine path constraints, taking into account relative cost effectiveness. For SHEVPS technology, the existing engine was replaced with Eng26, a full Atkinson cycle engine.

SKIP logic was also used to constrain adoption for SHEVPS, P2HCR0, P2HCR1, and P2HCR1D. No SKIP logic applied to SHEVP2; P2HCR2 was restricted from all vehicles in the 2020 fleet, as discussed further in Section III.D.1.d)(1). These technologies were ''skipped'' for vehicles with engines[185] that met one of the following conditions:

- The engine belonged to an excluded manufacturer;[186]
- The engine belonged to a pickup truck (*i.e.,* the engine was on a vehicle assigned the ''pickup'' body style);
- The engine's peak horsepower was more than 405 HP; or if
- The engine was on a non-pickup vehicle but was shared with a pickup.

The reasons for these conditions are similar to those for the SKIP logic applied to HCR engine technologies, discussed in more detail above. In the real world, pickups and performance vehicles with certain powertrain configurations cannot adopt the technologies listed above and maintain vehicle performance without redesigning the entire powertrain. SKIP logic was put in place to prevent the model from pursuing compliance pathways that are ultimately unrealistic.

PHEV technologies superseded the micro, mild, and strong hybrids, and could only be replaced by full electric technologies. Plug-in hybrid technology paths were also mutually exclusive, with the PHEV20 technologies able to progress to the PHEV50 technologies.

The engine and transmission technologies on a vehicle were superseded when PHEV technologies were applied to a vehicle. For all plug-in technologies, the model applied an AT8L2 transmission. For PHEV20/50 and PHEV20H/50H, the vehicle received a full Atkinson cycle engine, Eng26. For PHEV20T/50T, the vehicle received a TURBO1 engine, Eng12.

SKIP logic applied to PHEV20/20H and PHEV50/50H under the same four conditions listed for the strong hybrid technologies in the previous section, for the same reasons previously discussed.

For the analysis, the adoption of BEVs and FCEVs was limited by both path logic and phase in caps. BEV200/300/400/500 and FCEV were applied as end-of-path technologies that superseded previous levels of electrification.

The main adoption feature applicable to BEVs and FCEVs is phase-in caps, which are defined in the CAFE Model input files as percentages that represent the maximum rate of increase in penetration rate for a given technology. They are accompanied by a phase-in start year, which determines the first year the phase-in cap applies. Together, the phase-in cap and start year determine the maximum penetration rate for a given technology in a given year; the maximum penetration rate equals the phase-in cap times the number of years elapsed since the phase-in start year. Note that phase-in caps *do not* inherently dictate how much a technology is applied by the model. Rather, they represent how much of the fleet *could* have a given technology by a given year. Because BEV200 costs less and has higher effectiveness values than other advanced electrification technologies,[187] the model will have vehicles adopt it first, until it is restricted by the phase-in cap.

Table III–18 shows the phase-in caps, phase-in year, and maximum penetration rate through 2050 for BEV and FCEV technologies. For comparison, the actual penetration rate of each technology in the 2020 baseline fleet is also listed in the fourth column from the left.

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[185] This refers to the engine assigned to the vehicle in the 2020 baseline fleet.

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

[187] This is because BEV200 uses fewer batteries and weighs less than BEVs with greater ranges.

Table III-18 – Phase-In Caps for Fuel Cell and Battery Electric Vehicle Technologies

Technology Name	Phase-In Cap	Phase-In Start Year	Actual Penetration Rate in 2020 (Baseline Fleet)	Maximum Penetration Rate in 2020	Maximum Penetration Rate in 2025	Maximum Penetration Rate in 2030	Maximum Penetration Rate in 2035	Maximum Penetration Rate in 2040	Maximum Penetration Rate in 2045	Maximum Penetration Rate in 2050
BEV200	0.09%	1998	0.53%	1.98%	2.43%	2.88%	3.33%	3.78%	4.23%	4.68%
BEV300	0.70%	2009	1.07%	7.70%	11.20%	14.70%	18.20%	21.70%	25.20%	28.70%
BEV400	1.25%	2016	0.25%	5.00%	11.25%	17.50%	23.75%	30.00%	36.25%	42.50%
BEV500	4.25%	2021	-	-	17.00%	38.25%	59.50%	80.75%	102.00%	123.25%
FCV	0.018%	2016	0.005%	0.072%	0.162%	0.252%	0.342%	0.432%	0.522%	0.612%

The BEV200 phase-in cap was informed by manufacturers' tendency to move away from low-range vehicle offerings, in part because of consumer hesitancy to adopt this technology. The advertised range on most electric vehicles does not reflect extreme cold and hot real-world driving conditions, affecting the utility of already low-range vehicles.[188] Many manufacturers have told DOT that the portion of consumers willing to accept a vehicle with less than 300 miles of electric range is extremely small, and many manufacturers do not plan to offer vehicles with less than 300 miles of electric range. For example, in February 2021, Tesla, the U.S.' highest-selling BEV manufacturer, discontinued the Standard Range Model Y because its range did not meet the company's ''standard of excellence.'' [189] Tesla does sell long-range versions of many of its vehicles.

Furthermore, the average BEV range has steadily increased over the past decade,[190] perhaps in part as batteries become more cost effective. EPA observed in its 2020 Automotive Trends Report that ''the average range of new EVs has climbed substantially. In model year 2019 the average new EV is projected to have a 252-mile range, or about three and a half times the range of an average EV in 2011. This difference is largely attributable to higher production of new EVs with much longer ranges.'' [191] The maximum growth rate for BEV200 in the model was set accordingly low to less than 0.1% per year. While this rate is significantly lower than that of the other BEV technologies, the BEV200 phase-in cap allows the penetration rate of low-range BEVs to grow by a multiple of what is currently observed in the market.

For BEV300, 400, and 500, phase-in caps are largely a reflection of the challenges facing the scalability of BEV manufacturing, and implementing BEV technology on many vehicle configurations, including larger vehicles. In the short term, the penetration of BEVs is largely limited by battery availability.[192] For example, Tesla has struggled to scale production of new cells for its vehicles, and it remains a bottleneck in the company's production capability.[193] The Director of Energy and Environmental Research at Toyota acknowledged in March 2021 that BEV adoption faces many challenges beyond battery availability, including ''the cost of batteries, the need for national infrastructure, long recharging times, limited driving range and the need for consumer behavioral change.'' [194] Incorporating battery packs that provide greater amounts of electric range into vehicles also poses its own engineering challenges. Heavy batteries and large packs may be difficult to integrate for many vehicle configurations. Pickup trucks and large SUVs in particular require higher levels of energy as the number of passengers and/or payload increases, for towing and other high-torque applications. DOT selected the BEV400 and 500 phase-in caps to reflect these concerns.

The phase-in cap for FCEVs was assigned based on existing market share as well as historical trends in FCEV production. FCEV production share in the past five years has been extremely low, and DOT set the phase-in cap accordingly.[195] As with BEV200, however, the phase-in cap still allows for the market share of FCVs to grow several times over.

(d) Electrification Effectiveness Modeling

For this analysis, DOT considers a range of electrification technologies which, when modeled, result in varying levels of effectiveness at reducing fuel consumption. As discussed above, the modeled electrification technologies include micro hybrids, mild hybrids, two different strong hybrids, two different plug-in hybrids with two separate all electric ranges, full electric vehicles and FCEVs. Each electrification technology consists of many complex sub-systems with unique component

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[188] AAA. ''AAA Electric Vehicle Range Testing.'' February 2019. *https://www.aaa.com/AAA/common/AAR/files/AAA-Electric-Vehicle-Range-Testing-Report.pdf.*

[189] Baldwin, Roberto. ''Tesla Model Y Standard Range Discontinued; CEO Musk Tweets Explanation.'' Car and Driver, 30 Apr. 2021, *www.caranddriver.com/news/a35602581/elon-musk-model-y-discontinued-explanation/.* Accessed May 20, 2020.

[190] 2020 EPA Automotive Trends Report, at 53, figure 4.14.

[191] 2020 EPA Automotive Trends Report, at 53.

[192] *See, e.g.,* Cohen, Ariel. ''Manufacturers Are Struggling To Supply Electric Vehicles With Batteries.'' Forbes, Forbes Magazine, 25 March 2020, *www.forbes.com/sites/arielcohen/2020/03/25/manufacturers-are-struggling-to-supply-electric-vehicles-with-batteries.* Accessed May 20, 2021.

[193] Hyatt, Kyle. ''Tesla Will Build an Electric Van Eventually, Elon Musk Says.'' Roadshow, CNET, 28 Jan. 2021, *www.cnet.com/roadshow/news/tesla-electric-van-elon-musk/.* Accessed May 20, 2021.

[194] *https://www.energy.senate.gov/services/files/E2EA0E4F-BAD9-452D-99CC-35BC204DE6F0.*

[195] 2020 EPA Automotive Trends Report, at 52, figure 4.13.

characteristics and operational modes. As discussed further below, the systems that contribute to the effectiveness of an electrified powertrain in the analysis include the vehicle's battery, electric motors, power electronics, and accessory loads. Procedures for modeling each of these sub-systems are broadly discussed below, in Section III.C.4, and the Autonomie model documentation.

Argonne used data from their Advanced Mobility Technology Laboratory (AMTL) to develop Autonomie's electrified powertrain models. The modeled powertrains are not intended to represent any specific manufacturer's architecture but are intended to act as surrogates predicting representative levels of effectiveness for each electrification technology.

Autonomie determines the effectiveness of each electrified powertrain type by modeling the basic components, or building blocks, for each powertrain, and then combining the components modularly to determine the overall efficiency of the entire powertrain. The basic building blocks that comprise an electrified powertrain in the analysis include the battery, electric motors, power electronics, and accessory loads. Autonomie identifies components for each electrified powertrain type, and then interlinks those components to create a powertrain architecture. Autonomie then models each electrified powertrain architecture and provides an effectiveness value for each architecture. For example, Autonomie determines a BEV's overall efficiency by considering the efficiencies of the battery, the electric traction drive system (the electric machine and power electronics) and mechanical power transmission devices. Or, for a SHEVP2, Autonomie combines a very similar set of components to model the electric portion of the hybrid powertrain, and then also includes the combustion engine and related power for transmission components. See TSD Chapter 3.3.4 for a complete discussion of electrification component modeling.

As discussed earlier in Section III.C.4, Autonomie applies different powertrain sizing algorithms depending on the type of vehicle considered because different types of vehicles not only contain different powertrain components to be optimized, but they must also operate in different driving modes. While the conventional powertrain sizing algorithm must consider only the power of the engine, the more complex algorithm for electrified powertrains must simultaneously consider multiple factors, which could include the engine power, electric machine power, battery power, and battery capacity. Also, while the resizing algorithm for all vehicles must satisfy the same performance criteria, the algorithm for some electric powertrains must also allow those electrified vehicles to operate in certain driving cycles, like the US06 cycle, without assistance of the combustion engine, and ensure the electric motor/generator and battery can handle the vehicle's regenerative braking power, all-electric mode operation, and intended range of travel.

To establish the effectiveness of the technology packages, Autonomie simulates the vehicles' performance on compliance test cycles, as discussed in Section III.C.4.[196] [197] [198] The range of effectiveness for the electrification technologies in this analysis is a result of the interactions between the components listed above and how the modeled vehicle operates on its respective test cycle. This range of values will result in some modeled effectiveness values being close to real-world measured values, and some modeled values that will depart from measured values, depending on the level of similarity between the modeled hardware configuration and the real-world hardware and software configurations. This modeling approach comports with the National Academy of Science 2015 recommendation to use full vehicle modeling supported by application of lumped improvements at the sub-model level.[199] The approach allows the isolation of technology effects in the analysis supporting an accurate assessment.

The range of effectiveness values for the electrification technologies, for all ten vehicle technology classes, is shown in Figure III–12. In the graph, the box shows the inner quartile range (IQR) of the effectiveness values and whiskers extend out 1.5 x IQR. The dots outside of the whiskers show values outside these bounds.

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[196] *See* U.S. EPA, ''How Vehicles are Tested.'' *https://www.fueleconomy.gov/feg/how_tested.shtml.* Last accessed May 6, 2021.

[197] *See* Autonomie model documentation, Chapter 6: Test Procedures and Energy Consumption Calculations.

[198] EPA Guidance Letter. ''EPA Test Procedures for Electric Vehicles and Plug-in Hybrids.'' Nov. 14, 2017. *https://www.fueleconomy.gov/feg/pdfs/EPA%20test%20procedure%20for%20EVs-PHEVs-11-14-2017.pdf.* Last accessed May 6, 2021.

[199] 2015 NAS report, at 292.

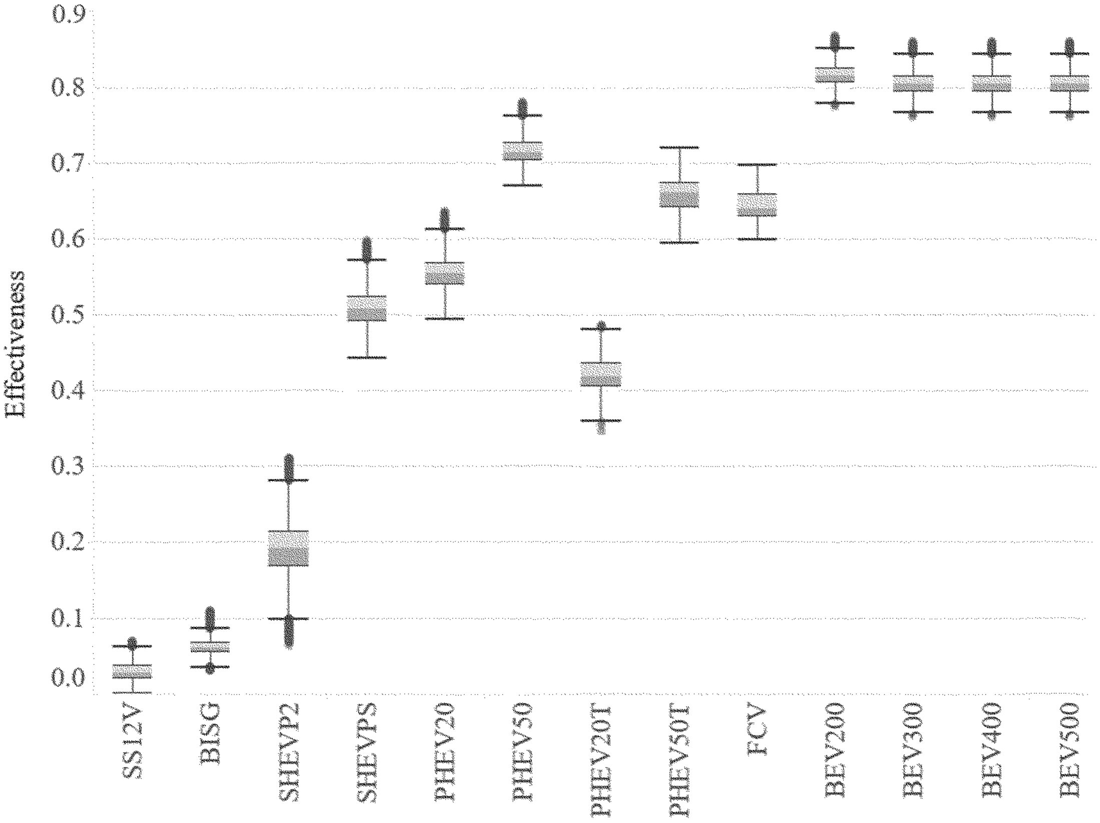

Figure III-12 – Electrification Technology Effectiveness Values for All the Vehicle Technology Classes[200]

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(e) Electrification Costs

The total cost to electrify a vehicle in this analysis is based on the battery the vehicle requires, the non-battery electrification component costs the vehicle requires, and the traditional powertrain components that must be added or removed from the vehicle to build the electrified powertrain.

We worked collaboratively with the experts at Argonne National Laboratory to generate battery costs using BatPaC, which is a model designed to calculate the cost of a vehicle battery for a specified battery power, energy, and type. Argonne used BatPaC v4.0 (October 2020 release) to create lookup tables for battery cost and mass that the Autonomie simulations referenced when a vehicle received an electrified powertrain. The BatPaC battery cost estimates are generated for a base year, in this case for MY 2020. Accordingly, our BatPaC inputs characterized the state of the market in MY 2020 and employed a widely utilized cell chemistry (NMC622),[201] average estimated battery pack production volume per plant (25,000), and a plant efficiency or plant cell yield value of 95%.

For two specific electrified vehicle applications, BEV400 and BEV500, we did not use BatPaC to generate battery pack costs. Rather, we scaled the BatPaC-generated BEV300 costs to match the range of BEV400 and BEV500 vehicles to compute a direct manufacturing cost for those vehicles' batteries. We initially examined using BatPaC to model the cost and weight of BEV400 and BEV500 packs, however, initial values from the model could not be validated and were based on assumptions for smaller sized battery packs. The initial results provided cost and weight estimates for BEV400 battery packs out of alignment with current examples of BEV400s in the market, and there are currently no examples of BEV500 battery packs in the market against which to validate the pack results.

Finally, to reflect how we expect batteries could fall in cost over the timeframe considered in the analysis, we applied a learning rate to the direct manufacturing cost. Broadly, the learning rate applied in this analysis reflects middle-of-the-road year-over-year improvements until MY 2032, and then the learning rates incrementally become shallower as battery technology is expected to mature in MY 2033 and beyond. Applying learning curves to the battery pack DMC in subsequent analysis years lowers the cost such that the cost of a battery pack in any future model year could be representative of the cost to manufacture a battery pack, regardless of potentially diverse parameters such as cell chemistry, cell format, or production volume.

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[200] The data used to create this figure can be found in the FE_1 Adjustments file.

[201] Autonomie model documentation, Chapter 5.9. Argonne surveyed A2Mac1 and TBS teardown reports for electrified vehicle batteries and of the five fully electrified vehicles surveyed, four of those vehicles used NMC622 and one used NMC532. *See also* Georg Bieker, A Global Comparison of the Life-Cycle Greenhouse Gas Emissions of Combustion Engine and Electric Passenger Cars, International Council on Clean Transportation (July 2021), *https://theicct.org/sites/default/files/publications/Global-LCA-passenger-cars-jul2021_0.pdf* (''For cars registered in 2021, the GHG emission factors of the battery production are based on the most common battery chemistry, NMC622-graphite batteries. . . .''); 2021 NAS report, at 5–92 (''. . . NMC622 is the most common cathode chemistry in 2019. . . .'').

TSD Chapter 3.3.5.1 includes more detail about the process we used to develop battery costs for this analysis. In addition, all BatPaC-generated direct manufacturing costs for all technology keys can be found in the CAFE Model's Battery Costs file, and the Argonne BatPaC Assumptions file includes the assumptions used to generate the costs, and pack costs, pack mass, cell capacity, $/kW at the pack level, and W/kg at the pack level for all vehicle classes.

Table III–19 and Table III–20 show an example of our battery pack direct manufacturing costs per kilowatt hour for BEV300s for all vehicle classes for the base year, MY 2020. The tables shown here demonstrate how the cost per kWh varies with the size of the battery pack. While the overall cost of a battery pack will go up for larger kWh battery packs, the cost per kWh goes down. The amortization of costs for components required in all battery packs across a larger number of cells results in this reduced cost per kWh.

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Table III-19 – BEV300 Battery Pack Direct Manufacturing Costs per Kilowatt/Hour for Compact - Medium Car Classes in MY 2020

BEV300			Energy, kWh				
			30.0	**50.0**	**70.0**	**90.0**	**120.0**
$/kWh at Pack Level (Total Energy)	Power, kW	20.0	$244	$186	$160	$145	$131
		40.0	$245	$187	$161	$145	$132
		60.0	$246	$188	$161	$146	$132
		80.0	$248	$188	$162	$146	$132
		100.0	$249	$189	$162	$146	$132
		120.0	$250	$190	$163	$147	$133
		140.0	$251	$190	$163	$147	$133
		160.0	$252	$191	$164	$147	$133
		180.0	$254	$192	$164	$148	$134
		200.0	$255	$193	$165	$148	$134
		240.0	$258	$194	$166	$149	$134
		280.0	$261	$196	$167	$150	$135
		320.0	$267	$197	$168	$151	$136
		400.0	$280	$201	$170	$152	$137

Table III-20 – BEV300 Battery Pack Direct Manufacturing Costs per Kilowatt/Hour for SUV and Pickup Classes in MY 2020

BEV300			Energy, kWh						
			30.0	50.0	70.0	90.0	120.0	140.0	160.0
$/kWh at Pack Level (Total Energy)	Power, kW	20.0	$252	$191	$164	$148	$133	$127	$122
		40.0	$253	$192	$164	$148	$133	$127	$122
		60.0	$254	$193	$165	$148	$134	$127	$122
		80.0	$255	$193	$165	$149	$134	$127	$122
		100.0	$257	$194	$166	$149	$134	$128	$122
		120.0	$258	$194	$166	$149	$134	$128	$123
		140.0	$259	$195	$167	$150	$135	$128	$123
		160.0	$260	$196	$167	$150	$135	$128	$123
		180.0	$261	$196	$167	$151	$135	$129	$123
		200.0	$262	$197	$168	$151	$135	$129	$123
		240.0	$265	$198	$169	$152	$136	$129	$124
		280.0	$268	$200	$170	$152	$136	$130	$124
		320.0	$273	$201	$171	$153	$137	$130	$125
		400.0	$286	$204	$173	$155	$138	$131	$125

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A range of parameters can ultimately influence battery pack manufacturing costs, including other vehicle improvements (*e.g.,* mass reduction technology, aerodynamic improvements, or tire rolling resistance improvements all affect the size and energy of a battery required to propel a vehicle where all else is equal), and the availability of materials required to manufacture the battery.[202] [203] Or, if manufacturers adopt more electrification technology than projected in this analysis, increases in battery pack production volume will likely lower actual battery pack costs.

Like the 2020 final rule, we compared our battery pack costs in future years to battery pack costs from other sources that may or may not account for some of these additional parameters, including varying potential future battery chemistry and learning rates. As discussed in TSD Chapter 3.3.5.1.4, our battery pack costs in 2025 and 2030 fell fairly well in the middle of other sources' cost projections, with Bloomberg New Energy Finance (BNEF) projections presenting the highest year-over-year cost reductions,[204] and MIT's Insights into Future Mobility report providing an upper bound of potential future costs.[205] ICCT presented a similar comparison of costs from several sources in its 2019 working paper, Update on Electric Vehicle Costs in the United States through 2030, and predicted battery pack costs in 2025 and 2030 would drop to approximately $104/kWh and $72/kWh, respectively,[206] which put their projections slightly higher than BNEF's 2019 projections. BNEF's more recent 2020 Electric Vehicle Outlook projected average pack cost to fall below $100/kWh by 2024,[207] while the 2021 NAS report projected that pack costs are projected to reach $90–115 kWh by 2025.[208]

That our projected costs seem to fall between several projections gives us some confidence that the costs in this NPRM could reasonably represent future battery pack costs across the industry during the rulemaking time frame. That said, we recognize that battery technology is currently under intensive development, and that characteristics such as cost and capability are rapidly changing. These advances are reflected in recent aggressive projections, like those from ICCT, BNEF, and the 2021 NAS report. As a result, we would like to seek comments, supported by data elements as outlined below, on these characteristics.

We seek comment on the input assumptions used to generate battery pack costs in BatPaC and the BatPaC-generated direct manufacturing costs for the base year (MY 2020). If commenters believe that different input assumptions should be used for battery chemistry,[209]

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[202] The cost of raw material also has a meaningful influence on the future cost of the battery pack. As the production volume goes up, the demand for battery critical raw materials also goes up, which has an offsetting impact on the efficiency gains achieved through economies of scale, improved plant efficiency, and advanced battery cell chemistries. We do not consider future battery raw material price fluctuations for this analysis, however that may be an area for further exploration in future analyses.

[203] *See, e.g.,* Jacky Wong, EV Batteries: The Next Victim of High Commodity Prices?, The Wall Street Journal (July 22, 2021), *https://www.wsj.com/articles/ev-batteries-the-next-victim-of-high-commodity-prices-11626950276.*

[204] *See* Logan Goldie-Scot, A Behind the Scenes Take on Lithium-ion Battery Prices, Bloomberg New Energy Finance (March 5, 2019), *https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/.*

[205] MIT Energy Initiative. 2019. *Insights into Future Mobility.* Cambridge, MA: MIT Energy Initiative. Available at *http://energy.mit.edu/insightsintofuturemobility.*

[206] Nic Lutsey and Michael Nicholas, Update on electric vehicle costs in the United States through 2030, ICCT (April 2, 2019), available at *https://theicct.org/publications/update-US-2030-electric-vehicle-cost.*

[207] Bloomberg New Energy Finance (BNEF), "Electric Vehicle Outlook 2020," *https://about.bnef.com/electric-vehicle-outlook/,* last accessed July 29, 2021.

[208] 2021 NAS report, at 5–121. The 2021 NAS report assumed a 7 percent cost reduction per year from 2018 through 2030.

[209] Note that stakeholders had commented to the 2020 final rule that batteries using NMC811 chemistry had either recently come into the market or was imminently coming into the market, and therefore DOT should have selected NMC811 as the

plant manufacturing volume, or plant efficiency in MY 2020, they should provide data or other information validating such assumptions. In addition, commenters should explain how these assumptions reasonably represent applications across the industry in MY 2020. This is important to align with our guiding principles to ensure that the CAFE Model's simulation of manufacturer compliance pathways results in impacts that we would reasonably expect to see in the real world. As discussed above, each technology model employed in the analysis is designed to be representative of a wide range of specific technology applications used in industry. Some vehicle manufacturer's systems may perform better and cost less than our modeled systems and some may perform worse and cost more. However, employing this approach will ensure that, on balance, the analysis captures a reasonable level of costs and benefits that would result from any manufacturer applying the technology. In this case, vehicle and battery manufacturers use different chemistries, cell types, and production processes to manufacture electric vehicle battery packs. Any proposed alternative costs for base year direct manufacturing costs should be able to represent the range of costs across the industry in MY 2020 based on different manufacturers using different approaches.

We also seek comment on the scaling used to generate direct manufacturing costs for BEV400 and BEV500 technologies. If commenters have additional data or information on the relationship between cost and weight for heavier battery packs used for these higher-range BEV applications, particularly in light truck vehicle segments, that would be helpful as well.

In addition, we seek comment on the learning rates applied to the battery pack costs and on the battery pack costs in future years. Recognizing that any battery pack cost projections for future years from our analysis or external analyses will involve assumptions that may or may not come to pass, it would be most helpful if commenters thoroughly explained the basis for any recommended learning rates, including references to publicly available data or models (and if such models are peer reviewed) where appropriate. Similarly, it would be helpful for commenters to note where external analyses may or may not take into account certain parameters in their battery pack cost projections, and whether we should attempt to incorporate those parameters in our analysis. For example, as discussed above, our analysis does not consider raw material price fluctuations; however, the price of battery pack raw materials will put a lower bound on NMC-based battery prices.[210]

It would also be helpful if commenters explained how learning rates or future cost projections could represent the state of battery technology across the industry. Like other technologies considered in this analysis, some battery and vehicle manufacturers have more experience manufacturing electric vehicle battery packs, and some have less, meaning that different manufacturers will be at different places along the learning curve in future years. Note also that comments should specify whether their referenced costs, either for MY 2020 or for future years, are for the battery cell or the battery pack.

Ensuring our learning rates encompass these diverse parameters will ensure that the analysis best predicts the costs and benefits associated with future standards. We will incorporate any new information received to the extent possible for the final rule and future analyses.

Recognizing again that battery technology is a rapidly evolving field and there are a range of external analyses that project battery pack costs declining at different rates across the next decade, as discussed above and further in the TSD, we performed four sensitivity studies around battery pack costs that are described in PRIA Chapter 7.2.2.5. The sensitivity studies examined the impacts of increasing and decreasing the direct cost of batteries and battery learning costs by 20 percent from central analysis levels, based on our survey of external analyses' battery pack cost projections that fell generally within +/−20% of our central analysis costs. We found that changing the battery direct manufacturing costs in MY 2020 without changing the learning rate did not produce meaningfully different outcomes for electric vehicle technology penetration in later years, although it resulted in the lowest technology costs. Keeping the same direct manufacturing costs and using a steeper battery learning rate produced slightly higher technology costs, compared to the sensitivity results that changed battery pack direct manufacturing cost and kept learning rate the same.

We seek comment on these conclusions, their implications for any potential updates to battery pack costs for the final rule, and any other external analyses that the agency should consider when validating future battery pack cost projections.

Next, each vehicle powertrain type also receives different non-battery electrification components. When researching costs for different non-battery electrification components, DOT found that different reports vary in components considered and cost breakdown. This is not surprising, as vehicle manufacturers use different non-battery electrification components in different vehicle's systems, or even in the same vehicle type, depending the application.[211] DOT developed costs for the major non-battery electrification components on a dollar per kilowatt hour basis using the costs presented in two reports. DOT used a $/kW cost metric for non-battery components to align with the normalized costs for a system's peak power rating as presented in U.S. DRIVE's Electrical and Electronics Technical Team (EETT) Roadmap report.[212] This approach captures components in some manufacturer's systems, but not all systems; however, DOT believes this is a reasonable metric and approach to use for this analysis given the differences in non-battery electrification component systems. This approach allows us to scale the cost of non-battery electrification components based on the requirements of the system. We also relied on a teardown study of a MY 2016 Chevrolet Bolt for non-battery component costs that were not explicitly estimated in the EETT Roadmap report.[213]

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appropriate chemistry for modeling battery pack costs. Similar to the other technologies considered in this analysis, DOT endeavors to use technology that is a reasonable representation of what the industry could achieve in the model year or years under consideration, in this case the base DMC year of 2020, as discussed above. At the time of this current analysis, the referenced A2Mac1 teardown reports and other reports provided the best available information about the range of battery chemistry actually employed in the industry. At the time of writing, DOT still has not found examples of NMC811 in commercial application across the industry in a way that DOT believes selecting NMC811 would have represented industry average performance in MY 2020. As discussed in TSD Chapter 3.3.5.1.4, DOT did analyze the potential future cost of NMC811 in the composite learning curve generated to ensure the battery learning curve projections are reasonable.

[210] *See, e.g.,* MIT Energy Initiative. 2019. *Insights into Future Mobility.* Cambridge, MA: MIT Energy Initiative. Available at *http://energy.mit.edu/insightsintofuturemobility,* at 78–9.

[211] For example, the MY 2020 Nissan Leaf does not have an active cooling system whereas Chevy Bolt uses an active cooling system.

[212] U.S. DRIVE, Electrical and Electronics Technical Team Roadmap (Oct. 2017), available at *https://www.energy.gov/sites/prod/files/2017/11/f39/EETT%20Roadmap%2010-27-17.pdf.*

[213] Hummel et al., UBS Evidence Lab Electric Car Teardown—Disruption Ahead?, UBS (May 18, 2017), *https://neo.ubs.com/shared/d1wkuDlEbYPjF/.*

To develop the learning curves for non-battery electrification components, DOT used cost information from Argonne's 2016 Assessment of Vehicle Sizing, Energy Consumption, and Cost through Large-Scale Simulation of Advanced Vehicle Technologies report.[214] The report provided estimated cost projections from the 2010 lab year to the 2045 lab year for individual vehicle components.[215] [216] DOT considered the component costs used in electrified vehicles, and determined the learning curve by evaluating the year over year cost change for those components. Argonne recently published a 2020 version of the same report that included high and low cost estimates for many of the same components, that also included a learning rate.[217] DOT's learning estimates generated using the 2016 report fall fairly well in the middle of these two ranges, and therefore staff decided that continuing to apply the learning curve estimates based on the 2016 report was reasonable. There are many sources that DOT staff could have picked to develop learning curves for non-battery electrification component costs, however given the uncertainty surrounding extrapolating costs out to MY 2050, DOT believes these learning curves provide a reasonable estimate.

Table III–21 shows an example of how the non-battery electrification component costs are computed for the Medium Car and Medium SUV non-performance vehicle classes.

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Table III-21 – Example Non-Battery Components for Medium Car and SUV Non-Performance Classes

Electric Powertrain	Traction Motor calculated using Peak Power (kW)	Motor-Generator calculated using Continuous Power (kW)	Total Cost of ETDS (Motor and Inverter)	DC to DC Converter	On-board Charger	Power Distribution Cables	Total DMC of Electrical Components	Total Electrification RPE	DMC of CVT or AT8L2	RPE Cost of CVT or AT8L2	Total Electrification Cost (DMC)	Total Electrification Cost (RPE) - from Technologies file
Medium Car – Non-Performance												
SHEVP2	28.01	0	$516	$184	$0	$460	$1,160	$1,566.37	$1,655	$2,473	$2,815	$4,006
PHEV20T	38.95	0	$717	$184	$174	$460	$1,536	$2,027.04	$1,655	$2,473	$3,191	$4,457
PHEV50T	95.21	0	$1,753	$184	$174	$460	$2,572	$3,394.53	$1,655	$2,473	$4,227	$5,817
SHEVPS	72.62	37.61	$2,030	$184	$0	$460	$2,674	$3,570.16	$1,686	$2,518	$4,360	$6,088
PHEV20	74.66	38.92	$2,091	$184	$174	$460	$2,910	$3,841.04	$1,686	$2,518	$4,596	$6,345
Medium SUV – Non-Performance												
SHEVP2	29.14	0	$537	$184	$0	$460	$1,181	$1,594.46	$1,655	$2,473	$2,836	$4,034
PHEV20T	43.32	0	$798	$184	$174	$460	$1,616	$2,133.26	$1,655	$2,473	$3,271	$4,563
PHEV50T	110.72	0	$2,039	$184	$174	$460	$2,857	$3,771.52	$1,655	$2,473	$4,512	$6,194
SHEVPS	79.32	41.74	$2,229	$184	$0	$460	$2,874	$3,836.40	$1,686	$2,518	$4,559	$6,355
PHEV20	81.81	43.01	$2,298	$184	$174	$460	$3,117	$4,114.25	$1,686	$2,518	$4,803	$6,618

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[214] Moawad, Ayman, Kim, Namdoo, Shidore, Neeraj, and Rousseau, Aymeric. Assessment of Vehicle Sizing, Energy Consumption and Cost Through Large Scale Simulation of Advanced Vehicle Technologies (ANL/ESD–15/28). United States (2016). Available at *https://www.autonomie.net/pdfs/Report%20ANL%20ESD-1528%20-%20Assessment%20of%20Vehicle%20Sizing,%20Energy%20Consumption%20and%20Cost%20through%20Large%20Scale%20Simulation%20of%20Advanced%20Vehicle%20Technologies%20-%201603.pdf.*

[215] ANL/ESD–15/28 at 116.

[216] DOE's lab year equates to five years after a model year, *e.g.,* DOE's 2010 lab year equates to MY 2015.

[217] Islam, E., Kim, N., Moawad, A., Rousseau, A. "Energy Consumption and Cost Reduction of Future Light-Duty Vehicles through Advanced Vehicle Technologies: A Modeling Simulation Study Through 2050", Report to the U.S. Department of Energy, Contract ANL/ESD–19/10, June 2020 *https://www.autonomie.net/pdfs/ANL%20-%20Islam%20-%202020%20-%20Energy%20Consumption%20and%20Cost%20Reduction%20of%20Future%20Light-Duty%20Vehicles%20through%20Advanced%20Vehicle%20Technologies%20A%20Modeling%20Simulation%20Study%20Through%202050.pdf.*

TSD Chapter 3.3.5.2 contains more information about the non-battery electrification components relevant to each specific electrification technology and the sources used to develop these costs. We seek comment on these costs, the appropriateness of the sources used to develop these costs, and the $/kW metric used to size specific non-battery electrification components. In addition, we seek comment on the learning rate applied to non-battery electrification components.

Finally, the cost of electrifying a vehicle depends on the other powertrain components that must be added or removed from a vehicle with the addition of the electrification technology. Table III–22 below provides a breakdown of each electrification component included for each electrification technology type, as well as where to find the costs in each CAFE Model input file.

Table III-22 – Breakdown of the Electrification Costs by Electrification Technology Type

Electrification Technology Type	Technologies File Vehicle Tabs	Technologies File Engine Tabs	Battery Cost File
Micro Hybrid	Motor/generator	-N/A	Battery Pack
Mild Hybrid	Motor/generator, DC/DC converter, other components	-N/A	Battery Pack
P2 Strong Hybrid	DC/DC converter, on-board charger, high voltage cables, e-motor, AT8L2 transmission, and power electronics	IC engine*	Battery Pack
PS Strong Hybrid	DC/DC converter, on-board charger, high voltage cables, e-motor, CVTL2 transmission, and power electronics	IC engine	Battery Pack
Plug-in Hybrid (PHEV 20T/50T)	DC/DC converter, on-board charger, high voltage cables, e-motor, AT8L2 transmission, and power electronics	IC engine	Battery Pack
Plug-in Hybrid (PHEV 20/50 and 20H/50H)	DC/DC converter, on-board charger, high voltage cables, e-motor, CVTL2 transmission, and power electronics	IC engine	Battery Pack
BEVs	DC/DC converter, on-board charger, high voltage cables, e-motor	ETD System	Battery Pack
FCEVs	Fuel cell system, e-motor, H_2 Tank, transmission, and power electronics	-N/A	N/A

*The engine cost for a P2 Hybrid is based on engine technology that is used in the conventional powertrain.

As shown in Table III–22, DOT used the cost of the CVTL2 as a proxy for the cost of an eCVT used in PS hybrid vehicles. In its recent 2021 report, the NAS estimated the cost of eCVTs to be lower than DOT's cost estimate for CVTL2.[218] DOT is investigating the cost assumptions used for the PS hybrid transmission and may update those costs for the final rule depending on information submitted by stakeholders or other research. DOT seeks comment on the appropriateness of the cost estimate for eCVTs in the 2021 NAS report, or any other data that could be made public on the costs of eCVTs.

The following example in Table III–23 shows how the costs are computed for a vehicle that progresses from a lower level to a higher level of electrified powertrain. The table shows the components that are removed and the components that are added as a GMC Acadia progresses from a MY 2024 vehicle with only SS12V electrification technology to a BEV300 in MY 2025. The total cost in MY 2025 is a net cost addition to the vehicle. The same methodology could be used for any other technology advancement in the electric technology tree path.[219]

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[218] A detailed cost comparison between our costs and the 2021 NAS report costs is discussed in TSD Chapter 3.3.5.3.3.

[219] Please note that in this calculation the CAFE Model accounts for the air conditioning and off-cycle technologies (g/mile) applied to each vehicle model. The cost for the AC/OC adjustments are located in the CAFE Model Scenarios file. The air conditioning and off-cycle cost values are discussed further in TSD Chapter 3.8.

Table III-23 – Technology Cost Change for GMC Acadia Example

	Technology Removed	Technology Added	MY 2025 Cost of Technology (2018$)	MY 2025 Overall Technology Cost (2018$)
MY 2024				888.7
Removed Technologies	Engine (DOHC)		(5830.76)	(5482.2)
	VVT		(221.54)	(5703.74)
	SGDI		(501.67)	(6205.41)
	DEAC		(203.35)	(6408.76)
	Transmission (AT9L2)		(2498.29)	(8907.05)
	EPS		(117.28)	(9024.33)
	SS12V		(247.43)	(9271.76)
	SS12V battery		(308.44)	(9580.2)
	AERO0		(0)	(9580.2)
Added Technologies		BEV300 - ETDS	3581.65	(5998.55)
		IACC	146.68	(5851.87)
		Non-battery components	1137.67	(4714.2)
		Battery Pack Cost	17955.29	13241.09
		AERO20	248.9	13489.99
		Total Air Conditioning/Off-Cycle (AC/OC) Adjustments[219]	72.71	13562.7
MY 2025				13562.7

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TSD Chapter 3.3.5.3 includes more details about how the costs associated with the internal combustion engine, transmission, electric machine(s), non-battery electrification components, and battery pack for each electrified technology type are combined to create a full electrification system cost.

4. Mass Reduction

Mass reduction is a relatively cost-effective means of improving fuel economy, and vehicle manufacturers are expected to apply various mass reduction technologies to meet fuel economy standards. Reducing vehicle mass can be accomplished through several different techniques, such as modifying and optimizing vehicle component and system designs, part consolidation, and adopting lighter weight materials (advanced high strength steel, aluminum, magnesium, and plastics including carbon fiber reinforced plastics).

The cost for mass reduction depends on the type and amount of materials used, the manufacturing and assembly processes required, and the degree to which changes to plants and new manufacturing and assembly equipment is needed. In addition, manufacturers may develop expertise and invest in certain mass reduction strategies that may affect the approaches for mass reduction they consider and the associated costs. Manufacturers may also consider vehicle attributes like noise-vibration-harshness (NVH), ride quality, handling, crash safety and various acceleration metrics when considering how to implement any mass reduction strategy. These are considered to be aspects of performance, and for this analysis any identified pathways to compliance are intended to maintain performance neutrality. Therefore, mass reduction via elimination of, for example, luxury items such as climate control, or interior vanity mirrors, leather padding, etc., is not considered in the mass reduction pathways for this analysis.

The automotive industry uses different metrics to measure vehicle weight. Some commonly used measurements are vehicle curb weight,[220] gross vehicle weight (GVW),[221] gross vehicle weight rating (GVWR),[222] gross combined weight (GCVW),[223] and equivalent test weight (ETW),[224] among others. The vehicle curb weight is the most commonly used measurement when comparing vehicles. A vehicle's curb weight is the weight of the vehicle including fluids, but without a driver, passengers, and cargo. A vehicle's glider weight, which is vehicle curb weight minus the powertrain weight, is used to track the potential opportunities for weight reduction not including the powertrain. A glider's subsystems may consist of the vehicle body, chassis, interior, steering,

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[220] This is the weight of the vehicle with all fluids and components but without the drivers, passengers, and cargo.

[221] This weight includes all cargo, extra added equipment, and passengers aboard.

[222] This is the maximum total weight of the vehicle, passengers, and cargo to avoid damaging the vehicle or compromising safety.

[223] This weight includes the vehicle and a trailer attached to the vehicle, if used.

[224] For the EPA two-cycle regulatory test on a dynamometer, an additional weight of 300 lbs is added to the vehicle curb weight. This additional 300 lbs represents the weight of the driver, passenger, and luggage. Depending on the final test weight of the vehicle (vehicle curb weight plus 300 lbs), a test weight category is identified using the table published by EPA according to 40 CFR 1066.805. This test weight category is called ''Equivalent Test Weight'' (ETW).

electrical accessory, brake, and wheels systems. The percentage of weight assigned to the glider will remain constant for any given rule but may change overall. For example, as electric powertrains including motors, batteries, inverters, etc. become a greater percent of the fleet, glider weight percentage will change compared to earlier fleets with higher dominance of internal combustion engine (ICE) powertrains.

For this analysis, DOT considered six levels of mass reduction technology that include increasing amounts of advanced materials and mass reduction techniques applied to the glider. The mass change associated with powertrain changes is accounted for separately. The following sections discuss the assumptions for the six mass reduction technology levels, the process used to assign initial analysis fleet mass reduction assignments, the effectiveness for applying mass reduction technology, and mass reduction costs.

(a) Mass Reduction in the CAFE Model

The CAFE Model considers six levels of mass reduction technologies that manufacturers could use to comply with CAFE standards. The magnitude of mass reduction in percent for each of these levels is shown in Table III–24 for mass reductions for light trucks, passenger cars and for gliders.

Table III-24 – Mass Reduction Technology Level and Associated Glider and Curb Mass Reduction

MR Level	Percent Glider Weight	Percent Vehicle Curb Weight (Passenger Cars)	Percent Vehicle Curb Weight (Light Trucks)
MR0	0%	0.00%	0.00%
MR1	5%	3.55%	3.55%
MR2	7.5%	5.33%	5.33%
MR3	10%	7.10%	7.10%
MR4	15%	10.65%	10.65%
MR5	20%	14.20%	14.20%
MR6	28%	20.00%	20.00%

For this analysis, DOT considers mass reduction opportunities from the glider subsystems of a vehicle first, and then consider associated opportunities to downsize the powertrain, which are accounted for separately.[225] As explained below, in the Autonomie simulations, the glider system includes both primary and secondary systems from which a percentage of mass is reduced for different glider weight reduction levels; specifically, the glider includes the body, chassis, interior, electrical accessories, steering, brakes and wheels. In this analysis, DOT assumed the glider share is 71% of vehicle curb weight. The Autonomie model sizes the powertrain based on the glider weight and the mass of some of the powertrain components in an iterative process. The mass of the powertrain depends on the powertrain size. Therefore, the weight of the glider impacts the weight of the powertrain.[226]

DOT uses glider weight to apply non-powertrain mass reduction technology in the CAFE Model and use Autonomie simulations to determine the size of the powertrain and corresponding powertrain weight for the respective glider weight. The combination of glider weight (after mass reduction) and re-sized powertrain weight equal the vehicle curb weight.

While there are a range of specific mass reduction technologies that may be applied to vehicles to achieve each of the six mass reduction levels, there are some general trends that are helpful to illustrate some of the more widely used approaches. Typically, MR0 reflects vehicles with widespread use of mild steel structures and body panels, and very little or no use of high strength steel or aluminum. MR0 reflects materials applied to average vehicles in the MY 2008 timeframe. MR1–MR3 can be achieved with a steel body structure. In going from MR1 to MR3, expect that mild steel to be replaced by high strength and then advanced high strength steels. In going from MR3 to MR4 aluminum is required. This will start at using aluminum closure panels and then to get to MR4 the vehicle's primary structure will need to be mostly made from aluminum. In the vast majority of cases, carbon fiber technology is necessary to reach MR5, perhaps with a mix of some aluminum. MR6 can really only be attained in anything resembling a passenger car by make nearly every structural component from carbon fiber. This mean the body structure and closure panels like hoods and door skins are wholly made from carbon fiber. There may be some use of aluminum in the suspension. TSD Chapter 3.4 includes more discussion of the challenges involved with adopting large amounts of carbon fiber in the vehicle fleet in the coming years.

As discussed further below, the cost studies used to generate the cost curves assume mass can be reduced in levels that require different materials and different components to be utilized, in a specific order. DOT's mass reduction levels are loosely based on what materials and components that would be required to be used for each percent of mass reduction, based on the conclusions of those studies.

(b) Mass Reduction Analysis Fleet Assignments

To assign baseline mass reduction levels (MR0 through MR6) for vehicles in the MY 2020 analysis fleet, DOT used previously developed regression models to estimate curb weight for each vehicle based on observable vehicle attributes.

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[225] When the mass of the vehicle is reduced by an appropriate amount, the engine may be downsized to maintain performance. *See* Section III.C.4 for more details.

[226] Since powertrains are sized based on the glider weight for the analysis, glider weight reduction beyond a threshold amount during a redesign will lead to re-sizing of the powertrain. For the analysis, the glider was used as a base for the application of any type of powertrain. A conventional powertrain consists of an engine, transmission, exhaust system, fuel tank, radiator and associated components. A hybrid powertrain also includes a battery pack, electric motor(s), generator, high voltage wiring harness, high voltage connectors, inverter, battery management system(s), battery pack thermal system, and electric motor thermal system.

DOT used these models to establish a baseline (MR0) curb weight for each vehicle, and then determined the existing mass reduction technology level by finding the difference between the vehicles actual curb weight to the estimated regression-based value, and comparing the difference to the values in Table III–24. DOT originally developed the mass reduction regression models using MY 2015 fleet data; for this analysis, DOT used MY 2016 and 2017 analysis fleet data to update the models.

DOT believes the regression methodology is a technically sound approach for estimating mass reduction levels in the analysis fleet. For a detailed discussion about the regression development and use please see TSD Chapter 3.4.2.

Manufacturers generally apply mass reduction technology at a vehicle platform level (*i.e.,* using the same components across multiple vehicle models that share a common platform) to leverage economies of scale and to manage component and manufacturing complexity, so conducting the regression analysis at the platform level leads to more accurate estimates for the real-world vehicle platform mass reduction levels. The platform approach also addresses the impact of potential weight variations that might exist for specific vehicle models, as all the individual vehicle models are aggregated into the platform group, and are effectively averaged using sales weighting, which minimizes the impact of any outlier vehicle configurations.

(c) Mass Reduction Adoption Features

Given the degree of commonality among the vehicle models built on a single platform, manufacturers do not have complete freedom to apply unique technologies to each vehicle that shares the platform. While some technologies (*e.g.,* low rolling resistance tires) are very nearly ''bolt-on'' technologies, others involve substantial changes to the structure and design of the vehicle, and therefore affect all vehicle models that share a platform. In most cases, mass reduction 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. Similar to the application of engine and transmission technologies, the CAFE Model defines a platform ''leader'' as the vehicle variant of a given platform that has the highest level of observed mass reduction present in the analysis fleet. If there is a tie, the CAFE Model begins mass reduction technology on the vehicle with the highest sales volume in model year 2020. If there remains a tie, the model begins by choosing the vehicle with the highest manufacturer suggested retail price (MSRP) in MY 2020. As the model applies technologies, it effectively levels up all variants on a platform to the highest level of mass reduction technology on the platform. For example, if the platform leader model is already at MR3 in MY 2020, and a ''follower'' platform model starts at MR0 in MY 2020, the follower platform model will get MR3 at its next redesign, assuming no further mass reduction technology is applied to the leader model before the follower models next redesign.

In addition to the platform-sharing logic employed in the model, DOT applied phase-in caps for MR5 and MR6 (15 percent and 20 percent reduction of a vehicle's curb weight, respectively), based on the current state of mass reduction technology. As discussed above, for nearly every type of vehicle, with the exception of the smallest sports cars, a manufacturer's strategy to achieve mass reduction consistent with MR5 and MR6 will require extensive use of carbon fiber technologies in the vehicles' primary structures. For example, one way of using carbon fiber technology to achieve MR6 is to develop a carbon fiber monocoque structure. A monocoque structure is one where the outer most skins support the primary loads of the vehicle. For example, they do not have separate non-load bearing aero surfaces. All of the vehicle's primary loads are supported by the monocoque. In the most structurally efficient automotive versions, the monocoque is made from multiple well-consolidated plies of carbon fiber infused with resin. Such structures can require low hundreds of pounds of carbon fiber for most passenger vehicles. Add to this another roughly equivalent mass of petroleum-derived resins and even at aspirational prices for dry carbon fiber of $10–20 per pound it is easy to see how direct materials alone can easily climb into the five-figure dollar range per vehicle.

High CAFE stringency levels will push the CAFE Model to select compliance pathways that include these higher levels of mass reduction for vehicles produced in the mid and high hundreds of thousands of vehicles per year. DOT assumes, based on material costs and availability, that achieving MR6 levels of mass reduction will cost tens of thousands of dollars per car. Therefore, application of such technology to high volume vehicles is unrealistic today and will, with certainty, remain so for the next several years.

The CAFE Model applies technologies to vehicles that provide a cost-effective pathway to compliance. In some cases, the direct manufacturing cost, indirect costs, and applied learning factor do not capture all the considerations that make a technology more or less costly for manufacturers to apply in the real world. For example, there are direct labor, R&D overhead, manufacturing overhead, and amortized tooling costs that will likely be higher for carbon fiber production than current automotive steel production, due to fiber handling complexities. In addition, R&D overhead will also increase because of the knowledge base for composite materials in automotive applications is simply not as deep as it is for steel and aluminum. Indeed, the intrinsic anisotropic mechanical properties of composite materials compared to the isotropic properties of metals complicates the design process. Added testing of these novel anisotropic structures and their associated costs will be necessary for decades. Adding up all these contributing costs, the price tag for a passenger car or truck monocoque would likely be multiple tens of thousands of dollars per vehicle. This would be significantly more expensive than transitioning to hybrid or fully electric powertrains and potentially less effective at achieving CAFE compliance.

In addition, the CAFE Model does not currently enable direct accounting for the stranded capital associated with a transition away from stamped sheet metal construction to molded composite materials construction. For decades, or in some cases half-centuries, car manufacturers have invested billions of dollars in capital for equipment that supports the industry's sheet metal forming paradigm. A paradigm change to tooling and equipment developed to support molding carbon fiber panels and monocoque chassis structures would leave that capital stranded in equipment that would be rendered obsolete. Doing this is possible, but the financial ramifications are not currently reflected in the CAFE Model for MR5 and MR6 compliance pathways.

Financial matters aside, carbon fiber technology and how it is best used to produce lightweight primary automotive structures is far from mature. In fact, no car company knows for sure the best way to use carbon fiber to make a passenger car's primary structure. Using this technology in passenger cars is far more complex than using it in racing cars where passenger egress, longevity, corrosion protection, crash protection, etc. are lower on the list of priorities for the design team. BMW may be the manufacturer most able accurately opine on the viability of carbon fiber technology for primary structure on high-volume passenger cars, and even it decided to use a mixed materials solution for their next generation of EVs (the iX and i4) after the i3, thus eschewing a wholly carbon fiber monocoque structure.

Another factor limiting the application of carbon fiber technology to mass volume passenger vehicles is indeed the availability of dry carbon fibers. There is high global demand from a variety of industries for a limited supply of carbon fibers. Aerospace, military/defense, and industrial applications demand most of the carbon fiber currently produced. Today, only roughly 10% of the global dry fiber supply goes to the automotive industry, which translates to the global supply base only being able to support approximately 70k cars.[227]

To account for these cost and production considerations, including the limited global supply of dry carbon fiber, DOT applied phase-in caps that limited the number of vehicles that can achieve MR5 and M6 levels of mass reduction in the CAFE Model. DOT applied a phase-in cap for MR5 level technology so that 75 percent of the vehicle fleet starting in 2020 could employ the technology, and the technology could be applied to 100 percent of the fleet by MY 2022. DOT also applied a phase-in cap for MR6 technology so that five percent of the vehicle fleet starting in MY 2020 could employ the technology, and the technology could be applied to 10 percent of the fleet by MY 2025.

To develop these phase-in caps, DOT chose a 40,000 unit thresholds for both MR5 and MR6 technology (80,000 units total), because it roughly reflects the number of BMW i3 cars produced per year worldwide.[228] As discussed above, the BMW i3 is the only high-volume vehicle currently produced with a primary structure mostly made from carbon fiber (except the skateboard, which is aluminum). Because mass reduction is applied at the platform level (meaning that every car of a given platform would receive the technology, not just special low volume versions of that platform), only platforms representing 40,000 vehicles or less are eligible to apply MR5 and MR6 toward CAFE compliance. Platforms representing high volume sales, like a Chevrolet Traverse, for example, where hundreds of thousands are sold per year, are therefore blocked from access to MR5 and MR6 technology. There are no phase in caps for mass reduction levels MR1, MR2, MR3, or MR4.

In addition to determining that the caps were reasonable based on current global carbon fiber production, DOT determined that the MR5 phase-in cap is consistent with the DOT lightweighting study that found that a 15 percent curb weight reduction for the fleet is possible within the rulemaking timeframe.[229]

These phase-in caps appropriately function as a proxy for the cost and complexity currently required (and that likely will continue to be required until manufacturing processes evolve) to produce carbon fiber components. Again, MR6 technology in this analysis reflects the use of a significant share of carbon fiber content, as seen through the BMW i3 and Alfa Romeo 4c as discussed above.

Given the uncertainty and fluid nature of knowledge around higher levels of mass reduction technology, DOT welcomes comments on how to most cost effectively use carbon fiber technology in high-volume passenger cars. Financial implementation estimates for this technology are equally as welcome.

(d) Mass Reduction Effectiveness Modeling

As discussed in Section III.C.4, Argonne developed a database of vehicle attributes and characteristics for each vehicle technology class that included over 100 different attributes. Some examples from these 100 attributes include frontal area, drag coefficient, fuel tank weight, transmission housing weight, transmission clutch weight, hybrid vehicle components, and weights for components that comprise engines and electric machines, tire rolling resistance, transmission gear ratios, and final drive ratio. Argonne used these attributes to ‘‘build’’ each vehicle that it used for the effectiveness modeling and simulation. Important for precisely estimating the effectiveness of different levels of mass reduction is an accurate list of initial component weights that make up each vehicle subsystem, from which Autonomie considered potential mass reduction opportunities.

As stated above, glider weight, or the vehicle curb weight minus the powertrain weight, is used to determine the potential opportunities for weight reduction irrespective of the type of powertrain.[230] This is because weight reduction can vary depending on the type of powertrain. For example, an 8-speed transmission may weigh more than a 6-speed transmission, and a basic engine without variable valve timing may weigh more than an advanced engine with variable valve timing. Autonomie simulations account for the weight of the powertrain system inherently as part of the analysis, and the powertrain mass accounting is separate from the application and accounting for mass reduction technology levels that are applied to the glider in the simulations. Similarly, Autonomie also accounts for battery and motor mass used in hybrid and electric vehicles separately. This secondary mass reduction is discussed further below.

Accordingly, in the Autonomie simulations, mass reduction technology is simulated as a percentage of mass removed from the specific subsystems that make up the glider, as defined for that set of simulations (including the non-powertrain secondary mass systems such as the brake system). For the purposes of determining a reasonable percentage for the glider, DOT in consultation with Argonne examined glider weight data available in the A2Mac1 database,[231] in addition to the NHTSA MY 2014 Chevrolet Silverado lightweighting study (discussed further below). Based on these studies, DOT assumed that the glider weight comprised 71 percent of the vehicle curb weight. TSD Chapter 3.4.4 includes a detailed breakdown of the components that DOT considered to arrive at the conclusion that a glider, on average, represents 71% of a vehicle's curb weight.

Any mass reduction due to powertrain improvements is accounted for separately from glider mass reduction. Autonomie considers several components for powertrain mass reduction, including engine downsizing,

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[227] J. Sloan, ‘‘Carbon Fiber Suppliers Gear up for Next Generation Growth,’’ *compositesworld.com,* February 11, 2020.

[228] However, even this number is optimistic because only a small fraction of i3 cars are sold in the U.S. market, and combining MR5 and MR6 allocations equates to 80k vehicles, not 40k. Regardless, if the auto industry ever seriously committed to using carbon fiber in mainstream high-volume vehicles, competition with the other industries would rapidly result in a dramatic increase in price for dry fiber. This would further stymie the deployment of this technology in the automotive industry.

[229] Singh, Harry. (2012, August). Mass Reduction for Light-Duty Vehicles for Model Years 2017–2025. (Report No. DOT HS 811 666). Program Reference: DOT Contract DTNH22–11–C–00193. Contract Prime: Electricore, Inc, at 356, Figure 397.

[230] Depending on the powertrain combination, the total curb weight of the vehicle includes glider, engine, transmission and/or battery pack and motor(s).

[231] A2Mac1: Automotive Benchmarking, *https://a2mac1.com.*

and transmission, fuel tank, exhaust systems, and cooling system lightweighting.

The 2015 NAS report suggested an engine downsizing opportunity exists when the glider mass is lightweighted by at least 10%. The 2015 NAS report also suggested that 10% lightweighting of the glider mass alone would boost fuel economy by 3% and any engine downsizing following the 10% glider mass reduction would provide an additional 3% increase in fuel economy.[232] The 2011 Honda Accord and 2014 Chevrolet Silverado lightweighting studies applied engine downsizing (for some vehicle types but not all) when the glider weight was reduced by 10 percent. Accordingly, this analysis limited engine resizing to several specific incremental technology steps as in the 2018 CAFE NPRM (83 FR 42986, Aug. 24, 2018) and 2020 final rule; important for this discussion, engines in the analysis were only resized when mass reduction of 10% or greater was applied to the glider mass, or when one powertrain architecture was replaced with another architecture.

Specifically, we allow engine resizing upon adoption of 7.1%, 10.7%, 14.2%, and 20% curb weight reduction, but not at 3.6% and 5.3%.[233] Resizing is also allowed upon changes in powertrain type or the inheritance of a powertrain from another vehicle in the same platform. The increments of these higher levels of mass reduction, or complete powertrain changes, more appropriately match the typical engine displacement increments that are available in a manufacturer's engine portfolio.

Argonne performed a regression analysis of engine peak power versus weight for a previous analysis based on attribute data taken from the A2Mac1 benchmarking database, to account for the difference in weight for different engine types. For example, to account for weight of different engine sizes like 4-cylinder versus 8-cylinder, Argonne developed a relationship curve between peak power and engine weight based on the A2Mac1 benchmarking data. We use this relationship to estimate mass for all engine types regardless of technology type (*e.g.,* variable valve lift and direct injection). DOT applied weight associated with changes in engine technology by using this linear relationship between engine power and engine weight from the A2Mac1 benchmarking database. When a vehicle in the analysis fleet with an 8-cylinder engine adopted a more fuel-efficient 6-cylinder engine, the total vehicle weight would reflect the updated engine weight with two less cylinders based on the peak power versus engine weight relationship.

When Autonomie selects a powertrain combination for a lightweighted glider, the engine and transmission are selected such that there is no degradation in the performance of the vehicle relative to the baseline vehicle. The resulting curb weight is a combination of the lightweighted glider with the resized and potentially new engine and transmission. This methodology also helps in accurately accounting for the cost of the glider and cost of the engine and transmission in the CAFE Model.

Secondary mass reduction is possible from some of the components in the glider after mass reduction has been incorporated in primary subsystems (body, chassis, and interior). Similarly, engine downsizing and powertrain secondary mass reduction is possible after certain level of mass reduction is incorporated in the glider. For the analysis, the agencies include both primary mass reduction, and when there is sufficient primary mass reduction, additional secondary mass reduction. The Autonomie simulations account for the aggregate of both primary and secondary glider mass reduction, and separately for powertrain mass.

Note that secondary mass reduction is integrated into the mass reduction cost curves. Specifically, the NHTSA studies, upon which the cost curves depend, first generated costs for lightweighting the vehicle body, chassis, interior, and other primary components, and then calculated costs for lightweighting secondary components. Accordingly, the cost curves reflect that, for example, secondary mass reduction for the brake system is only applied after there has been sufficient primary mass reduction to allow the smaller brake system to provide safe braking performance and to maintain mechanical functionality.

DOT enhanced the accuracy of estimated engine weights by creating two curves to represent separately naturally aspirated engine designs and turbocharged engine designs.[234] This achieves two benefits. First, small naturally aspirated 4-cylinder engines that adopted turbocharging technology reflected the increased weight of associated components like ducting, clamps, the turbocharger itself, a charged air cooler, wiring, fasteners, and a modified exhaust manifold. Second, larger cylinder count engines like naturally aspirated 8-cylinder and 6-cylinder engines that adopted turbocharging and downsized technologies would have lower weight due to having fewer engine cylinders. For this analysis, a naturally aspirated 8-cylinder engine that adopts turbocharging technology and is downsized to a 6-cylinder turbocharged engine appropriately reflects the added weight of the turbocharging components, and the lower weight of fewer cylinders.

The range of effectiveness values for the mass reduction technologies, for all ten vehicle technology classes are shown in Figure III–13. In the graph, the box shows the inner quartile range (IQR) of the effectiveness values and whiskers extend out 1.5 × IQR. The dots outside of the whiskers show a few values outside these ranges. As discussed earlier, Autonomie simulates all possible combinations of technologies for fuel consumption improvements. For a few technology combinations mass reduction has minimal impact on effectiveness on the regulatory 2-cycle test. For example, if an engine is operating in an efficient region of the fuel map on the 2-cycle test further reduction of mass may have smaller improvement on the regulatory cycles. Figure III–13 shows the range improvements based on the full range of other technology combinations considered in the analysis.

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[232] National Research Council. 2015. Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles. Washington, DC—The National Academies Press. *https://doi.org/10.17226/21744.*

[233] These curb weight reductions equate to the following levels of mass reduction as defined in the analysis: MR3, MR4, MR5 and MR6, but not MR1 and MR2; additional discussion of engine resizing for mass reduction can be found in Section III.C.4 and TSD Chapter 2.4.

[234] *See* Autonomie model documentation, Chapter 5.2.9. Engine Weight Determination.

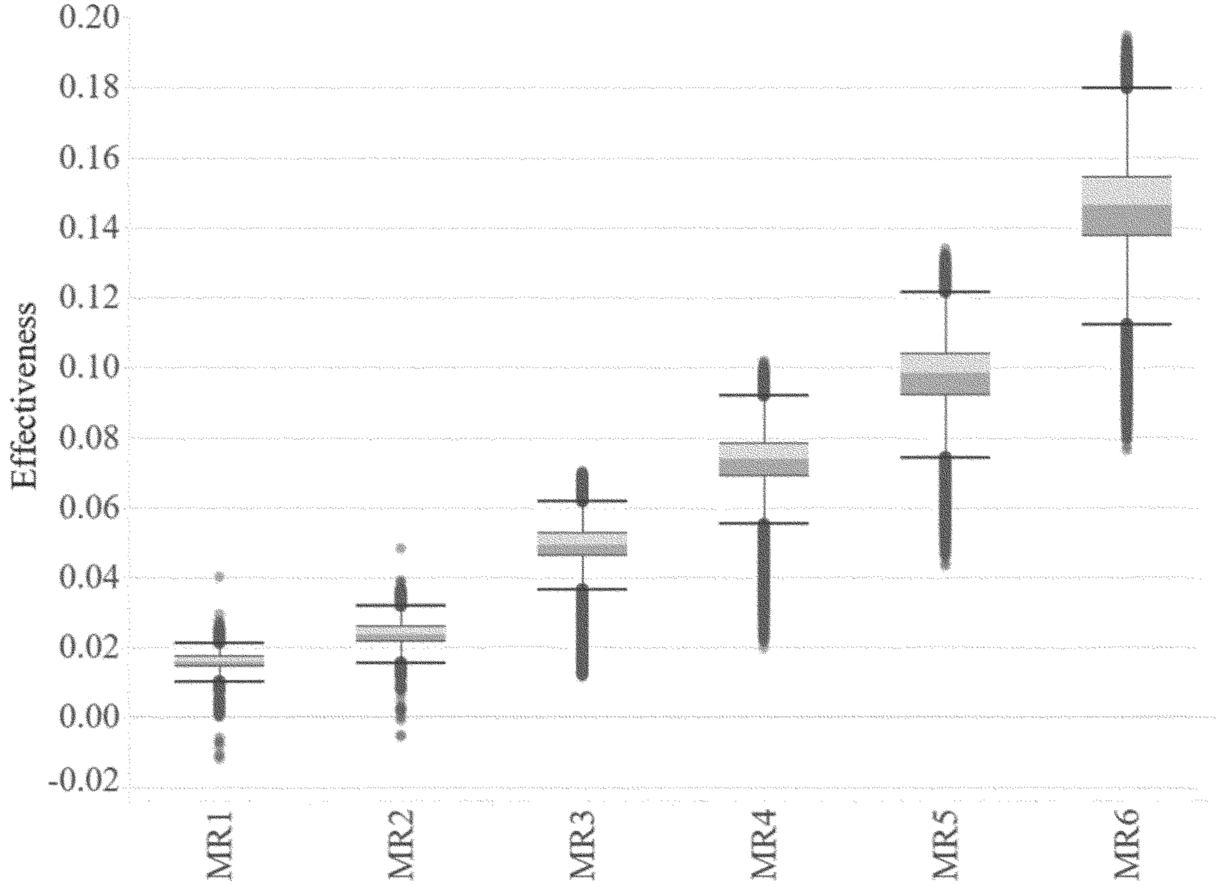

Figure III-13 – Mass Reduction Technologies Effectiveness Values for all the Vehicle Technology Classes

(e) Mass Reduction Costs

The CAFE Model analysis handles mass reduction technology costs differently than all other technology costs. Mass reduction costs are calculated as an average cost per pound over the baseline (MR0) for a vehicle's glider weight. While the definitions of glider may vary, DOT referenced the same dollar per pound of curb weight to develop costs for different glider definitions. In translating these values, DOT took care to track units ($/kg vs. $/lb) and the reference for percentage improvements (glider vs. curb weight).

DOT calculated the cost of mass reduction on a glider weight basis so that the weight of each powertrain configuration could be directly and separately accounted for. This approach provides the true cost of mass reduction without conflating the mass change and costs associated with downsizing a powertrain or adding additional advanced powertrain technologies. Hence, the mass reduction costs in this proposal reflect the cost of mass reduction in the glider and do not include the mass reduction associated with engine downsizing. The mass reduction and costs associated with engine downsizing are accounted for separately.

A second reason for using glider share instead of curb weight is that it affects the absolute amount of curb weight reduction applied, and therefore cost per pound for the mass reduction changes with the change in the glider share. The cost for removing 20 percent of the glider weight when the glider represents 75 percent of a vehicle's curb weight is not the same as the cost for removing 20 percent of the glider weight when the glider represents 50 percent of the vehicle's curb weight. For example, the glider share of 79 percent of a 3,000-pound curb weight vehicle is 2,370 lbs, while the glider share of 50 percent of a 3,000-pound curb weight vehicle is 1,500 lbs, and the glider share of 71 percent of a 3,000-pound curb weight vehicle is 2,130 lbs. The mass change associated with 20 percent mass reduction is 474 lbs for 79 percent glider share (=[3,000 lbs × 79% × 20%]), 300 lbs for 50 percent glider share (=[3,000 lbs × 50% × 20%]), and 426 lbs for 71 percent glider share (=[3,000 lbs × 71% × 20%]). The mass reduction cost studies that DOT relied on to develop mass reduction costs for this analysis show that the cost for mass reduction varies with the amount of mass reduction. Therefore, for a fixed glider mass reduction percentage, different glider share assumptions will have different costs.

DOT considered several sources to develop the mass reduction technology cost curves. Several mass reduction studies have used either a mid-size passenger car or a full-size pickup truck as an exemplar vehicle to demonstrate the technical and cost feasibility of mass reduction. While the findings of these studies may not apply directly to different vehicle classes, the cost estimates derived for the mass reduction technologies identified in these studies can be useful for formulating general estimates of costs. As discussed further below, the mass reduction cost curves developed for this analysis are based on two lightweighting studies, and DOT also updated the curves based on more recent studies to better account for the cost of carbon fiber needed for the highest levels of mass reduction technology. The two studies used for MR1 through MR4 costs included the teardown of a MY 2011 Honda Accord and a MY 2014 Chevrolet Silverado pickup truck, and the carbon fiber costs required for MR5 and MR6 were updated based on the 2021 NAS report.[235]

Both teardown studies are structured to derive the estimated cost for each of the mass reduction technology levels. DOT relied on the results of those studies because they considered an extensive range of material types, material gauge, and component redesign while taking into account real world constraints such as manufacturing and assembly methods and complexity, platform-sharing, and maintaining vehicle utility, functionality and attributes, including safety, performance, payload capacity, towing capacity, handling, NVH, and other characteristics. In addition, DOT determined that the baseline vehicles and mass reduction technologies assessed in the studies are still reasonably representative of the technologies that may be applied to vehicles in the MY 2020 analysis fleet to achieve up to MR4 level mass reduction in the rulemaking timeframe. DOT adjusted the cost estimates derived from the two studies to reflect the assumption that a vehicle's glider weight consisted of 71% of the vehicle's curb weight, and mass reduction as it pertains to achieving MR0–MR6 levels would only come from the glider.

As discussed above, achieving the highest levels of mass reduction often necessitates extensive use of advanced materials like higher grades of aluminum, magnesium, or carbon fiber. For the 2020 final rule, DOT provided a survey of information available regarding carbon fiber costs compared to the costs DOT presented in the final rule based on the Honda Accord and Chevrolet Silverado teardown studies. In the Honda Accord study, the estimated cost of carbon fiber was $5.37/kg, and the cost of carbon fiber used in the Chevy Silverado study was $15.50/kg. The $15.50 estimate closely matched the cost estimates from a BMW i3 teardown analysis,[236] the cost figures provided by Oak Ridge National Laboratory for a study from the IACMI Composites Institute,[237] and from a Ducker Worldwide presentation at the CAR Management Briefing Seminar.[238]

For this analysis, DOT relied on the cost estimates for carbon fiber construction that the National Academies detailed in the 2021 Assessment of Technologies for Improving Fuel Economy of Light-Duty Vehicles—Phase 3 recently completed by the National Academies.[239] The study indicates that the sum of direct materials costs plus manufacturing costs for carbon fiber composite automotive components is $25.97 per pound in high volume production. In order to use this cost in the CAFE Model it must be put in terms of dollars per pound saved. Using an average vehicle curb weight of 4000 lbs, a 71% glider share and the percent mass savings associated with MR5 and MR6, it is possible to calculate the number of pounds to be removed to attain MR5 and MR6. Also taken from the NAS study is the assertion that carbon fiber substitution for steel in an automotive component results in a 50% mass reduction. Combining all this together, carbon fiber technology offers weight savings at $24.60 per pound saved. This dollar per pound savings figure must also be converted to a retail price equivalent (RPE) to account for various commercial costs associated with all automotive components. This is accomplished by multiplying $24.60 by the factor 1.5. This brings the cost per pound saved for using carbon fiber to $36.90 per pound saved.[240] The analysis uses this cost for achieving MR5 and MR6.

Table III–25 and Table III–26 show the cost values (in dollars per pound) used in the CAFE Model with MR1–4 costs based on the cost curves developed from the MY 2011 Honda Accord and MY 2014 Chevrolet Silverado studies, and the updated MR5 and MR6 values that account for the updated carbon fiber costs from the 2021 NAS report. Both tables assume a 71% glider share.

Table III-25 – Mass Reduction Costs for MY 2020 in CAFE Model for Small Car, Small Car Performance, Medium Car, Medium Car Performance, Small SUV, Small SUV Performance

	Percentage Reduction in Glider Weight	Percentage Reduction in Curb Weight	Cost of Mass Reduction ($/lbs)
MR0	0.00%	0.00%	0.00
MR1	5.00%	3.55%	0.46
MR2	7.50%	5.33%	0.86
MR3	10.00%	7.10%	1.22
MR4	15.00%	10.65%	1.59
MR5	20.00%	14.20%	36.90
MR6	28.00%	20%	36.90

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[235] 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 and MR6) were the same for all segments.

[236] Singh, Harry, FSV Body Structure Comparison with 2014 BMW i3, Munro and Associates for World Auto Steel (June 3, 2015).

[237] IACMI Baseline Cost and Energy Metrics (March 2017), available at *https://iacmi.org/wp-content/uploads/2017/12/IACMI-Baseline-Cost-and-Energy-Metrics-March-2017.pdf.*

[238] Ducker Worldwide, The Road Ahead—Automotive Materials (2016), *https://societyofautomotiveanalysts.wildapricot.org/resources/Pictures/SAA%20Sumit%20slides%20for%20Abey%20Abraham%20of%20Ducker.pdf.*

[239] 2021 NAS report, at 7–242–3.

[240] *See* MR5 and MR6 CFRP Cost Increase Calculator.xlsx in the docket for this action.

There is a dramatic increase in cost going from MR4 to MR5 and MR6 for all classes of vehicles. However, while the increase in cost going from MR4 to MR5 and MR6 is dramatic, the MY 2011 Honda Accord study, the MY 2014 Chevrolet Silverado study, and the 2021 NAS report all included a steep increase to achieve the highest levels of mass reduction technology. As noted above, DOT seeks comment on any additional information about the costs of achieving the highest levels of mass reduction technology, including from publicly available sources or data that could be made publicly available.

Table III–27 provides an example of mass reduction costs in 2018$ over select model years for the medium car and pickup truck technology classes as a dollar per pound value. The table shows how the $/lb value for each mass reduction level decreases over time because of cost learning. For a full list of the $/lb mass reduction costs used in the analysis across all model years, see the Technologies file.

Table III-27 – Examples of the $/lb Mass Reduction Costs in 2018$ for Medium Car and Pickup Truck Vehicle Classes

Technology	Medium Car Costs (2018$)/lbs			Pickup Costs (2018$)/lbs		
	MY 2020	MY 2025	MY 2030	MY 2020	MY 2025	MY 2030
MR0	0.00	0.00	0.00	0.00	0.00	0.00
MR1	0.46	0.42	0.39	0.30	0.27	0.25
MR2	0.86	0.78	0.73	0.70	0.63	0.59
MR3	1.22	1.11	1.03	1.25	1.13	1.06
MR4	1.59	1.34	1.21	1.70	1.44	1.30
MR5	36.90	31.44	26.93	36.90	31.44	26.93
MR6	36.90	31.44	26.93	36.90	31.44	26.93

5. Aerodynamics

The energy required to overcome aerodynamic drag accounts for a significant portion of the energy consumed by a vehicle and can become the dominant factor for a vehicle's energy consumption at high speeds. Reducing aerodynamic drag can, therefore, be an effective way to reduce fuel consumption and emissions.

Aerodynamic drag is proportional to the frontal area (A) of the vehicle and coefficient of drag (C_d), such that aerodynamic performance is often expressed as the product of the two values, C_dA, which is also known as the drag area of a vehicle. The coefficient of drag (C_d) is a dimensionless value that essentially represents the aerodynamic efficiency of the vehicle shape. The frontal area (A) is the cross-sectional area of the vehicle as viewed from the front. It acts with the coefficient of drag as a sort of scaling factor, representing the relative size of the vehicle shape that the coefficient of drag describes. The force imposed by aerodynamic drag increases with the square of vehicle velocity, accounting for the largest contribution to road loads at higher speeds.

Aerodynamic drag reduction can be achieved via two approaches, either by reducing the drag coefficient or reducing vehicle frontal area, with two different categories of technologies, passive and active aerodynamic technologies. Passive aerodynamics refers to aerodynamic attributes that are inherent to the shape and size of the vehicle, including any components of a fixed nature. Active aerodynamics refers to technologies that variably deploy in response to driving conditions. These include technologies such as active grille shutters, active air dams, and active ride height adjustment. It is important to note that manufacturers may employ both passive and active aerodynamic technologies to achieve aerodynamic drag values.

The greatest opportunity for improving aerodynamic performance is during a vehicle redesign cycle when significant changes to the shape and size of the vehicle can be made. Incremental improvements may also be achieved during mid-cycle vehicle refresh using restyled exterior components and add-on devices. Some examples of potential technologies applied during mid-cycle refresh are restyled front and rear fascia, modified front air dams and rear valances, addition of rear deck lips and underbody panels, and low-drag exterior mirrors. While manufacturers may nudge the frontal area of the vehicle during redesigns, large changes in frontal area are typically not possible without impacting the utility and interior space of the vehicle. Similarly, manufacturers may improve C_d by changing the frontal shape of the vehicle or lowering the height of the vehicle, among other approaches, but the form drag of certain body styles and airflow needs for engine cooling often limit how much C_d may be improved.

The following sections discuss the four levels of aerodynamic improvements considered in the CAFE Model, how the agency assigned baseline aerodynamic technology levels to vehicles in the MY 2020 fleet, the effectiveness improvements for the addition of aerodynamic technologies to vehicles, and the costs for adding that aerodynamic technology.

(a) Aerodynamic Technologies in the CAFE Model

DOT bins aerodynamic improvements into four levels—5%, 10%, 15% and 20% aerodynamic drag improvement values over a baseline computed for each vehicle body style—which correspond to AERO5, AERO10, AERO15, and AERO20, respectively.

The aerodynamic improvements technology pathway consists of a linear progression, with each level superseding all previous levels, as seen in Figure III–14.

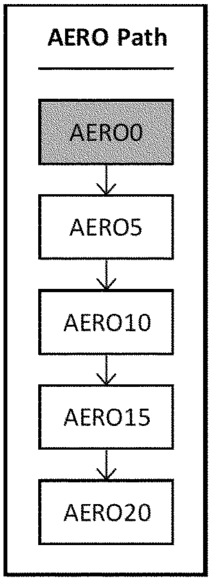

Figure III-14 – Technology Pathway for Levels of Aerodynamic Drag Reduction

While the four levels of aerodynamic improvements are technology-agnostic, DOT built a pathway to compliance for each level based on aerodynamic data from a National Research Council (NRC) of Canada-sponsored wind tunnel testing program. The program included an extensive review of production vehicles utilizing these technologies, and industry comments.[241] [242] Again, these technology combinations are intended to show a *potential* way for a manufacturer to achieve each aerodynamic improvement level; however, in the real world, manufacturers may implement different combinations of aerodynamic technologies to achieve a percentage improvement over their baseline vehicles.

Table III–28 and Table III–29 show the aerodynamic technologies that could be used to achieve 5%, 10%, 15% and 20% improvements in passenger cars, SUVs, and pickup trucks. As discussed further in Section III.D.5.c, AERO20 cannot be applied to pickup trucks in the model, which is why there is no pathway to AERO20 shown in Table III–29. While some aerodynamic improvement technologies can be applied across vehicle classes, like active grille shutters (used in the 2015 Chevrolet Colorado),[243] DOT determined that there are limitations that make it infeasible for vehicles with some body styles to achieve a 20% reduction in the coefficient of drag from their baseline. This technology path is an example of how a manufacturer *could* reach each AERO level, but they would not necessarily be *required* to use the technologies.

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[241] Larose, G., Belluz, L., Whittal, I., Belzile, M. et al., ''Evaluation of the Aerodynamics of Drag Reduction Technologies for Light-duty Vehicles—a Comprehensive Wind Tunnel Study,'' SAE Int. J. Passeng. Cars—Mech. Syst. 9(2):772–784, 2016, *https://doi.org/10.4271/2016-01-1613.*

[242] Larose, Guy & Belluz, Leanna & Whittal, Ian & Belzile, Marc & Klomp, Ryan & Schmitt, Andreas. (2016). Evaluation of the Aerodynamics of Drag Reduction Technologies for Light-duty Vehicles—a Comprehensive Wind Tunnel Study. SAE International Journal of Passenger Cars—Mechanical Systems. 9. 10.4271/2016–01–1613.

[243] Chevrolet Product Information, available at *https://media.chevrolet.com/content/media/us/en/chevrolet/vehicles/colorado/2015/_jcr_content/iconrow/textfile/file.res/15-PG-Chevrolet-Colorado-082218.pdf.*

Table III-28 – Combinations of Technologies That Could Achieve Aerodynamic Improvements Used in the Current Analyses for Passenger Cars and SUVs

Aero Improvement Level	Components	Effectiveness (%)
AERO5	Front Styling	2.0%
	Roof Line raised at forward of B-pillar	0.5%
	Faster A pillar rake angle	0.5%
	Shorter C pillar	1.0%
	Low drag wheels	1.0%
AERO10	Rear Spoiler	1.0%
	Wheel Deflector / Air outlet inside wheel housing	1.0%
	Bumper Lip	1.0%
	Rear Diffuser	2.0%
AERO15	Underbody Cover Incl. Rear axle cladding)	3.0%
	Lowering ride height by 10mm	2.0%
AERO20	Active Grill Shutters	3.0%
	Extend Air dam	2.0%

Table III-29 – Combinations of Technologies That Could Achieve Aerodynamic Improvements Used in the Current Analyses for Pickup Trucks

Aero Improvement Level	Components	Effectiveness (%)
AERO5	Whole Body Styling (Shape Optimization)	1.5%
	Faster A pillar rake angle	0.5%
	Rear Spoiler	1.0%
	Wheel Deflector / Air outlet inside wheel housing	1.0%
	Bumper Lip	1.0%
AERO10	Rear Diffuser	2.0%
	Underbody Cover Incl. Rear axle cladding)	3.0%
AERO15	Active Grill Shutters	3.0%
	Extend Air dam	2.0%

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As discussed further in Section III.D.8, this analysis assumes manufacturers apply off-cycle technology at rates defined in the Market Data file. While the AERO levels in the analysis are technology-agnostic, achieving AERO20 improvements does assume the use of active grille shutters, which is an off-cycle technology.

(b) Aerodynamics Analysis Fleet Assignments

DOT uses a relative performance approach to assign an initial level of aerodynamic drag reduction technology to each vehicle. Each AERO level represents a percent reduction in a vehicle's aerodynamic drag coefficient (C_d) from a baseline value for its body style. For a vehicle to achieve AERO5, the C_d must be at least 5% below the baseline for the body style; for AERO10, 10% below the baseline, and so on. Baseline aerodynamic assignment is therefore a three step process: Each vehicle in the fleet is assigned a body style, the average drag coefficient is calculated for each body style, and the drag coefficient for each vehicle model is compared to the average for the body style.

Every vehicle in the fleet is assigned a body style; available body styles included convertible, coupe, sedan, hatchback, wagon, SUV, pickup, minivan, and van. These assignments do not necessarily match the body styles used by manufacturers for marketing purposes. Instead, they are assigned based on analyst judgement, taking into account how a vehicle's AERO and vehicle technology class assignments are affected. Different body styles offer different utility and have varying levels of baseline form drag. In addition, frontal area is a major factor in aerodynamic forces, and the frontal area varies by vehicle. This analysis considers both frontal area and body style as utility factors affecting aerodynamic forces; therefore, the analysis assumes all reduction in aerodynamic drag forces come from improvement in the drag coefficient.

Average drag coefficients for each body style were computed using the MY 2015 drag coefficients published by manufacturers, which were used as the baseline values in the analysis. DOT harmonizes the Autonomie simulation baselines with the analysis fleet assignment baselines to the fullest extent possible.[244]

The drag coefficients used for each vehicle in the MY 2020 analysis fleet are sourced from manufacturer specification sheets, when possible. However, drag coefficients for the MY 2020 vehicles were not consistently reported publicly. If no drag coefficient was reported, analyst judgment is sometimes used to assign an AERO level. If no level was manually assigned, the drag coefficient obtained from manufacturers to build the MY 2016 fleet,[245] was used, if available. The MY 2016 drag coefficient values may not accurately reflect the current technology content of newer vehicles but are, in many cases, the most recent data available.

(c) Aerodynamics Adoption Features

As already discussed, DOT engineers use a relative performance approach to assign current aerodynamic technology (AERO) level to a vehicle. For some body styles with different utility, such as pickup trucks, SUVs and minivans, frontal area can vary, and this can affect the overall aerodynamic drag forces. In order to maintain vehicle utility and functionality related to passenger space and cargo space, we assume all technologies that improve aerodynamic drag forces do so by reducing C_d while maintaining frontal area.

Technology pathway logic for levels of aerodynamic improvement consists of a linear progression, with each level superseding all previous ones. Technology paths for AERO are illustrated in Figure III–14.

The highest levels of AERO are not considered for certain body styles. In these cases, this means that AERO20, and sometimes AERO15, can neither be assigned in the baseline fleet nor adopted by the model. For these body styles, there are no commercial examples of drag coefficients that demonstrate the required AERO15 or AERO20 improvement over baseline levels. DOT also deemed the most advanced levels of aerodynamic drag simulated as not technically practicable given the form drag of the body style and costed technology, especially given the need to maintain vehicle functionality and utility, such as interior volume, cargo area, and ground clearance. In short, DOT 'skipped' AERO15 for minivan body styles, and 'skipped' AERO20 for convertible, minivan, pickup, and wagon body styles.

DOT also does not allow application of AERO15 and AERO20 technology to vehicles with more than 780 horsepower. There are two main types of vehicles that informed this threshold: performance internal combustion engine (ICE) vehicles and high-power battery electric vehicles (BEVs). In the case of the former, the agency 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 vehicles with internal combustion engines without reducing horsepower. The baseline fleet includes 1,655 units of sales volume with limited application of aerodynamic technologies because of ICE vehicle performance.[246]

In the case of high-power battery electric vehicles, the 780-horsepower threshold is set above the highest peak system horsepower present on a BEV in the 2020 fleet. BEVs have different aerodynamic behavior and considerations than ICE vehicles, allowing for features such as flat underbodies that significantly reduce drag.[247] BEVs are therefore more likely to achieve higher AERO levels, so the horsepower threshold is set high enough that it does not restrict AERO15 and AERO20 application. Note that the CAFE Model does not force high levels of AERO adoption; rather, higher AERO levels are usually adopted organically by BEVs because significant drag reduction allows for smaller batteries and, by extension, cost savings. BEVs represent 252,023 units of sales volume in the baseline fleet.[248]

(d) Aerodynamics Effectiveness Modeling

To determine aerodynamic effectiveness, the CAFE Model and Autonomie used individually assigned road load technologies for each vehicle to appropriately assign initial road load levels and appropriately capture benefits of subsequent individual road load improving technologies.

The current analysis included four levels of aerodynamic improvements, AERO5, AERO10, AERO15, and AERO20, representing 5, 10, 15, and 20 percent reduction in drag coefficient (C_d), respectively. DOT assumed that aerodynamic drag reduction could only come from reduction in C_d and not from reduction of frontal area, to maintain vehicle functionality and utility, such as passenger space, ingress/egress ergonomics, and cargo space.

The effectiveness values for the aerodynamic improvement levels relative to AERO0, for all ten vehicle technology classes, are shown in Figure III–15. Each of the effectiveness values shown is representative of the improvements seen for upgrading only the listed aerodynamic technology level for a given combination of other technologies. In other words, the range of effectiveness values seen for each specific technology (*e.g.,* AERO 15) represents the addition of AERO15 technology (relative to AERO0 level) for every technology combination that could select the addition of AERO15. It must be emphasized that the change in fuel consumption values between entire technology keys is used,[249] and not the individual technology effectiveness values. Using the change between whole technology keys captures the complementary or non-complementary interactions among technologies. The box shows the inner quartile range (IQR) of the effectiveness values and whiskers extend out 1.5 x IQR. The dots outside the whiskers show effectiveness values outside those thresholds.

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[244] *See* TSD Chapter 2.4.1 for a table of vehicle attributes used to build the Autonomie baseline vehicle models. That table includes a drag coefficient for each vehicle class.

[245] *See* 83 FR 42986 (Aug. 24, 2018). The MY 2016 fleet was built to support the 2018 NPRM.

[246] Market Data file.

[247] 2020 EPA Automotive Trends Report, at 227.

[248] Market Data file.

[249] Technology key is the unique collection of technologies that constitutes a specific vehicle, *see* TSD Chapter 2.4.7 for more detail.

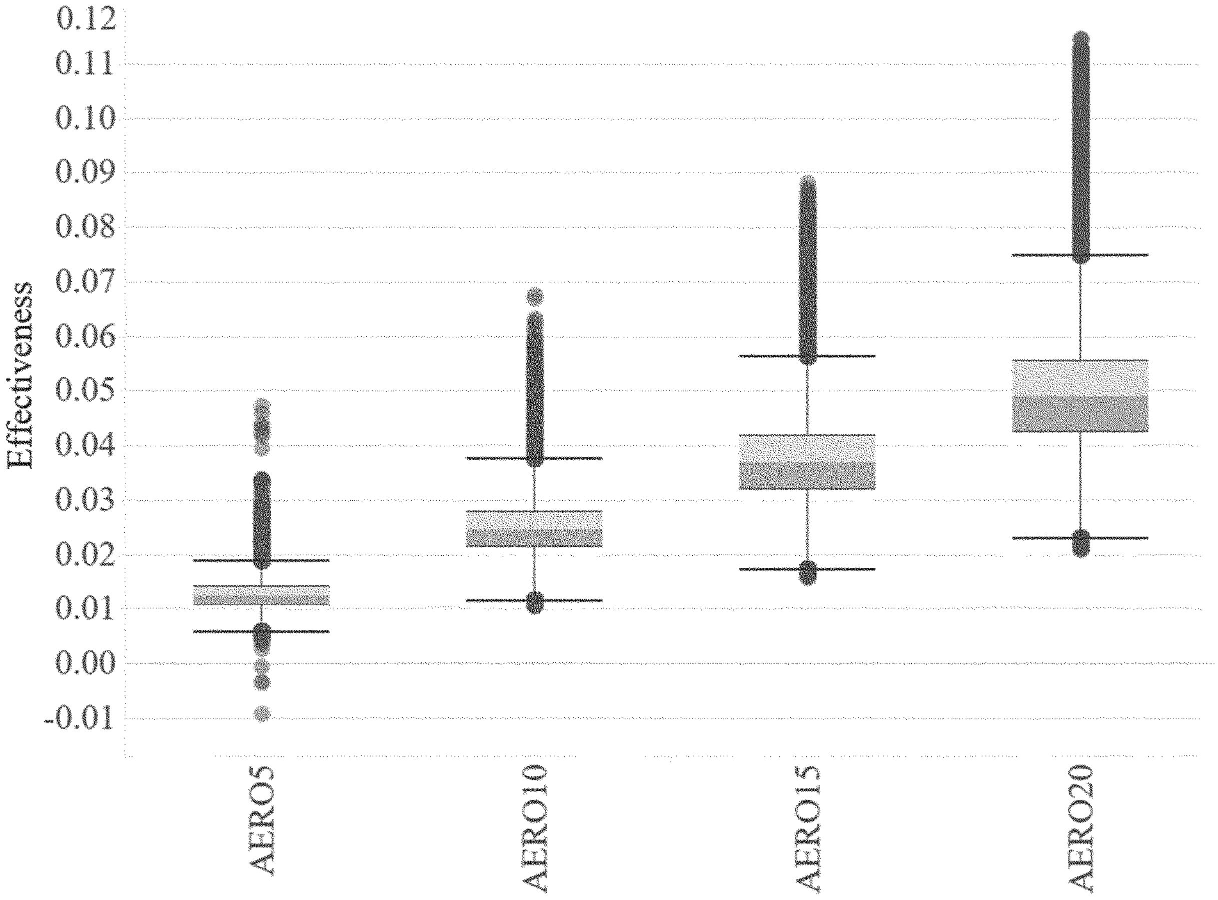

Figure III-15 – AERO Technology Effectiveness[250]

(e) Aerodynamics Costs

This analysis uses the AERO technology costs established in the 2020 final rule that are based on confidential business information submitted by the automotive industry in advance of the 2018 NPRM,[251] and on DOT's assessment of manufacturing costs for specific aerodynamic technologies.[252] DOT received no additional comments from stakeholders regarding the costs established in the 2018 NPRM, and continued to use the established costs for the 2020 final rule and this analysis.

Table III–30 shows examples of costs for AERO technologies as applied to the medium car and pickup truck vehicle classes in select model years. The cost to achieve AERO5 is relatively low, as most of the improvements can be made through body styling changes. The cost to achieve AERO10 is higher than AERO5, due to the addition of several passive aerodynamic technologies, and the cost to achieve AERO15 and AERO20 is higher than AERO10 due to use of both passive and active aerodynamic technologies. For a full list of all absolute aerodynamic technology costs used in the analysis across all model years see the Technologies file.

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[250] The data used to create this figure can be found in the FE_1 Improvements file.

[251] *See* the PRIA accompanying the 2018 NPRM, Chapter 6.3.10.1.2.1.2 for a discussion of these cost estimates.

[252] *See* the FRIA accompanying the 2020 final rule, Chapter VI.C.5.e.

Table III-30 – Examples of Costs for Aerodynamic Reduction Technologies in 2018$ for Medium Cars and Pickup Trucks for Select Model Years

Technology	Medium Car Costs (2018$)			Pickup Costs (2018$)		
	MY 2020	MY 2025	MY 2030	MY 2020	MY 2025	MY 2030
AERO0	0.00	0.00	0.00	0.00	0.00	0.00
AERO5	53.96	48.70	45.73	53.96	48.70	45.73
AERO10	110.32	99.56	93.49	110.32	99.56	93.49
AERO15	155.88	140.68	132.10	275.80	248.90	233.72
AERO20	275.80	248.90	233.72	-	-	-

6. Tire Rolling Resistance

Tire rolling resistance is a road load force that arises primarily from the energy dissipated by elastic deformation of the tires as they roll. Tire design characteristics (for example, materials, construction, and tread design) have a strong influence on the amount and type of deformation and the energy it dissipates. Designers can select these characteristics to minimize rolling resistance. However, these characteristics may also influence other performance attributes, such as durability, wet and dry traction, handling, and ride comfort.

Lower-rolling-resistance tires have characteristics that reduce frictional losses associated with the energy dissipated mainly in the deformation of the tires under load, thereby improving fuel economy. Low rolling resistance tires are increasingly specified by OEMs in new vehicles and are also increasingly available from aftermarket tire vendors. They commonly include attributes such as higher inflation pressure, material changes, tire construction optimized for lower hysteresis, geometry changes (*e.g.,* reduced aspect ratios), and reduced sidewall and tread deflection. These changes are commonly accompanied by additional changes to vehicle suspension tuning and/or suspension design to mitigate any potential impact on other performance attributes of the vehicle.

DOT continues to assess the potential impact of tire rolling resistance changes on vehicle safety. DOT has been following the industry developments and trends in application of rolling resistance technologies to light duty vehicles. As stated in the National Academies Press (NAP) special report on Tires and Passenger Vehicle Fuel Economy,[253] national crash data does not provide data about tire structural failures specifically related to tire rolling resistance, because the rolling resistance of a tire at a crash scene cannot be determined. However, other metrics like brake performance compliance test data are helpful to show trends like that stopping distance has not changed in the last ten years,[254] during which time many manufacturers have installed low rolling resistance tires in their fleet—meaning that manufacturers were successful in improving rolling resistance while maintaining stopping distances through tire design, tire materials, and/or braking system improvements. In addition, NHTSA has addressed other tire-related issues through rulemaking,[255] and continues to research tire problems such as blowouts, flat tires, tire or wheel deficiency, tire or wheel failure, and tire degradation.[256] However, there are currently no data connecting low rolling resistance tires to accident or fatality rates.

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[253] Tires and Passenger Vehicle Fuel Economy: Informing Consumers, Improving Performance—Special Report 286 (2006), available at *https://www.nap.edu/read/11620/chapter/6.*

[254] See, *e.g.,* NHTSA Office of Vehicle Safety Compliance, Compliance Database, *https://one.nhtsa.gov/cars/problems/comply/index.cfm.*

[255] 49 CFR 571.138, Tire pressure monitoring systems.

[256] Tire-Related Factors in the Pre-Crash Phase, DOT HS 811 617 (April 2012), available at *https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811617.*

NHTSA conducted tire rolling resistance tests and wet grip index tests on original equipment tires installed on new vehicles. The tests showed that there is no degradation in wet grip index values (no degradation in traction) for tires with improved rolling resistance technology. With better tire design, tire compound formulations and improved tread design, tire manufacturers have tools to balance stopping distance and reduced rolling resistance. Tire manufacturers can use ''higher performance materials in the tread compound, more silica as reinforcing fillers and advanced tread design features'' to mitigate issues related to stopping distance.[257]

The following sections discuss levels of tire rolling resistance technology considered in the CAFE Model, how the technology was assigned in the analysis fleet, adoption features specified to maintain performance, effectiveness, and cost.

(a) Tire Rolling Resistance in the CAFE Model

DOT continues to consider two levels of improvement for low rolling resistance tires in the analysis: The first level of low rolling resistance tires considered reduced rolling resistance 10 percent from an industry-average baseline rolling resistance coefficient (RRC) value, while the second level reduced rolling resistance 20 percent from the baseline.[258]

DOT selected the industry-average RRC baseline of 0.009 based on a CONTROLTEC study prepared for the California Air Resources Board,[259] in addition to confidential business information submitted by manufacturers prior to the 2018 NPRM analysis. The average RRC from the CONTROLTEC study, which surveyed 1,358 vehicle models, was 0.009.[260] CONTROLTEC also compared the findings of their survey with values provided by Rubber Manufacturers Association (renamed as USTMA–U.S. Tire Manufacturers Association) for original equipment tires. The average RRC from the data provided by RMA was 0.0092,[261] compared to average of 0.009 from CONTROLTEC.

In past agency actions, commenters have argued that based on available data on current vehicle models and the likely possibility that there would be additional tire improvements over the next decade, DOT should consider ROLL30 technology, or a 30 percent reduction of tire rolling resistance over the baseline.[262]

As stated in the Joint TSD for the MY 2017–2025 final rule (77 FR 62624, Oct. 15, 2012) and 2020 final rule, tire technologies that enable rolling resistance improvements of 10 and 20 percent have been in existence for many years.[263] Achieving improvements of up to 20 percent involves optimizing and integrating multiple technologies, with a primary contributor being the adoption of a silica tread technology. Tire suppliers have indicated that additional innovations are necessary to achieve the next level of low rolling resistance technology on a commercial basis, such as improvements in material to retain tire pressure, tread design to manage both stopping distance and wet traction, and development of carbon black material for low rolling resistance without the use of silica to reduce cost and weight.[264]

The agency believes that the tire industry is in the process of moving automotive manufacturers towards higher levels of rolling resistance technology in the vehicle fleet. Importantly, as shown below, the MY 2020 fleet does include a higher percentage of vehicles with ROLL20 technology than the MY 2017 fleet. However, DOT 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, or adopting improved tires along with active chassis control,[265] among other technologies, will not be available for widespread commercial adoption in the fleet during the rulemaking timeframe. As a result, the agency continues to not to incorporate 30 percent reduction in rolling resistance technology. DOT will consider adding an advanced level of tire rolling resistance technology to future analyses, and invites comment on any updated information on manufacturers' capabilities to add tires with higher levels of rolling resistance to their vehicles, and consumers' willingness to accept these tires on their vehicles.

(b) Tire Rolling Resistance Analysis Fleet Assignments

Tire rolling resistance is not a part of tire manufacturers' publicly released specifications and thus it is difficult to assign this technology to the analysis fleet. Manufacturers also often offer multiple wheel and tire packages for the same nameplates, further increasing the complexity of this assignment. DOT employed an approach consistent with previous rulemaking in assigning this technology. DOT relied on previously submitted rolling resistance values that were supplied by manufacturers in the process of building older fleets and bolstered it with agency-sponsored tire rolling testing by Smithers.[266]

DOT carried over rolling resistance assignments for nameplates where manufacturers had submitted data on the vehicles' rolling resistance values, even if the vehicle was redesigned. If Smithers data was available, DOT replaced any older or missing values with that updated data. Those vehicles for which no information was available from either previous manufacturer submission or Smithers data were assigned to ROLL0. All vehicles under the same nameplate were assigned the same rolling resistance technology level even if manufacturers do outfit different trim levels with different wheels and tires.

The MY 2020 analysis fleet includes the following breakdown of rolling resistance technology: 44% at ROLL0, 20% at ROLL10, and 36% at ROLL20, which shows that the majority of the fleet has now adopted some form of improved rolling resistance technology. The majority of the change from the MY 2017 analysis fleet has been in implementing ROLL20 technology. There is likely more proliferation of rolling resistance technology, but we would need further information from manufacturers in order to account for it. DOT invites comment from manufacturers on whether these rolling

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[257] Jesse Snyder, A big fuel saver: Easy-rolling tires (but watch braking) (July 21, 2008), *https://www.autonews.com/article/20080721/OEM01/307219960/a-big-fuel-saver-easy-rolling-tires-but-watch-braking.* Last visited December 3, 2019.

[258] To achieve ROLL10, the tire rolling resistance must be at least 10 percent better than baseline (.0081 or better). To achieve ROLL20, the tire rolling resistance must be at least 20 percent better than baseline (.0072 or better).

[259] Technical Analysis of Vehicle Load Reduction by CONTROLTEC for California Air Resources Board (April 29, 2015).

[260] 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.

[261] Technical Analysis of Vehicle Load Reduction by CONTROLTEC for California Air Resources Board (April 29, 2015) at page 40.

[262] NHTSA–2018–0067–11985.

[263] EPA–420–R–12–901, at page 3–210.

[264] 2011 NAS report, at 103.

[265] Mohammad Mehdi Davari, Rolling resistance and energy loss in tyres (May 20, 2015), available at *https://www.sveafordon.com/media/42060/SVEA-Presentation_Davari_public.pdf.* Last visited December 30, 2019.

[266] See memo to Docket No. NHTSA–2021–0053, Evaluation of Rolling Resistance and Wet Grip Performance of OEM Stock Tires Obtained from NCAP Crash Tested Vehicles Phase One and Two. NHTSA used tire rolling resistance coefficient values from this project to assign baseline tire rolling resistance technology in the MY 2020 analysis fleet and is therefore providing the draft project appendices for public review and comment.

resistance values are still applicable, or any updated rolling resistance values that could be incorporated in a publicly available analysis fleet. If manufacturers submit updated information on baseline rolling resistance assignments DOT may update those assignments for the final rule.

(c) Tire Rolling Resistance Adoption Features

Rolling resistance technology can be adopted with either a vehicle refresh or redesign. In some cases, low rolling resistance tires can affect traction, which may adversely impact acceleration, braking, and handling characteristics for some high-performance vehicles. Similar to past rulemakings, the agency recognizes that to maintain performance, braking, and handling functionality, some high-performance vehicles would not adopt low rolling resistance tire technology. For cars and SUVs with more than 405 horsepower (hp), the agency restricted the application of ROLL20. For cars and SUVs with more than 500 hp, the agency restricted the application of any additional rolling resistance technology (ROLL10 or ROLL20). The agency developed these cutoffs based on a review of confidential business information and the distribution of rolling resistance values in the fleet.

(d) Tire Rolling Resistance Effectiveness Modeling

As discussed above, the baseline rolling resistance value from which rolling resistance improvements are measured is 0.009, based on a thorough review of confidential business information submitted by industry, and a review of other literature. To achieve ROLL10, the tire rolling resistance must be at least 10 percent better than baseline (.0081 or better). To achieve ROLL20, the tire rolling resistance must be at least 20 percent better than baseline (.0072 or better).

DOT determined effectiveness values for rolling resistance technology adoption using Autonomie modeling. Figure III–16 below shows the range of effectiveness values used for adding tire rolling resistance technology to a vehicle in this analysis. The graph shows the change in fuel consumption values between entire technology keys,[267] and not the individual technology effectiveness values. Using the change between whole technology keys captures the complementary or non-complementary interactions among technologies. In the graph, the box shows the interquartile range (IQR) of the effectiveness values and whiskers extend out 1.5 x IQR. The dots outside of the whiskers show values for effectiveness that are outside these bounds.

The data points with the highest effectiveness values are almost all exclusively BEV and FCV technology combinations for medium sized nonperformance cars. The effectiveness for these vehicles, when the low rolling resistance technology is applied, is amplified by a complementary effect, where the lower rolling resistance reduces road load and allows a smaller battery pack to be used (and still meet range requirements). The smaller battery pack reduces the overall weight of the vehicle, further reducing road load, and improving fuel efficiency. This complimentary effect is experience by all the vehicle technology classes, but the strongest effect is on the midsized vehicle non-performance classes and is only captured in the analysis through the use of full vehicle simulations, demonstrating the full interactions of the technologies.

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[267] Technology key is the unique collection of technologies that constitutes a specific vehicle, *see* TSD Chapter 2.4.7 for more information.

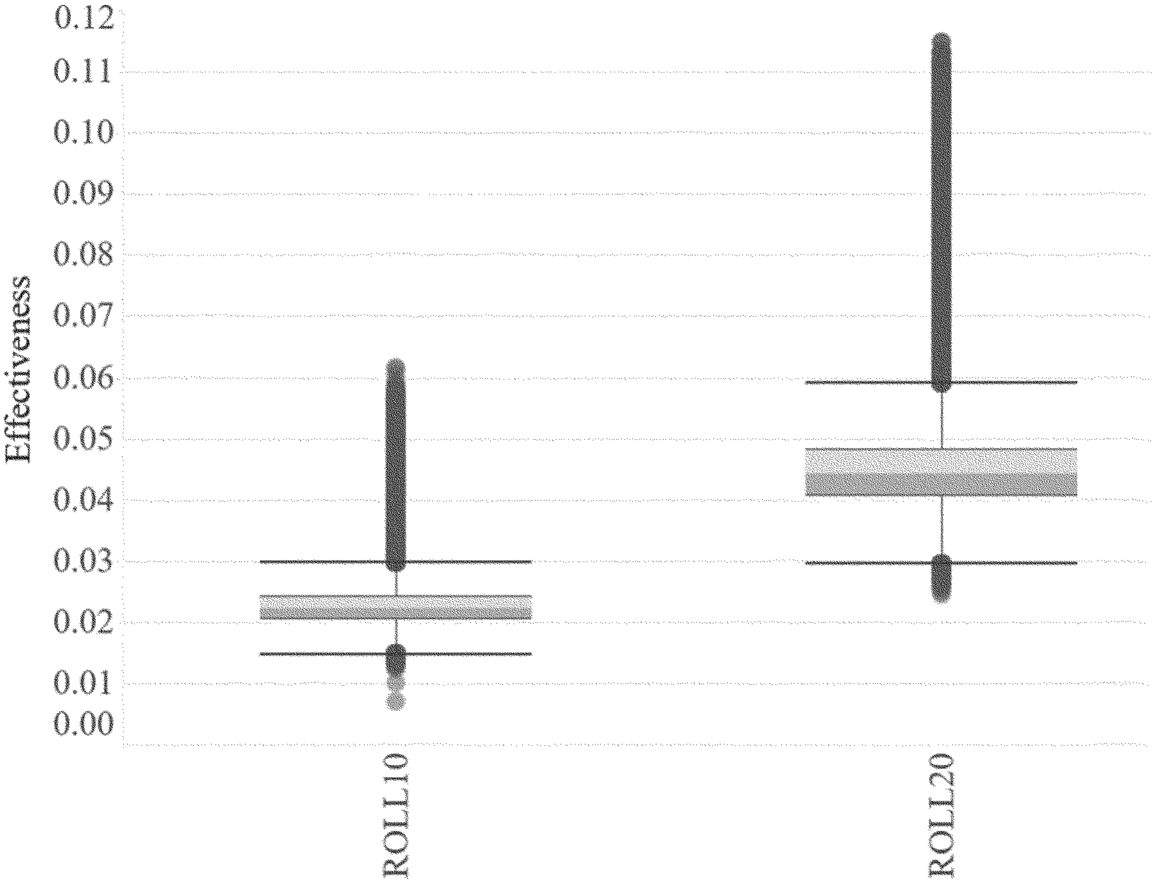

Figure III-16 – ROLL Technology Effectiveness

(e) Tire Rolling Resistance Costs

DOT continues to use the same DMC values for ROLL technology that were used for the 2020 final rule which are based on NHTSA's MY 2011 CAFE final rule (74 FR 14196, March 30, 2009) and the 2006 NAS/NRC report.[268] Table III–31 shows the different levels of tire rolling resistance technology cost for all vehicle classes across select model years, which shows how the learning rate for ROLL technologies impacts the cost. For all ROLL absolute technology costs used in the analysis across all model years see the Technologies file.

Table III-31 – Examples of Costs for Rolling Resistance Reduction Technologies in 2018$ for Select Model Years

Technology	MY 2020	MY 2025	MY 2030
ROLL0	0.00	0.00	0.00
ROLL10	7.13	6.52	6.16
ROLL20	51.18	44.04	40.70

7. Other Vehicle Technologies

Four other vehicle technologies were included in the analysis—electric power steering (EPS), improved accessory devices (IACC), low drag brakes (LDB), and secondary axle disconnect (SAX). The effectiveness of these technologies was applied directly in the CAFE Model with unique effectiveness values for each technology and for each technology class, rather than using Autonomie effectiveness estimates. This methodology was used in these four cases because the effectiveness of these technologies varies little with combinations of other technologies. Also, applying these technologies directly in the CAFE Model significantly reduces the number of Autonomie simulations that are needed.

(a) Electric Power Steering

Electric power steering reduces fuel consumption by reducing load on the engine. Specifically, it reduces or eliminates the parasitic losses associated with engine-driven power

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[268] "Tires and Passenger Vehicle Fuel Economy," Transportation Research Board Special Report 286, National Research Council of the National Academies, 2006, Docket No. EPA–HQ–OAR–2009–0472–0146.

steering pumps, which pump hydraulic fluid continuously through the steering actuation system even when no steering input is present. By selectively powering the electric assist only when steering input is applied, the power consumption of the system is reduced in comparison to the traditional ''always-on'' hydraulic steering system. Power steering may be electrified on light duty vehicles with standard 12V electrical systems and is also an enabler for vehicle electrification because it provides power steering when the engine is off (or when no combustion engine is present).

Power steering systems can be electrified in two ways. Manufacturers may choose to eliminate the hydraulic portion of the steering system and provide electric-only power steering (EPS) driven by an independent electric motor, or they may choose to move the hydraulic pump from a belt-driven configuration to a stand-alone electrically driven hydraulic pump. The latter system is commonly referred to as electro-hydraulic power steering (EHPS). As discussed in the rulemakings, manufacturers have informed DOT that full EPS systems are being developed for all types of light-duty vehicles, including large trucks.

DOT described in past rulemakings that, like low drag brakes, EPS can be difficult to observe and assign to the analysis fleet, however, it is found more frequently in publicly available information than low drag brakes. Based on comments received during the 2020 rulemaking, the agency increased EPS application rate to nearly 90 percent for the 2020 final rule. The agency is maintaining this level of EPS fleet penetration for this analysis, recognizing that some specialized, unique vehicle types or configurations still implement hydraulically actuated power steering systems for the baseline fleet model year.

The effectiveness of both EPS and EHPS is derived from the decoupling of the pump from the crankshaft and is considered to be practically the same for both. Thus, a single effectiveness value is used for both EPS and EHPS. As indicated in the following table, the effectiveness of EPS and EHPS varies based on the vehicle technology class it is being applied to. This variance is a direct result of vehicle size and the amount of energy required to turn the vehicle's two front wheels about their vertical axis. More simply put, more energy is required for vehicles that weigh more and, typically, have larger tire contact patches.

Table III-32 – Fuel Consumption Improvement Values for Electric Power Steering

Tech Class	EPS
SmallCar	1.50%
SmallCarPerf	
MedCar	1.30%
MedCarPerf	
SmallSUV	1.20%
SmallSUVPerf	
MedSUV	1.00%
MedSUVPerf	
Pickup	0.80%
PickupHT	

(b) Improved Accessories

Engine accessories typically include the alternator, coolant pump, cooling fan, and oil pump, and are traditionally mechanically driven via belts, gears, or directly by other rotating engine components such as camshafts or the crankshaft. These can be replaced with improved accessories (IACC), which may include high efficiency alternators, electrically driven (*i.e.,* on-demand) coolant pumps, electric cooling fans, variable geometry oil pumps, and a mild regeneration strategy. Replacing lower-efficiency and/or mechanically-driven components with these improved accessories results in a reduction in fuel consumption, as the improved accessories can conserve energy by being turned on/off ''on demand'' in some cases, driven at partial load as needed, or by operating more efficiently.

For example, electric coolant pumps and electric powertrain cooling fans provide better control of engine cooling. Flow from an electric coolant pump can be varied, and the cooling fan can be shut off during engine warm-up or cold ambient temperature conditions, reducing warm-up time, fuel enrichment requirements, and, ultimately reducing parasitic losses.

IACC technology is difficult to observe and therefore there is uncertainty in assigning it to the analysis fleet. As in the past, DOT relies on industry-provided information and comments to assess the level of IACC technology applied in the fleet. DOT believes there continues to be opportunity for further implementation of IACC. The MY 2020 analysis fleet has an IACC fleet penetration of approximately eight percent compared to the six percent value in the MY 2017 analysis fleet used for the 2020 final rule analysis.

The agency believes improved accessories may be incorporated in coordination with powertrain related changes occurring at either a vehicle refresh or vehicle redesign. This coordination with powertrain changes enables related design and tooling changes to be implemented and systems development, functionality and durability testing to be conducted in a single product change program to efficiently manage resources and costs.

This analysis carries forward work on the effectiveness of IACC systems conducted in the Draft TAR and EPA Proposed Determination that is originally founded in the 2002 NAS Report[269] and confidential manufacturer data. This work involved gathering information by monitoring

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[269] National Research Council 2002. *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards.* Washington, DC: The National Academies Press. *https://doi.org/10.17226/10172.*

press reports, holding meetings with suppliers and OEMs, and attending industry technical conferences. The resulting effectiveness estimates we use are shown below. As indicated in the following table, the effectiveness of IACC is simulated with differing values based on the vehicle technology class it is being applied to. This variance, like EPS, is a direct result of vehicle size and the amount of energy required perform the work necessary for the vehicle to operate as expected. This variance is related to the amount energy generated by the alternator, the size of the coolant pump to the cool the necessary systems, the size of the cooling fan required, among other characteristics and it directed related to a vehicle size and mass.

Table III-33 – Fuel Consumption Improvement Values for Improved Accessories

Tech Class	IACC
SmallCar	1.85%
SmallCarPerf	
MedCar	2.36%
MedCarPerf	
SmallSUV	1.74%
SmallSUVPerf	
MedSUV	2.34%
MedSUVPerf	
Pickup	2.15%
PickupHT	

(c) Low Drag Brakes

Since 2009, for the MY 2011 CAFE final rule, DOT has defined low drag brakes (LDB) as brakes that reduce the sliding friction of disc brake pads on rotors when the brakes are not engaged because the brake pads are pulled away from the rotating disc either by mechanical or electric methods.[270] DOT estimated the effectiveness of LDB technology to be a range from 0.5–1.0 percent, based on CBI data. DOT applied a learning curve to the estimated cost for LDB, but noted that the technology was considered high volume, mature, and stable. DOT explained that confidential manufacturer comments in response to the NPRM for MY 2011 (73 FR 24352, May 2, 2008) indicated that most passenger cars have already adopted LDB technology, but ladder frame trucks have not.

DOT and EPA continued to use the same definition for LDB in the MY 2012–2016 rule (75 FR 25324, May 7, 2010), with an estimated effectiveness of up to 1 percent based on CBI data.[271] DOT only allowed LDB technology to be applied to large car, minivan, medium and large truck, and SUV classes because the agency determined the technology was already largely utilized in most other subclasses. The 2011 NAS committee also utilized NHTSA and EPA's definition for LDB and added that most new vehicles have low-drag brakes.[272] The committee confirmed that the impact over conventional brakes may be about a 1 percent reduction of fuel consumption.

For the MY 2017–2025 rule, however, DOT and EPA updated the effectiveness estimate for LDB to 0.8 percent based on a 2011 Ricardo study and updated lumped-parameter model.[273] The agencies considered LDB technology to be off the learning curve (*i.e.,* the DMC does not change year-over-year). The 2015 NAS report continued to use the agencies' definition for LDB and commented that the 0.8 percent effectiveness estimate is a reasonable estimate.[274] The 2015 NAS committee did not opine on the application of LDB technology in the fleet. The agencies used the same definition, cost, and effectiveness estimates for LDB in the Draft TAR, but also noted the existence of zero drag brake systems which use electrical actuators that allow brake pads to move farther away from the rotor.[275] However, the agencies did not include zero drag brake technology in either compliance simulation. EPA continued with this approach in its first 2017 Final Determination that the standards through 2025 were appropriate.[276]

In the 2020 final rule, the agencies applied LDB sparingly in the MY 2017 analysis fleet using the same cost and effectiveness estimates from the 2011 Ricardo study, with approximately less than 15% of vehicles being assigned the technology. In addition, DOT noted the existence of zero drag brakes in production for some BEVs, similar to the summary in the Draft TAR, but did not opine on the existence of zero drag brakes in the fleet. Some stakeholders commented to the 2020 final rule that other vehicle technologies, including LDB, were actually overapplied in the analysis fleet.

For this action, DOT considered the conflicting statements that LDB were both universally applied in new vehicles and that the new vehicle fleet still had space to improve LDB technology. DOT determined that LDB technology as previously defined going back to the MY 2011 rule (74 FR 14196, March 30, 2009) was universally

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[270] Final Regulatory Impact Analysis, Corporate Average Fuel Economy for MY 2011 Passenger Cars and Light Trucks (March 2009), at V–135.

[271] Final Regulatory Impact Analysis, Corporate Average Fuel Economy for MY 2012–MY 2016 Passenger Cars and Light Trucks (March 2010), at 249.

[272] 2011 NAS report, at 104.

[273] Joint Technical Support Document: Final Rulemaking for 2017–2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards (August 2012), at 3–211.

[274] 2015 NAS report, at 231.

[275] Draft TAR, at 5–207.

[276] EPA Proposed Determination TSD, at 2–422.

applied in the MY 2020 fleet. However, DOT determined that zero drag brakes, the next level of brake technology, was sparingly applied in the MY 2020 analysis fleet. Currently, DOT does not believe that zero drag brake systems will be available for wide scale application in the rulemaking timeframe and did not include it as a technology for this analysis. DOT will consider how to define a new level of low drag brake technology that either encompasses the definition of zero drag brakes or similar technology in future rulemakings. We invite comment on the issue, and any available data regarding use of such systems on current and forthcoming production vehicles, any available data regarding system costs and efficacy in reducing drag (*i.e.,* force at different speeds) and vehicle fuel economy levels (*i.e.,* through coastdown testing).

(d) Secondary Axle Disconnect

All-wheel drive (AWD) and four-wheel drive (4WD) vehicles provide improved traction by delivering torque to the front and rear axles, rather than just one axle. When a second axle is rotating, it tends to consume more energy because of additional losses related to lubricant churning, seal friction, bearing friction, and gear train inefficiencies.[277] Some of these losses may be reduced by providing a secondary axle disconnect function that disconnects one of the axles when driving conditions do not call for torque to be delivered to both.

The terms AWD and 4WD are often used interchangeably, although they have also developed a colloquial distinction, and are two separate systems. The term AWD has come to be associated with light-duty passenger vehicles providing variable operation of one or both axles on ordinary roads. The term 4WD is often associated with larger truck-based vehicle platforms providing a locked driveline configuration and/or a low range gearing meant primarily for off-road use.

Many 4WD vehicles provide for a single-axle (or two-wheel) drive mode that may be manually selected by the user. In this mode, a primary axle (usually the rear axle) will be powered, while the other axle (known as the secondary axle) is not. However, even though the secondary axle and associated driveline components are not receiving engine power, they are still connected to the non-driven wheels and will rotate when the vehicle is in motion. This unnecessary rotation consumes energy,[278] and leads to increased fuel consumption that could be avoided if the secondary axle components were completely disconnected and not rotating.

Light-duty AWD systems are often designed to divide variably torque between the front and rear axles in normal driving to optimize traction and handling in response to driving conditions. However, even when the secondary axle is not necessary for enhanced traction or handling, in traditional AWD systems it typically remains engaged with the driveline and continues to generate losses that could be avoided if the axle was instead disconnected. The SAX technology observed in the marketplace disengages one axle (typically the rear axle) for two-wheel drive (2WD) operation but detects changes in driving conditions and automatically engages AWD mode when it is necessary. The operation in 2WD can result in reduced fuel consumption. For example, Chrysler has estimated the secondary axle disconnect feature in the Jeep Cherokee reduces friction and drag attributable to the secondary axle by 80% when in disconnect mode.[279]

Observing SAX technology on actual vehicles is very difficult. Manufacturers do not typically identify the technology on technical specifications or other widely available information. The agency employed an approach consistent with previous rulemaking in assigning this technology. Specifically, the agency assigned SAX technology based on a combination of publicly available information and previously submitted confidential information. In the analysis fleet, 38% of the vehicles that had AWD or 4WD are determined to have SAX technology. All vehicles in the analysis fleet with front-wheel drive (FWD) or rear-wheel drive (RWD) have SAX skipped since SAX technology is a way to emulate FWD or RWD in AWD and 4WD vehicles, respectively. The agency does not allow for the application of SAX technology to FWD or RWD vehicles because they do not have a secondary driven axle to disconnect.

SAX technology can be adopted by any vehicle in the analysis fleet, including those with a HEV or BEV powertrain,[280] which was identified as having AWD or 4WD. It does not supersede any technology or result in any other technology being excluded for future implementation for that vehicle. SAX technology can be applied during any refresh or redesign. DOT seeks comment on whether it is appropriate for SAX technology to be allowed to be applied to BEVs, or if the technology only provides benefits to ICE vehicles.

This analysis carries forward work on the effectiveness of SAX systems conducted in the Draft TAR and EPA Proposed Determination.[281] This work involved gathering information by monitoring press reports, holding meetings with suppliers and OEMs, and attending industry technical conferences. DOT does not simulate SAX effectiveness in the Autonomie modeling because, similar to LDB, IACC, and EFR, the fuel economy benefits from the technology are not fully captured on the two-cycle test. The secondary axle disconnect effectiveness values, for the most part, have been accepted as plausible based on the rulemaking record and absence of contrary comments. As such, the agency has prioritized its extensive Autonomie vehicle simulation work toward other technologies that are emerging or considered more critical for total system effectiveness. The resulting effectiveness estimates we use are shown below. The agency welcomes comment on these effectiveness values and will consider any material data providing revised, or confirmatory, values for those being used in the analysis.

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[277] Pilot Systems, ‘‘AWD Component Analysis’’, Project Report, performed for Transport Canada, Contract T8080-
150132, May 31, 2016.

[278] Any time a drivetrain component spins it consumes some energy, primarily to overcome frictional forces.

[279] Brooke, L. ‘‘Systems Engineering a new 4x4 benchmark’’, *SAE Automotive Engineering,* June 2, 2014.

[280] The inefficiencies addressed on ICEs by SAX technology may not be similar enough, or even present, in HEVs or BEVs.

[281] Draft TAR, at 5–412; Proposed Determination TSD, at 2–422.

Table III-34 – Fuel Consumption Improvement Values for Secondary Axle Disconnect

Tech Class	SAX
SmallCar	1.40%
SmallCarPerf	
MedCar	1.40%
MedCarPerf	
SmallSUV	1.40%
SmallSUVPerf	
MedSUV	1.30%
MedSUVPerf	
Pickup	1.60%
PickupHT	

(e) Other Vehicle Technology Costs

The cost estimates for EPS, IACC, SAX, and LDB[282] rely on previous work published as part of past rulemakings with learning applied to those cost values which is founded in the 2002 NAS report.[283] The cost values are the same values that were used for the Draft TAR and 2020 final rule, updated to 2018 dollars. Table III–35 shows examples of costs for these technologies across select model years. Note that these costs are the same for all vehicle technology classes. For all absolute EPS, IACC, LDB, and SAX technology costs across all model years, see the Technologies file.

Table III-35 – Examples of Costs for EPS, IACC, LDB, and SAX Technologies in 2018$ for Select Model Years

Technology	MY 2020	MY 2025	MY 2030
EPS	126.53	117.28	110.90
IACC	169.70	146.67	135.17
LDB	86.42	78.35	73.12
SAX	88.69	80.34	75.15

8. Simulating Air Conditioning Efficiency and Off-Cycle Technologies

Off-cycle and air conditioning (A/C) efficiency technologies can provide fuel economy benefits in real-world vehicle operation, but those benefits cannot be fully captured by the traditional 2-cycle test procedures used to measure fuel economy.[284] Off-cycle technologies include technologies like high efficiency alternators and high efficiency exterior lighting.[285] A/C efficiency technologies are technologies that reduce the operation of or the loads on the compressor, which pressurizes A/C refrigerant. The less the compressor operates or the more efficiently it operates, the less load the compressor places on the engine, resulting in better fuel efficiency.

Vehicle manufacturers have the option to generate credits for off-cycle technologies and improved A/C systems under the EPA's CO_2 program and receive a fuel consumption improvement value (FCIV) equal to the value of the benefit not captured on the 2-cycle test under NHTSA's CAFE program. The FCIV is not a ''credit'' in the NHTSA CAFE program,[286] but the FCIVs increase the reported fuel economy of a manufacturer's fleet, which is used to determine compliance. EPA applies FCIVs during determination of a fleet's final average fuel economy reported to NHTSA.[287]

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[282] Note that because LDB technology is applied universally as a baseline technology in the MY 2020 fleet, there is functionally zero costs for this technology associated with this proposed rulemaking.

[283] National Research Council 2002. *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards.* Washington, DC: The National Academies Press. *https://doi.org/10.17226/10172.*

[284] *See* 49 U.S.C 32904(c) (''The Administrator shall measure fuel economy for each model and calculate average fuel economy for a manufacturer under testing and calculation procedures prescribed by the Administrator. . . . the Administrator shall use the same procedures for passenger automobiles the Administrator used for model year 1975 (weighted 55 percent urban cycle and 45 percent highway cycle), or procedures that give comparable results.'').

[285] 40 CFR 86.1869–12(b)—Credit available for certain off-cycle technologies.

[286] Unlike, for example, the statutory overcompliance credits prescribed in 49 U.S.C. 32903.

[287] 49 U.S.C. 32904(c)–(e). EPCA granted EPA authority to establish fuel economy testing and calculation procedures. *See* Section VII for more information.

FCIVs are only calculated and applied at a fleet level for a manufacturer and are based on the volume of the manufacturer's fleet that contain qualifying technologies.[288]

There are three pathways that can be used to determine the value of A/C efficiency and off-cycle adjustments. First, manufacturers can use a predetermined list or ''menu'' of g/mi values that EPA established for specific off-cycle technologies.[289] Second, manufacturers can use 5-cycle testing to demonstrate off-cycle CO_2 benefit;[290] the additional tests allow emissions benefits to be demonstrated over some elements of real-world driving not captured by the 2-cycle compliance tests, including high speeds, rapid accelerations, hot temperatures, and cold temperatures. Third, manufacturers can seek EPA approval, through a notice and comment process, to use an alternative methodology other than the menu or 5-cycle methodology for determining the off-cycle technology improvement values.[291] For further discussion of the A/C and off-cycle compliance and application process, see Section VII.

DOT and EPA have been collecting data on the application of these technologies since implementing the A/C and off-cycle programs.[292] [293] Most manufacturers are applying A/C efficiency and off-cycle technologies; in MY 2019, 17 manufacturers employed A/C efficiency technologies and 20 manufacturers employed off-cycle technologies, though the level of deployment varies by manufacturer.[294]

Manufacturers have only recently begun including detailed information on off-cycle and A/C efficiency technologies equipped on vehicles in compliance reporting data. For this analysis, though, such information was not sufficiently complete to support a detailed representation of the application of off-cycle technology to specific vehicle model/configurations in the MY 2020 fleet. To account for the A/C and off-cycle technologies equipped on vehicles and the potential that manufacturers will apply additional A/C and off-cycle technologies in the rulemaking timeframe, DOT specified model inputs for A/C efficiency and off-cycle fuel consumption improvement values in grams/mile for each manufacturer's fleet in each model year. DOT estimated future values based on an expectation that manufacturers already relying heavily on these adjustments would continue do so, and that other manufacturers would, over time, also approach the limits on adjustments allowed for such improvements.

The next sections discuss how the CAFE Model simulates the effectiveness and cost for A/C efficiency and off-cycle technology adjustments.

(a) A/C and Off-Cycle Effectiveness Modeling in the CAFE Model

In this analysis, the CAFE Model applies A/C and off-cycle flexibilities to manufacturer's CAFE regulatory fleet performance in a similar way to the regulation.[295] In the analysis and after the first MY, A/C efficiency and off-cycle FCIVs apply to each manufacturer's regulatory fleet after the CAFE Model applies conventional technologies for a given standard. That is, conventional technologies are applied to each manufacturers' vehicles in each MY to assess the 2-cycle sales weighted harmonic average CAFE rating. Then, the CAFE Model assesses the CAFE rating to use for a manufacturer's compliance value after applying the A/C efficiency and off-cycle FCIVs designated in the Market Data file. This assessment of adoption of conventional technology and the A/C efficiency and off-cycle technology occurs on a year-by-year basis in the CAFE Model. The CAFE Model attempts to apply technologies and flexibilities in a way that both minimizes cost and allows the manufacturer to meet their standards without over or under complying.

To determine how manufacturers might adopt A/C efficiency and off-cycle technologies in the rulemaking timeframe, DOT began with data from EPA's 2020 Trends Report and CBI compliance material from manufacturers.[296] [297] DOT used manufacturer's MY 2020 A/C efficiency and off-cycle FCIVs as a starting point, and then extrapolated values in each MY until MY 2026, for light trucks to the proposed regulatory cap, for each manufacturer's fleets by regulatory class.

To determine the rate at which to extrapolate the addition of A/C and off-cycle technology adoption for each manufacturer, DOT reviewed historical A/C and off-cycle technology applications, each manufacturer's fleet composition (*i.e.,* breakdown between passenger cars (PCs) and light trucks (LTs)), availability of A/C and off-cycle technologies that manufacturers could still use, and CBI compliance data. Different manufacturers showed different levels of historical A/C efficiency and off-cycle technology adoption; therefore, different manufacturers hit the proposed regulatory caps for A/C efficiency technology for both their PC and LT fleets, and different manufacturers hit caps for off-cycle technologies in the LT regulatory class. DOT declined to extrapolate off-cycle technology adoption for PCs to the proposed regulatory cap for a few reasons. First, past EPA Trends Reports showed that many manufacturers did not adopt off-cycle technology to their passenger car fleets. Next, manufacturers limited PC offerings in MY 2020 as compared to historical trends. Last, CBI compliance data available to DOT indicated a lower adoption of menu item off-cycle technologies to PCs compared to LTs. DOT accordingly limited the application of off-cycle FCIVs to 10 g/mi for PCs but allowed LTs to apply 15 g/mi of off-cycle FCIVs. The inputs for A/C efficiency technologies were set to 5 g/mi and 7.2 g/mi for PCs and LTs, respectively. DOT allowed A/C efficiency technologies to reach the regulatory caps by MY 2024, which is the first year of standards assessed in this analysis.

DOT decided to apply the FCIVs in this way because the A/C and off-cycle

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[288] 40 CFR 600.510–12(c).

[289] *See* 40 CFR 86.1869–12(b). The TSD for the 2012 final rule for MYs 2017 and beyond provides technology examples and guidance with respect to the potential pathways to achieve the desired physical impact of a specific off-cycle technology from the menu and provides the foundation for the analysis justifying the credits provided by the menu. The expectation is that manufacturers will use the information in the TSD to design and implement off-cycle technologies that meet or exceed those expectations in order to achieve the real-world benefits of off-cycle technologies from the menu.

[290] *See* 40 CFR 86.1869–12(c). EPA proposed a correction for the 5-cycle pathway in a separate technical amendments rulemaking. *See* 83 FR 49344 (Oct. 1, 2019). EPA is not approving credits based on the 5-cycle pathway pending the finalization of the technical amendments rule.

[291] *See* 40 CFR 86.1869–12(d).

[292] *See* 77 FR at 62832, 62839 (Oct. 15, 2012). EPA introduced A/C and off-cycle technology credits for the CO_2 program in the MY 2012–2016 rule and revised the program in the MY 2017–2025 rule and NHTSA adopted equivalent provisions for MYs 2017 and later in the MY 2017–2025 rule.

[293] Vehicle and Engine Certification. Compliance Information for Light-Duty Gas (GHG) Standards. Compliance Information for Light-Duty Greenhouse Gas (GHG) Standards | Certification and Compliance for Vehicles and Engines | U.S. EPA. Last Accessed May 24, 2021.

[294] *See* 2020 EPA Automotive Trends Report, at 91.

[295] 49 CFR 531.6 and 49 CFR 533.6 Measurement and Calculation procedures.

[296] Vehicle and Engine Certification. Compliance Information for Light-Duty Gas (GHG) Standards. Compliance Information for Light-Duty Greenhouse Gas (GHG) Standards | Certification and Compliance for Vehicles and Engines | U.S. EPA. Last Accessed May 24, 2021.

[297] 49 U.S.C. 32907.

technologies are generally more cost-effective than other technologies. The details of this assessment (and the calculation) are further discussed in the CAFE Model Documentation.[298] The A/C efficiency and off-cycle adjustment schedules used in this analysis are shown in TSD Chapter 3.8 and in the Market Data file's Credits and Adjustments worksheet.

(b) A/C and Off-Cycle Costs

For this analysis, A/C and off-cycle technologies are applied independently of the decision trees using the extrapolated values shown above, so it is necessary to account for the costs of those technologies independently. Table III–36 shows the costs used for A/C and off-cycle FCIVs in this analysis. The costs are shown in dollars per gram of CO_2 per mile ($ per g/mile). The A/C efficiency and off-cycle technology costs are the same costs used in the EPA Proposed Determination and described in the EPA Proposed Determination TSD.[299]

To develop the off-cycle technology costs, DOT selected the 2nd generic 3 gram/mile package estimated to cost $170 (in 2015$) to apply in this analysis in $ per gram/mile. DOT updated the costs used in the Proposed Determination TSD from 2015$ to 2018$, adjusted the costs for RPE, and applied a relatively flat learning rate. We seek comment on whether these costs are still appropriate, or whether a different $ per gram/mile cost should be used. If commenters believe a different $ per gram/mile cost should be used, we request commenters provide any data or information on which any alternative costs are based. This should include a description of how the alternative costs are representative of costs across the industry, and whether the $ per gram/mile estimate is based on a package of specific off-cycle technologies.

Similar to off-cycle technology costs, DOT used the cost estimates from EPA Proposed Determination TSD for A/C efficiency technologies that relied on the 2012 rulemaking TSD.[300] DOT updated these costs to 2018$ and adjusted for RPE for this analysis, and applied the same mature learning rate that DOT applied for off-cycle technologies.

Table III-36 – Estimated Costs ($ per g/mi) for A/C and Off-Cycle Adjustments

Model Year	A/C Efficiency	A/C Leakage	Off-Cycle
2020	4.30	10.76	83.79
2025	3.89	9.72	77.47
2030	3.52	8.79	71.83

E. Consumer Responses to Manufacturer Compliance Strategies

The previous subsections in Section III have so far discussed how manufacturers might respond to changes to the standards. While the technology analysis is informative of the different compliance strategies available to manufactures, the tangible costs and benefits that accrue because of CAFE standards are dependent on how consumers respond to the decisions made by manufacturers. Many, if not most, of the benefits and costs resulting from changes to CAFE standards are private benefits that accrue to the buyers of new cars and trucks, produced in the model years under consideration. These benefits and costs largely flow from the changes to vehicle ownership and operating costs that result from improved fuel economy, and the cost of the technology required to achieve those improvements. The remaining external benefits are also derived from how consumers use—or do not use—vehicles. The next few subsections walk through how the analysis models consumer responses to changing vehicles and prices. NHTSA requests comment on the following discussion.

1. Macroeconomic and Consumer Behavior Assumptions

This proposal includes a comprehensive economic analysis of the impacts of altering the CAFE standards. Most of the effects measured are influenced by macroeconomic conditions that are exogenous to the agency's influence. For example, fuel prices are mainly determined by global demand, and yet they determine how much fuel efficiency technology manufacturers will apply to U.S.-bound vehicles, how much consumers are willing to pay for a new vehicle, the amount of travel in which all users engage, and the value of each gallon saved from higher CAFE standards. Constructing these forecasts requires robust projections of macroeconomic variables that span the timeframe of the analysis, including real U.S. Gross Domestic Product (GDP), consumer confidence, U.S. population, and real disposable personal income.

In order to ensure internal consistency within the analysis, relevant economic assumptions are derived from the same source. The analysis presented in this analysis employs forecasts developed by DOT using the U.S. Energy Information Administration's (EIA's) National Energy Model System (NEMS). EIA is an agency within the U.S. Department of Energy (DOE) which collects, analyzes, and disseminates independent and impartial energy information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment. EIA uses NEMS to produce its Annual Energy Outlook (AEO), which presents forecasts of future fuel prices, among many other energy-related variables. The analysis employs forecasts of fuel prices, real U.S. GDP, real disposable personal income, U.S. population, and fuel prices from the AEO 2021 Reference Case. The agency also uses a forecast of consumer confidence to project sales from the IHS Markit Global Insight long-term macroeconomic model. The IHS Markit Global Insight model is also used by EIA for the AOE.

While these macroeconomic assumptions are some of the most critical inputs to the analysis, they are also subject to the most uncertainty—particularly over the full lifetimes of the vehicles affected by this proposed rule. The agency uses low and high cases from the AEO as bounding cases for sensitivity analyses. The purpose of the sensitivity analyses, discussed in greater

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[298] CAFE Model Documentation, S5.

[299] EPA PD TSD. EPA–420–R–16–021. November 2016. At 2–423–2–245. *https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100Q3L4.pdf.* Last accessed May 24, 2021.

[300] Joint NHTSA and EPA 2012 TSD, *see* Section 5.1.

detail in PRIA Chapter 6 and PRIA Chapter 7, is not to posit a more credible future state of the world than the central case assumes—we assume the central case is the most likely future state of the world—but rather to measure the degree to which important outcomes can change under different assumptions about fuel prices.

The first year simulated in this analysis is 2020, though it is based on observational data (rather than forecasts) to the greatest extent possible. The elements of the analysis that rely most heavily on the macroeconomic inputs—aggregate demand for VMT, new vehicle sales, used vehicle retirement rates—all reflect the relatively rapid climb back to pre-pandemic growth rates (in all the regulatory alternatives).

See TSD Chapter 4.1 for a more complete discussion of the macroeconomic assumptions made for the analysis.

Another key assumption that permeates throughout the analysis is how much consumers are willing to pay for fuel economy. Increased fuel efficiency offers vehicle owners significant savings; in fact, the analysis shows that fuel savings exceed the technology cost to comply with even the most stringent standards analyzed by this proposal at a 3% discount rate. It would be reasonable to assume that consumers value the full value of fuel savings as they would be better off not having to spend more of their disposable income on fuel. If consumers did value the full amount of fuel savings, fuel-efficient vehicles would functionally be *cheaper* for consumers to own when considering both purchasing and operational costs, and thus making the vehicles offered under the stricter alternatives more attractive than similar models offered in the baseline. Recent econometric research remains divided between studies that conclude has shown that consumers may value most, if not all of potential fuel savings, and those that conclude that consumers significantly undervalue expected fuel savings (NASEM, 2021, p. 11–351).[301] [302] [303]

If buyers fully value the savings in fuel costs that result from higher fuel economy, manufacturers would be expected to supply the improvements that buyers demand, and vehicle demand would be expected to fully consider both future fuel cost savings consumers would realize from owning—and potentially re-selling—more fuel-efficient models and increased cost of vehicles due to technological and design changes made to increase fuel economy. If instead, consumers systematically undervalue future fuel savings, the result would be an underinvestment in fuel-saving technology. In that case, more stringent fuel economy standards would also lead manufacturers to adopt improvements in fuel economy that improve consumer welfare (*e.g.,* Allcott et al., 2014; Heutel, 2015).

There is substantial evidence that consumers do not fully value lifetime fuel savings. Even though the average fuel economy of new vehicles reached an all-time high in MY 2020 of 25.7 MPG,[304] this is still significantly below the fuel economy of the fleet's most efficient vehicles that are readily available to consumers.[305] Manufacturers have repeatedly informed the agency that consumers only value between 2 to 3 years-worth of fuel savings when making purchasing decisions. The potential for car buyers voluntarily to forego improvements in fuel economy that offer savings exceeding their initial costs is one example of what is often termed the ''energy-efficiency gap.'' This appearance of such a gap, between the level of energy efficiency that would minimize consumers' overall expenses and what they actually purchase, is typically based on engineering calculations that compare the initial cost for providing higher energy efficiency to the discounted present value of the resulting savings in future energy costs. There has long been an active debate about why such a gap might arise and whether it actually exists. Economic theory predicts that economically rational individuals will purchase more energy-efficient products only if the savings in future energy costs they offer promise to offset their higher initial costs. On the other hand, behavioral economics has documented numerous situations in which the decision-making of consumers differs in important ways from the predictions of economic consumer model (*e.g.,* Dellavigna, 2009).

A behavioral explanation of such 'undervaluation' of the savings from purchasing higher-mpg models is myopia or present bias; consumers may give undue focus to short-term costs and insufficient attention to long-term benefits.[306] This situation could arise because they are unsure of the fuel savings that will be achieved in real-world driving, what future fuel prices will be, how long they will own a new vehicle, whether they will drive it enough to realize the promised savings. As a consequence, they may view choosing to purchase or not purchase a fuel-efficient technology as a risky bet; behavioral economics has demonstrated that faced with the decision to accept or reject a risky choice, some consumers weigh potential losses approximately twice as heavily as potential gains, significantly undervaluing the choice relative to its expected value (*e.g.,* Kahneman and Tversky, 1979; Kahneman, 2011). In the context of a choice to pay more for a fuel-saving technology, loss aversion has been shown to have the potential to cause undervaluation of future fuel savings similar to that reported by manufacturers (Greene, 2011; Greene et al., 2013).[307] The behavioral model holds that consumers' decisions are affected by the context, or framing, of choices. As explained in NASEM (2021), Ch. 11.3.3, it is possible that consumers respond to changes in fuel economy regulations differently than they respond to manufacturers voluntarily offering the option to purchase fuel economy technology to new car buyers. We explain this differential more thoroughly in TSD Chapter 4.2.1.1, but here is the contextual explanation for the differential valuation. If a consumer is thinking about buying a new car and is looking at two models, one that includes voluntarily added fuel economy technology and is more expensive and another that does not, she may buy the cheaper, less fuel efficient version even if the more expensive model will save

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[301] There is a great deal of work attempting to test the question whether consumers are adequately informed about, and sufficiently attentive to, potential fuel savings at the time of purchase. The existing research is not conclusive and leaves many open questions. On the one hand, there is significant support for the proposition that consumers are responsive to changes in fuel costs. See, *e.g.,* Busse et al.; Sallee, et al. On the other hand, there is also support for the proposition that many consumers do not, in fact, give full or sufficient attention to potential savings from fuel-efficient vehicles, and thus make suboptimal decisions. See Duncan et al.; Gillingham et al.

[302] Allcott, H. and C. Knittel, 2019. ''Are Consumers Poorly Informed about Fuel Economy? Evidence from Two Experiments'', AEJ: Economic Policy, 11(1): 1–37.

[303] D. Duncan, A. Ku, A. Julian, S. Carley, S. Siddiki, N. Zirogiannis and J. Graham, 2019. ''Most Consumers Don't Buy Hybrids: Is Rational Choice a Sufficient Explanation?'', J. of Benefit-Cost Analysis, 10(1): 1–38.

[304] *See* EPA 2020 Automotive Trends Report at 6, available at *https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1010U68.pdf.*

[305] *Id.* At 9.

[306] Gillingham et al., 2021, which is an AEJ: Economic Policy paper, just published on consumer myopia in vehicle purchases; a standard reference on present bias generally is O'Donoghue and Rabin, AER: Papers and Proceedings, 2015.

[307] Application of investment under uncertainty will yield similar results as costs may be more certain and up front while the fuel savings or benefits of the investment may be perceived as more uncertain and farther into future, thereby reducing investments in fuel saving technologies.

money in the long run. But if, instead, the consumer is faced with whether to buy a new car at all as opposed to keeping an older one, if all new cars contain technology to meet fuel economy standards, then she may view the decision differently. Will, for example, an extra $1,000 for a new car—a $1,000 that the consumer will more than recoup in fuel savings—deter her from buying the new car, especially when most consumers finance cars over a number of years rather than paying the $1,000 cost up front (therefore any increase in monthly payment would be partly or entirely offset with lower fuel costs)? In additon, the fact that standards generally increase gradually over a period of years allows time for consumers and other information sources to verify that fuel savings are real and of substantial value.

Another alternative is that consumers view the increase in immediate costs associated with fuel economy technology in the context of tradeoffs they must make amongst their purchasing decisions. American households must choose how to spend their income amongst many competing goods and services, including how much to spend on a new vehicle. They may also decide to opt for another form of transportation. While a consumer may recognize and value the potential long-term value of fuel savings, they may also prefer to spend their money on other items, either in the form of other vehicle attributes—such as picking a truck with a larger flatbed or upgrading to a more luxurious trim package—or other unrelated goods and services. The same technologies that can be used to increase fuel economy can also be used to enable increased vehicle power or weight while maintaining fuel economy. While increased fuel efficiency will free up disposable income throughout the lifetime of the vehicle (and may even exceed the additional upfront costs to purchase a more expensive fuel-efficient vehicle), the value of owning a different good sooner may provide consumers even more benefit.

As explained more thoroughly in TSD Chapter 4.2.1.1, the analysis assumes that potential car and light truck buyers value only the undiscounted savings in fuel costs from purchasing a higher-mpg model they expect to realize over the first 30 months they own it. Depending on the discount rate buyers are assumed to apply, this amounts to 25–30% of the expected savings in fuel costs over its entire lifetime. These savings would offset only a fraction of the expected increase in new car and light truck prices that the agency estimates will be required for manufacturers to recover their increased costs for making required improvements to fuel economy. The agency seeks comment on whether 30 months of undiscounted fuel savings is an appropriate measure for the analysis of consumer willingness to pay for fuel economy. The assumption also has important implications for other outcomes of the model, including for VMT, safety, and air pollution emissions projections. If NHTSA is incorrect about the undervaluation of fuel economy in the context of regulatory standards and its effect on car sales, correcting the assumption should result in improved safety outcomes and additional declines in conventional air pollutants. If commenters believe a different amount of time should be used for the payback assumption, it would be most helpful to NHTSA if commenters could define the amount of time, provide an explanation of why that amount of time is preferable, provide any data or information on which the amount of time is based, and provide any discussion of how changing this assumption would interact with other elements in the analysis.

2. Fleet Composition

The composition of the on-road fleet—and how it changes in response to CAFE standards—determines many of the costs and benefits of the proposal. For example, how much fuel the light-duty consumes is dependent on the number of new vehicles sold, older (and less efficient) vehicles retired, and how much those vehicles are driven.

Prior to the 2020 CAFE standards, all previous CAFE rulemaking analyses used static fleet forecasts that were based on a combination of manufacturer compliance data, public data sources, and proprietary forecasts (or product plans submitted by manufacturers). When simulating compliance with regulatory alternatives, those analyses projected identical sales and retirements across the alternatives, for each manufacturer down to the make/model level—where the exact same number of each model variant was assumed to be sold in a given model year under both the least stringent alternative (typically the baseline) and the most stringent alternative considered (intended to represent ''maximum technology'' scenarios in some cases). To the extent that an alternative matched the assumptions made in the production of the proprietary forecast, using a static fleet based upon those assumptions may have been warranted.

However, a fleet forecast is unlikely to be representative of a broad set of regulatory alternatives with significant variation in the cost of new vehicles. A number of commenters on previous regulatory actions and peer reviewers of the CAFE Model encouraged consideration of the potential impact of fuel efficiency standards on new vehicle prices and sales, the changes to compliance strategies that those shifts could necessitate, and the downstream impact on vehicle retirement rates. In particular, the continued growth of the utility vehicle segment causes changes within some manufacturers' fleets as sales volumes shift from one region of the footprint curve to another, or as mass is added to increase the ride height of a vehicle on a sedan platform to create a crossover utility vehicle, which exists on the same place of the footprint curve as the sedan upon which it might be based.

The analysis now dynamically simulates changes in the vehicle fleet's size, composition, and usage as manufacturers and consumers respond to regulatory alternatives, fuel prices, and macroeconomic conditions. The analysis of fleet composition is comprised of two forces, how new vehicle sales—the flow of new vehicles into the registered population—changes in response to regulatory alternatives, and the influence of economic and regulatory factors on vehicle retirement (otherwise known as scrappage). Below are brief descriptions that of how the agency models sales and scrappage. For a full explanation, refer to TSD Chapter 4.2. Particularly given the broad uncertainty discussed in TSD Chapter 4.2, NHTSA seeks comment on the discussion below and the associated discussions in the TSD, on the internal structure of the sales and scrappage modules, and whether and how to change the sales and scrappage analyses for the final rule.

(a) Sales

For the purposes of regulatory evaluation, the relevant sales metric is the difference between alternatives rather than the absolute number of sales in any of the alternatives. As such, the sales response model currently contains three parts: A nominal forecast that provides the level of sales in the baseline (based upon macroeconomic inputs, exclusively), a price elasticity that creates sales differences relative to that baseline in each year, and a fleet share model that produces differences in the passenger car and light truck market share in each alternative. The nominal forecast does not include price and is merely a (continuous) function of several macroeconomic variables that are provided to the model as inputs. The price elasticity is also specified as an input, but this analysis assumes a unit elastic response of −1.0—meaning that a one percent increase in the average price of a new vehicle produces a one percent decrease in total sales. NHTSA seeks comment on this assumption. The price change on which the elasticity acts is calculated net of some portion of the future fuel savings that accrue to new vehicle buyers (2.5 years' worth, in this analysis, as discussed in the previous section).

The current baseline sales module reflects the idea that total new vehicle sales are primarily driven by conditions in the economy that are exogenous to the automobile industry. Over time, new vehicle sales have been cyclical—rising when prevailing economic conditions are positive (periods of growth) and falling during periods of economic contraction. While the kinds of changes to vehicle offerings that occur as a result of manufacturers' compliance actions exert some influence on the total volume of new vehicle sales, they are not determinative. Instead, they drive the kinds of marginal differences between regulatory alternatives that the current sales module is designed to simulate—more expensive vehicles, generally, reduce total sales but only marginally.

The first component of the sales response model is the nominal forecast, which is a function (with a small set of inputs) that determines the size of the new vehicle market in each calendar year in the analysis for the baseline. It is of some relevance that this statistical model is intended only as a means to project a baseline sales series. Past reviewers expressed concerns about the possibility of econometrically estimating an industry average price elasticity in a way that isolates the causal effect of new vehicle prices on new vehicle sales (and properly addresses the issue of endogeneity between sales and price). The nominal forecast model does not include prices and is not intended for statistical inference around the question of price response in the new vehicle market. The economic response to the pandemic has created uncertainty, particularly in the near-term, around pace at which the market for automobiles will recover—and the scale and timing of the recovery's peak—before returning to its long-term trend. DOT will continue to monitor macroeconomic data and new vehicle sales and update its baseline forecast as appropriate.

The second component of the sales response model captures how price changes affect the number of vehicles sold. The price elasticity is applied to the percentage change in average price (in each year). The price change does not represent an increase/decrease over the last observed year, but rather the percentage change relative to the baseline for that year. In the baseline, the average price is defined as the observed new vehicle price in 2019 (the last historical year before the simulation begins) plus the average regulatory cost associated with the baseline alternative.[308] The central analysis in this proposal simulates multiple programs simultaneously (CAFE final standards, EPA final greenhouse gas standards, ZEV, and the California Framework Agreement), and the regulatory cost includes both technology costs and civil penalties paid for non-compliance (with CAFE standards) in a model year. Because the elasticity assumes no perceived change in the quality of the product, and the vehicles produced under different regulatory scenarios have inherently different operating costs, the price metric must account for this difference. The price to which the unit elasticity is applied in this analysis represents the residual price change *between scenarios* after accounting for 2.5 years' worth of fuel savings to the new vehicle buyer.

The third and final component of the sales model is the dynamic fleet share module (DFS). Some commenters to previous rules noted that the market share of SUVs continues to grow, while conventional passenger car body-styles continue to lose market share. For instance, in the 2012 final rule, the agencies projected fleet shares based on the continuation of the baseline standards (MYs 2012–2016) and a fuel price forecast that was much higher than the realized prices since that time. As a result, that analysis assumed passenger car body-styles comprising about 70 percent of the new vehicle market by 2025, which was internally consistent. The reality, however, has been quite different. The CAFE Model includes the DFS model in an attempt to address these market realities.

The DFS distributes the total industry sales across two different body-types: ''cars'' and ''light trucks.'' While there are specific definitions of ''passenger cars'' and ''light trucks'' that determine a vehicle's regulatory class, the distinction used in this phase of the analysis is more simplistic. All body-styles that are obviously cars—sedans, coupes, convertibles, hatchbacks, and station wagons—are defined as ''cars'' for the purpose of determining fleet share. Everything else—SUVs, smaller SUVs (crossovers), vans, and pickup trucks—are defined as ''light trucks''—even though they may not be treated as such for compliance purposes. The DFS uses two functions from the National Energy Modeling System (NEMS) used in the 2017 AEO to independently estimate the share of passenger cars and light trucks, respectively, given average new market attributes (fuel economy, horsepower, and curb weight) for each group and current fuel prices, as well as the prior year's market share and prior year's attributes. The two independently estimated shares are then normalized to ensure that they sum to one.

These shares are applied to the total industry sales derived in the first stage of the sales response. This produces total industry volumes of car and light truck body styles. Individual model sales are then determined from there based on the following sequence: (1) Individual manufacturer shares of each body style (either car or light truck) times the total industry sales of that body style, then (2) each vehicle within a manufacturer's volume of that body-style is given the same percentage of sales as appear in the 2020 fleet. This implicitly assumes that consumer preferences for particular styles of vehicles are determined in the aggregate (at the industry level), but that manufacturers' sales shares of those body styles are consistent with MY 2020 sales. Within a given body style, a manufacturer's sales shares of individual models are also assumed to be constant over time. This approach implicitly assumes that manufacturers are currently pricing individual vehicle models within market segments in a way that maximizes their profit. Without more information about each OEM's true cost of production and operation, fixed and variables costs, and both desired and achievable profit margins on individual vehicle models, there is no basis to assume that strategic shifts within a manufacturer's portfolio will occur in response to standards.

The DFS model show passenger car styles gaining share with higher fuel prices and losing them when prices are decline. Similarly, as fuel economy increases in light truck models, which offer consumers other desirable attributes beyond fuel economy (ride height or interior volume, for example) their relative share increases. However, this approach does not suggest that consumers dislike fuel economy in passenger cars, but merely recognizes

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[308] The CAFE Model currently operates as if all costs incurred by the manufacturer as a consequence of meeting regulatory requirements, whether those are the cost of additional technology applied to vehicles in order to improve fleetwide fuel economy or civil penalties paid when fleets fail to achieve their standard, are ''passed through'' to buyers of new vehicles in the form of price increases.

the fact that fuel economy has diminishing returns in terms of fuel savings. As the fuel economy of light trucks increases, the tradeoff between passenger car and light truck purchases increasingly involves a consideration of other attributes. The coefficients also show a relatively stronger preference for power improvements in cars than light trucks because that is an attribute where trucks have typically outperformed cars, just as cars have outperformed trucks for fuel economy.

For years, some commenters encouraged the agency to consider vehicle attributes beyond price and fuel economy when estimating a sales response to fuel economy standards, and suggested that a more detailed representation of the new vehicle market would allow the agency to simulate strategic mix shifting responses from manufacturers and diverse attribute preferences among consumers. Doing so would have required a discrete choice model (at some level). Discrete models are highly sensitive on their inputs and typically fit well on a single year of data (a cross-section of vehicles and buyers). This approach misses relevant trends that build over time, such as rising GDP or shifting consumer sentiment toward emerging technologies and are better used for analysis as opposed to prediction. While the agency believes that these challenges provide a reasonable basis for not employing a discrete choice model in the current CAFE Model, the agency also believes these challenges are not insurmountable, and that some suitable variant of such models may yet be developed for use in future fuel economy rulemakings. The agency has not abandoned the idea and plans to continue experimenting with econometric specifications that address heterogeneous consumer preferences in the new vehicle market as they further refine the analytical tools used for regulatory analysis. The agency seeks suggestions on how to incorporate other vehicle attributes into the current analysis, or, alternatively, methods to implement a discrete choice model that can capture changing technologies and consumer trends over an extended time-period.

(b) Scrappage

New and used vehicles are substitutes. When the price of a good's substitute increases/decreases, the demand curve for that good shifts upwards/downwards and the equilibrium price and quantity supplied also increases/decreases. Thus, increasing the quality-adjusted price of new vehicles will result in an increase in equilibrium price and quantity of used vehicles. Since, by definition, used vehicles are not being ''produced'' but rather ''supplied'' from the existing fleet, the increase in quantity must come via a reduction in their scrappage rates. Practically, when new vehicles become more expensive, demand for used vehicles increases (and they become more expensive). Because used vehicles are more valuable in such circumstances, they are scrapped at a lower rate, and just as rising new vehicle prices push marginal prospective buyers into the used vehicle market, rising used vehicle prices force marginal prospective buyers of used vehicles to acquire older vehicles or vehicles with fewer desired attributes. The effect of fuel economy standards on scrappage is partially dependent on how consumers value future fuel savings and our assumption that consumers value only the first 30 months of fuel savings.

Many competing factors influence the decision to scrap a vehicle, including the cost to maintain and operate it, the household's demand for VMT, the cost of alternative means of transportation, and the value that can be attained through reselling or scrapping the vehicle for parts. A car owner will decide to scrap a vehicle when the value of the vehicle is less than the value of the vehicle as scrap metal, plus the cost to maintain or repair the vehicle. In other words, the owner gets more value from scrapping the vehicle than continuing to drive it, or from selling it. Typically, the owner that scraps the vehicle is not the first owner.

While scrappage decisions are made at the household level, the agency is unaware of sufficient household data to sufficiently capture scrappage at that level. Instead, the agency uses aggregate data measures that capture broader market trends. Additionally, the aggregate results are consistent with the rest of the CAFE Model as the model does not attempt to model how manufacturers will price new vehicles; the model instead assumes that all regulatory costs to make a particular vehicle compliant are passed onto the purchaser who buys the vehicle. It is more likely that manufacturers will defray a portion of the increased regulatory cost across its vehicles or to other manufacturers' buyers through the sale of credits.

The most predictive element of vehicle scrappage is 'engineering scrappage.' This source of scrappage is largely determined by the age of a vehicle and the durability of a specific model year vintage, which the agency uses proprietary vehicle registration data from IHS/Polk to collect vehicle age and durability. Other factors include fuel economy and new vehicle prices. For historical data on new vehicle transaction prices, the agency uses National Automobile Dealers Association (NADA) Data.[309] The data consists of the average transaction price of all light-duty vehicles; since the transaction prices are not broken-down by body style, the model may miss unique trends within a particular vehicle body style. The transaction prices are the amount consumers paid for new vehicles and exclude any trade-in value credited towards the purchase. This may be particularly relevant for pickup trucks, which have experienced considerable changes in average price as luxury and high-end options entered the market over the past decade. Future models will further consider incorporating price series that consider the price trends for cars, SUVs and vans, and pickups separately. The other source of vehicle scrappage is from cyclical effects, which the model captures using forecasts of GDP and fuel prices.

Vehicle scrappage follows a roughly logistic function with age—that is, when a vintage is young, few vehicles in the cohort are scrapped, as they age, more and more of the cohort are retired and the instantaneous scrappage (the rate at which vehicles are scrapped) reaches a peak, and then scrappage declines as vehicles enter their later years as fewer and fewer of the cohort remains on the road. The analysis uses a logistic function to capture this trend of vehicle scrappage with age. The data shows that the durability of successive model years generally increases over time, or put another way, historically newer vehicles last longer than older vintages. However, this trend is not constant across all vehicle ages—the instantaneous scrappage rate of vehicles is generally lower for later vintages up to a certain age, but increases thereafter so that the final share of vehicles remaining converges to a similar share remaining for historically observed vintages.[310] The agency uses fixed effects to capture potential changes in durability across model years and to ensure that vehicles approaching the end of their life are scrapped in the analysis, the agency applies a decay function to vehicles after they reach age 30. The macroeconomic conditions variables discussed above are included

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[309] The data can be obtained from NADA. For reference, the data for MY 2020 may be found at *https://www.nada.org/nadadata/.*

[310] Examples of why durability may have changed are new automakers entering the market or general changes to manufacturing practices like switching some models from a car chassis to a truck chassis.

in the logistic model to capture cyclical effects. Finally, the change in new vehicle prices projected in the model (technology costs minus 30 months of fuel savings) are included which generates differing scrappage rates across the alternatives.

In addition to the variables included in the scrappage model, the agency considered several other variables that likely either directly or indirectly influence scrappage in the real world including, maintenance and repair costs, the value of scrapped metal, vehicle characteristics, the quantity of new vehicles purchased, higher interest rates, and unemployment. These variables were excluded from the model either because of a lack of underlying data or modeling constraints. Their exclusion from the model is not intended to diminish their importance, but rather highlights the practical constraints of modeling intricate decisions like scrappage.

3. Changes in Vehicle Miles Traveled (VMT)

In the CAFE Model, VMT is the product of average usage per vehicle in the fleet and fleet composition, which is itself a function of new vehicle sales and vehicle retirement decisions, otherwise known as scrappage. These three components—average vehicle usage, new vehicle sales, and older vehicle scrappage—jointly determine total VMT projections for each alternative. VMT directly influences many of the various effects of fuel economy standards that decision-makers consider in determining what levels of standards to set. For example, the value of fuel savings is a function of a vehicle's efficiency, miles driven, and fuel price. Similarly, factors like criteria pollutant emissions, congestion, and fatalities are direct functions of VMT.

It is the agency's perspective that the total demand for VMT should not vary excessively across alternatives. The basic travel needs for an average household are unlikely to be influenced heavily by the stringency of the CAFE standards, as the daily need for a vehicle will remain the same. That said, it is reasonable to assume that fleets with differing age distributions and inherent cost of operation will have slightly different annual VMT (even without considering VMT associated with rebound miles); however, the difference could conceivably be small. Based on the structure of the CAFE Model, the combined effect of the sales and scrappage responses would create small percentage differences in total VMT across the range of regulatory alternatives if steps are not taken to constrain VMT. Because VMT is related to many of the costs and benefits of the program, even small magnitude differences in VMT across alternatives can have meaningful impacts on the incremental net benefit analysis. Furthermore, since decisions about alternative stringencies look at the incremental costs and benefits across alternatives, it is more important that the analysis capture the variation of VMT across alternatives than to accurately predict total VMT within a scenario.

To ensure that travel demand remains consistent across the different regulatory scenarios, the CAFE Model begins with a model of aggregate VMT developed by the Federal Highway Administration (FHWA) that is used to produce their official annual VMT forecasts. These estimates provide the aggregate VMT of all model years and body styles for any given calendar year and are same across regulatory alternatives for each year in the analysis.

Since vehicles of different ages and body styles carry different costs and benefits, to account properly for the average value of consumer and societal costs and benefits associated with vehicle usage under various CAFE alternatives, it is necessary to partition miles by age and body type. The agency created ''mileage accumulation schedules'' using IHS-Polk odometer data to construct mileage accumulation schedules as an initial estimate of how much a vehicle expected to drive at each age throughout its life. The agency uses simulated new vehicle sales, annual rates of retirement for used vehicles, and the mileage accumulation schedules to distribute VMT across the age distribution of registered vehicles in each calendar year to preserve the non-rebound VMT constraint.

The fuel economy rebound effect—a specific example of the well-documented energy efficiency rebound effect for energy-consuming capital goods—refers to the tendency of motor vehicles' use (as measured by VMT) to increase when their fuel economy is improved and, as a result, the cost per mile (CPM) of driving declines. Establishing more stringent CAFE standards than the baseline level will lead to comparatively higher fuel economy for new cars and light trucks, thus decreasing the amount of fuel consumed and increasing the amount of travel in which new car and truck buyers engage. The agency recognizes that the value selected for the rebound effect influences overall costs and benefits associated with the regulatory alternatives under consideration as well as the estimates of lives saved under various regulatory alternatives, and that the rebound estimate, along with fuel prices, technology costs, and other analytical inputs, is part of the body of information that agency decision-makers have considered in determining the appropriate levels of the CAFE standards in this proposal. We also note that the rebound effect diminishes the economic and environmental benefits associated with increased fuel efficiency.

The agency conducted a review of the literature related to the fuel economy rebound effect, which is extensive and covers multiple decades and geographic regions. The totality of evidence, without categorically excluding studies on grounds that they fail to meet certain criteria, and evaluating individual studies based on their particular strengths, suggests that a plausible range for the rebound effect is 10–50 percent. The central tendency of this range appears to be at or slightly above its midpoint, which is 30 percent. Considering only those studies that the agency believes are derived from extremely robust and reliable data, employ identification strategies that are likely to prove effective at isolating the rebound effect, and apply rigorous estimation methods suggests a range of approximately 10–45 percent, with most of their estimates falling in the 15–30 percent range.

A case can also be made to support values of the rebound effect falling in the 5–15 percent range. There is empirical evidence supported by theory, that the rebound effect has been declining over time due to factors such as increasing income that affects the value of time, increasing fuel economy that makes the fuel cost of driving a smaller share of the total costs of vehicle travel, as well as diminishing impacts of increased car ownership and rates of license holding on vehicle travel. Lower rebound estimates are associated with studies that include recently published analyses using U.S. data, and to accord the most weight to research that relies on measures of vehicle use derived from odometer readings, controls for the potential endogeneity of fuel economy, and estimates the response of vehicle use to variation in fuel economy itself, rather than to fuel cost per distance driven or fuel prices. This approach suggests that the rebound effect is likely in the range from 5–15 percent and is more likely to lie toward the lower end of that range.

The agency selected a rebound magnitude of 15% for the analysis because it was well-supported by the totality of the evidence and aligned well with FHWA's estimated elasticity for travel (14.6%). However, recognizing the uncertainty surrounding the rebound value, we also examine the sensitivity of estimated impacts to values of the rebound ranging from 10 percent to 20 percent. NHTSA seeks comment on the above discussion, and whether to consider a different value for the rebound effect for the final rule analysis.

In order to calculate total VMT *with* rebound, the CAFE Model applies the price elasticity of VMT (taken from the FHWA forecasting model) to the full change in CPM and the initial VMT schedule, but applies the (user defined) rebound parameter to the incremental percentage change in CPM between the non-rebound and full CPM calculations to the miles applied to each vehicle during the reallocation step that ensured adjusted non-rebound VMT matched the non-rebound VMT constraint.

The approach in the model is a combination of top-down (relying on the FHWA forecasting model to determine total light-duty VMT in a given calendar year), and bottom-up (where the composition and utilization of the on-road fleet determines a base level of VMT in a calendar year, which is constrained to match the FHWA model). While the agency and the model developers agree that a joint household consumer choice model—if one could be developed adequately and reliably to capture the myriad circumstances under which families and individuals make decisions relating to vehicle purchase, use, and disposal—would reflect decisions that are made at the household level, it is not obvious, or necessarily appropriate, to model the national program at that scale in order to produce meaningful results that can be used to inform policy decisions.

The most useful information for policymakers relates to national impacts of potential policy choices. No other element of the rulemaking analysis occurs at the household level, and the error associated with allocating specific vehicles to specific households over the course of three decades would easily dwarf any error associated with the estimation of these effects in aggregate. We have attempted to incorporate estimates of changes to the new and used vehicle markets at the highest practical levels of aggregation, and worked to ensure that these effects produce fleetwide VMT estimates that are consistent with the best, current projections given our economic assumptions. While future work will always continue to explore approaches to improve the realism of CAFE policy simulation, there are important differences between small-scale econometric studies and the kind of flexibility that is required to assess the impacts of a broad range of regulatory alternatives over multiple decades. To assist with creating even more precise estimates of VMT, the agency requests comment on alternative approaches to simulate VMT demand.

See TSD Chapter 4.3 for a complete accounting of how the agency models VMT.

4. Changes to Fuel Consumption

The agency uses the fuel economy and age and body-style VMT estimates to determine changes in fuel consumption. The agency 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 Environmental Impacts of Regulatory Alternatives

This proposal includes the adoption of electric vehicles and other fuel-saving technologies, which produce additional co-benefits. These co-benefits include reduced vehicle tailpipe emissions during operation as well as reduced upstream emissions during petroleum extraction, transportation, refining, and finally fuel transportation, storage, and distribution. This section provides an overview of how we developed input parameters for criteria pollutants, greenhouse gases, and air toxics. This section also describes how we generated estimates of how these emissions could affect human health, in particular criteria pollutants known to cause poor air quality and damage human health when inhaled.

The rule implements an emissions inventory methodology for estimating impacts. Vehicle emissions inventories are often described as three-legged stools, comprised of activity (*i.e.,* miles traveled, hours operated, or gallons of fuel burned), population (or number of vehicles), and emission factors. An emissions factor is a representative rate that attempts to relate the quantity of a pollutant released to the atmosphere per unit of activity.[311]

In this rulemaking, upstream emission factors are on a fuel volume basis and tailpipe emission factors are on a distance basis. Simply stated, the rule's upstream emission inventory is the product of the per-gallon emission factor and the corresponding number of gallons of gasoline or diesel consumed. Similarly, the tailpipe emission inventory is the product of the per-mile emission factor and the appropriate miles traveled estimate. The only exceptions are that tailpipe sulfur oxides (SO_X) and carbon dioxide (CO_2) also use a per-gallon emission factor in the CAFE Model. The activity levels—both miles traveled and fuel consumption—are generated by the CAFE Model, while the emission factors have been incorporated from other Federal models.

For this rule, vehicle tailpipe (downstream) and upstream emission factors and subsequent inventories were developed independently from separate data sources. Upstream emission factors are estimated from a lifecycle emissions model developed by the U.S. Department of Energy's (DOE) Argonne National Laboratory, the Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) Model.[312] Tailpipe emission factors are estimated from the regulatory highway emissions inventory model developed by the U.S. Environmental Protection Agency's (EPA) National Vehicle and Fuel Emissions Laboratory, the Motor Vehicle Emission Simulator (MOVES3). Data from GREET and MOVES3 have been utilized to update the CAFE Model for this rulemaking.

The changes in adverse health outcomes due to criteria pollutants emitted, such as differences in asthmatic episodes and hospitalizations due to respiratory or cardiovascular distress, are generally reported in incidence per ton values. Incidence values were developed using several EPA studies and recently updated from the 2020 final rule to better account for the emissions source sectors used in the CAFE Model analysis.

Chapter 5 of the TSD accompanying this proposal includes the detailed discussion of the procedures we used to simulate the environmental impact of regulatory alternatives, and the implementation of these procedures into the CAFE Model is discussed in detail in the CAFE Model Documentation. Further discussion of how the health impacts of upstream and tailpipe criteria pollutant emissions have been monetized in the analysis can be found in Section III.G.2.b)(2). The Supplemental Environmental Impact Statement accompanying this analysis also includes a detailed discussion of both criteria pollutant and GHG emissions and their impacts. NHTSA

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[311] USEPA, Basics Information of Air Emissions Factors and Quantification, *https://www.epa.gov/air-emissions-factors-and-quantification/basic-information-air-emissions-factors-and-quantification.*

[312] U.S. Department of Energy, Argonne National Laboratory, Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) Model, Last Update: 9 Oct. 2020, *https://greet.es.anl.gov/.*

seeks comment on the following discussion.

1. Activity Levels Used To Calculate Emissions Impacts

Emission inventories in this rule vary by several key activity parameters, especially relating to the vehicle's model year and relative age. Most importantly, the CAFE Model accounts for vehicle sales, turnover, and scrappage as well as travel demands over its lifetime. Like other models, the CAFE Model includes procedures to estimate annual rates at which new vehicles are purchased, driven, and subsequently scrapped. Together, these procedures result in, for each vehicle model in each model year, estimates of the number remaining in service in each calendar year, as well as the annual mileage accumulation (*i.e.,* VMT) at each age. Inventories by model year are derived from the annual mileage accumulation rates and corresponding emission factors.

As discussed in Section III.C.2, for each vehicle model/configuration in each model year from 2020 to 2050 for upstream estimates and 2060 for tailpipe estimates, the CAFE Model estimates and records the fuel type (*e.g.,* gasoline, diesel, electricity), fuel economy, and number of units sold in the U.S. The model also makes use of an aggregated representation of vehicles sold in the U.S. during 1975–2019. The model estimates the numbers of each cohort of vehicles remaining in service in each calendar year, and the amount of driving accumulated by each such cohort in each calendar year.

The CAFE Model estimates annual vehicle-miles of travel (VMT) for each individual car and light truck model produced in each model year at each age of their lifetimes, which extend for a maximum of 40 years. Since a vehicle's age is equal to the current calendar year minus the model year in which it was originally produced, the age span of each vehicle model's lifetime corresponds to a sequence of 40 calendar years beginning in the calendar year corresponding to the model year it was produced.[313] These estimates reflect the gradual decline in the fraction of each car and light truck model's original model year production volume that is expected to remain in service during each year of its lifetime, as well as the well-documented decline in their typical use as they age. Using this relationship, the CAFE Model calculates fleet-wide VMT for cars and light trucks in service during each calendar year spanned in this analysis.

Based on these estimates, the model also calculates quantities of each type of fuel or energy, including gasoline, diesel, and electricity, consumed in each calendar year. By combining these with estimates of each model's fuel or energy efficiency, the model also estimates the quantity and energy content of each type of fuel consumed by cars and light trucks at each age, or viewed another way, during each calendar year of their lifetimes. As with the accounting of VMT, these estimates of annual fuel or energy consumption for each vehicle model and model year combination are combined to calculate the total volume of each type of fuel or energy consumed during each calendar year, as well as its aggregate energy content.

The procedures the CAFE Model uses to estimate annual VMT for individual car and light truck models produced during each model year over their lifetimes and to combine these into estimates of annual fleet-wide travel during each future calendar year, together with the sources of its estimates of their survival rates and average use at each age, are described in detail in Section III.E.2. The data and procedures it employs to convert these estimates of VMT to fuel and energy consumption by individual model, and to aggregate the results to calculate total consumption and energy content of each fuel type during future calendar years, are also described in detail in that same section.

The model documentation accompanying this NPRM describes these procedures in detail.[314] The quantities of travel and fuel consumption estimated for the cross section of model years and calendar years constitutes a set of ''activity levels'' based on which the model calculates emissions. The model does so by multiplying activity levels by emission factors. As indicated in the previous section, the resulting estimates of vehicle use (VMT), fuel consumption, and fuel energy content are combined with emission factors drawn from various sources to estimate emissions of GHGs, criteria air pollutants, and airborne toxic compounds that occur throughout the fuel supply and distribution process, as well as during vehicle operation, storage, and refueling. Emission factors measure the mass of each GHG or criteria pollutant emitted per vehicle-mile of travel, gallon of fuel consumed, or unit of fuel energy content. The following sections identifies the sources of these emission factors and explains in detail how the CAFE Model applies them to its estimates of vehicle travel, fuel use, and fuel energy consumption to estimate total annual emissions of each GHG, criteria pollutant, and airborne toxic.

2. Simulating Upstream Emissions Impacts

Building on the methodology for simulating upstream emissions impacts used in prior CAFE rules, this analysis uses emissions factors developed with the U.S. Department of Energy's Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) Model, specifically GREET 2020.[315] The analysis includes emissions impacts estimates for regulated criteria pollutants,[316] greenhouse gases,[317] and air toxics.[318]

The upstream emissions factors included in the CAFE Model input files include parameters for 2020 through 2050 in five-year intervals (*e.g.,* 2020, 2025, 2030, and so on). For gasoline and diesel fuels, each analysis year includes upstream emissions factors for the four following upstream emissions processes: Petroleum extraction, petroleum transportation, petroleum refining, and fuel transportation, storage, and distribution (TS&D). In contrast, the upstream electricity emissions factor is only a single value per analysis year. We briefly discuss the components included in each upstream emissions factor here, and a more detailed discussion is included in Chapter 5 of the TSD accompanying this proposal and the CAFE Model Documentation.

The first step in the process for calculating upstream emissions includes any emissions related to the extraction, recovery, and production of petroleum-based feedstocks, namely conventional crude oil, oil sands, and shale oils. Then, the petroleum transportation process accounts for the transport

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[313] In practice, many vehicle models bearing a given model year designation become available for sale in the preceding calendar year, and their sales can extend through the following calendar year as well. However, the CAFE Model does not attempt to distinguish between model years and calendar years; vehicles bearing a model year designation are assumed to be produced and sold in that same calendar year.

[314] CAFE Model documentation is available at *https://www.nhtsa.gov/corporate-average-fuel-economy/compliance-and-effects-modeling-system.*

[315] U.S. Department of Energy, Argonne National Laboratory, Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) Model, Last Update: 9 Oct. 2020, *https://greet.es.anl.gov/.*

[316] Carbon monoxide (CO), volatile organic compounds (VOCs), nitrogen oxides (NO_X), sulfur oxides (SO_X), and particulate matter with 2.5-micron (μm) diameters or less ($PM_{2.5}$).

[317] Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

[318] Acetaldehyde, acrolein, benzene, butadiene, formaldehyde, diesel particulate matter with 10-micron (μm) diameters or less (PM_{10}).

processes of crude feedstocks sent for domestic refining. The petroleum refining calculations are based on the aggregation of fuel blendstock processes rather than the crude feedstock processes, like the petroleum extraction and petroleum transportation calculations. The final upstream process after refining is the transportation, storage, and distribution (TS&D) of the finished fuel product.

The upstream gasoline and diesel emissions factors are aggregated in the CAFE Model based on the share of fuel savings leading to reduced domestic oil fuel refining and the share of reduced domestic refining from domestic crude oil. The CAFE Model applies a fuel savings adjustment factor to the petroleum refining process and a combined fuel savings and reduced domestic refining adjustment to both the petroleum extraction and petroleum transportation processes for both gasoline and diesel fuels and for each pollutant. These adjustments are consistent across fuel types, analysis years, and pollutants, and are unchanged from the 2020 final rule. Additional discussion of the methodology for estimating the share of fuel savings leading to reduced domestic oil refining is located in Chapter 6.2.4.3 of the TSD. NHTSA seeks comment on the methodology used and specifically whether all of the change in refining would happen domestically, rather than the current division between domestic and non-domestic refining.

Upstream electricity emissions factors are also calculated using GREET 2020. GREET 2020 projects a national default electricity generation mix for transportation use from the latest Annual Energy Outlook (AEO) data available from the previous year. As discussed above, the CAFE Model uses a single upstream electricity factor for each analysis year.

3. Simulating Tailpipe Emissions Impacts

Tailpipe emission factors are generated using the latest regulatory model for on-road emission inventories from the U.S. Environmental Protection Agency, the Motor Vehicle Emission Simulator (MOVES3), November 2020 release. MOVES3 is a state-of-the-science, mobile-source emissions inventory model for regulatory applications.[319] New MOVES3 tailpipe emission factors have been incorporated into the CAFE parameters, and these updates supersede tailpipe data previously provided by EPA from MOVES2014 for past CAFE analyses. MOVES3 accounts for a variety of processes related to emissions impacts from vehicle use, including running exhaust, start exhaust, refueling displacement vapor loss, brakewear, and tirewear, among others.

The CAFE Model uses tailpipe emissions factors for all model years from 2020 to 2060 for criteria pollutants and air toxics. To maintain continuity in the historical inventories, only emission factors for model years 2020 and after were updated; all emission factors prior to MY 2020 were unchanged from previous CAFE rulemakings. In addition, the updated tailpipe data in the current CAFE reference case no longer account for any fuel economy improvements or changes in vehicle miles traveled from the 2020 final rule. In order to avoid double-counting effects from the previous rulemaking in the current rulemaking, the new tailpipe baseline backs out 1.5% year-over-year stringency increases in fuel economy, and 0.3% VMT increases assumed each year (20% rebound on the 1.5% improvements in stringency). Note that the MOVES3 data do not cover all the model years and ages required by the CAFE Model, MOVES only generates emissions data for vehicles made in the last 30 model years for each calendar year being run. This means emissions data for some calendar year and vehicle age combinations are missing. To remedy this, we take the last vehicle age that has emissions data and forward fill those data for the following vehicle ages. Due to incomplete available data for years prior to MY 2020, tailpipe emission factors for MY 2019 and earlier have not been modified and continue to utilize MOVES2014 data.

For tailpipe CO_2 emissions, these factors are defined based on the fraction of each fuel type's mass that represents carbon (the carbon content) along with the mass density per unit of the specific type of fuel. To obtain the emission factors associated with each fuel, the carbon content is then multiplied by the mass density of a particular fuel as well as by the ratio of the molecular weight of carbon dioxide to that of elemental carbon. This ratio, a constant value of 44/12, measures the mass of carbon dioxide that is produced by complete combustion of mass of carbon contained in each unit of fuel. The resulting value defines the emission factor attributed to CO_2 as the amount of grams of CO_2 emitted during vehicle operation from each type of fuel. This calculation is repeated for gasoline, E85, diesel, and compressed natural gas (CNG) fuel types. In the case of CNG, the mass density and the calculated CO_2 emission factor are denoted as grams per standard cubic feet (scf), while for the remainder of fuels, these are defined as grams per gallon of the given fuel source. Since electricity and hydrogen fuel types do not cause CO_2 emissions to be emitted during vehicle operation, the carbon content, and the CO_2 emission factors for these two fuel types are assumed to be zero. The mass density, carbon content, and CO_2 emission factors for each fuel type are defined in the Parameters file.

The CAFE Model calculates CO_2 tailpipe emissions associated with vehicle operation of the surviving on-road fleet by multiplying the number of gallons (or scf for CNG) of a specific fuel consumed by the CO_2 emissions factor for the associated fuel type. More specifically, the amount of gallons or scf of a particular fuel are multiplied by the carbon content and the mass density per unit of that fuel type, and then applying the ratio of carbon dioxide emissions generated per unit of carbon consumed during the combustion process.[320]

4. Estimating Health Impacts From Changes in Criteria Pollutant Emissions

The CAFE Model computes select health impacts resulting from three criteria pollutants: NO_X, SO_X,[321] and $PM_{2.5}$. Out of the six criteria pollutants currently regulated, NO_X, SO_X, and $PM_{2.5}$ are known to be emitted regularly from mobile sources and have the most adverse effects to human health. These health impacts include several different morbidity measures, as well as low and high mortality estimates, and are measured by the number of instances predicted to occur per ton of emitted pollutant.[322] The model reports total health impacts by multiplying the estimated tons of each criteria pollutant by the corresponding health incidence per ton value. The inputs that inform the calculation of the total tons of emissions resulting from criteria pollutants are discussed above. This section discusses how the health

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[319] U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Motor Vehicle Emission Simulator (MOVES), Last Updated: March 2021, *https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves.*

[320] Chapter 3, Section 4 of the CAFE Model Documentation provides additional description for calculation of CO_2 tailpipe emissions with the model.

[321] Any reference to SO_X in this section refers to the sum of sulfur dioxide (SO_2) and sulfate particulate matter (pSO_4) emissions, following the methodology of the EPA papers cited.

[322] The complete list of morbidity impacts estimated in the CAFE Model is as follows: Acute bronchitis, asthma exacerbation, cardiovascular hospital admissions, lower respiratory symptoms, minor restricted activity days, non-fatal heart attacks, respiratory emergency hospital admissions, respiratory emergency room visits, upper respiratory symptoms, and work loss days.

incidence per ton values were obtained. See Section III.G.2.b)(2) and Chapter 6.2.2 of the TSD accompanying this proposal for information regarding the monetized damages arising from these health impacts.

The SEIS that accompanies this proposal also includes a detailed discussion of the criteria pollutants and air toxics analyzed and their potential health effects. In addition, consistent with past analyses, NHTSA will perform full-scale photochemical air quality modeling and present those results in the Final SEIS associated with the final rule. That analysis will provide additional assessment of the human health impacts from changes in $PM_{2.5}$ and ozone associated with this rule. NHTSA will also consider whether such modeling could practicably and meaningfully be included in the FRIA, noting that compliance with CAFE standards is based on the *average* performance of manufacturers' production for sale *throughout* the U.S., and that the FRIA will involve sensitivity analysis spanning a range of model inputs, many of which impact estimates of future emissions from passenger cars and light trucks. Chapter 6 of the PRIA includes a discussion of overall changes in health impacts associated with criteria pollutant changes across the different rulemaking scenarios.

In previous rulemakings, health impacts were split into two categories based on whether they arose from upstream emissions or tailpipe emissions. In the current analysis, these health incidence per ton values have been updated to reflect the differences in health impacts arising from each emission source sector, according to the latest publicly available EPA reports. Five different upstream emission source sectors (Petroleum Extraction, Petroleum Transportation, Refineries, Fuel Transportation, Storage and Distribution, and Electricity Generation) are now represented. As the health incidences for the different source sectors are all based on the emission of one ton of the same pollutants, NO_X, SO_X, and $PM_{2.5}$, the differences in the incidence per ton values arise from differences in the geographic distribution of the pollutants, a factor which affects the number of people impacted by the pollutants.[323]

The CAFE Model health impacts inputs are based partially on the structure of EPA's 2018 technical support document, Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors (referred to here as the 2018 EPA source apportionment TSD),[324] which reported benefit per ton values for the years 2016, 2020, 2025, and 2030.[325] For the years in between the source years used in the input structure, the CAFE Model applies values from the closest source year. For instance, 2020 values are applied for 2020–2022, and 2025 values are applied for 2023–2027. For further details, see the CAFE Model documentation, which contains a description of the model's computation of health impacts from criteria pollutant emissions.

Despite efforts to be as consistent as possible between the upstream emissions sectors utilized in the CAFE Model with the 2018 EPA source apportionment TSD, the need to use up-to-date sources based on newer air quality modeling updates led to the use of multiple papers. In addition to the 2018 EPA source apportionment TSD used in the 2020 final rule, DOT used additional EPA sources and conversations with EPA staff to appropriately map health incidence per ton values to the appropriate CAFE Model emissions source category.

We understand that uncertainty exists around the contribution of VOCs to $PM_{2.5}$ formation in the modeled health impacts from the petroleum extraction sector; however, based on feedback to the 2020 final rule we believe that the updated health incidence values specific to petroleum extraction sector emissions may provide a more appropriate estimate of potential health impacts from that sector's emissions than the previous approach of applying refinery sector emissions impacts to the petroleum extraction sector. That said, we are aware of work that EPA has been doing to address concerns about the BPT estimates, and NHTSA will work further with EPA to update and synchronize approaches to the BPT estimates.

The basis for the health impacts from the petroleum extraction sector was a 2018 oil and natural gas sector paper written by EPA staff (Fann et al.), which estimated health impacts for this sector in the year 2025.[326] This paper defined the oil and gas sector's emissions not only as arising from petroleum extraction but also from transportation to refineries, while the CAFE/GREET component is composed of only petroleum extraction. After consultation with the authors of the EPA paper, it was determined that these were the best available estimates for the petroleum extraction sector, notwithstanding this difference. Specific health incidence per pollutant were not reported in the paper, so EPA staff sent BenMAP health incidence files for the oil and natural gas sector upon request. DOT staff then calculated per ton values based on these files and the tons reported in the Fann et al. paper.[327] The only available health impacts corresponded to the year 2025. Rather than trying to extrapolate, these 2025 values were used for all the years in the CAFE Model structure: 2020, 2025, and 2030.[328] This simplification implies an overestimate of damages in 2020 and an underestimate in 2030.[329]

The petroleum transportation sector and fuel TS&D sector did not correspond to any one EPA source sector in the 2018 EPA source apportionment TSD, so a weighted average of multiple different EPA sectors was used to determine the health impact per ton values for those sectors. We used a combination of different EPA mobile source sectors from two different papers, the 2018 EPA source apportionment TSD,[330] and a 2019 mobile source sectors paper (Wolfe et al.)[331] to generate these values. The health incidence per ton values associated with the refineries sector and

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[323] *See* Environmental Protection Agency (EPA). 2018. Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors. *https://www.epa.gov/sites/production/files/2018-02/documents/sourceapportionmentbpttsd_2018.pdf.*

[324] Environmental Protection Agency (EPA). 2018. Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors. *https://www.epa.gov/sites/production/files/2018-02/documents/sourceapportionmentbpttsd_2018.pdf.*

[325] As the year 2016 is not included in this analysis, the 2016 values were not used.

[326] Fann, N., Baker, K. R., Chan, E., Eyth, A., Macpherson, A., Miller, E., & Snyder, J. (2018). Assessing Human Health $PM_{2.5}$ and Ozone Impacts from U.S. Oil and Natural Gas Sector Emissions in 2025. *Environmental science & technology*, 52(15), 8095–8103 (*hereinafter* Fann et al.).

[327] Nitrate-related health incidents were divided by the total tons of NO_X projected to be emitted in 2025, sulfate-related health incidents were divided by the total tons of projected SO_X, and EC/OC (elemental carbon and organic carbon) related health incidents were divided by the total tons of projected EC/OC. Both Fann et al. and the 2018 EPA source apportionment TSD define primary $PM_{2.5}$ as being composed of elemental carbon, organic carbon, and small amounts of crustal material. Thus, the EC/OC BenMAP file was used for the calculation of the incidents per ton attributable to $PM_{2.5}$.

[328] These three years are used in the CAFE Model structure because it was originally based on the estimate provided in the 2018 EPA source apportionment TSD.

[329] *See* EPA. 2018. Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors. *https://www.epa.gov/sites/production/files/2018-02/documents/sourceapportionmentbpttsd_2018.pdf* p.9.

[330] Environmental Protection Agency (EPA). 2018. Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors. *https://www.epa.gov/sites/production/files/2018-02/documents/sourceapportionmentbpttsd_2018.pdf.*

[331] Wolfe et al. 2019. Monetized health benefits attributable to mobile source emissions reductions across the United States in 2025. *https://pubmed.ncbi.nlm.nih.gov/30296769/.*

electricity generation sector were drawn solely from the 2018 EPA source apportionment TSD.

The CAFE Model follows a similar process for computing health impacts resulting from tailpipe emissions as it does for calculating health impacts from upstream emissions. Previous rulemakings used the 2018 EPA source apportionment TSD as the source for the health incidence per ton, matching the CAFE Model tailpipe emissions inventory to the ''on-road mobile sources sector'' in the TSD. However, a more recent EPA paper from 2019 (Wolfe et al.)[332] computes monetized damage costs per ton values at a more disaggregated level, separating on-road mobile sources into multiple categories based on vehicle type and fuel type. Wolfe et al. did not report incidences per ton, but that information was obtained through communications with EPA staff.

The methodology for generating values for each emissions category in the CAFE Model is discussed in detail in Chapter 5 of the TSD accompanying this proposal. The Parameters file contains all of the health impact per ton of emissions values used in this proposal.

G. Simulating Economic Impacts of Regulatory Alternatives

This section describes the agency's approach for measuring the economic costs and benefits that will result from establishing alternative CAFE standards for future model years. The benefit and cost measures the agency uses are important considerations, because as Office of Management and Budget (OMB) Circular A–4 states, benefits and costs reported in regulatory analyses must be defined and measured consistently with economic theory, and should also reflect how alternative regulations are anticipated to change the behavior of producers and consumers from a baseline scenario.[333] For CAFE standards, those include vehicle manufacturers, buyers of new cars and light trucks, owners of used vehicles, and suppliers of fuel, all of whose behavior is likely to respond in complex ways to the level of CAFE standards that DOT establishes for future model years.

It is important to report the benefits and costs of this proposed action in a format that conveys useful information about how those impacts are generated and also distinguishes the impacts of those economic consequences for private businesses and households from the effects on the remainder of the U.S. economy. A reporting format will accomplish this objective to the extent that it clarifies who incurs the benefits and costs of the proposed, and shows how the economy-wide or ''social'' benefits and costs of the proposed action are composed of its direct effects on vehicle producers, buyers, and users, plus the indirect or ''external'' benefits and costs it creates for the general public.

Table III–37 and Table III–38 present the incremental economic benefits and costs of the proposed action and the alternatives (described in detail in Section IV) to increase CAFE standards for model years 2024–26 at three percent and seven percent discount rates in a format that is intended to meet these objectives. The tables include costs which are transfers between different economic actors—these will appear as both a cost and a benefit in equal amounts (to separate affected parties). Societal cost and benefit values shown elsewhere in this document do not show costs which are transfers for the sake of simplicity but report the same net societal costs and benefits. The proposed action and the alternatives would increase costs to manufacturers for adding technology necessary to enable new cars and light trucks to comply with fuel economy and emission regulations. It may also increase fine payments by manufacturers who would have achieved compliance with the less demanding baseline standards. Manufacturers are assumed to transfer these costs on to buyers by charging higher prices; although this reduces their revenues, on balance, the increase in compliance costs and higher sales revenue leaves them financially unaffected. Since the analysis assumes that manufacturers are left in the same economic position regardless of the standards, they are excluded from the tables.

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[332] Wolfe et al. 2019. Monetized health benefits attributable to mobile source emissions reductions across the United States in 2025. *https://pubmed.ncbi.nlm.nih.gov/30296769/*.

[333] White House Office of Management and Budget, *Circular A–4: Regulatory Analysis,* September 17, 2003 (*https://obamawhitehouse.archives.gov/omb/circulars_a004_a-4/*), Section E.

Table III-37 – Incremental Benefits and Costs Over the Lifetimes of Total Fleet Produced Through 2029 (2018$ Billions), 3% Percent Discount Rate, by Alternative

Alternative:	1	2	3
Private Costs			
Technology Costs to Increase Fuel Economy	34.3	67.6	100.1
Increased Maintenance and Repair Costs	-	-	-
Sacrifice in Other Vehicle Attributes	-	-	-
Consumer Surplus Loss from Reduced New Vehicle Sales	0.1	0.6	1.3
Safety Costs Internalized by Drivers	6.2	8.2	11.2
Subtotal - Incremental Private Costs	40.6	76.3	112.7
External Costs			
Congestion and Noise Costs from Rebound-Effect Driving	7.3	10.1	13.5
Safety Costs Not Internalized by Drivers	7.5	15.8	23.2
Loss in Fuel Tax Revenue	11.0	18.9	27.0
Subtotal - Incremental External Costs	25.9	44.7	63.6
Total Incremental Social Costs	66.5	121.1	176.3
Private Benefits			
Reduced Fuel Costs[334]	47.9	73.0	103.8
Benefits from Additional Driving	12.3	15.3	20.8
Less Frequent Refueling	-0.5	-0.8	0.3
Subtotal - Incremental Private Benefits	59.7	87.6	124.8
External Benefits			
Reduction in Petroleum Market Externality	0.9	1.5	2.1
Reduced Climate Damages	20.3	32.0	45.6
Reduced Health Damages	1.7	0.4	0.3
Subtotal - Incremental External Benefits	22.8	33.9	48.0
Total Incremental Social Benefits	82.6	121.4	172.9
Net Incremental Social Benefits	**16.1**	**0.3**	**-3.4**

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[334] A portion of Reduced Fuel Costs represent the benefit to consumers of not having to pay taxes on avoided gasoline consumption. This amount offsets the Loss in Fuel Tax Revenue in External Costs. For example, the $47.9 billion in Reduced Fuel Costs in alternative 1 represents $11 billion of avoided fuel taxes and $36.9 billion in gasoline savings.

Table III-38 – Incremental Benefits and Costs Over the Lifetimes of Total Fleet Produced Through 2029 (2018$ Billions), 7% Percent Discount Rate, by Alternative

Alternative:	1	2	3
Private Costs			
Technology Costs to Increase Fuel Economy	28.1	55.0	81.4
Increased Maintenance and Repair Costs	-	-	-
Sacrifice in Other Vehicle Attributes	-	-	-
Consumer Surplus Loss from Reduced New Vehicle Sales	0.1	0.5	1.1
Safety Costs Internalized by Drivers	3.7	4.9	6.8
Subtotal - Incremental Private Costs	31.9	60.4	89.3
External Costs			
Congestion and Noise Costs from Rebound-Effect Driving	4.8	6.8	9.3
Safety Costs Not Internalized by Drivers	5.5	11.6	17.3
Loss in Fuel Tax Revenue	7.0	11.9	17.0
Subtotal - Incremental External Costs	17.3	30.3	43.5
Total Incremental Social Costs	49.3	90.7	132.8
Private Benefits			
Reduced Fuel Costs	29.7	44.9	63.7
Benefits from Additional Driving	7.5	9.3	12.7
Less Frequent Refueling	-0.4	-0.6	0.0
Subtotal - Incremental Private Benefits	36.8	53.6	76.4
External Benefits			
Reduction in Petroleum Market Externality	0.5	0.9	1.3
Reduced Climate Damages	13.3	21.0	29.9
Reduced Health Damages	0.9	0.1	-0.1
Subtotal - Incremental External Benefits	14.8	22.0	31.2
Total Incremental Social Benefits	51.6	75.6	107.6
Net Incremental Social Benefits	**2.3**	**-15.1**	**-25.2**

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Compared to the baseline standards, if the preferred alternative is finalized, the analysis shows that buyers of new cars and light trucks will incur higher purchasing prices and financing costs, which will lead to some buyers dropping out of the new vehicle market. Drivers of new vehicles will also experience a slight uptick in the risk of being injured in a crash because of mass reduction technologies employed to meet the increased standards. While this effect is not statistically significant, NHTSA provides these results for transparency, and to demonstrate that their inclusion does not affect NHTSA's proposed policy decision. Because of the increasing price of new vehicles, some owners may delay retiring and replacing their older vehicles with newer models. In effect, this will transfer some driving that would have been done in newer vehicles under the baseline scenario to older models within the legacy fleet, thus increasing costs for injuries (both fatal and less severe) and property damages sustained in motor vehicle crashes. This stems from the fact that cars and light trucks have become progressively more protective in crashes over time (and also slightly less prone to certain types of crashes, such as rollovers). Thus, shifting some travel from newer to older models would increase injuries and damages sustained by drivers and passengers because they are traveling in less safe vehicles and not because it changes the risk profiles of drivers themselves. These costs are largely driven by assumptions regarding consumer valuation of fuel efficiency and an assumption that more fuel-efficient vehicles are less preferable to consumers than their total cost to improve fuel economy. These are issues on which we seek comments.

In exchange for these costs, consumers will benefit from new cars and light trucks with better fuel economy. Drivers will experience lower costs as a consequence of new vehicles' decreased fuel consumption, and from fewer refueling stops required because of their increased driving range. They will experience mobility benefits as they use newly purchased cars and light trucks more in response to their lower operating costs. On balance, consumers of new cars and light trucks produced during the model years subject to this proposed action will experience significant economic benefits.

Table III–37 and Table III–38 also show that the changes in fuel consumption and vehicle use resulting from this proposed action will in turn generate both benefits and costs to society writ large. These impacts are ''external,'' in the sense that they are by-products of decisions by private firms and individuals that alter vehicle use and fuel consumption but are experienced broadly throughout society rather than by the firms and individuals who indirectly cause them. In terms of costs, additional driving by consumers of new vehicles in response to their lower operating costs will increase the external costs associated with their contributions to traffic delays and noise levels in urban areas, and these additional costs will be experienced throughout much of the society. While most of the risk of additional driving or delaying purchasing a newer vehicle are internalized by those who make those decisions, a portion of the costs are borne by other road users. Finally, since owners of new vehicles will be consuming less fuel, they will pay less in fuel taxes.

Society will also benefit from more stringent standards. Increased fuel efficiency will reduce the amount of petroleum-based fuel consumed and refined domestically, which will decrease the emissions of carbon dioxide and other greenhouse gases that contribute to climate change, and, as a result, the U.S. (and the rest of world) will avoid some of the economic damages from future changes in the global climate. Similarly, reduced fuel production and use will decrease emissions of more localized air pollutants (or their chemical precursors), and the resulting decrease in the U.S. population's exposure to harmful levels of these pollutants will lead to lower costs from its adverse effects on health. Decreasing consumption and imports of crude petroleum for refining lower volumes of gasoline and diesel will also accrue some benefits throughout to the U.S., in the form of potential gains of energy security as businesses and households that are dependent on fuel are subject to less sudden and sharp changes in energy prices.

On balance, Table III–37 and Table III–38 show that both consumers and society as a whole will experience net economic benefits from the proposed action. The following subsections will briefly describe the economic costs and benefits considered by the agency. For a complete discussion of the methodology employed and the results, see TSD Chapter 6 and PRIA Chapter 6, respectively. The safety implications of the proposal—including the monetary impacts—are reserved for Section III.H. NHTSA seeks comment on the following discussion.

1. Private Costs and Benefits

(a) Costs to Consumers

(1) Technology Costs

The proposed action and the alternatives would increase costs to manufacturers for adding technology necessary to enable new cars and light trucks to comply with fuel economy and emission regulations. Manufacturers are assumed to transfer these costs on to buyers by charging higher prices. See Section III.C.6 and TSD Chapter 2.5.

(2) Consumer Sales Surplus

Buyers who would have purchased a new vehicle with the baseline standards in effect but decide not to do so in response to the changes in new vehicles' prices due to more stringent standards in place will experience a decrease in welfare. The collective welfare loss to those ''potential'' new vehicle buyers is measured by the foregone consumer surplus they would have received from their purchase of a new vehicle in the baseline.

Consumer surplus is a fundamental economic concept and represents the net value (or net benefit) a good or service provides to consumers. It is measured as the difference between what a consumer is willing to pay for a good or service and the market price. OMB Circular A–4 explicitly identifies consumer surplus as a benefit that should be accounted for in cost-benefit analysis. For instance, OMB Circular A–4 states the ''net reduction in total surplus (consumer plus producer) is a real cost to society,'' and elsewhere elaborates that consumer surplus values be monetized ''when they are significant.'' [335]

Accounting for the portion of fuel savings that the average new vehicle buyer demands, and holding all else equal, higher average prices should depress new vehicle sales and by extension reduce consumer surplus. The inclusion of consumer surplus is not only consistent with OMB guidance, but with other parts of the regulatory analysis. For instance, we calculate the increase in consumer surplus associated with increased driving that results from the decrease in the cost per mile of operation under more stringent regulatory alternatives, as discussed in Section III.G.1.b)(3). The surpluses associated with sales and additional mobility are inextricably linked as they capture the direct costs and benefits accrued by purchasers of new vehicles. The sales surplus captures the welfare loss to consumers when they forego a new vehicle purchase in the presence of higher prices and the additional mobility measures the benefit increased mobility under lower operating expenses.

The agency estimates the loss of sales surplus based on the change in quantity of vehicles projected to be sold after adjusting for quality improvements attributable to fuel economy. For additional information about consumer sales surplus, see TSD Chapter 6.1.5.

(3) Ancillary Costs of Higher Vehicle Prices

Some costs of purchasing and owning a new or used vehicle scale with the value of the vehicle. Where fuel economy standards increase the transaction price of vehicles, they will affect both the absolute amount paid in sales tax and the average amount of financing required to purchase the vehicle. Further, where they increase the MSRP, they increase the appraised value upon which both value-related registration fees and a portion of insurance premiums are based. The analysis assumes that the transaction price is a set share of the MSRP, which allows calculation of these factors as shares of MSRP. For a detailed explanation of how the agency estimates these costs, see TSD Chapter 6.1.1.

These costs are included in the consumer per-vehicle cost-benefit analysis but are not included in the societal cost-benefit analysis because they are assumed to be transfers from consumers to governments, financial institutions, and insurance companies.

(b) Benefits to Consumers

(1) Fuel Savings

The primary benefit to consumers of increasing CAFE standards are the additional fuel savings that accrue to new vehicle owners. Fuel savings are calculated by multiplying avoided fuel consumption by fuel prices. Each vehicle of a given body style is assumed to be driven the same as all the others of a comparable age and body style in each calendar year. The ratio of that cohort's VMT to its fuel efficiency produces an estimate of fuel consumption. The difference between fuel consumption in the baseline, and in each alternative, represents the gallons (or energy) saved. Under this assumption, our estimates of fuel consumption from increasing the fuel economy of each individual model depend only on how much its fuel economy is increased, and do not reflect whether its actual use differs from other

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[335] OMB Circular A–4, at 37–38.

models of the same body type. Neither do our estimates of fuel consumption account for variation in how much vehicles of the same body type and age are driven each year, which appears to be significant (see TSD Chapter 4.3.1.2). Consumers save money on fuel expenditures at the average retail fuel price (fuel price assumptions are discussed in detail in TSD Chapter 4.1.2), which includes all taxes and represents an average across octane blends. For gasoline and diesel, the included taxes reflect both the Federal tax and a calculated average state fuel tax. Expenditures on alternative fuels (E85 and electricity, primarily) are also included in the calculation of fuel expenditures, on which fuel savings are based. And while the included taxes net out of the social benefit cost analysis (as they are a transfer), consumers value each gallon saved at retail fuel prices including any additional fees such as taxes.

See TSD Chapter 6.1.3 for additional details. In the TSD, the agency considers the possibility that several of the assumptions made about vehicle use could lead to misstating the benefits of fuel savings. The agency notes that these assumptions are necessary to model fuel savings and likely have minimal impact to the accuracy of this analysis.

Technologies that can be used to improve fuel economy can also be used to increase other vehicle attributes, especially acceleration performance, weight, and energy-using accessories. While this is most obvious for technologies that improve the efficiency of engines and transmissions, it is also true of technologies that reduce mass, aerodynamic drag, rolling resistance or any road or accessory load. The exact nature of the potential to trade-off attributes for fuel economy varies with the technology, but at a minimum, increasing vehicle efficiency or reducing loads allows a more powerful engine to be used while achieving the same level of fuel economy. How consumers value increased fuel economy and how fuel economy regulations affect manufacturers' decisions about how to use efficiency improving technologies can have important effects on the estimated costs, benefits, and indirect impacts of fuel economy standards.

NHTSA's preliminary regulatory impact analysis assumes that consumers will purchase, and manufacturers will supply, fuel economy technologies in the absence of fuel economy standards if the technology ''pays for itself'' in fuel savings over the first 30 months vehicle use. This assumption is based on statements manufacturers have made to us and to NASEM CAFE committees and has been deployed in NHTSA's prior analyses of fuel economy standards. However, classical economic concepts suggest that deploying this assumption may be problematic when the baseline standards are binding—meaning that they constrain consumers' behavior to vehicles that are more fuel efficient than they would have chosen in the absence of fuel economy standards. To demonstrate this, we introduce a standard economic model of consumer optimization subject to a budgetary constraint.[336]

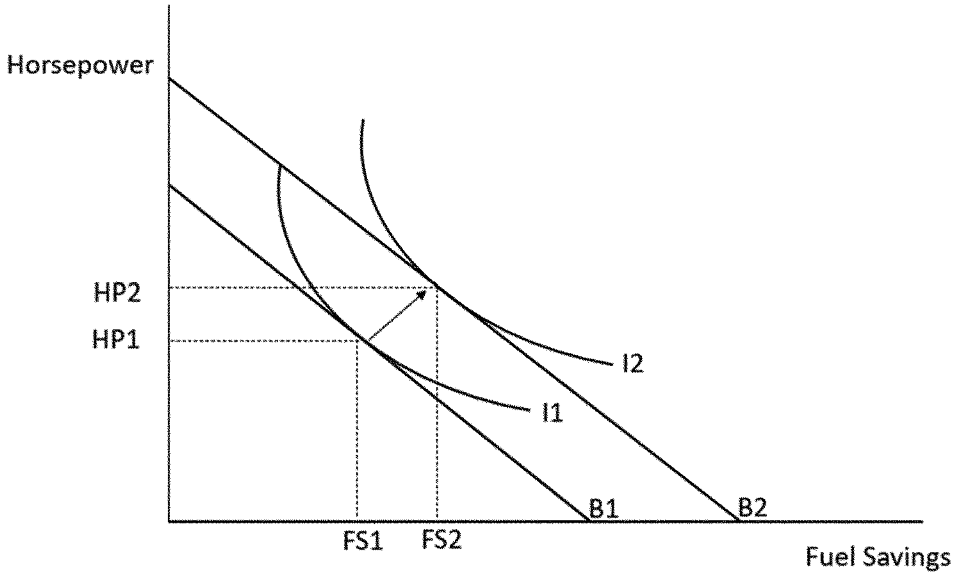

Figure III-17 – Constrained Optimization Model of Consumer Preferences Between Horsepower and Fuel Economy in the Absence of Fuel Economy Standards

Figure III–17 models consumer behavior when constrained by a budget. Line B1 represents the consumer's original budget constraint. Curve I1 is called an indifference curve, which shows each combination of horsepower, which we use here to represent a variety of attributes that could be traded-off for increased fuel economy, and fuel savings between which a consumer is indifferent. The curvature of the indifference curve reflects the principle of diminishing marginal utility—the idea that consumers value consumption of the first unit of any product greater than subsequent units. Curve I1 represents the highest utility achievable when subject to budget constraint B1, as the consumer may select the combination of performance and fuel economy represented by point (HP1, FS1)—which is the point of tangency between I1 and B1. When new technology becomes available that

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[336] Note that the following section examines whether consumers are rational in their fuel economy consumption patterns. This analysis could represent a scenario where consumers are rational, or one in which the underweight future fuel savings in their car purchasing decisions.

makes either fuel economy or performance (or both) more affordable, the consumer's budget constraint shifts from B1 to B2, and the consumer can now achieve the point of tangency between I2 and B2 (HP2, FS2). In this case, both fuel economy and performance are modeled as normal goods—meaning that as they become more affordable, consumers will elect to consume more of each.

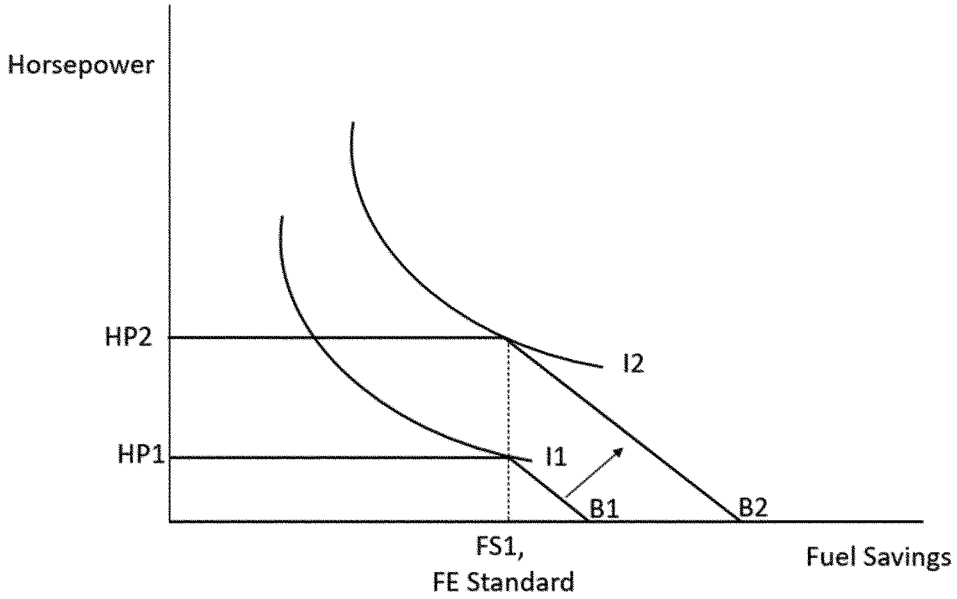

Figure III-18 – Constrained Optimization Model of Consumer Preferences Between Horsepower and Fuel Economy in the Presence of Binding Fuel Economy Standards

A different analysis is required when fuel economy standards also bind on consumer decisions. Here, minimum fuel economy standards eliminate some combinations of performance and fuel economy, creating a corner solution in the budget constraint. Figure III–18 shows this effect, as the consumer will elect the point of tangency with budget constraint B1 at the corner solution at (HP1 and FS1), which is also the minimum fuel economy standard. When new technology is introduced (or becomes cheaper) which makes fuel economy and performance more affordable, the consumer's budget constraint shifts from B1 to B2 again, but the existing fuel economy standard is still binding, so a corner solution remains at FS1. The consumer will choose the corner combination of fuel economy and performance again, where I2 is tangent with B2, at point (FS1, HP2). *Note that the consumer has elected to improve performance from HP1 to HP2 but has not elected to improve fuel economy.*

This model implies that fuel economy standards prevent consumers from achieving their optimal bundle of fuel economy and performance given their current preferences, creating an opportunity cost to consumers in the form of lost performance. The constrained optimization model can be slightly tweaked to show this loss to consumers. In this example, the y-axis uses the composite good M reflecting all other goods and services, including performance. This makes the interpretation of the y axis simpler, as it can be more easily translated into dollars.

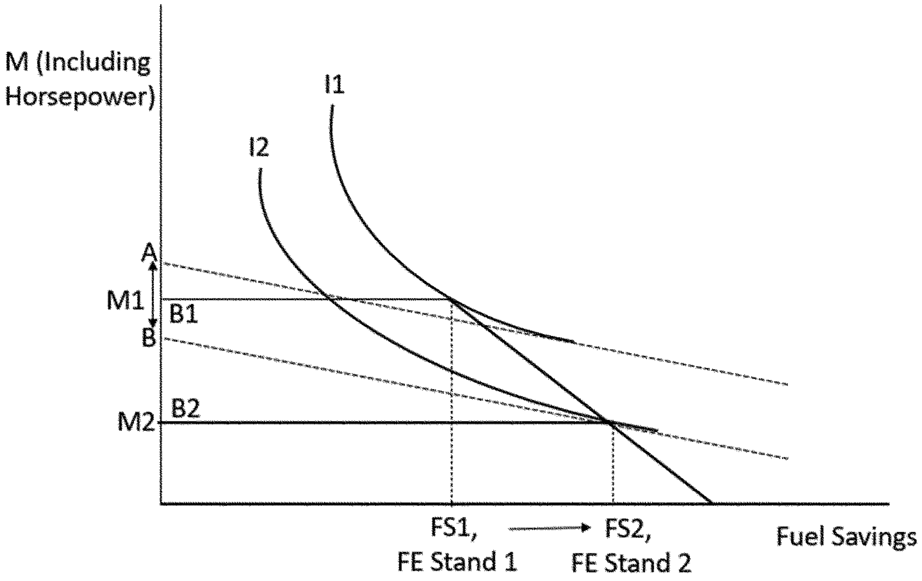

Figure III-19 – Constrained Optimization Model of Consumer Preferences Between Horsepower and Fuel Economy Showing Opportunity Cost of Fuel Economy Standards

Figure III–19 shows the effect of new binding fuel economy standards on consumer behavior. The consumer begins at point (M1, FS1) on indifference curve I1. If more stringent fuel economy standards were in place, the consumer would shift to the lower indifference curve I2—reflecting a lower level of utility—and would consume at point (M2, FS2). One concept from the economics literature for valuing the change in welfare from a change in prices or quality (or in this case fuel economy standards) is to look at the compensating variation between the original and final equilibrium. The compensating variation is the amount of money that a consumer would need to return to their original indifference curve.[337] It is found by finding the point of tangency with the new indifference curve at the new marginal rate of substitution between the two products and finding the equivalent point on the old indifference curve. Figure III–19 shows this as the distance between points A and B on the Y-axis.[338]

The above logic appears to explain the trends in fuel economy and vehicle performance (measured by horsepower/pound) between 1986 and 2004, when gasoline prices fluctuated between $2.00 and $2.50 per gallon and new light duty vehicle fuel economy standards remained nearly constant Figure III–20. Over the same period numerous advanced technologies with the potential to increase fuel economy were adopted. However, the fuel economy of new light duty vehicles did not increase. In fact, increases in the market share of light trucks caused fuel economy to decline somewhat.

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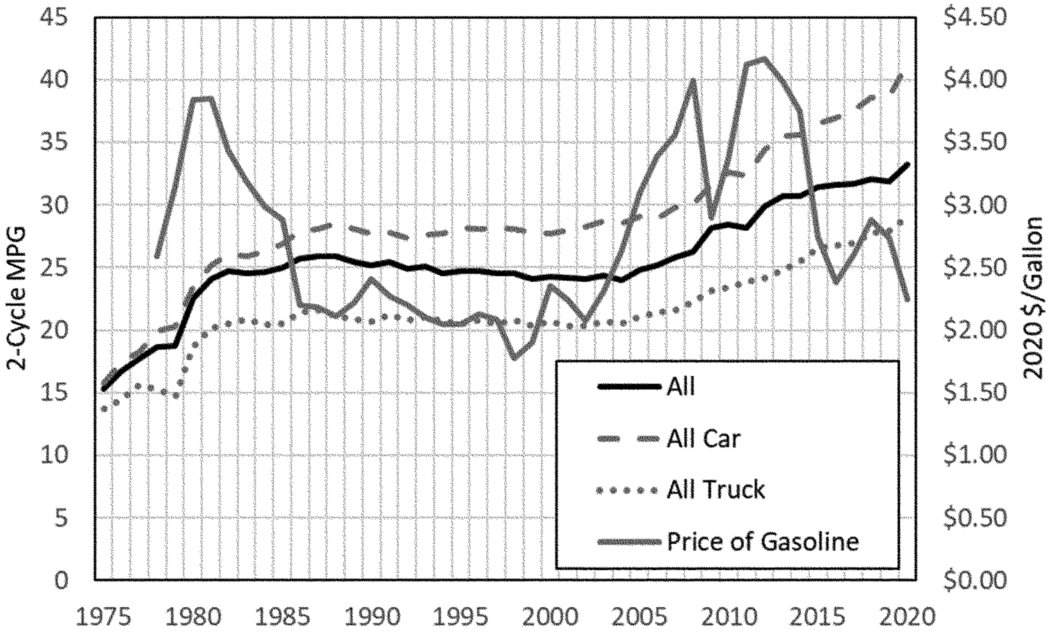
[337] There is a very similar concept for valuing this opportunity cost known as the equivalent variation. NHTSA presents the compensating variation here for simplicity but acknowledges that the equivalent variation is an equally valid approach.

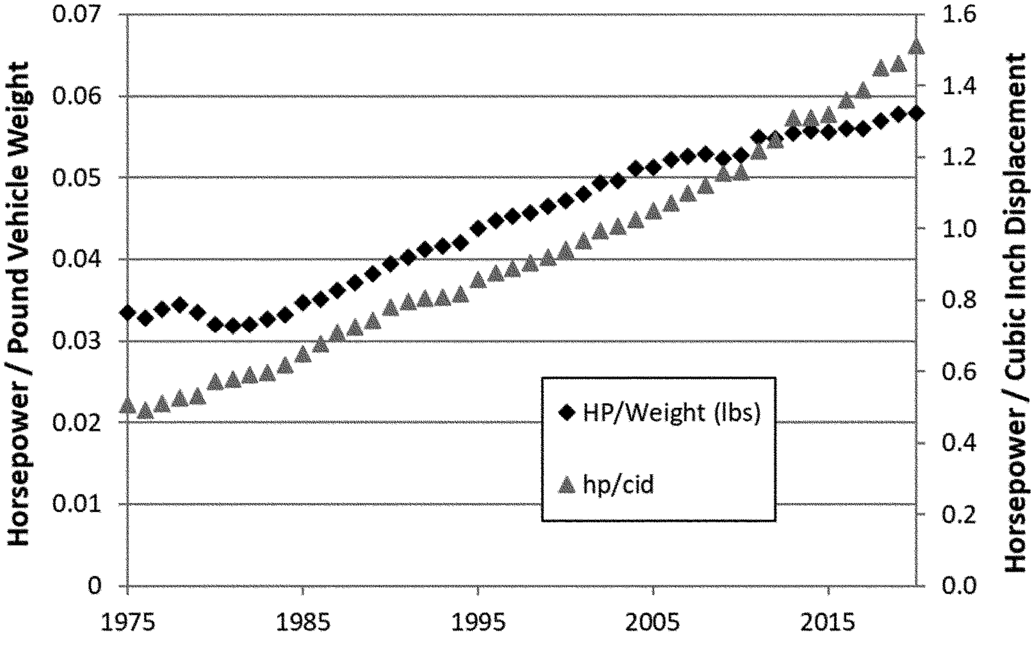
[338] Boardman, Greenberg, Vining, Weimer (2011). *Cost-Benefit Analysis; Concepts and Practice.* Pgs. 69–73.



Sources: EPA 2020 Automotive Trends Report; EIA Monthly Energy Review, 5/21; Federal Reserve Bank of St. Louis, CPI-U

Figure III-20 – Test Cycle Combined Fuel Economy and Gasoline Price: 1975-2020

On the other hand, from 1986–2004 the acceleration performance of light-duty vehicles increased by 45% (Figure III–21). Advances in engine technology are reflected in the steadily increasing ratio of power output to engine size, measured by displacement. Without increased fuel economy standards, all the potential of advanced technology appears to have gone into increasing performance and other attributes (for example average weight also increased by 27% from 1986–2004) and none to increasing fuel economy. Fuel economy remained nearly constant at the levels required by the car and light truck standards, consistent with the idea the standards were a binding constraint on the fuel economy of new vehicles. The pattern for periods of price shocks and increasing standards is different, however, as can be seen in Figure III–20. In the early period up to 1986, there is almost no change in performance and vehicle weight decreased. However, in the more recent period post-2004, performance continued to increase although apparently at a slower rate than during the 1986–2004 period and vehicle weight changed very little. The large and rapid price increases appear to have been an important factor. Even before manufacturers can respond to prices and regulations by adding fuel economy technologies to new vehicles, demand can respond by shifting towards smaller, lighter and less powerful makes and models. The period of voluntary increase in fuel economy is consistent with the constrained optimization problem presented above if fuel economy standards no longer constrained consumer behavior after the change in fuel prices.



Source: EPA, 2020 Automotive Trends Report.

Figure III-21 – Trends in Performance and Engine Technology: 1975-2020

If this constrained optimization model is a reliable predictor of consumer behavior for some substantive portion of the new vehicle market, it would have important implications for how NHTSA models baseline consumer choices. In this case, it would mean that as technology that could improve fuel economy is added absent standards, it would be primarily geared towards enhancing performance rather than fuel economy. Depending on how consumers value future fuel savings, it might be appropriate for NHTSA to change its methods of analysis to reflect consumer preferences for performance, and to develop methods for valuing the opportunity cost to consumers for constraining them to more fuel efficient options. NHTSA seeks comment on the analysis presented in this section and its implications for the assumptions that consumers will add technologies that payback within thirty months. It also seeks comment on possible approaches to valuing the opportunity cost to consumers.

Potential Implications of Behavioral Theories for Fuel Economy Standards

In this proposed rule, the cost-effectiveness of technology-based fuel economy improvements is used to estimate fuel economy improvements by manufacturers in the No-Policy case and to estimate components of the benefits and costs of alternative increases in fuel economy standards. In the interest of insuring that our theory and methods reflect the best current understanding of how consumers perceive the value of technology-based fuel economy improvements, we are seeking comment on our current, and possible alternative representations of how consumers value fuel economy when purchasing a new vehicle and while owning and operating it, and how manufacturers decide to implement fuel economy technologies.[339] We are particularly interested in comments on our assumption that in our Alternative 0 (no change in existing standards) manufacturers will implement technologies to improve fuel economy even if existing standards do not require them to do so, provided that the first 30 months of fuel savings will be greater than or equal to the cost of the technology. We are also interested in comments concerning our use of the difference between the price consumers pay for increased fuel economy and the value of fuel savings over the first 30 month for estimating the impacts of the standards on new and used vehicle markets. Finally, we are interested in comments on when attributes that can be traded-off for increased fuel economy should be considered opportunity costs of increasing fuel economy.

How manufacturers choose to implement technologies that can increase fuel economy depends on consumers' willingness to pay (WTP) for fuel economy and the other attributes the technologies can improve. Consumers' WTP for increasing levels of an attribute defines the consumers' demand function for that attribute. Here, we consider how consumers' WTP for increased fuel economy (WTP_{FE}) and for performance (WTP_{HP}), where $_{FE}$ stands for fuel economy and $_{HP}$ stands for ''Horse Power''/performance, and the cost of technology (C) affect manufacturers' decisions about how to implement the technologies with and without fuel economy standards. For the purpose of this discussion, it is convenient to think of fuel economy in terms of its inverse, the rate of fuel consumption per mile. While miles per gallon (mpg) delivers decreasing fuel savings per mpg, decreasing fuel consumption delivers constant fuel savings per gallon per mile (gpm) reduced. Thinking in terms of gpm is appropriate because fuel economy standards are in fact defined in terms of the inverse of fuel economy, *i.e.,* gpm.

In the CAFE Model we typically assume that for a technology that can improve fuel economy, consumers are willing to pay an amount equal to the first thirty months of fuel savings (WTP_{30FE}). This is an important assumption for several reasons. The market will tend to equilibrate the ratio of consumers' WTP for fuel economy

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[339] We are making a distinction between consumers choices when presented with technology-based fuel economy improvements versus consumers' choices among various makes and models of vehicles. The latter topic is also of interest and is discussed in (*see* TSD, Ch. 4.2.1).

divided by its cost to the ratio of consumers' WTP for other attributes divided by their cost. The value of the first thirty months of fuel savings is typically about one-fourth of the value of savings over the expected life of a vehicle, discounted at annual rates between 3% and 7%. Arguably, this represents an important undervaluing of technology-based fuel economy improvement relative to its true economic value. Our use of the 30-month payback assumption is based on statements manufacturers have made to us and to NASEM CAFE committees. It is also based on the fact that repeated assessments of the potential for technology to improve fuel economy have consistently found a substantial potential to cost-effectively increase fuel economy. But it is also partly based on the fact that the substantial literature that has endeavored to infer consumers' WTP for fuel economy is approximately evenly divided between studies that support severe undervaluation and those that support valuation at approximately full lifetime discounted present value (*e.g.,* Greene et al., 2018; Helfand and Wolverton, 2011; Greene, 2010; for a more complete discussion see TSD, Ch. 6.1.6). The most recent studies based on detailed data and advanced methods of statistical inference have not resolved the issue (NASEM, 2021, Ch. 11.3).

If consumers value technology-based fuel economy improvements at only a small fraction of their lifetime present value and the market equates WTP_{30FE}/C to WTP_{HP}/C, the market will tend to oversupply performance relative to fuel economy (Allcott et al., 2014; Heutel, 2015). The WTP_{30FE} assumption also has important consequences when fuel economy standards are in effect. Alternative 0 in this proposed rule assumes not only that the SAFE standards are in effect but that the manufacturers who agreed to the California Framework will be bound by that agreement. If those existing regulations are binding, it is likely that $WTP_{HP} > WTP_{30FE}$. (For simplicity we assume that over the range of fuel economy and performance achievable by the technology, both WTP values are constant.)[340] This outcome would be expected in a market where consumers undervalue fuel savings in their normal car buying decisions and standards require levels of fuel economy beyond what they are willing to pay.[341] This is illustrated in Figure III–22. The initial consumer demand function for vehicles (D_0) is shifted upward by WTP_{30FE} to represent the consumer demand function for the increased fuel economy the technology could produce (D_{30FE}) and by WTP_{HP} to represent the demand function (D_{HP}) for the potential increase in performance. Because the technology has a cost (C), the manufacturers' supply function (S_0) shifts upward to $S_1 = S_0 + C$.[342] If the cost of the technology exceeds consumers' WTP for either the fuel economy or the performance it can deliver, the technology will not be adopted in the absence of regulations requiring it. In Figure III–22 we show the case where $C < WTP_{30FE} < WTP_{HP}$. In this case, using the technology to increase performance provides the greatest increase in sales and revenues: $Q_{HP} > Q_{30FE} > Q_0$. Since both WTP values are assumed to be approximately constant over the range of improvement the technology can provide, there is no possible combination of fuel economy and performance improvement that would produce a larger increase in sales than using the technology entirely to increase performance.[343] Importantly, as long as $C < WTP_{HP}$, the actual cost of the technology does not affect the manufacturer's decision to use 100% of its potential to increase performance and 0% to increase fuel economy. The technology's payback period for the increase in fuel economy is irrelevant. If we reverse the relative WTP values (*i.e.,* $WTP_{30FE} > WTP_{HP}$), then the manufacturer will choose to use 100% of the technology's potential to increase fuel economy and 0% to increase performance, assuming constant WTP values.[344] This conclusion may contradict our current method, which assumes that even with increasing fuel economy standards in Alternative 0, manufacturers will adopt fuel economy technologies with $WTP_{30FE} < C$ and use them to increase fuel economy rather than performance.

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[340] Although there are diminishing returns to increased miles per gallon, in terms of fuel savings in gallons or dollars, there are not diminishing returns to reductions in fuel consumption per mile, except due to decreasing marginal utility of income. WTP_{HP} likely decreases with increasing performance, but if the changes are not too large, the assumption of constant WTP is reasonable.

[341] If there are no binding regulatory constraints and fuel economy and other vehicle attributes are normal goods, consumers will elect more of each in the event technological progress makes it possible to afford them. This simplifying assumption is consistent with a scenario where consumers' baseline vehicle choices are constrained by regulatory standards. See above for more discussion.

[342] The supply function for new cars is assumed to be perfectly elastic for the sake of simplicity of exposition. Note that if the cost of the technology exceeds consumers' WTP for both fuel economy and performance, the technology will not be adopted in the absence of regulations requiring it.

[343] In fact, all that is required is that over the range of increases achievable by the technology, $WTP_{HP} > WTP_{FE}$.

[344] However, as noted above, the market will tend to equate WTP_{HP}/C to WTP_{FE}/C, so if there is sufficient variation in WTP_{HP} over the range of values achievable by the technology, some of each will be provided.

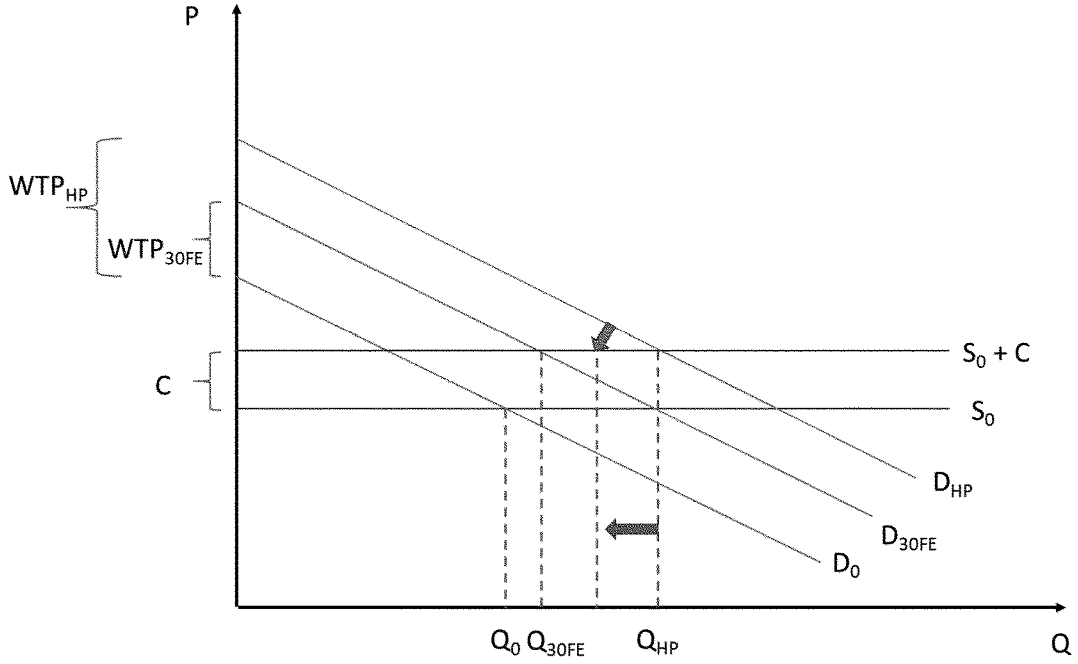

Figure III-22 – Manufacturers Decision to Adopt a Technology When $WTP_{HP} > WTP_{30FE} > C$

Because the expected present value of fuel savings is several times the 30-month value, it is quite possible that the WTP for performance lies between the lifetime present value of fuel savings and the 30-month value: $WTP_{PVFE} > WTP_{HP} > WTP_{30FE}$. This possibility is illustrated in Figure III–23, in which there are three demand functions in addition to the initial demand function, D_0. In Figure III–23, if the consumer were willing to pay for the full present value of fuel savings, the technology would be applied 100% to increasing fuel economy, provided $C < WTP_{PVFE}$. But if standards were binding and the consumer were willing to pay for only 30 months of fuel savings, the technology would be applied 100% to increasing performance, provided $C < WTP_{HP}$. Suppose that the cost of the technology is not C, but a much smaller value, say $c < C$ and $c < WTP_{30FE}$. Assuming consumers value increased fuel economy at WTP_{30FE}, it remains the case that all the technology's potential will be applied to increasing performance because that gives the greatest increase in sales. The implication is that when there is a binding fuel economy standard, as long as $WTP_{HP} > WTP_{30FE}$, no technologies would be used to increase fuel economy in the absence of a regulatory requirement to do so. If consumers' WTP for fuel economy is WTP_{30FE} and regulatory standards are binding, $WTP_{HP} > WTP_{FE}$ seems likely.

If $WTP_{30FE} < WTP_{HP}$ (recalling that HP can represent attributes in addition to fuel economy), the above analysis of producer behavior contradicts the current operation of the CAFE Model, which assumes that manufacturers will apply technologies whose costs are less than WTP_{30FE} to improving fuel economy in the absence of regulations requiring them to do so. For the final rule, NHTSA is considering changing the assumption that in the absence of standards that require it, manufactures will adopt technologies to improve fuel economy that have a payback period of 30 months or less, in favor of the above analysis. We are interested in receiving comments that specifically address the validity of the current and proposed approach.

As discussed in TSD Chapter 4.2.1.1, there is no consensus in the literature about how consumers value fuel economy improvements when making vehicle purchases. In this and past analyses, we have assumed that consumers value only the first 30 months of fuel savings when making vehicle purchase decisions. This value is a small fraction, approximately one fourth of the expected present value of future fuel savings over the typical life of a light-duty vehicle, assuming discount rates in the range of 3% to 7% per year. On the other hand, when estimating the societal value of fuel economy improvements, we use the full present value of discounted fuel savings over the expected life of the vehicle because it represents a real resource savings. However, the possibility that consumers' perceptions of utility at the time of purchase (decision utility) may differ from the utility consumers experience while consuming a good and that experienced utility may be the preferrable metric for policy evaluation has been raised in the economic literature (Kahneman and Sugden, 2005). In our methods, we use WTP_{30FE} to represent consumers' decision utility. Gallons saved over the life of a vehicle, valued at the current price of gasoline, and discounted to present value appears to be an appropriate measure of experienced utility. The large difference between our measure of decision utility and lifetime present value fuel savings as a measure of experienced utility has potentially important implications for how we estimate the impacts of fuel economy standards on new vehicle sales and the used vehicle market. It seems plausible that as consumers experience the fuel savings benefits of increased fuel economy, their valuation of the fuel economy increases required by regulation may adjust over time towards the full lifetime discounted present value. In addition, behavioral economic theory accepts that consumers' willingness to pay for fuel economy may change depending on the context of consumers' car purchase decisions. The implications of such possibilities are analyzed below. We are interested in how they might affect our current methods for estimate the impacts of standards on new vehicle sales and the used vehicle market, and whether any changes to our current methods are appropriate.

The existence of fuel economy standards changes manufacturers' decision making. First, if a standard is set at a level that requires only part of the technological potential to increase fuel economy, if $C < WTP_{HP}$, and $WTP_{HP} > WTP_{30FE}$, the remainder of the technology's potential will be used to provide some increase in performance. This appears to have occurred post 2004 when the rate of improvement in performance slowed while fuel economy improved. Assuming that consumers value fuel economy improvement at time of purchase at WTP_{30FE}, there would be a consumers' surplus cost of foregone performance equal to the cross-hatched trapezoid in Figure III–23. The foregone performance cost will be less than what it would have been if none of the technology's potential to increase fuel economy were used to increase performance. Even if the cost of the technology is less than WTP_{30FE}, the technology will be applied to improve fuel economy only up to the required level and the remainder of its potential will be used to increase performance. If the cost of applying enough of the technology to achieve the fuel economy standard is greater than WTP_{HP}, there would be no cost of foregone performance since the cost of applying the technology to increasing fuel economy exceeds its opportunity cost when applied to increase performance.[345] In that case, the technology cost represents the full cost of the fuel economy improvement, since that cost exceeds consumers' WTP for the performance it could produce. On the other hand, if under regulatory standards consumers valued fuel economy at WTP_{PVFE}, there would also be no opportunity cost of performance because $WTP_{PVFE} > WTP_{HP}$.

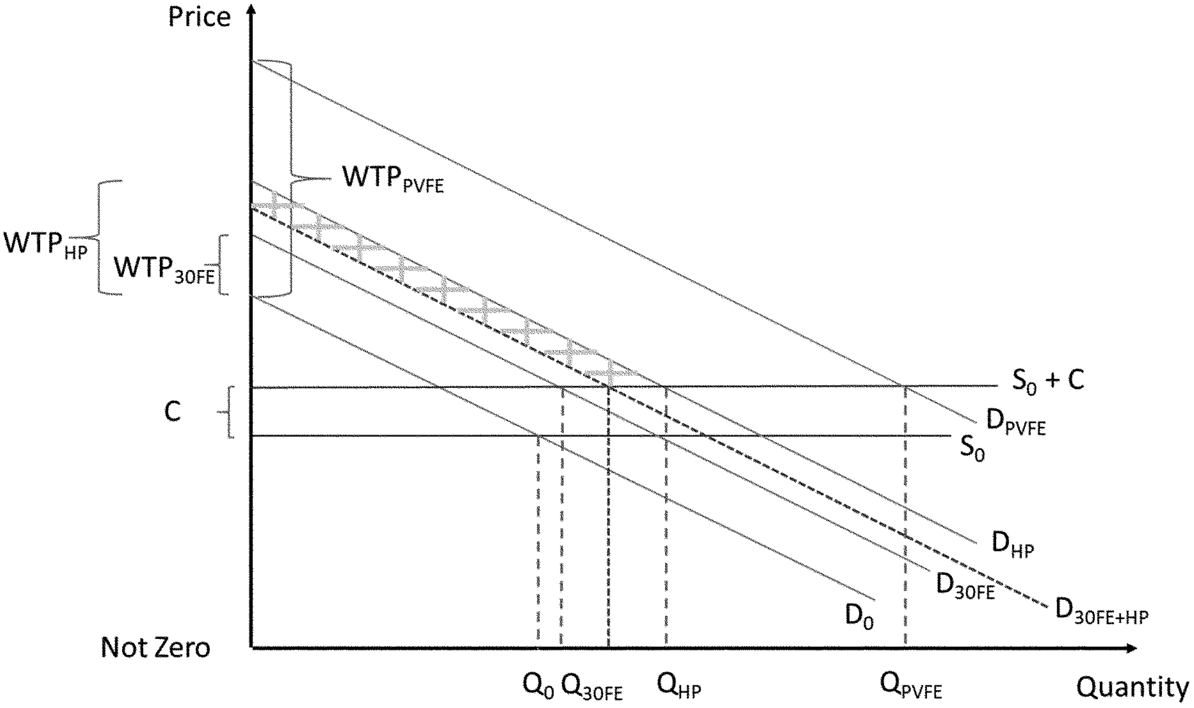

Figure III-23 – Manufacturers' Decision to Adopt Technology with Fuel Economy Standards

Because the CAFE Model estimates the effects of standards on new vehicle sales and scrappage based on the difference between the cost of technology and the perceived value of fuel savings at the time a new vehicle is purchased, whether consumers perceive the value differently in regulated and unregulated markets is an important question. Traditional utility theory of consumer decision making does not allow that consumers' preference rankings depend on the context of the choices they make. However, in addition to the theory of utility maximizing rational economic behavior, modern economics includes the insights and findings of behavioral economics, which has established many examples of human decision making that differ in important ways from the rational economic model. In particular, the behavioral model allows the possibility that consumers' preferences and decision-making processes often do change depending on the context or framing of choices. The possibility that behavioral theories of decision making may be useful for understanding how consumers value fuel economy and for evaluating the costs and benefits of fuel economy standards was noted in the most recent NASEM (2021) report. An explanation of the different contexts helps to illustrate this point. If a consumer is thinking about buying a new car and is looking at two models, one that includes fuel economy technology and is more expensive and another that does not, she may buy the cheaper, less fuel efficient version even if the more expensive model will save

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[345] This is because using the technology to increase performance would not be the second-best use of the cost of increasing fuel economy. The second-best use would instead be to invest the cost at a market rate of return.

money in the long run. But if, instead, the consumer is faced with whether to buy a new car at all as opposed to keeping an older one, if all new cars contain technology to meet fuel economy standards then she may view the decision differently. Will, for example, an extra $1,000 for a new car—a $1,000 that the consumer will more than recoup in fuel savings—deter her from buying the new car, especially when most consumers finance cars over a number of years rather than paying the $1,000 cost up front and will therefore partly or entirely offset any increase in monthly payment with lower fuel costs? In addition, the fact that standards generally increase gradually over a period of years allows time for consumers and other information sources to verify that fuel savings are real and of substantial value.

The CAFE Model's representation of consumers' vehicle choices under regulation reflects the ''Gruenspecht Effect'', the theory that regulation will inevitably cause new vehicles to be less desirable than they would have been in the absence of regulation, which will inevitably lead to reduced new vehicle sales, higher prices for used vehicles and slower turnover of the vehicle stock. However, if consumers severely undervalue fuel savings at the time of vehicle purchase, not only is that itself a market failure (a large discrepancy between decision and experienced utility) but it raises important questions about what causes such undervaluation and whether consumers' perceptions may change as the benefits of increased fuel economy are realized or whether the different framing of new vehicle choices in a regulated market might partially or entirely mitigate that undervaluation. The 2021 NASEM report asserts that if the behavioral model is correct, consumers might value fuel savings at or near their full lifetime discounted present value, potentially reversing the Gruenspecht Effect.

''On the other hand, the Gruenspecht effect is not predicted by the behavioral model, under which it is not only possible but likely that if the fuel savings from increased fuel economy exceed its cost, consumers will find the more fuel-efficient vehicles required by regulation to be preferable to those that would otherwise have been produced.'' ''It is possible that sales would increase rather than decrease and likewise manufacturers' profits. In that case, increased new vehicle sales would reduce used vehicle prices, benefiting buyers of used vehicles and accelerating the turnover of the vehicle stock.''[346]

NHTSA is interested in comments that can help contribute to resolving or improving our understanding of this issue and its implications for how the costs and benefits of fuel economy standards should be estimated.

(2) Refueling Benefit

Increasing CAFE standards, all else being equal, affect the amount of time drivers spend refueling their vehicles in several ways. First, they increase the fuel economy of ICE vehicles produced in the future, which increases vehicle range and decreases the number of refueling events for those vehicles. Conversely, to the extent that more stringent standards increase the purchase price of new vehicles, they may reduce sales of new vehicles and scrappage of existing ones, causing more VMT to be driven by older and less efficient vehicles which require more refueling events for the same amount of VMT driven. Finally, sufficiently stringent standards may also change the number of electric vehicles that are produced, and shift refueling to occur at a charging station, rather than at the pump—changing per-vehicle lifetime expected refueling costs.

The agency estimates these savings by calculating the amount of refueling time avoided—including the time it takes to find, refuel, and pay—and multiplying it by DOT's value of time of travel savings estimate. For a full description of the methodology, refer to TSD Chapter 6.1.4.

(3) Additional Mobility

Any increase in travel demand provides benefits that reflect the value to drivers and other vehicle occupants of the added—or more desirable—social and economic opportunities that become accessible with additional travel. Under the alternatives in this analysis, the fuel cost per mile of driving would decrease as a consequence of the higher fuel economy levels they require, thus increasing the number of miles that buyers of new cars and light trucks would drive as a consequence of the well-documented fuel economy rebound effect.

The fact that drivers and their passengers elect to make more frequent or longer trips to gain access to these opportunities when the cost of driving declines demonstrates that the benefits they gain by doing so exceed the costs they incur. At a minimum, the benefits must equal the cost of the fuel consumed to travel the additional miles (or they would not have occurred). The cost of that energy is subsumed in the simulated fuel expenditures, so it is necessary to account for the benefits associated with those miles traveled here. But the benefits must also offset the economic value of their (and their passengers') travel time, other vehicle operating costs, and the economic cost of safety risks due to the increase in exposure that occurs with additional travel. The amount by which the benefits of this additional travel *exceeds* its economic costs measures the net benefits drivers and their passengers experience, usually referred to as increased consumer surplus.

TSD Chapter 6.1.5 explains the agency's methodology for calculating additional mobility.

2. External Costs and Benefits

(a) Costs

(1) Congestion and Noise

Increased vehicle use associated with the rebound effect also contributes to increased traffic congestion and highway noise. Although drivers obviously experience these impacts, they do not fully value their impacts on other system users, just as they do not fully value the emissions impacts of their own driving. Congestion and noise costs are ''external'' to the vehicle owners whose decisions about how much, where, and when to drive more—or less—in response to changes in fuel economy result in these costs. Therefore, unlike changes in the costs incurred by drivers for fuel consumption or safety risks they willingly assume, changes in congestion and noise costs are not offset by corresponding changes in the travel benefits drivers experience.

Congestion costs are limited to road users; however, since road users include a significant fraction of the U.S. population, changes in congestion costs are treated as part of the rule's economic impact on the broader society instead of as a cost or benefit to private parties. Costs resulting from road and highway noise are even more widely dispersed, because they are borne partly by surrounding residents, pedestrians, and other non-road users, and for this reason are also considered as a cost to the society as a whole.

To estimate the economic costs associated with changes in congestion and noise caused by differences in miles driven, the agency updated the underlying components of the cost estimates of per-mile congestion and noise costs from increased automobile and light truck use provided in FHWA's 1997 Highway Cost Allocation Study. The agencies previously relied on this study in the 2010, 2011, and 2012 final rules, and updating the individual underlying components for congestion

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[346] NASEM, 2021, p. 11–357.

costs in this analysis improves currency and internal consistency with the rest of the analysis. See TSD Chapter 6.2 for details on how the agency calculated estimate the economic costs associated with changes in congestion and noise caused by differences in miles driven. NHTSA specifically seeks comment on the congestion costs employed in this analysis, and whether and how to change them for the analysis for the final rule.

(2) Fuel Tax Revenue

As mentioned in III.G.1.b)(1), a portion of the fuel savings experienced by consumers includes avoided fuel taxes. While fuel taxes are treated as a transfer within the analysis and do not affect net benefits, the agency provides an estimate here to show the potential impact to state and local governments.

(b) Benefits

(1) Reduced Climate Damages

Extracting and transporting crude petroleum, refining it to produce transportation fuels, and distributing fuel generate additional emissions of GHGs and criteria air pollutants beyond those from cars' and light trucks' use of fuel. By reducing the volume of petroleum-based fuel produced and consumed, adopting higher CAFE standards will thus mitigate global climate-related economic damages caused by accumulation of GHGs in the atmosphere, as well as the more immediate and localized health damages caused by exposure to criteria pollutants. Because they fall broadly on the U.S.—and global, in the case of climate damages—population, reducing them represents an external benefit from requiring higher fuel economy.

NHTSA estimates the global social benefits of CO_2, CH_4, and N_2O emission reductions expected from this proposed rule using the social cost of greenhouse gases (SC–GHG) estimates presented in the Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990 (''February 2021 TSD''). These SC–GHG estimates are interim values developed under Executive Order (E.O.) 13990 for use in benefit-cost analyses until updated estimates of the impacts of climate change can be developed based on the best available science and economics. NHTSA uses the SC–GHG interim values to estimate the benefits of decreased fuel consumption stemming from the proposal.

The SC–GHG estimates used in our analysis were developed over many years, using transparent process, peer-reviewed methodologies, the best science available at the time of that process, and with input from the public. Specifically, in 2009, an interagency working group (IWG) that included the DOT and other executive branch agencies and offices was established to ensure that agencies were using the best available science and to promote consistency in the social cost of carbon dioxide (SC–CO_2) values used across agencies. The IWG published SC–CO_2 estimates in 2010. These estimates were updated in 2013 based on new versions of each IAM. In August 2016 the IWG published estimates of the social cost of methane (SC–CH_4) and nitrous oxide (SC–N_2O) using methodologies that are consistent with the methodology underlying the SC–CO_2 estimates. Executive Order 13990 (issued on January 20, 2021) re-established the IWG and directed it to publish interim SC–GHG values for CO_2, CH_4, and N_2O within thirty days. Furthermore, the E.O. tasked the IWG with devising long-term recommendations to update the methodologies used in calculating these SC–GHG values, based on ''the best available economics and science,'' and incorporating principles of ''climate risk, environmental justice, and intergenerational equity''.[347] The E.O. also instructed the IWG to take into account the recommendations from the NAS committee convened on this topic, published in 2017.[348] The February 2021 TSD provides a complete discussion of the IWG's initial review conducted under E.O. 13990.

NHTSA is using the IWG's interim values, published in February 2021 in a technical support document, for the CAFE analysis in this NPRM.[349] This approach is the same as that taken in DOT regulatory analyses over 2009 through 2016. If the IWG issues new estimates before the final rule, the agency will consider revising the estimates within the CAFE Model time permitting. We request comment on this approach to estimating social benefits of reducing GHG emissions in this rulemaking in light of the ongoing interagency process.

NHTSA notes that the primary analysis for this proposal estimates benefits from reducing emissions of CO_2 and other GHGs that incorporate a 2.5% discount rate for distant future climate damages, while discounting costs and non-climate related benefits using a 3% rate. NHTSA also presents cost and benefits estimates in the primary analysis that reflect a 3% discount rate for reductions in climate-related damages while discounting costs and non-climate related benefits at 7%. NHTSA believes this approach represents an appropriate treatment of the intergenerational issues presented by emissions that result in climate-related damages over a very-long time horizon, and is within scope of the IWG's *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide* that recommends discounting future climate damages at rates of 2.5%, 3%, and 5%.[350]

In addition, NHTSA emphasize the importance and value of considering the benefits calculated using all four SC–GHG estimates for each of three greenhouse gases. NHTSA includes the social costs of CO_2, CH_4, and N_2O calculated using the four different estimates recommended in the February 2021 TSD (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate) in the PRIA.

The February 2021 TSD does not specify how agencies should combine its estimates of benefits from reducing GHG emissions that reflect these alternative discount rates with the discount rates for nearer-term benefits and costs prescribed in OMB Circular A–4. Instead, it provides agencies with broad flexibility in implementing the February 2021 TSD. However, the February 2021 TSD does identify 2.5% as the ''average certainty-equivalent rate using the mean-reverting and random walk approaches from Newell and Pizer (2003) starting at a discount rate of 3 percent.'' [351] As such, NHTSA believes using a 2.5% discount rate for climate-related damages is consistent with the IWG guidance.

This section provides further discussion of the discount rates that NHTSA uses in its regulatory analysis

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[347] Executive Order on Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis. (2021). Available at *https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/20/executive-order-protecting-public-health-and-environment-and-restoring-science-to-tackle-climate-crisis/.*

[348] National Academies of Science (NAS). (2017). Valuing Climate Damage: Updating Estimation of the Social Cost of Carbon Dioxide. Available at *https://www.nap.edu/catalog/24651/valuing-climate-damages-updating-estimation-of-the-social-cost-of.*

[349] Interagency Working Group on Social Cost of Greenhouse Gases, United States Government. (2021). *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990,* available at *https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf?source=email.*

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

[351] *Ibid.*

and presents results of a sensitivity analysis using a 3% discount rate for reductions in climate-related damages. NHTSA welcomes public comment on its selection of 2.5% for climate-related damages and will consider other discount rates for the final rule.

For a full discussion of the agency's quantification of GHGs, see TSD Chapter 6.2.1 and the PRIA.

(a) Discount Rates Accounting for Intergenerational Impacts

A standard function of regulatory analysis is to evaluate tradeoffs between impacts that occur at different points in time. Many, if not most, Federal regulations involve costly upfront investments that generate future benefits in the form of reductions in health, safety, or environmental damages. To evaluate these tradeoffs, the analysis must account for the social rate of time preference—the broadly observed social preference for benefits that occur sooner versus those that occur further in the future.[352] This is accomplished by discounting impacts that occur further in the future more than impacts that occur sooner.

OMB Circular A–4 affirmed the appropriateness of accounting for the social rate of time preference in regulatory analyses and prescribed discount rates of 3% and 7% for doing so. The 3% discount rate was chosen to represent the ''consumption rate of interest'' approach, which discounts future costs and benefits to their present values using the rate at which consumers appear to make tradeoffs between current consumption and equal consumption opportunities deferred to the future. OMB Circular A–4 reports a real rate of return on 10-year Treasury notes of 3.1% between 1973 and its 2003 publication date and interprets this as approximating the rate at which society is indifferent between consumption today and in the future.

The 7% rate reflects the opportunity cost of capital approach to discounting, where the discount rate approximates the foregone return on private investment if the regulation were to divert resources from capital formation. OMB Circular A–4 cites pre-tax rates of return on capital as part of its selection of the 7% rate.[353] The IWG rejected the use of the opportunity cost of capital approach to discounting reductions in climate-related damages because ''consumption rate of interest is the correct discounting concept to use when future damages from elevated temperatures are estimated in consumption-equivalent units as is done in the IAMs used to estimate the SC–GHG (National Academies 2017).''[354]

As the IWG states, ''GHG emissions are stock pollutants, where damages are associated with what has accumulated in the atmosphere over time, and they are long lived such that subsequent damages resulting from emissions today occur over many decades or centuries depending on the specific greenhouse gas under consideration.''[355] OMB Circular A–4 states that impacts occurring over such intergenerational time horizons require special treatment:

> Special ethical considerations arise when comparing benefits and costs across generations. Although most people demonstrate time preference in their own consumption behavior, it may not be appropriate for society to demonstrate a similar preference when deciding between the well-being of current and future generations. Future citizens who are affected by such choices cannot take part in making them, and today's society must act with some consideration of their interest.[356]

In addition to the ethical considerations, Circular A–4 also identifies uncertainty in long-run interest rates as a potential justification for using lower rates to discount intergenerational impacts. As Circular A–4 states, ''Private market rates provide a reliable reference for determining how society values time within a generation, but for extremely long time periods no comparable private rates exist.''[357] The social costs of distant future climate damages—and by implication, the value of reducing them by lowering emissions of GHGs—are highly sensitive to the discount rate, and the present value of reducing climate damages grows at an increasing rate as the discount rate used in the analysis declines. This ''non-linearity'' means that even if uncertainty about the exact value of the long-run interest rate is equally distributed between values above and below the 3% consumption rate of interest, the probability-weighted (or ''expected'') present value of a unit reduction in climate damages will be higher than the value calculated using a 3% discount rate. The effect of such uncertainty about the correct discount rate can thus be accounted for by using a lower ''certainty-equivalent'' rate to discount distant future damages.

The IWG identifies ''a plausible range of certainty-equivalent constant consumption discount rates: 2.5, 3, and 5 percent per year.'' The IWG's justification for its selection of these rates is summarized in this excerpt from its 2021 guidance:

> The 3 percent value was included as consistent with estimates provided in OMB's Circular A–4 (OMB 2003) guidance for the consumption rate of interest. . . .The upper value of 5 percent was included to represent the possibility that climate-related damages are positively correlated with market returns, which would imply a certainty equivalent value higher than the consumption rate of interest. The low value, 2.5 percent, was included to incorporate the concern that interest rates are highly uncertain over time. It represents the average certainty-equivalent rate using the mean-reverting and random walk approaches from Newell and Pizer (2003) starting at a discount rate of 3 percent. Using this approach, the certainty equivalent is about 2.2 percent using the random walk model and 2.8 percent using the mean reverting approach. Without giving preference to a particular model, the average of the two rates is 2.5 percent. Additionally, a rate below the consumption rate of interest would also be justified if the return to investments in climate mitigation are negatively correlated with the overall market rate of return. Use of this lower value was also deemed responsive to certain judgments based on the prescriptive or normative approach for selecting a discount rate and to related ethical objections that have been raised about rates of 3 percent or higher.

Because the certainty-equivalent discount rate will lie progressively farther below the best estimate of the current rate as the time horizon when future impacts occur is extended, the IWG's recent guidance also suggest that it may be appropriate to use a discount rate that declines over time to account for interest rate uncertainty, as has been recommended by the National Academies and EPA's Science Advisory Board.[358] The IWG mentioned that it will consider these recommendations and the relevant academic literature on declining rates in developing its final

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[352] This preference is observed in many market transactions, including by savers that expect a return on their investments in stocks, bonds, and other equities; firms that expect positive rates of return on major capital investments; and banks that demand positive interest rates in lending markets.

[353] OMB Circular A–4.

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

[355] *Ibid.*

[356] OMB Circular A–4.

[357] *Ibid.*

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

guidance on the social cost of greenhouse gases.

The IWG 2021 interim guidance also presented new evidence on the consumption-based discount rate suggesting that a rate lower than 3% may be appropriate. For example, the IWG replicated OMB Circular A–4's original 2003 methodology for estimating the consumption rate using the average return on 10-year Treasury notes over the last 30 years and found a discount rate close to 2%. They also presented rates over a longer time horizon, finding an average rate of 2.3% from 1962 to the present. Finally, they summarized results from surveys of experts on the topic and found a ''surprising degree of consensus'' for using a 2% consumption rate of interest to discount future climate-related impacts.[359]

NHTSA expects that the Interagency Working Group will continue to develop its final guidance on the appropriate discount rates to use for reductions in climate damages as NHTSA develops its final rule. If new guidance is issued in time for NHTSA's final rule, NHTSA will incorporate the IWG's updated guidance in the final regulatory analysis.

(b) Discount Rates Used in This Proposal for Climate-Related Benefits

As indicated above, NHTSA's primary analysis presents cost and benefit estimates using a 2.5% discount rate for reductions in climate-related damages and 3% for non-climate related impacts. NHTSA also presents cost and benefits estimates using a 3% discount rate for reductions in climate-related damages alongside estimates of non-climate related impacts discounted at 7%. This latter pairing of a 3% rate for discounting benefits from reducing climate-related damages with a 7% discount rate for non-climate related impacts is consistent with NHTSA's past practice.[360] However, NHTSA's pairing of 2.5% for climate-related damage reductions with 3% for non-climate related impacts is novel in this proposal.

As discussed above, the IWG's guidance indicates that uncertainty in long-run interest rates suggests that a lower ''certainty-equivalent'' discount rate is appropriate for intergenerational impacts, and identifies 2.5%, 3%, and 5% as ''certainty-equivalent'' discount rates. NHTSA emphasizes the importance and value of considering the benefits calculated using all four SC–GHG estimates for each of three greenhouse gases. NHTSA includes the social costs of CO_2, CH_4, and N_2O calculated using the four different estimates recommended in the February 2021 TSD (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate) in the PRIA. For presentation purposes in this rule, NHTSA shows two primary estimates. NHTSA believes that pairing OMB's 3% estimate of the consumption discount rate for near-term costs and benefits with the IWG's lower certainty-equivalent rate of 2.5% is consistent with current interim guidance in the February 2021 TSD. NHTSA also believe that its pairing of the 3% certainty-equivalent rate for climate-related benefits with OMB's 7% discount rate is consistent with guidance from the February 2021 TSD for GHGs and OMB Circular A–4 for other costs and benefits.

In addition, NHTSA presents a sensitivity analysis where both distant future and nearer-term GHG impacts are discounted using the 3% rate combined with all other costs and benefits discounted at 3%.

Table III-39 – Comparison of Results Using a 3% Discount Rate for All Impacts Except GHGs with Impacts Using Either 2.5% or 3% for Climate-Related Benefits, Model Years 1981 through 2029

	Totals	
	3%/2.5% SC-GHG Discount Rate	3%/3% SC-GHG Discount Rate
Costs	121.1	121.1
Benefits	121.4	110.5
Net Benefits	0.3	-10.6

Table III-40 – Comparison of Results Using a 3% Discount Rate for All Impacts Except GHGs with Impacts Using Either 2.5% or 3% for Climate-Related Benefits, Calendar Years 2021 through 2050

	Totals	
	3%/2.5% SC-GHG Discount Rate	3%/3% SC-GHG Discount Rate
Costs	333.6	333.6
Benefits	433.6	391.7
Net Benefits	100	58.1

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[359] *Ibid.*

[360] *See, e.g.,* the 2012 and 2020 final CAFE rules.

NHTSA seeks comment on the above discussion.

(2) Reduced Health Damages

The CAFE Model estimates monetized health effects associated with emissions from three criteria pollutants: NO_X, SO_x, and $PM_{2.5}$. As discussed in Section III.F above, although other criteria pollutants are currently regulated, only impacts from these three pollutants are calculated since they are known to be emitted regularly from mobile sources, have the most adverse effects to human health, and there exist several papers from the EPA estimating the benefits per ton of reducing these pollutants. Other pollutants, especially those that are precursors to ozone, are more difficult to model due to the complexity of their formation in the atmosphere, and EPA does not calculate benefit-per-ton estimates for these. The CAFE Model computes the monetized impacts associated with health damages from each pollutant by multiplying monetized health impact per ton values by the total tons of these pollutants, which are emitted from both upstream and tailpipe sources. Chapter 5 of the TSD accompanying this proposal includes a detailed description of the emission factors that inform the CAFE Model's calculation of the total tons of each pollutant associated with upstream and tailpipe emissions.

These monetized health impacts per ton values are closely related to the health incidence per ton values described above in Section III.F and in detail in Chapter 5.4 of the TSD. We use the same EPA sources that provided health incidence values to determine which monetized health impacts per ton values to use as inputs in the CAFE Model. Like the estimates associated with health incidences per ton of criteria pollutant emissions, we used multiple EPA papers and conversations with EPA staff to appropriately account for monetized damages for each pollutant associated with the source sectors included in the CAFE Model, based on which papers contained the most up-to-date data.[361] The various emission source sectors included in the EPA papers do not always correspond exactly to the emission source categories used in the CAFE Model.[362] In those cases, we mapped multiple EPA sectors to a single CAFE source category and computed a weighted average of the health impact per ton values.

The EPA uses the value of a statistical life (VSL) to estimate premature mortality impacts, and a combination of willingness to pay estimates and costs of treating the health impact for estimating the morbidity impacts.[363] EPA's 2018 technical support document, ''Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors,'' [364] (referred to here as the 2018 EPA source apportionment TSD) contains a more detailed account of how health incidences are monetized. It is important to note that the EPA sources cited frequently refer to these monetized health impacts per ton as ''benefits per ton,'' since they describe these estimates in terms of emissions avoided. In the CAFE Model input structure, these are generally referred to as monetized health impacts or damage costs associated with pollutants emitted, not avoided, unless the context states otherwise.

The CAFE Model health impacts inputs are based partially on the structure the 2018 EPA source apportionment TSD, which reported benefits per ton values for the years 2020, 2025, and 2030. For the years in between the source years used in the input structure, the CAFE Model applies values from the closest source year. For instance, the model applies 2020 monetized health impact per ton values for calendar years 2020–2022 and applies 2025 values for calendar years 2023–2027. For some of the monetized health damage values, in order to match the structure of other impacts costs, DOT staff developed proxies for 7% discounted values for specific source sectors by using the ratio between a comparable sector's 3% and 7% discounted values. In addition, we used implicit price deflators from the Bureau of Economic Analysis (BEA) to convert different monetized estimates to 2018 dollars, in order to be consistent with the rest of the CAFE Model inputs.

This process is described in more detail in Chapter 6.2.2 of the TSD accompanying this proposal. In addition, the CAFE Model documentation contains more details of the model's computation of monetized health impacts. All resulting emissions damage costs for criteria pollutants are located in the Criteria Emissions Cost worksheet of the Parameters file.

(3) Reduction in Petroleum Market Externality

By amending existing standards, the proposal would decrease domestic consumption of gasoline, producing a correspondingly decrease in the Nation's demand for crude petroleum, a commodity that is traded actively in a worldwide market. Although the U.S. accounts for a sufficient (albeit diminishing) share of global oil consumption that the resulting decrease in global petroleum demand will exert some downward pressure on worldwide prices.

U.S. consumption and imports of petroleum products have three potential effects on the domestic economy that are often referred to collectively as ''energy security externalities,'' and increases in their magnitude are sometimes cited as possible social costs of increased U.S. demand for petroleum. First, any increase in global petroleum prices that results from higher U.S. gasoline demand will cause a transfer of revenue to oil producers worldwide from consumers of petroleum, because consumers throughout the world are ultimately subject to the higher global price that results. Although this transfer is simply a shift of resources that produces no change in global economic welfare, the financial drain it produces on the U.S. economy is sometimes cited as an external cost of increased U.S. petroleum consumption because consumers of petroleum products are unlikely to consider it.

As the U.S. approaches self-sufficiency in petroleum production (the Nation became a net exporter of petroleum in 2020), this transfer is increasingly from U.S. consumers of refined petroleum products to U.S. petroleum producers, so it not only leaves welfare unaffected, but even ceases to be a financial burden on the U.S. economy. In fact, as the U.S. becomes a larger net petroleum exporter, any transfer from global consumers to petroleum producers would become a financial benefit to the U.S. economy. Nevertheless, uncertainty in the Nation's long-term import-export balance makes it difficult to project precisely how these effects might

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[361] Environmental Protection Agency (EPA). 2018. Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors. *https://www.epa.gov/sites/production/files/2018–02/documents/sourceapportionmentbpttsd_2018.pdf;* Wolfe et al. 2019. Monetized health benefits attributable to mobile source emissions reductions across the United States in 2025. *https://pubmed.ncbi.nlm.nih.gov/30296769/;* Fann et al. 2018. Assessing Human Health $PM_{2.5}$ and Ozone Impacts from U.S. Oil and Natural Gas Sector Emissions in 2025. *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6718951/.*

[362] The CAFE Model's emission source sectors follow a similar structure to the inputs from GREET. *See* Chapter 5.2 of the TSD accompanying this proposal for further information.

[363] Although EPA and DOT's VSL values differ, DOT staff determined that using EPA's VSL was appropriate here, since it was already included in these monetized health impact values, which were best suited for the purposes of the CAFE Model.

[364] *See* Environmental Protection Agency (EPA). 2018. Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors. *https://www.epa.gov/sites/production/files/2018–02/documents/sourceapportionmentbpttsd_2018.pdf.*

change in response to increased consumption.

Higher U.S. petroleum consumption can also increase domestic consumers' exposure to oil price shocks and thus increase potential costs to all U.S. petroleum users (including those outside the light duty vehicle sector, whose consumption would be unaffected by this proposed rule) from possible interruptions in the global supply of petroleum or rapid increases in global oil prices. Because users of petroleum products are unlikely to consider the effect of their increased purchases on these risks, their economic value is often cited as an external cost of increased U.S. consumption.

Finally, some analysts argue that domestic demand for imported petroleum may also influence U.S. military spending; because the increased cost of military activities would not be reflected in the price paid at the gas pump, this is often suggested to represent a third category of external costs form increased U.S. petroleum consumption. For example, NHTSA has received extensive comments to past actions from the group Securing America's Energy Future on this topic.

Each of these three factors would be expected to decrease—albeit by a limited magnitude—as a consequence of decrease in U.S. petroleum consumption resulting from the proposed standards. TSD Chapter 6.2.4 provides a comprehensive explanation of the agency's analysis of these three impacts.

(4) Changes in Labor

As vehicle prices rise, we expect consumers to purchase fewer vehicles than they would have at lower prices. If manufacturers produce fewer vehicles as a consequence of lower demand, manufacturers may need less labor to produce their fleet and dealers may need less labor to sell the vehicles. Conversely, as manufacturers add equipment to each new vehicle, the industry will require labor resources to develop, sell, and produce additional fuel-saving technologies.[365] We also account for the possibility that new standards could shift the relative shares of passenger cars and light trucks in the overall fleet. Since the production of different vehicles involves different amounts of labor, this shift impacts the quantity of estimated labor.

The analysis considers the direct labor effects that the CAFE standards have across the automotive sector. The facets include (1) dealership labor related to new light-duty vehicle unit sales; (2) assembly labor for vehicles, engines, and transmissions related to new vehicle unit sales; and (3) labor related to mandated additional fuel savings technologies, accounting for new vehicle unit sales. The labor utilization analysis is intentionally narrow in its focus and does not represent an attempt to quantify the overall labor or economic effects of this rulemaking because adjacent employment factors and consumer spending factors for other goods and services are uncertain and difficult to predict. We do not consider how direct labor changes may affect the macro economy and potentially change employment in adjacent industries. For instance, we do not consider possible labor changes in vehicle maintenance and repair, nor changes in labor at retail gas stations. We also do not consider possible labor changes due to raw material production, such as production of aluminum, steel, copper, and lithium, nor does the agency consider possible labor impacts due to changes in production of oil and gas, ethanol, and electricity.

All labor effects are estimated and reported at a national level, in person-years, assuming 2,000 hours of labor per person-year.[366] These labor hours are not converted into monetized values because we assume that the labor costs are included into a new vehicle's purchasing price. The analysis estimates labor effects from the forecasted CAFE Model technology costs and from review of automotive labor for the MY 2020 fleet. The agency uses information about the locations of vehicle assembly, engine assembly, and transmission assembly, and the percent of U.S. content of vehicles collected from American Automotive Labeling Act (AALA) submissions for each vehicle in the reference fleet.[367] The analysis assumes the portion of parts that are made in the U.S. will remain constant for each vehicle as manufacturers add fuel-savings technologies. This should not be misconstrued as a prediction that the percentage of U.S.-made parts—and by extension U.S. labor—will remain constant, but rather that the agency does not have a clear basis to project where future productions may shift. The analysis also uses data from the National Automotive Dealers Association (NADA) annual report to derive dealership labor estimates.

In sum, the analysis shows that the increased labor from production of new technologies used to meet the preferred alternative will outweigh any decreases attributable to the change in new vehicle sales. For a full description of the process the agency uses to estimate labor impacts, see TSD Chapter 6.2.5.

3. Costs and Benefits Not Quantified

In addition to the costs and benefits described above, Table III–37 and Table III–38 each include two line-items without values. The first is maintenance and repair costs. Many of the technologies manufacturers apply to vehicles to meet CAFE standards are sophisticated and costly. The technology costs capture only the initial or ''upfront'' costs to incorporate this equipment into new vehicles; however, if the equipment is costlier to maintain or repair—which is likely either because the materials used to produce the equipment are more expensive or the equipment is significantly more complex than less fuel efficient alternatives and requires more time and labor—then consumers will also experience increased costs throughout the lifetime of the vehicle to keep it operational. The agency does not calculate the additional cost of repair and maintenance currently because it lacks a basis for estimating the incremental change attributable to the standards. The agency seeks comment on methods for estimating these costs.

The second item is the potential sacrifice in other vehicle attributes. In addition to fuel economy, potential buyers of new cars and light trucks value other features such as their seating and cargo-carrying capacity, ride comfort, safety, and performance. Changing some of these other features, however, can affect vehicles' fuel economy, so manufacturers will carefully consider tradeoffs among them when deciding how to comply with stricter CAFE standards. Currently the analysis assumes that these vehicle attributes will not change as a result of these rules,[368] but in practice manufacturers may need to make practical design changes to meet the standards. Even if manufacturers are able to hold vehicles' other attributes at *today's* levels while meeting higher fuel economy targets, manufacturers may have to dedicate additional resources to comply with stricter CAFE targets and forego improvements in other vehicle attributes. The potential loss of other

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[365] For the purposes of this analysis, DOT assumes a linear relationship between labor and production volumes.

[366] The agencies recognize a few local production facilities may contribute meaningfully to local economies, but the analysis reports only on national effects.

[367] 49 CFR part 583.

[368] *See* TSD Chapter 2.4.5.

vehicle attributes is an opportunity cost to consumers.

The agency has previously attempted to model the potential sacrifice in other vehicle attributes in sensitivity analyses. In those other rulemakings, the agency acknowledged that it is extremely difficult to quantify the potential loss of other vehicle attributes. To accurately do so requires extensive projections about which and how much of other attributes will be sacrificed and a detailed accounting of how much value consumers assigned to those attributes. The agency modeled the loss in other vehicle attributes using published empirical estimates of tradeoffs between higher fuel economy and improvements to other attributes, together with estimates of the values buyers attach to those attributes. The agency is unsure whether this is an appropriate methodology since there is uncertainty about how much fuel economy consumers are willing to pay for and how consumers value other vehicle attributes. The agency seeks comment on alternative methods for estimating the potential sacrifice in other vehicle attributes.

H. Simulating Safety Effects of Regulatory Alternatives

The primary objective of CAFE standards is to achieve maximum feasible fuel economy, thereby reducing fuel consumption. In setting standards to achieve this intended effect, the potential of the standards to affect vehicle safety is also considered. As a safety agency, the agency has long considered the potential for adverse safety consequences when establishing CAFE standards.

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

1. Changes in Vehicle Mass. Similar to previous analyses, the agency calculates the safety impact of changes in vehicle mass made to reduce fuel consumption and comply with the standards. Statistical analysis of historical crash data indicates reducing mass in heavier vehicles generally improves safety, while reducing mass in lighter vehicles generally reduces safety. The agency's crash simulation modeling of vehicle design concepts for reducing mass revealed similar effects. These observations align with the role of mass disparity in crashes; when vehicles of different masses collide, the smaller vehicle will experience a larger change in velocity (and, by extension, force) which increases the risk to its occupants.

2. Impacts of Vehicle Prices on Fleet Turnover. Vehicles have become safer over time through a combination of new safety regulations and voluntary safety improvements. The agency expects this trend to continue as emerging technologies, such as advanced driver assistance systems, are incorporated into new vehicles. Safety improvements will likely continue regardless of changes to CAFE standards.

As discussed in Section III.E.2, technologies added to comply with fuel economy standards have an impact on vehicle prices, therefore slowing the acquisition of newer vehicles and retirement of older ones. The delay in fleet turnover caused by the effect of new vehicle prices affect safety by slowing the penetration of new safety technologies into the fleet.

The standards also influence the composition of the light-duty fleet. As the safety provided by light trucks, SUVs and passenger cars responds differently to technology that manufacturers employ to meet the standards—particularly mass reduction—fleets with different compositions of body styles will have varying numbers of fatalities, so changing the share of each type of light-duty vehicle in the projected future fleet impacts safety outcomes.

3. Increased driving because of better fuel economy. The ''rebound effect'' predicts consumers will drive more when the cost of driving declines. More stringent standards reduce vehicle operating costs, and in response, some consumers may choose to drive more. Additional driving increases exposure to risks associated with motor vehicle travel, and this added exposure translates into higher fatalities and injuries.

The contributions of the three factors described above generate the differences in safety outcomes among regulatory alternatives.[369] The agency's analysis makes extensive efforts to allocate the differences in safety outcomes between the three factors. Fatalities expected during future years under each alternative are projected by deriving a fleet-wide fatality rate (fatalities per vehicle mile of travel) that incorporates the effects of differences in each of the three factors from baseline conditions and multiplying it by that alternative's expected VMT. Fatalities are converted into a societal cost by multiplying fatalities with the DOT-recommended value of a statistical life (VSL) supplemented by economic impacts that are external to VSL measurements. Traffic injuries and property damage are also modeled directly using the same process and valued using costs that are specific to each injury severity level.

All three factors influence predicted fatalities, but only two of them—changes in vehicle mass and in the composition of the light-duty fleet in response to changes in vehicle prices—impose increased risks on drivers and passengers that are not compensated for by accompanying benefits. In contrast, increased driving associated with the rebound effect is a consumer choice that reveals the benefit of additional travel. Consumers who choose to drive more have apparently concluded that the utility of additional driving exceeds the additional costs for doing so, including the crash risk that they perceive additional driving involves. As discussed in Chapter 7 of the accompanying Technical Support Document, the benefits of rebound driving are accounted for by offsetting a portion of the added safety costs.

The agency categorizes safety outcome through three measures of light-duty vehicle safety: Fatalities to occupants occurring in crashes, serious injuries sustained by occupants, and the number of vehicles involved in crashes that cause property damage but no injuries. Counts of fatalities to occupants of automobiles and light trucks are obtained from the agency's Fatal Accident Reporting System (FARS). Estimates of the number of serious injuries to drivers and passengers of light-duty vehicles are tabulated from the agency's General Estimates System (GES), an annual sampling of motor vehicle crashes occurring throughout the U.S. 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 and light trucks involved in property damage-only (PDO) crashes each year were also developed using GES. NHTSA seeks comment on the following discussion.

1. Mass Reduction Impacts

Vehicle mass reduction can be one of the more cost-effective means of improving fuel economy, particularly for makes and models not already built with much high-strength steel or aluminum closures or low-mass components. Manufacturers have stated that they will continue to reduce vehicle

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[369] The terms safety performance and safety outcome are related but represent different concepts. When we use the term safety performance, we are discussing the intrinsic safety of a vehicle based on its design and features, while safety outcome is used to describe whether a vehicle has been involved in an accident and the severity of the accident. While safety performance influences safety outcomes, other factors such as environmental and behavioral characteristics also play a significant role.

mass to meet more stringent standards, and therefore, this expectation is incorporated into the modeling analysis supporting the standards. Safety trade-offs associated with mass-reduction have occurred in the past, particularly before CAFE standards were attribute-based; past safety trade-offs may have occurred because manufacturers chose at the time, in response to CAFE standards, to build smaller and lighter vehicles. In cases where fuel economy improvements were achieved through reductions in vehicle size and mass, the smaller, lighter vehicles did not fare as well in crashes as larger, heavier vehicles, on average. Although The agency now uses attribute-based standards, in part to reduce or eliminate the incentive to downsize vehicles to comply with CAFE standards, the agency must be mindful of the possibility of related safety trade-offs.

For this proposed rule, the agency employed the modeling technique developed in the 2016 Puckett and Kindelberger report to analyze the updated crash and exposure data by examining the cross sections of the societal fatality rate per billion vehicle miles of travel (VMT) by mass and footprint, while controlling for driver age, gender, and other factors, in separate logistic regressions for five vehicle groups and nine crash types.[370] The agency utilized the relationships between weight and safety from this analysis, expressed as percentage increases in fatalities per 100-pound weight reduction (which is how mass reduction is applied in the technology analysis; see Section III.D.4), to examine the weight impacts applied in this CAFE analysis. The effects of mass reduction on safety were estimated relative to (incremental to) the regulatory baseline in the CAFE analysis, across all vehicles for MY 2021 and beyond.

In computing the impact of changes in mass on safety, the agency is faced with competing challenges. Research has consistently shown that mass reduction affects ''lighter'' and ''heavier'' vehicles differently across crash types. The 2016 Puckett and Kindelberger report found mass reduction concentrated among the heaviest vehicles is likely to have a beneficial effect on overall societal fatalities, while mass reduction concentrated among the lightest vehicles is likely to have a detrimental effect on fatalities. 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. Mass reduction in heavier vehicles is more beneficial to the occupants of lighter vehicles than it is harmful to the occupants of the heavier vehicles. Mass reduction in lighter vehicles is more harmful to the occupants of lighter vehicles than it is beneficial to the occupants of the heavier vehicles.

To accurately capture the differing effect on lighter and heavier vehicles, the agency splits vehicles into lighter and heavier vehicle classifications in the analysis. However, this poses a challenge of creating statistically meaningful results. There is limited relevant crash data to use for the analysis. Each partition of the data reduces the number of observations per vehicle classification and crash type, and thus reduces the statistical robustness of the results. The methodology employed by the agency was designed to balance these competing forces as an optimal trade-off to accurately capture the impact of mass-reduction across vehicle curb weights and crash types while preserving the potential to identify robust estimates.

Comments on the NPRM (83 FR 42986, August 24, 2018) for the 2020 CAFE rule included suggestions that the sample of LTVs in the analysis should not include the medium- or heavy-duty (*i.e.,* truck-based vehicles with GVWR above 8,500 pounds) equivalents of light-duty vehicles in the sample (*e.g.,* Ford F–250 versus F–150, RAM 2500 versus RAM 1500, Chevrolet Suburban 2500 versus Chevrolet Suburban 1500), or Class 2b and 3 vehicles. For the proposal, NHTSA explored revising the analysis consistent with such comments. The process involved two key analytical steps: (1) Removing all case vehicles from the analysis whose GVWR exceeded 8,500 pounds; and (2) re-classifying all crash partners with GVWR above 8,500 pounds as heavy vehicles. The direct effects of these changes are: (1) The range of curb weights in the LTV sample is reduced, lowering the median curb weight from 5,014 pounds to 4,808 pounds; (2) the sample size of LTVs is reduced (the number of case LTVs under this alternative specification is approximately 18 percent lower than in the central analysis); and (3) the relative impact of crashes with LTVs on overall impacts on societal fatality rates decreases, while the corresponding impact of crashes with heavy vehicles increases.

The results from the exploratory analysis of this alternative approach are provided in Table III–41. The agency seeks comment on this alternative approach; public comment will inform the decision whether to incorporate the results into the CAFE Model. The primary functional change offered by the alternative approach is that the sample of vehicles classified as LTVs would be restricted to vehicles that would be subject to CAFE regulations. At the statistical level, the concerns raised in the agency's response to comment on the 2018 CAFE NPRM remain. In particular, including Class 2b and 3 vehicles in the analysis to determine the relationship of vehicle mass on safety has the added benefit of improving correlation constraints. Notably, curb weight increases faster than footprint for large light trucks and Class 2b and 3 pickup trucks and SUVs, in part because the widths of vehicles are constrained more tightly (*i.e.,* due to lane widths) than their curb weights. Including data from Class 2b and 3 pick-up truck and SUV fatal crashes provides data over a wider range of vehicle weights, which improves the ability to estimate the mass-crash fatality relationship. That is, by extending the footprint-curb weight-fatality data to include Class 2b and 3 trucks that are functionally and structurally similar to corresponding ½-ton models that are subject to CAFE regulation, the sample size and ranges of curb weights and footprint are improved. Sample size is a challenge for estimating relationships between curb weight and fatality risk for individual crash types in the main analysis; dividing the sample further or removing observations makes it increasingly difficult to identify meaningful estimates and the relationships that are present in the data, as shown in the sensitivity analysis below. For the proposal, the agency has determined that the benefit of the additional data points outweighs the concern that some of the vehicles used to determine the mass-safety coefficients are not regulated by CAFE vehicles.

The agency also explored three other alternative model specifications that are presented in Table III–41. The first alternative centers on aligning CUVs and minivans with the rest of the sample, by splitting these vehicles into two weight classes. The key factor restricting this change historically has been a low sample size for these vehicles; the exploratory analysis examined whether the current database (which, due to the range of CYs covered, contains a smaller share of CUVs and

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[370] Puckett, S.M. and Kindelberger, J.C. (2016, June). Relationships between Fatality Risk, Mass, and Footprint in Model Year 2003–2010 Passenger Cars and LTVs—Preliminary Report. (Docket No. 2016–0068). Washington, DC: National Highway Traffic Safety Administration.

minivans than the current fleet) contains a sufficient sample size to evaluate two weight classes for CUVs and minivans. A complicating factor in this analysis is that minivans tend to have higher curb weights than other CUVs, adding statistical burden in identifying meaningful effects of mass on societal fatality rates after accounting for body type in the weight class with the fewest minivans (*i.e.,* lighter CUVs and minivans).

The second alternative centers on aligning passenger cars with the rest of the sample by including cars that are equipped with all-wheel drive (AWD). In previous analyses, passenger cars with AWD were excluded from the analysis because they represented a sufficiently low share of the vehicle fleet that statistical relationships between AWD status and societal fatality risk were highly prone to being conflated with other factors associated with AWD status (*e.g.,* location, luxury vehicle status). However, the share of AWD passenger cars in the fleet has grown. Approximately one-quarter of the passenger cars in the database have AWD, compared to an approximately five-percent share in the MY 2000–2007 database. Furthermore, all other vehicle types in the analysis include AWD as an explanatory variable. Thus, the agency finds the inclusion of a considerable portion of the real-world fleet (*i.e.,* passenger cars with AWD) to be a meaningful consideration.

The third alternative is a minor procedural question: Whether to expand the CYs and MYs used to identify the distribution of fatalities across crash types. The timing of the safety databases places the years of the analysis used to establish the distribution of fatalities by crash type firmly within the central years of the economic downturn of the late 2000s and early 2010s. During these years, travel demand was below long-term trends, resulting in fewer crashes. In turn, applying the same window of CYs and MYs to the identification of the distribution of fatalities across crash types results in notably fewer crashes to incorporate into the analysis. The agency conducted exploratory analysis on the question of whether to add CYs and MYs to the range of crashes used to identify the distribution of fatalities across crash types; this analysis was conducted in concert with the two alternatives discussed directly above. Results incorporating these three alternatives are presented in Table III–41.

Table III-41 – Fatality Increase (%) per 100-Pound Mass Reduction While Holding Footprint Constant with Alternative Model Specifications - MY 2004-2011, CY 2006-2012

Vehicle Class	Point Estimates, Fatalities Weighted Across MY 2008-2011 in CY 2008-2012 (Original Weights)	Point Estimates, Fatalities Weighted Across MY 2007-2011 in CY 2007-2012	Point Estimates, Fatalities Weighted Across MY 2006-2011 in CY 2006-2012	Point Estimates, Fatalities Weighted Across MY 2004-2011 in CY 2006-2012 (Full Sample)
Cars < 3,201 Pounds (including AWD)	1.12%	1.12%	1.11%	1.12%
Cars 3,201+ Pounds (including AWD)	0.89%	0.87%	0.84%	0.86%
LTVs < 4,808 Pounds (No Class 2b/3)	0.26%	0.26%	0.26%	0.29%
LTVs 4,808+ Pounds (No Class 2b/3)	-0.16%	-0.17%	-0.16%	-0.17%
CUVs and Minivans < 3,955 Pounds	0.20%	0.19%	0.18%	0.18%
CUVs and Minivans 3,955+ Pounds	-0.52%	-0.52%	-0.53%	-0.51%

Under the alternative specification excluding Class 2b and Class 3 truck-based vehicles as case vehicles, the median curb weight for LTVs is 4,808 pounds, or 206 pounds lighter than in the central analysis. When splitting CUVs and minivans into two weight classes, the median curb weight for the vehicles is 3,955 pounds. Under this alternative specification, where Class 2b and Class 3 truck-based crash partners are shifted from truck-based LTVs to heavy-duty vehicles, the median curb weight for LTV crash partners is 4,216 pounds, or 144 pounds lighter than in the central analysis.

Re-classifying Class 2b and Class 3 truck-based vehicles has a strong effect on the point estimate for heavier LTVs. Critically, removing the heaviest trucks as case vehicles yields a much smaller point estimate (reduction in societal fatality rates of between 0.16% and 0.17% per 100-pound mass reduction, versus 0.61% in the central analysis). This result is consistent with a relationship where a key share of the sensitivity of fatality risk is attributed to the mass of the heaviest vehicles in the fleet (*i.e.,* supporting the role of mass dispersion in societal fatality rates). Importantly, the point estimate for lighter LTVs is not meaningfully different from the corresponding estimate in the central analysis (increase in societal fatality rates of between 0.26% and 0.29% per 100-pound mass reduction, versus 0.3% in the central analysis). Considered in concert, these results indicate that the most effective reductions in societal fatality rates via mass reduction in truck-based vehicles would arise not from lightweighting the heaviest vehicles subject to CAFE regulation, but rather from lightweighting similar, medium- and heavy-duty vehicles.

Including passenger cars with AWD in the analysis has little effect on the point estimate for lighter passenger cars (increase in societal fatality rates of approximately 1.1% per 100-pound mass reduction, versus 1.2% in the central analysis). However, this revision has a strong effect on the point estimate for heavier passenger cars (increase in societal fatality rates of between 0.84% and 0.89% per 100-pound mass reduction, versus 0.42% in the central analysis). This result supports a hypothesis that, after taking AWD status into account, mass reduction in heavier passenger cars is a more important driver of societal fatality rates than previously estimated. Although this result could be spurious, estimated confidence bounds (presented below) indicate that accounting for AWD status reduces uncertainty in the point estimate. The agency seeks comment on the inclusion of passenger cars with AWD when estimating the effects of mass reduction on societal fatality rates.

Splitting CUVs and minivans into two vehicle classes yields point estimates that are consistent with the point estimate for the consolidated CUV-minivan vehicle class (an average decrease in societal fatality rates of approximately 0.16% to 0.18% per 100-pound mass reduction across the two vehicle classes, versus a decrease of 0.25% in the central analysis). However, sample sizes half as large in the two vehicle classes relative to the consolidated vehicle class lead to very large estimated confidence bounds, as shown below. Due to this uncertainty, The agency does not feel that the current databases contain a large enough sample of CUVs and minivans to split these vehicles into two classes in the analysis; however, this issue will be re-examined when the next iteration of the databases is complete.

Extending the range of CYs and MYs used to establish the distribution of fatalities across crash types has a negligible effect on the point estimates. Based on the narrow ranges of results in Table III–41, The agency finds evidence supporting a flexible approach in the choice of CYs and MYs used in this manner. All else being equal, extending the range helps to mitigate the potential for individual crash types with large estimated effects to drive spurious effects on overall estimates through unrepresentatively high estimated shares of overall fatalities. As a hedge in this direction, the agency applied the estimates from the alternative specification with two additional CYs and MYs (*i.e.,* the second column from the right in Table III–41) when evaluating 95-percent confidence bounds for the alternative models considered here. The agency seeks comment on this approach to representing the distribution of fatalities across crash types.

A more detailed description of the mass-safety analysis can be found in Chapter 7 of the accompanying TSD.

2. Sales/Scrappage Impacts

The sales and scrappage responses to higher vehicle prices discussed in Section III.E.2 have important safety consequences and influence safety through the same basic mechanism, fleet turnover. In the case of the scrappage response, delaying fleet turnover keeps drivers in older vehicles which tend to be less safe than newer vehicles.[371] Similarly, the sales response slows the rate at which newer vehicles, and their associated safety improvements, enter the on-road population. The sales response also influences the mix of vehicles on the road—with more stringent CAFE standards leading to a higher share of light trucks sold in the new vehicle market, assuming all else is equal. This occurs because there is diminishing value to marginal improvements in fuel economy (there are fewer gallons to be saved), and as the difference in consumption between light trucks and passenger cars diminishes, the other attributes of the trucks will likely lead to increases in their market share—especially under lower gas prices. Light trucks have higher rates of fatal crashes when interacting with passenger cars and, as earlier discussed, different directional responses to mass reduction technology based on the existing mass and body style of the vehicle.

Any effects on fleet turnover (either from delayed vehicle retirement or deferred sales of new vehicles) will affect the distribution of both ages and model years present in the on-road 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 total number of on-road fatalities under each regulatory alternative. Similarly, the dynamic fleet share model captures the changes in the fleet's composition of cars and trucks. As cars and trucks have different fatality rates, differences in fleet composition across the alternatives will affect fatalities.

At the highest level, the agency calculates the impact of the sales and scrappage effects by multiplying the VMT of a vehicle by the fatality risk of that vehicle. For this analysis, calculating VMT is rather simple: The agency uses the distribution of miles calculated in TSD Chapter 4.3. The trickier aspect of the analysis is creating fatality rate coefficients. The fatality risk measures the likelihood that a vehicle will be involved in a fatal accident per mile driven. The agency calculates the fatality risk of a vehicle based on the vehicle's model year, age, and style, while controlling for factors which are independent of the intrinsic nature of the vehicle, such as behavioral characteristics. Using this same approach, the agency designed separate models for fatalities, non-fatal injuries, and property damaged vehicles.

The fatality risk projections described above capture the historical evolution of safety. Given that modern technologies are proliferating faster than ever and offer greater safety benefits than traditional safety improvements, the agency augmented the fatality risk projections with knowledge about forthcoming safety improvements. The agency applied detailed empirical estimates of the market uptake and improving effectiveness of crash avoidance technologies to estimate their effect on the fleet-wide fatality rate, including explicitly incorporating both the direct effect of those technologies on the crash involvement rates of new vehicles equipped with them, as well as the ''spillover'' effect of those technologies on improving the safety of occupants of vehicles that are not equipped with these technologies.[372]

The agency's approach to measuring these impacts is to derive effectiveness rates for these advanced crash-avoidance technologies from safety technology literature. The agency then applies these effectiveness rates to specific crash target populations for

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[371] *See* Passenger Vehicle Occupant Injury Severity by Vehicle Age and Model Year in Fatal Crashes, Traffic Safety Facts Research Note, DOT–HS–812–528, National Highway Traffic Safety Administration, April, 2018, and The Relationship Between Passenger Vehicle Occupant Injury Outcomes and Vehicle Age or Model Year in Police-Reported Crashes, Traffic Safety Facts Research Note, DOT–HS–812–937, National Highway Traffic Safety Administration, March, 2020.

[372] These technologies included Forward Collision Warning (FCW), Crash Imminent Braking (CIB), Dynamic Brake Support (DBS), Pedestrian AEB (PAEB), Rear Automatic Braking, Semi-automatic Headlamp Beam Switching, Lane Departure Warning (LDW), Lane Keep Assist (LKA), and Blind Spot Detection (BSD). While Autonomous vehicles offer the possibility of significantly reducing or eventually even eliminating the effect of human error in crash causation, a contributing factor in roughly 94% of all crashes, there is insufficient information and certainty regarding autonomous vehicles eventual impact to include them in this analysis.

which the crash avoidance technology is designed to mitigate and adjusted to reflect the current pace of adoption of the technology, including the public commitment by manufactures to install these technologies. The products of these factors, combined across all 6 advanced technologies, produce a fatality rate reduction percentage that is applied to the fatality rate trend model discussed above, which projects both vehicle and non-vehicle safety trends. The combined model produces a projection of impacts of changes in vehicle safety technology as well as behavioral and infrastructural trends. A much more detailed discussion of the methods and inputs used to make these projections of safety impacts from advanced technologies is included in Chapter 7 of the accompanying 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. They are a freely chosen activity resulting from reduced vehicle operational costs. As such, the agencies believe 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 consumers internalize 90 percent of this risk, which mostly offsets the societal impact of any added fatalities from this voluntary consumer choice. Additional discussion of internalized risk is contained in TSD Chapter 7.4.

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 value of a statistical life (VSL) as well as economic consequences such as medical and emergency care, insurance administrative costs, legal costs, and other economic impacts not captured in the VSL alone. These values were derived from data in Blincoe et al. (2015), adjusted to 2018 dollars, and updated to reflect the official DOT guidance on the value of a statistical life. 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, the agency applied a KABCO[373]/maximum abbreviated injury scale (MAIS) translator to GES KABCO based injury counts from 2010 through 2015. This produced the MAIS based injury profile. This profile was used to weight nonfatal injury unit costs derived from Blincoe et al., adjusted to 2018 economics and updated to reflect the official DOT guidance on the value of a statistical life. Property-damaged vehicle costs were also taken from Blincoe et al. and adjusted to 2018 economics. VSL does not affect property damage. This gives societal values of $10.8 million for each fatality, $132,000 for each nonfatal injury, and $7,100 for each property damaged vehicle.

5. Impacts of the Proposal on Safety

Table III–42 through Table III–44 summarize the safety impacts of the proposed standards on safety broken down by factor. These impacts are summarized over the lifetimes of model year 1981 through 2029 vehicles for all light passenger vehicles (including passenger cars and light trucks). Economic impacts are shown separately under both 3% and 7% discount rates. Model years 1981 through 2029 were examined because they represent the model years that might be affected by shifts in fleet composition due to the impact of higher new vehicle prices on sales of new vehicles and retention of older vehicles. Earlier years will be affected by slower scrappage rates and we expect the impacts of these standards will be fully realized in vehicle designs by MY 2029.

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[373] The ''KABCO'' injury scale also can be used for establishing crash costs. This scale was developed by the National Safety Council (NSC) and is frequently used by law enforcement for classifying injuries: K—Fatal; A—Incapacitating injury; B—Non-incapacitating injury; C—Possible injury; and O—No injury.

Table III-42 – Change in Safety Parameters from Alternative 0 (Baseline) for MY 1981-2029 for Total Fleet, 3% Percent Discount Rate, by Alternative

Alternative:	1	2	3
Fatalities			
Fatalities from Mass Changes	64	115	142
Fatalities from Rebound Effect	449	584	801
Fatalities from Sales/Scrappage	506	1,123	1,681
Total Changes in Fatalities	1,019	1,822	2,624
Fatality Costs ($b)			
Fatality Costs from Mass Changes	0.4	0.8	1.0
Fatality Costs from Rebound Effect	3.0	3.9	5.4
Fatality Costs from Sales/Scrappage	4.4	9.8	14.8
Total - Fatality Costs ($b)	7.8	14.5	21.1
Non-Fatal Crash Costs ($b)			
Non-Fatal Crash Costs from Mass Changes	0.5	0.9	1.1
Non-Fatal Crash Costs from Rebound Effect	3.2	4.3	5.9
Non-Fatal Crash Costs from Sales/Scrappage	1.2	2.8	4.1
Total - Non-Fatal Crash Costs ($b)	4.9	8.0	11.1
Property Damage Costs ($b)			
Property Damage Costs from Mass Changes	0.1	0.2	0.2
Property Damage Costs from Rebound Effect	0.7	0.9	1.2
Property Damage Costs from Sales/Scrappage	0.2	0.5	0.7
Total - Property Damage Costs ($b)	1.0	1.6	2.2
Total Crash Costs ($b)			
Crash Costs from Mass Changes	1.0	1.9	2.3
Crash Costs from Rebound Effect	6.9	9.1	12.5
Crash Costs from Sales/Scrappage	5.8	13.0	19.6
Total - Societal Crash Costs ($b)	13.7	24.0	34.4

Table III-43 – Change in Safety Parameters from Alternative 0 (Baseline) for MY 1981-2029 for Total Fleet, 7% Percent Discount Rate, by Alternative

Alternative:	1	2	3
Fatalities			
Fatalities from Mass Changes	64	115	142
Fatalities from Rebound Effect	449	584	801
Fatalities from Sales/Scrappage	506	1,123	1,681
Total Changes in Fatalities	1,019	1,822	2,624
Fatality Costs ($b)			
Fatality Costs from Mass Changes	0.3	0.5	0.6
Fatality Costs from Rebound Effect	1.7	2.2	3.1
Fatality Costs from Sales/Scrappage	3.3	7.2	11.0
Total - Fatality Costs ($b)	5.2	9.9	14.7
Non-Fatal Crash Costs ($b)			
Non-Fatal Crash Costs from Mass Changes	0.3	0.6	0.7
Non-Fatal Crash Costs from Rebound Effect	2.0	2.7	3.7
Non-Fatal Crash Costs from Sales/Scrappage	1.0	2.3	3.5
Total - Non-Fatal Crash Costs ($b)	3.3	5.6	7.9
Property Damage Costs ($b)			
Property Damage Costs from Mass Changes	0.1	0.1	0.1
Property Damage Costs from Rebound Effect	0.4	0.6	0.8
Property Damage Costs from Sales/Scrappage	0.2	0.4	0.6
Total - Property Damage Costs ($b)	0.7	1.1	1.5
Total Crash Costs ($b)			
Crash Costs from Mass Changes	0.6	1.2	1.4
Crash Costs from Rebound Effect	4.1	5.5	7.5
Crash Costs from Sales/Scrappage	4.5	9.9	15.1
Total - Societal Crash Costs ($b)	9.2	16.6	24.0

Table III-44 – Change in Non-Fatal Safety Parameters from Alternative 0 (Baseline) for MY 1981-2029 for Total Fleet, by Alternative

Alternative:	1	2	3
Non-Fatal Injuries			
Non-Fatal Injuries from Mass Changes	5,537	10,048	12,377
Non-Fatal Injuries from Rebound Effect	36,587	48,618	66,522
Non-Fatal Injuries from Sales/Scrappage	9,723	22,269	32,249
Total Changes in Non-Fatal Injuries	51,847	80,936	111,147
Property Damaged Vehicles			
Property Damaged Vehicles from Mass Changes	21,195	38,471	47,389
Property Damaged Vehicles from Rebound Effect	139,798	185,800	254,194
Property Damaged Vehicles from Sales/Scrappage	29,900	69,638	99,711
Total Changes in Property Damaged Vehicles	190,892	293,909	401,294

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As seen in the tables, all three safety factors—changes in mass, fleet turnover, and rebound—increase as the standards become more stringent. As expected, rebound fatalities grow at a constant rate as vehicles become more fuel efficient and are used more frequently. Mass reduction has a relatively minimal impact on safety and diminishes as stringency increases. This may point to either the fleet becoming more homogeneous and hence less mass disparate in crashes. Alternatively, the model may be capturing that there's little room for more mass reductions in particular models. The slowing of fleet turnover due to higher vehicle prices has the largest impact of the three factors and accelerates with higher alternatives. Of course, if the agency's assumptions overstate the rebound effect and/or slower fleet turnover, fatalities, injuries and property damage would be lower, and vice versa.

PRIA Chapter 5.5 discusses the results of the analysis in more detail and PRIA Chapter 5.6—Safety Impacts provides an overview of sensitivity analyses performed to isolate the uncertainty parameters of each of the three safety impacts.

IV. Regulatory Alternatives Considered in this NPRM

A. Basis for Alternatives Considered

Agencies typically consider regulatory alternatives in proposals as a way of evaluating the comparative effects of different potential ways of accomplishing their desired goal. NEPA requires agencies to compare the potential environmental impacts of their proposed actions to those of a reasonable range of alternatives. Executive Orders 12866 and 13563, as well as OMB Circular A–4, also encourage agencies to evaluate regulatory alternatives in their rulemaking analyses.

Alternatives analysis begins with a ''no-action'' alternative, typically described as what would occur in the absence of any regulatory action. This proposal includes a no-action alternative, described below, and three ''action alternatives.'' The proposed standards may, in places, be referred to as the ''preferred alternative,'' which is NEPA parlance, but NHTSA intends ''proposal'' and ''preferred alternative'' to be used interchangeably for purposes of this rulemaking.

Regulations regarding implementation of NEPA require agencies to ''rigorously explore and objectively evaluate all reasonable alternatives, and for alternatives which were eliminated from detailed study, briefly discuss the reasons for their having been eliminated.'' This does not amount to a requirement that agencies evaluate the widest conceivable spectrum of alternatives. Rather, the range of alternatives must be reasonable and consistent with the purpose and need of the action.

The different regulatory alternatives are defined in terms of percent-increases in CAFE stringency from year to year. Readers should recognize that those year-over-year changes in stringency are not measured in terms of mile per gallon differences (as in, 1 percent more stringent than 30 miles per gallon in one year equals 30.3 miles per gallon in the following year), but rather in terms of shifts in the footprint functions that form the basis for the actual CAFE standards (as in, on a gallon per mile basis, the CAFE standards change by a given percentage from one model year to the next). Under some alternatives, the rate of change is the same from year to year, while under others, it differs, and under some alternatives, the rate of change is different for cars and for trucks. One action alternative is more stringent than the proposal, while one is less stringent than the proposal. The alternatives considered in this proposal represent a reasonable range of possible final agency actions.

B. Regulatory Alternatives and Proposed CAFE Standards for MYs 2024–2026

The regulatory alternatives for this proposal are presented here as the percent-increases-per-year that they represent. The sections that follow will present the alternatives as the literal coefficients which define standards curves increasing at the given percentage rates and will also further explain the basis for the alternatives selected.

Table IV-1 – Regulatory Alternatives Considered in this Proposal

Regulatory Alternative	Year-Over-Year Stringency Increases (Passenger Cars)			Year-Over-Year Stringency Increases (Light Trucks)		
	2024	2025	2026	2024	2025	2026
Alternative 0 (No Action)	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%
Alternative 1	9.14%	3.26%	3.26%	11.02%	3.26%	3.26%
Alternative 2 (Preferred)	8%	8%	8%	8%	8%	8%
Alternative 3	10%	10%	10%	10%	10%	10%

As for past rulemaking analyses, NHTSA has analyzed each of the regulatory alternatives in a manner that estimates manufacturers' potential application of technology in response to the corresponding CAFE requirements and the estimated market demand for fuel economy, considering estimated fuel prices, estimated product development cadence, and the estimated availability, applicability, cost, and effectiveness of fuel-saving technologies. The analysis sometimes shows that specific manufacturers could increase CAFE levels beyond requirements in ways estimated to "pay buyers back" very quickly (*i.e.,* within 30 months) for the corresponding additional costs to purchase new vehicles through avoided fuel outlays. Consistent with the analysis published with the 2020 final rule, this analysis shows that if battery costs decline as projected while fuel prices increase as projected, BEVs should become increasingly attractive on this basis, such that the modeled application of BEVs (and some other technologies) clearly outstrips regulatory requirements after the mid-2030s.

The analysis accompanying the 2020 final rule presented such results for CAFE standards as well as—separately—CO_2 standards. New in this proposal, DOT has modified the CAFE Model to account for the *combined* effect of both CAFE and CO_2 standards, simulating technology application decisions each manufacturer could possibly make when faced with both CAFE standards and CO_2 standards (and also estimated market demand for fuel economy). This capacity was exercised for purposes of creating the baseline against which alternatives were analyzed, but not for purposes of modeling compliance with both agencies' proposals. Also, new for this proposal, DOT has further modified the CAFE Model to account for the "Framework" agreements California has reached with BMW, Ford, Honda, Volkswagen, and Volvo, and for the ZEV mandate that California and the "Section 177" states have adopted. The TSD elaborates on these new model capabilities. Generally speaking, the model treats each manufacturer as applying the following logic when making technology decisions:

1. What do I need to carry over from last year?
2. What should I apply more widely in order to continue sharing (of, *e.g.,* engines) across different vehicle models?
3. What new PHEVs or BEVs do I need to build in order to satisfy the ZEV mandates?
4. What further technology, if any, could I apply that would enable buyers to recoup additional costs within 30 months after buying new vehicles?
5. What additional technology, if any, should I apply in order to respond to CAFE and CO_2 standards?

All of the regulatory alternatives considered here include, for passenger cars, the following coefficients defining the combination of baseline Federal CO_2 standards and the California Framework agreement.

Table IV-2 – Passenger Car CO_2 Target Function Coefficients

	2022	2023	2024	2025	2026
a (g/mi)	159	156	154	151	149
b (g/mi)	217	214	210	207	203
c (g/mi per s.f.)	3.88	3.82	3.77	3.71	3.65
d (g/mi)	-0.1	-0.4	-0.6	-0.9	-1.2
e (s.f.)	41	41	41	41	41
f (s.f.)	56	56	56	56	56
g (g/mi)	151	146	140	135	130
h (g/mi)	207	199	192	185	178
i (g/mi per s.f.)	3.70	3.56	3.43	3.30	3.18
j (g/mi)	-0.4	-0.4	-0.4	-0.3	-0.3

Coefficients *a, b, c, d, e,* and *f* define the current Federal CO_2 standards for passenger cars. Analogous to coefficients defining CAFE standards, coefficients *a* and *b* specify minimum and maximum passenger car CO_2 targets in each model year. Coefficients *c* and *d* specify the slope and intercept of the linear portion of the CO_2 target function, and coefficients *e* and *f* bound the region within which CO_2 targets are defined by this linear form. Coefficients *g, h, i,* and *j* define the CO_2 targets applicable to BMW, Ford, Honda, Volkswagen, and Volvo, pursuant to the agreement these manufacturers have reached with California. Beyond 2026, the MY 2026 Federal standards apply to all manufacturers, including these five manufacturers. The coefficients shown in Table IV–3 define the corresponding CO_2 standards for light trucks.

Table IV-3 – Light Truck CO_2 Target Function Coefficients

	2022	2023	2024	2025	2026
a (g/mi)	203	200	196	193	190
b (g/mi)	324	319	314	309	304
c (g/mi per s.f.)	4.44	4.37	4.31	4.23	4.17
d (g/mi)	20.6	20.2	19.6	19.6	19.0
e (s.f.)	41	41	41	41	41
f (s.f.)	74	74	74	74	74
g (g/mi)	188	181	175	168	162
h (g/mi)	322	310	299	288	277
i (g/mi per s.f.)	4.12	3.97	3.82	3.68	3.54
j (g/mi)	19.1	18.4	17.7	17.0	16.4

All of the regulatory alternatives considered here also include NHTSA's estimates of ways each manufacturer could introduce new PHEVs and BEVs in response to ZEV mandates. As discussed in greater detail below, these estimates force the model to convert specific vehicle model/configurations to either a BEV200, BEV300, or BEV400 at the earliest estimated redesign. These ''ZEV Candidates'' define an *incremental* response to ZEV mandates (*i.e.,* beyond PHEV and BEV production through MY 2020) comprise the following shares of manufacturers' MY 2020 production for the U.S. market as shown in Table IV–4.

Table IV-4 – ZEV "Candidates" as Share of MY 2020 Production

Manufacturer	BEV200	BEV300	BEV400
BMW		1.9%	
Daimler	2.6%		0.8%
FCA		1.1%	
Ford	0.1%	1.1%	
GM		1.0%	
Honda		1.8%	
Hyundai		1.3%	
Kia	1.7%	0.5%	
Jaguar – Land Rover	0.2%	1.4%	
Mazda	3.1%		
Mitsubishi	0.6%	1.2%	
Nissan		0.5%	
Subaru		2.2%	
Tesla			
Toyota	1.2%	0.7%	
Volvo	2.3%	0.7%	
VWA		1.5%	

For example, while Tesla obviously need not introduce additional BEVs to comply with ZEV mandates, our analysis indicates Nissan could need to increase BEV offerings modestly to do so, and Mazda and some other manufacturers may need to do considerably more than Nissan to introduce new BEV offerings.

This representation of CO_2 standards and ZEV mandates applies equally to all regulatory alternatives, and NHTSA's analysis applies the CAFE Model to examine each alternative treating each manufacturer as responding jointly to the entire set of requirements. This is distinct from model application of BEVs for compliance purposes under the compliance simulations of the different action alternatives which inform decision-makers regarding potential effects of the standards.

Chapter 1 of the TSD contains extensive discussion of the development of the No-Action Alternative, and explains the reasons for and effect of apparent ''over-compliance'' with the No-Action Alternative, which reduces costs and benefits attributable to the proposed CAFE standards and other action alternatives. NHTSA seeks comment broadly on that discussion and whether and how to change its approach to developing the No-Action Alternative for the final rule. NHTSA also specifically seeks comment on whether and how to add to the No-Action Alternative for the final rule an estimation of GHG standards that California and the Section 177 states might separately enforce if California's waiver of CAA preemption was re-established.

1. No-Action Alternative

The No-Action Alternative (also sometimes referred to as ''Alternative 0'') applies the CAFE target curves set in 2020 for MYs 2024–2026, which raised stringency by 1.5 percent per year for both passenger cars and light trucks.

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Table IV-5 – Characteristics of No-Action Alternative – Passenger Cars

	2024	2025	2026
a (mpg)	51.78	52.57	53.37
b (mpg)	38.74	39.33	39.93
c (gpm per s.f.)	0.000433	0.000427	0.000420
d (gpm)	0.00155	0.00152	0.00150

Table IV-6 – Characteristics of No-Action Alternative – Light Trucks

	2024	2025	2026
a (mpg)	41.55	42.18	42.82
b (mpg)	26.82	27.23	27.64
c (gpm per s.f.)	0.000484	0.000477	0.000469
d (gpm)	0.00423	0.00417	0.00410

These equations are presented graphically in Figure IV–1 and Figure IV–2, where the x-axis represents vehicle footprint and the y-axis represents fuel economy, showing that in ''CAFE space,'' targets are higher in fuel economy for smaller footprint vehicles and lower for larger footprint vehicles.

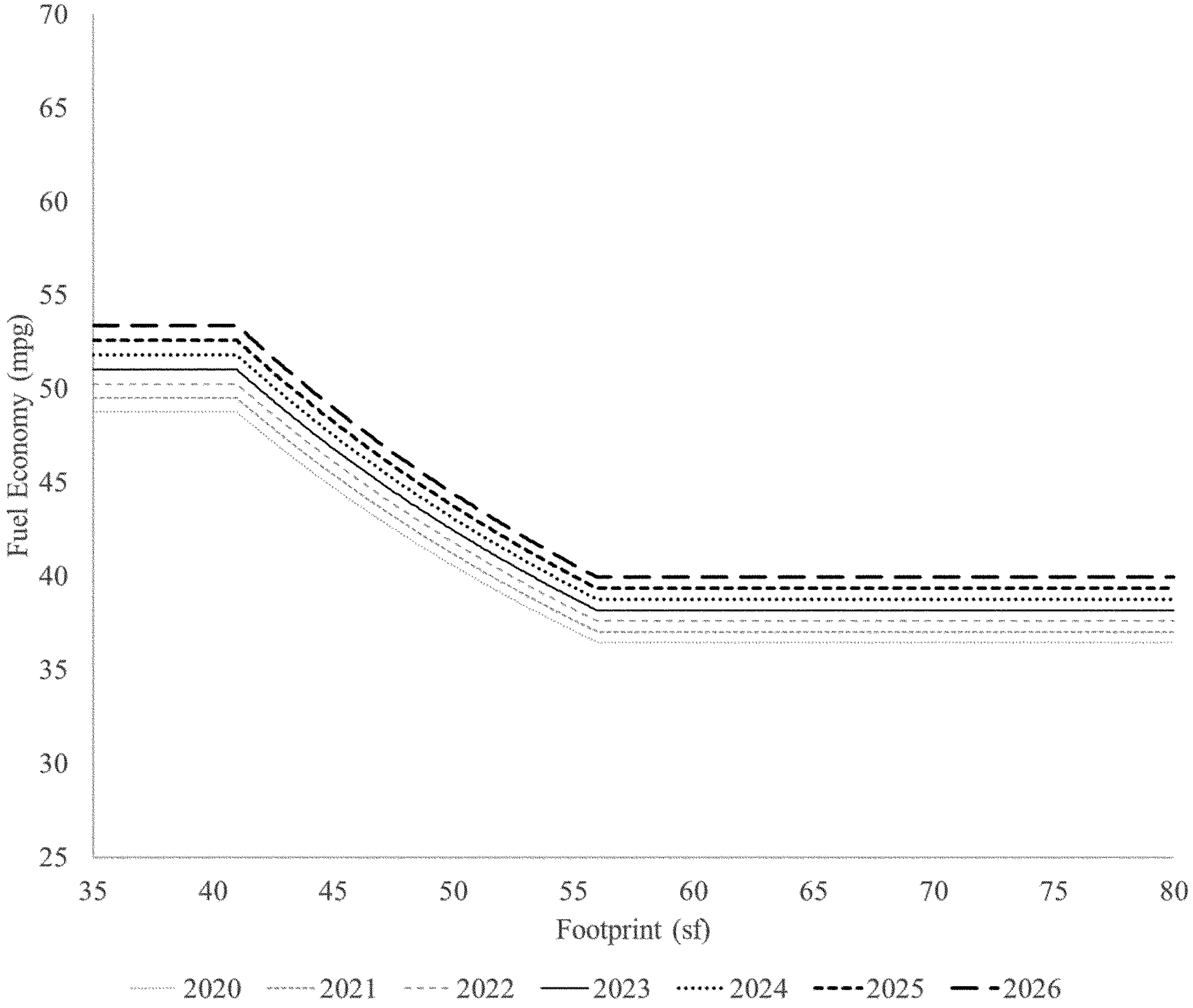

Figure IV-1 – No-Action Alternative, Passenger Car Fuel Economy Target Curves

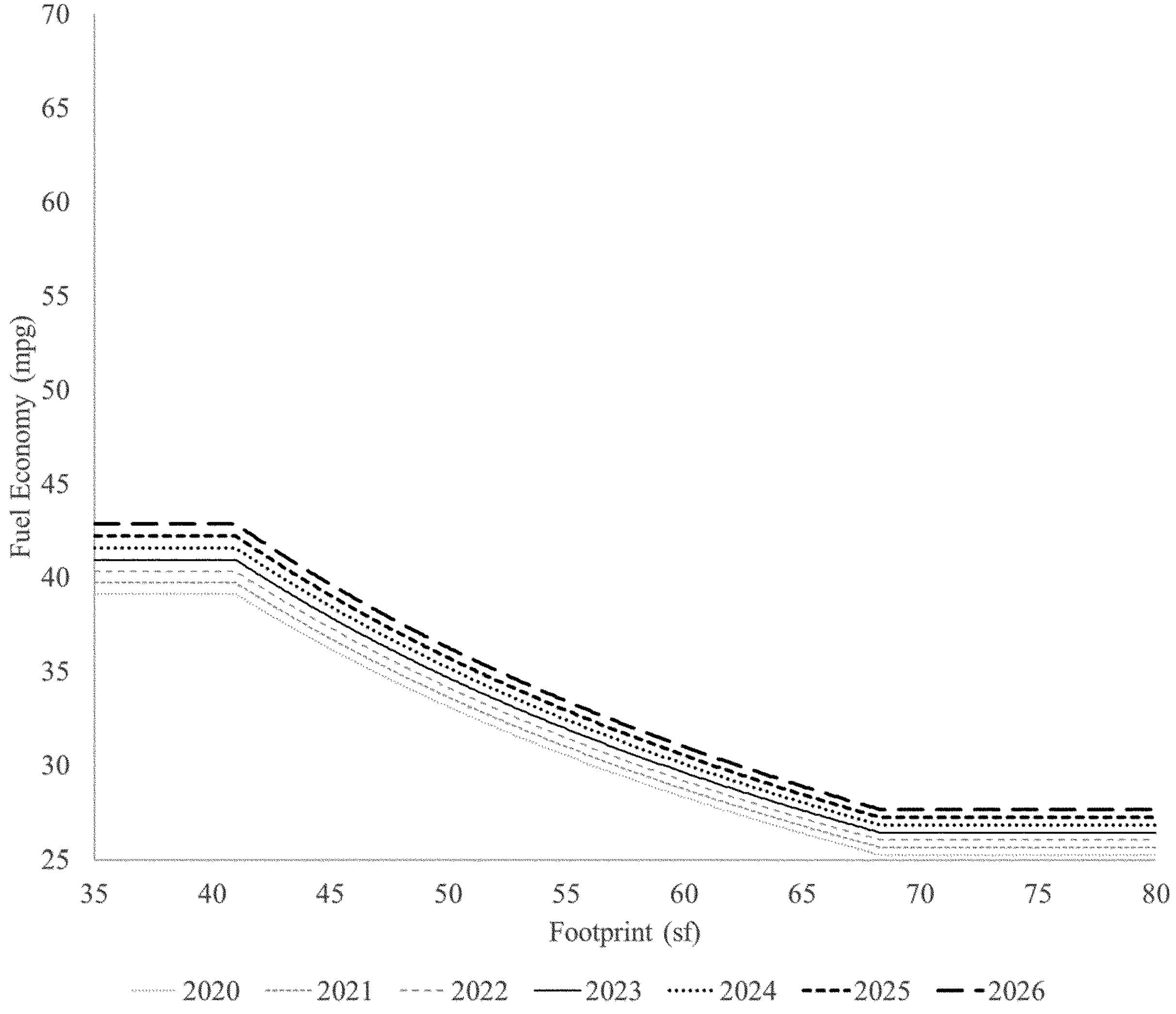

Figure IV-2 – No-Action Alternative, Light Truck Fuel Economy Target Curves

NHTSA must also set a minimum standard for domestically manufactured passenger cars, which is often referred to as the "MDPCS." Any time NHTSA establishes or changes a passenger car standard for a model year, the MDPCS must also be evaluated or re-evaluated and established accordingly, but for purposes of the No-Action alternative, the MDPCS is as it was established in the 2020 final rule, as shown in Table IV–7.

Table IV-7 – No-Action Alternative - Minimum Domestic Passenger Car Standard

2024	2025	2026
41.8 mpg	42.4 mpg	43.1 mpg

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As the baseline against which the Action Alternatives are measured, the No-Action Alternative also includes several other actions that NHTSA believes will occur in the absence of further regulatory action. First, NHTSA has included California's ZEV mandate as part of the No-Action Alternative. NHTSA has already proposed to rescind the 2019 "SAFE I" rule,[374] and EPA has reopened consideration of whether to grant California a waiver to consider its ZEV mandate,[375] although California does not currently possess a waiver of preemption under the CAA and NHTSA regulations currently purport to preempt the California ZEV program. Although neither of these actions has yet been finalized, it is reasonably foreseeable that manufacturers selling vehicles in California and in the Section 177 states could be required to comply with the ZEV mandate during the timeframe of this rulemaking. Second, NHTSA has included the agreements made between California and BMW, Ford, Honda, VWA, and Volvo, because these agreements by their terms are contracts,

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[374] 86 FR 25980 (May 12, 2021).

[375] 86 FR 22421 (Apr. 28, 2021).

even though they were entered into voluntarily.[376] NHTSA did so by including EPA's baseline (*i.e.,* 2020) GHG standards in its analysis, and introducing more stringent GHG target functions during MYs 2022–2026, but treating only these five manufacturers as subject to these more stringent target functions. Because a significant portion of the market voluntarily adopted the California framework, presumably because the manufacturers who joined believed it could be met, and because that adoption is contractually binding once entered into, it is reasonable to assume that it will occur as expected during the rulemaking timeframe, and thus, reasonable to include in the No-Action Alternative. As in past analyses, NHTSA's analysis further assumes that, beyond any technology applied in response to CAFE standards, EPA GHG standards, California/OEM agreements, and ZEV mandates applicable in California and the Section 177 states, manufacturers could also make any additional fuel economy improvements estimated to reduce owners' estimated average fuel outlays during the first 30 months of vehicle operation by more than the estimated increase in new vehicle price.

NHTSA accomplished much of this through expansion of the CAFE Model after the prior rulemaking. The previous version of the model had been extended to apply to GHG standards as well as CAFE standards but had not been published in a form that simulated simultaneous compliance with both sets of standards. As discussed at greater length in the current CAFE Model documentation, the updated version of the model simulates all the following simultaneously:

1. Compliance with CAFE standards
2. Compliance with GHG standards applicable to all manufacturers
3. Compliance with alternative GHG standards applicable to a subset of manufacturers
4. Compliance with ZEV mandates
5. Further fuel economy improvements applied if sufficiently cost-effective for buyers

Inclusion of these actions in the No-Action Alternative means that they are necessarily included in each of the Action Alternatives. That is, the impacts of all the alternatives evaluated in this proposal are against the backdrop of these State and voluntary actions by automakers. This is important to remember, because it means that automakers will be taking actions to improve fuel economy even in the absence of new CAFE standards, and that costs and benefits attributable to those actions are therefore *not* attributable to possible future CAFE standards.

2. Alternative 1

Alternative 1 would increase CAFE stringency for MY 2024 by 9.14% for passenger cars and 11.02% for light trucks and increase stringency in MYs 2025 and 2026 by 3.26% per year for both passenger cars and light trucks. NHTSA calculates that the stringency of Alternative 1 in each of MYs 2024–2026 is equivalent to the average stringency of the California framework agreement applied to all manufacturers in those model years. NHTSA calculated the stringency values using a spreadsheet, shown in TSD Chapter 1, assuming manufacturers would achieve a one percent reduction in stringency each model year under the California framework through the application of ZEV vehicle multipliers. The spreadsheet applies a normalized stringency value of 100 percent in MY 2021 for both CO_2 standards and CAFE standards.

Informed by these calculations, NHTSA defined Alternative 1 by applying the CAFE equivalent stringency increases in MYs 2024–2026, resulting in the coefficients listed in Table IV–8 and Table IV–9.

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Table IV-8 – Characteristics of Alternative 1 – Passenger Cars

	2024	2025	2026
a (mpg)	56.15	58.04	60.00
b (mpg)	42.00	43.41	44.88
c (gpm per s.f.)	0.000400	0.000387	0.000374
d (gpm)	0.00141	0.00136	0.00132

Table IV-9 – Characteristics of Alternative 1 – Light Trucks[377]

	2024	2025	2026
a (mpg)	46.17	47.73	49.34
b (mpg)	27.73	28.67	29.63
c (gpm per s.f.)	0.000436	0.000422	0.000408
d (gpm)	0.00377	0.00365	0.00353

These equations are represented graphically in Figure IV–4 and Figure IV–4.

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[376] *See https://ww2.arb.ca.gov/news/framework-agreements-clean-cars.*

[377] For this and other action alternatives, readers may note that the cutpoint for large trucks is further to the right than in the 2020 final rule. The 2020 final rule (and its preceding NPRM) did not contain an adjustment to the right cutpoint that had been finalized in 2012. Because comments were not received to the NPRM, the lack of adjustment was finalized. Considering the question again for this proposal, NHTSA believes that moving the cutpoint to the right for large trucks (consistent with the intent and requirements in 2012) is reasonable, given the rate of increase in stringency for this proposal.

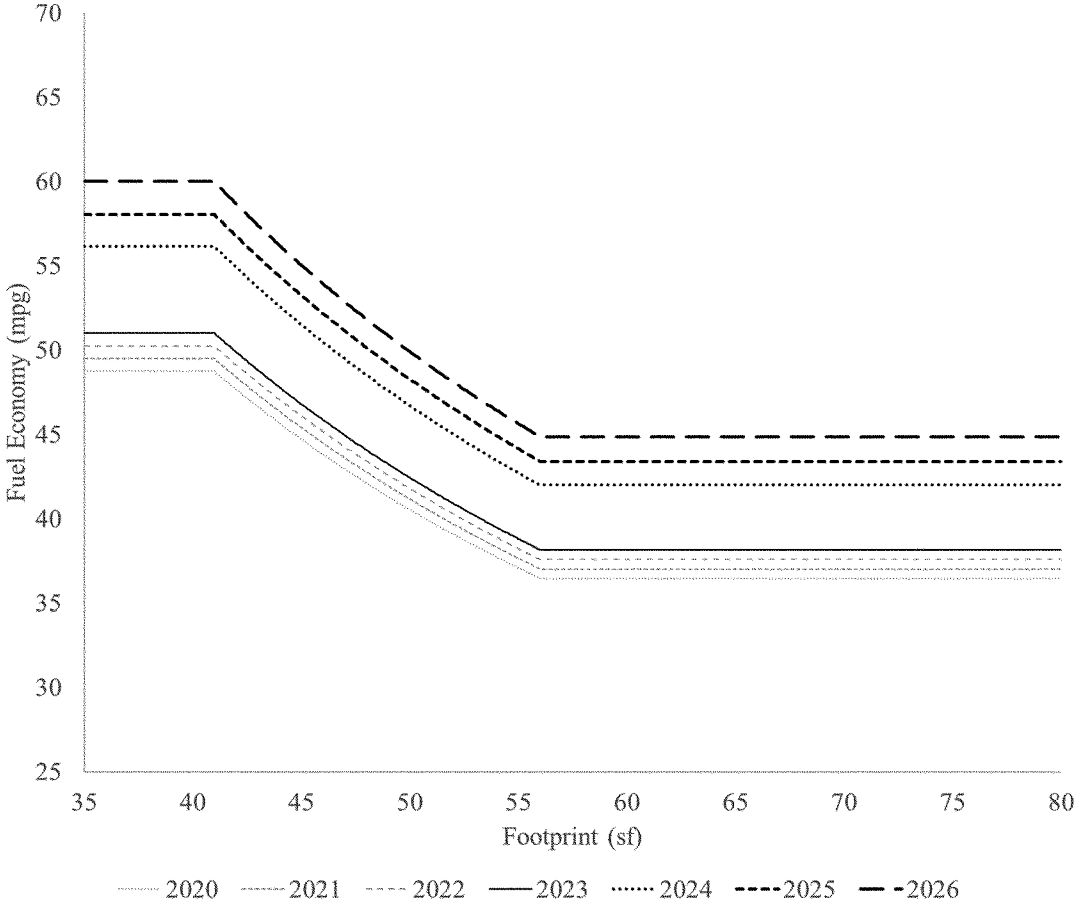

Figure IV-3 – Alternative 1, Passenger Car Fuel Economy, Target Curves

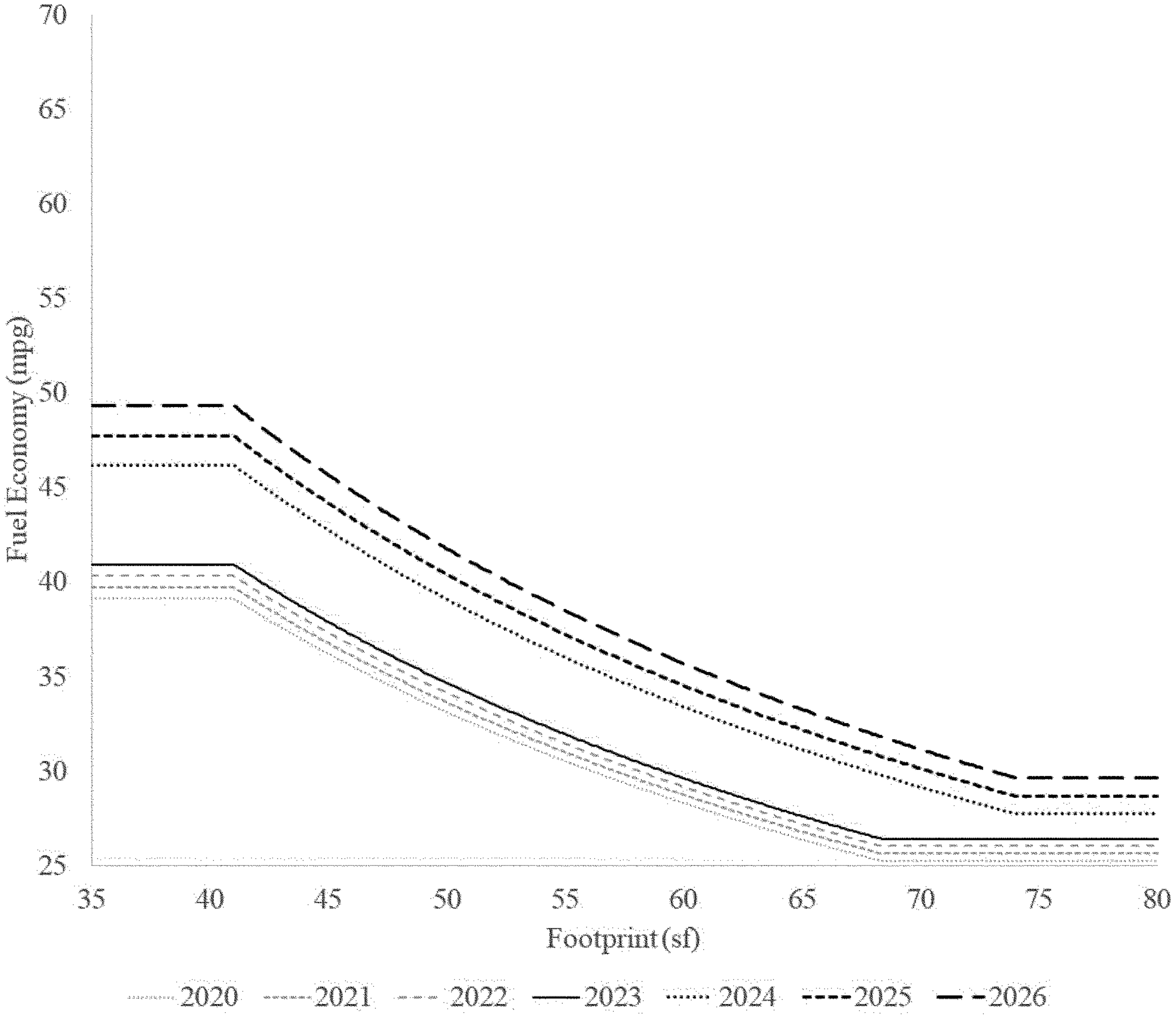

Figure IV-4 – Alternative 1, Light Truck Fuel Economy, Target Curves

Under this alternative, the MDPCS is as shown in Table IV–10.

Table IV-10 – Alternative 1 - Minimum Domestic Passenger Car Standard

2024	2025	2026
44.9 mpg	46.5 mpg	48.0 mpg

NHTSA considered this alternative as a way to evaluate the effects of industry-wide CAFE standards approximately harmonized with the California framework agreement applied to signatory OEMs' production for the U.S. market.[378] The fact that five major manufacturers voluntarily bound themselves to the framework levels, not just for MYs 2024–2026 but for MYs 2021–2026, is a relevant data point in terms of their technological feasibility and economic practicability for the fleet as a whole. NHTSA seeks comment on whether Alternative 1 (as defined by the rate of increase and the curve coefficients) appropriately captures its stated goal of approximating the fuel savings that would occur under an industry-wide application of fuel economy standards harmonized with the California framework, or whether changes might be appropriate for the final rule. NHTSA asks that commenters explain the specific technical basis for any requested changes, as well as the basis for determining that the resultant CAFE standards could meet EPCA's

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[378] CAFE standards defining this alternative reflect the fact that EPCA does not provide a basis for CAFE standards to include ''multipliers'' applicable to PHEV and/or BEV production volumes, as well as the fact that EPCA's treatment of BEV energy consumption is different from the ''0 grams/mile'' treatment for purposes of determining compliance with GHG emissions standards.

requirement that NHTSA select the maximum feasible standard for each fleet in each model year.

3. Alternative 2

Alternative 2 would increase CAFE stringency at 8 percent per year, which NHTSA calculates would result in total lifetime fuel savings from vehicles produced during MYs 2021–2029 similar to total lifetime fuel savings that would occur if the fuel economy standards harmonized with California framework agreement had applied to all manufacturers during MYs 2021–2026.

Table IV-11 – Characteristics of Alternative 2 – Passenger Cars

	2024	2025	2026
a (mpg)	55.44	60.26	65.50
b (mpg)	41.48	45.08	49.00
c (gpm per s.f.)	0.000405	0.000372	0.000343
d (gpm)	0.00144	0.00133	0.00122

Table IV-12 – Characteristics of Alternative 2 – Light Trucks

	2024	2025	2026
a (mpg)	44.48	48.35	52.56
b (mpg)	26.74	29.07	31.60
c (gpm per s.f.)	0.000452	0.000416	0.000382
d (gpm)	0.00395	0.00364	0.00334

Under this alternative, the MDPCS is as shown in Table IV–13.

Table IV-13 – Alternative 2 - Minimum Domestic Passenger Car Standard

2024	2025	2026
44.4 mpg	48.2 mpg	52.4 mpg

NHTSA considered this alternative as a way to evaluate the effects of CAFE standards that sought to achieve the fuel savings that would be achieved if fuel economy standards harmonized with the California framework agreement had been applied to all vehicle manufacturers from its beginning the time the framework was agreed. As for Alternative 1, the fact that five major manufacturers voluntarily bound themselves to these levels, not just for MYs 2024–2026 but for MYs 2021–2026, is a relevant data point in terms of their technological feasibility and economic practicability for the fleet as a whole.[379] NHTSA seeks comment on whether Alternative 2 (as defined by the rate of increase and the curve coefficients) appropriately captures its stated goal of representing the fuel savings achievement that would be achieved if fuel economy standards harmonized with the California framework agreement were applied to all companies at a national level over MYs 2021–2026, or whether changes might be appropriate for the final rule. NHTSA asks that commenters explain the specific technical basis for any requested changes, as well as the basis for determining that the resultant CAFE standards could meet EPCA's requirement that NHTSA select the maximum feasible standard for each fleet in each model year.

As another possibility, NHTSA could modify Alternative 2 by increasing the stringency of CAFE standards by 10 percent between model years 2025 and 2026, rather than by 8 percent. Shown graphically, this possibility would look as shown in Figure IV–5.

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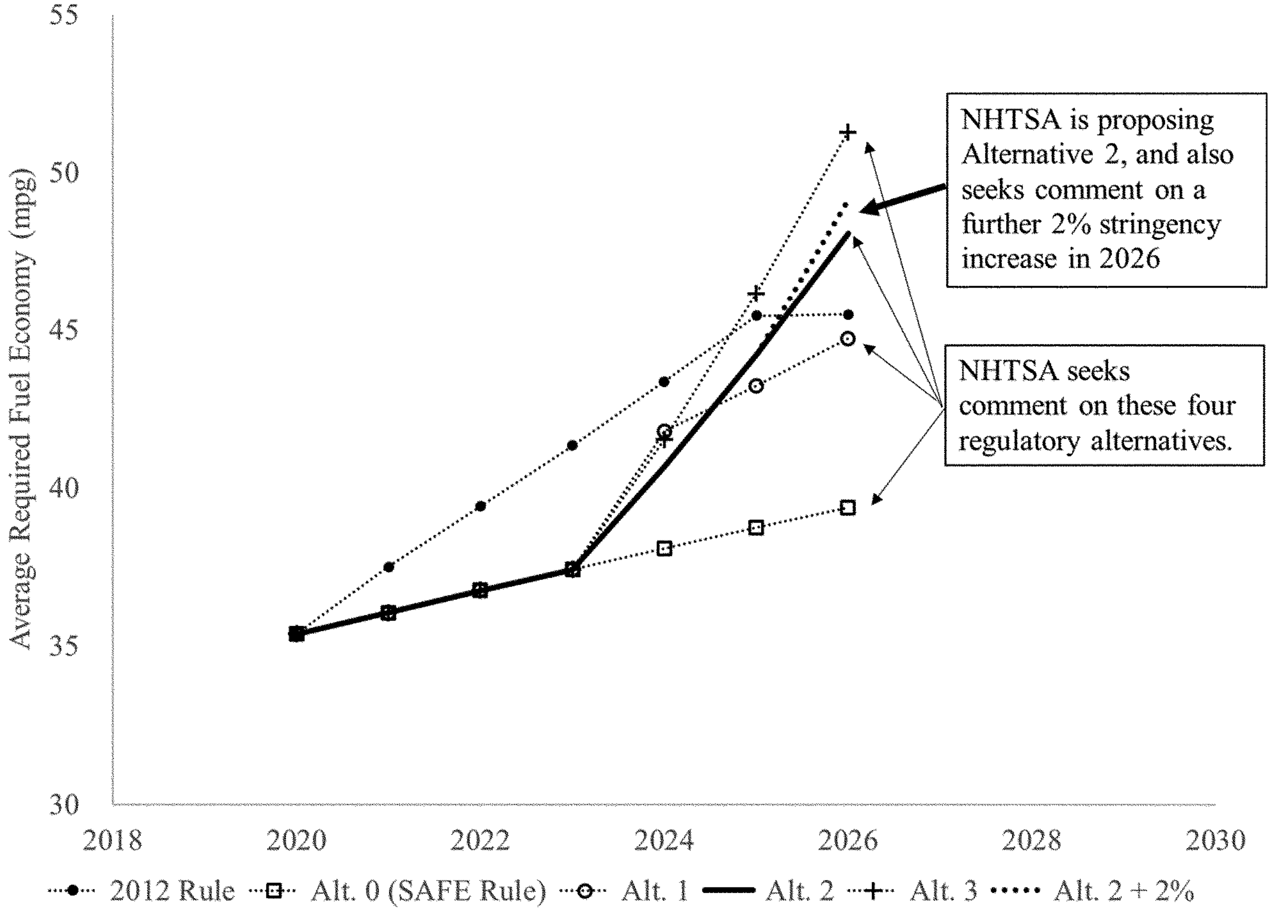
[379] Section VI discusses economic practicability in more detail, including NHTSA's long-standing interpretation that economic practicability need not mean that the standards are comfortably achievable for every single manufacturer individually, as long as they appear economically practicable for the fleet as a whole.



NHTSA is proposing Alternative 2, and also seeks comment on a further 2% stringency increase in 2026

NHTSA seeks comment on these four regulatory alternatives.

Figure IV-5 – Graphic Representation of Possible Other Alternative

NHTSA seeks comment on this option as well as on Alternative 2.

4. Alternative 3

Alternative 3 would increase CAFE stringency at 10 percent per year, which NHTSA calculates would result in total lifetime fuel savings from vehicles produced during MYs 2021–2029 similar to total lifetime fuel savings that would have occurred if NHTSA had promulgated final CAFE standards for MYs 2021–2025 at the augural levels announced in 2012 and, in addition, if NHTSA had also promulgated MY 2026 standards that reflected a continuation of that average rate of stringency increase (4.48% for passenger cars and 4.54% for light trucks).

Table IV-14 – Characteristics of Alternative 3 – Passenger Cars

	2024	2025	2026
a (mpg)	56.67	62.97	69.96
b (mpg)	42.40	47.11	52.34
c (gpm per s.f.)	0.000396	0.000356	0.000321
d (gpm)	0.00141	0.00127	0.00114

Table IV-15 – Characteristics of Alternative 3 – Light Trucks

	2024	2025	2026
a (mpg)	45.47	50.53	56.14
b (mpg)	27.34	30.38	33.75
c (gpm per s.f.)	0.000442	0.000398	0.000358
d (gpm)	0.00387	0.00348	0.00313

These equations are represented graphically in Figure IV–6 and Figure IV–7.

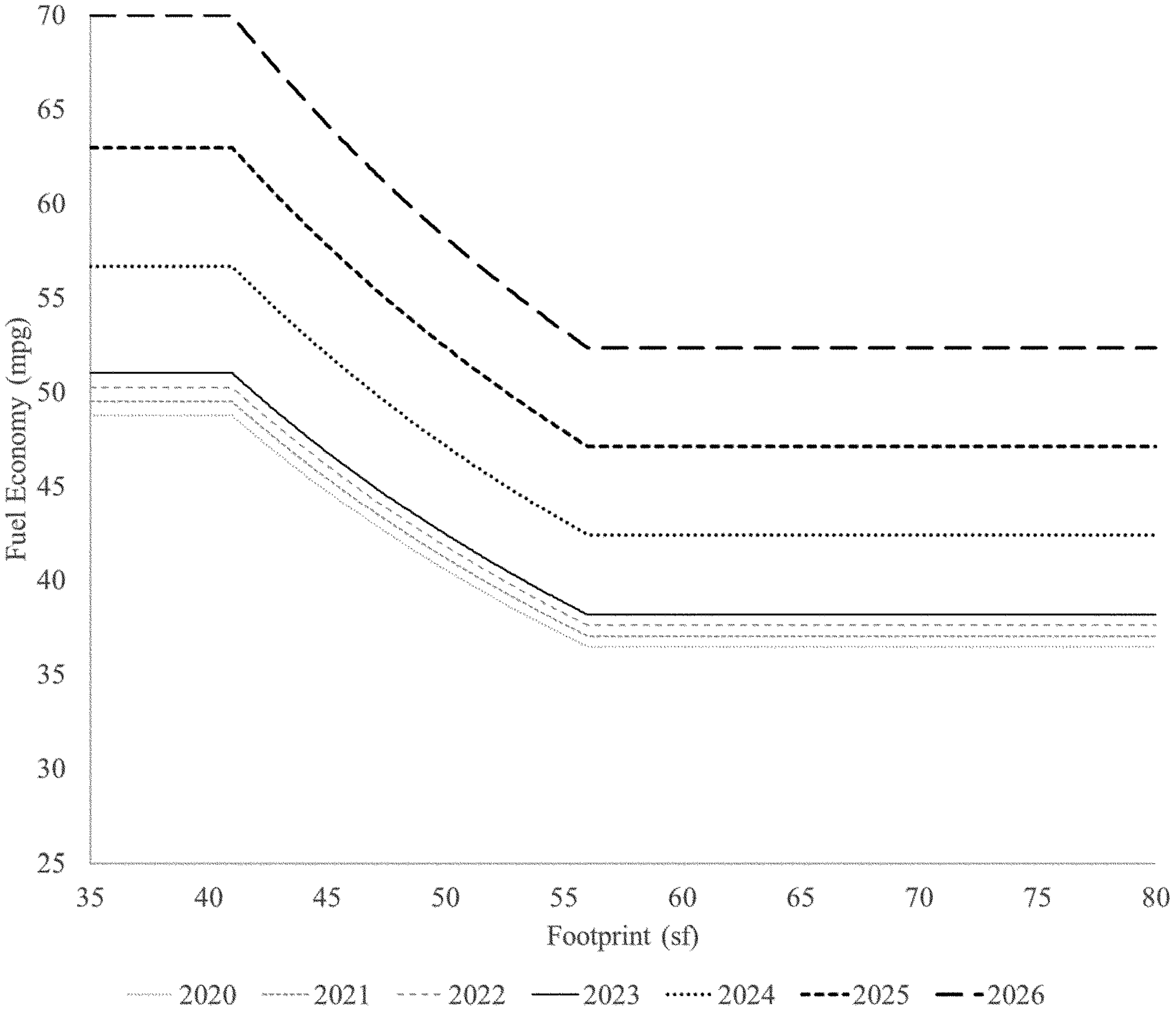


Figure IV-6 – Alternative 3, Passenger Car Fuel Economy, Target Curves

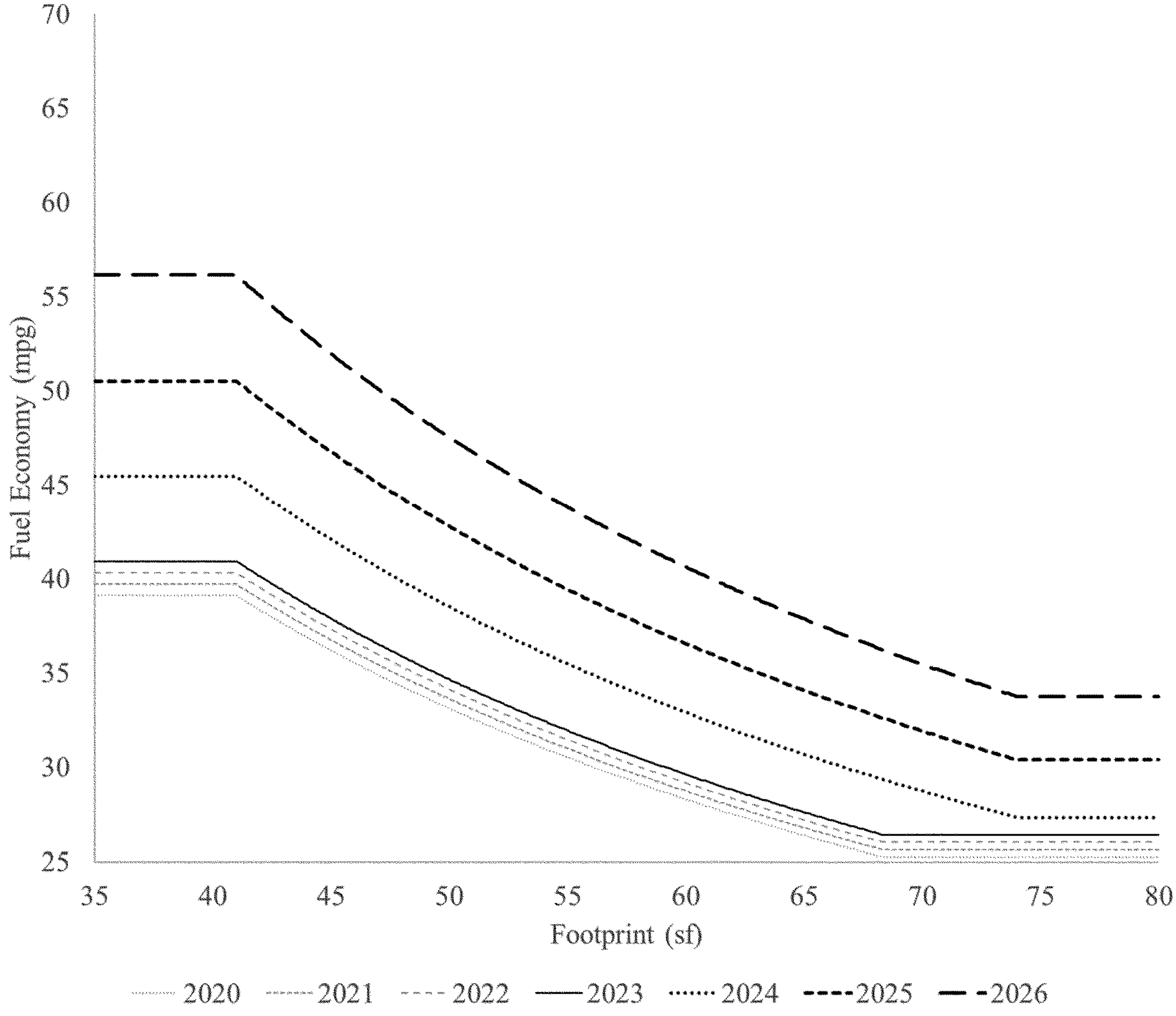


Figure IV-7 – Alternative 3, Light Truck Fuel Economy, Target Curves

Under this alternative, the MDPCS is as follows in Table IV–16.

Table IV-16 – Alternative 3 – Minimum Domestic Passenger Car Standard

2024	2025	2026
45.4 mpg	50.4 mpg	56.0 mpg

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NHTSA considered this alternative as a way to evaluate the effects of CAFE standards that would return to a fuel consumption trajectory exemplified by the standards announced in 2012. NHTSA seeks comment on whether Alternative 3 (as defined by the rate of increase and the curve coefficients) appropriately captures this goal, or whether changes might be appropriate for the final rule. NHTSA asks that commenters explain the specific technical basis for any requested changes, as well as the basis for determining that the resultant CAFE standards could meet EPCA's requirement that NHTSA select the maximum feasible standard for each fleet in each model year. While NHTSA believes that this alternative may be beyond maximum feasible based on the information currently before us, as discussed in more detail in Section VI, all alternatives remain under consideration for the final rule. Moreover, because Alternative 3 produces significant social benefits, NHTSA seeks comment on whether to adopt a more stringent increase from MY 2025 to MY 2026, as described above, that would parallel the year over year increase Alternative 3 analyzes.

V. Effects of the Regulatory Alternatives

A. Effects on Vehicle Manufacturers

Each of the regulatory alternatives NHTSA has considered would increase the stringency of both passenger car and light truck CAFE standards in each of model years 2024–2026. To estimate the potential impacts of each of these alternatives, NHTSA has, as for all recent rulemakings, assumed that standards would continue unchanged after the last model year (in this case, 2026) to be covered by newly issued standards. It is possible that the size and composition of the fleet (*i.e.,* in terms of distribution across the range of vehicle footprints) could change over time, affecting the average fuel economy requirements under both the passenger car and light truck standards, and for the overall fleet. If fleet changes differ from NHTSA's projections, average requirements could, therefore, also differ from NHTSA's projections. At this time, NHTSA estimates that, under each of the regulatory alternatives, average fuel economy requirements could increase as summarized in the following three tables.

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Table V-1 – Estimated Required Average Fuel Economy (mpg), Passenger Car Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	43.3	43.9	44.6	45.2	45.9	46.6	47.3	47.3	47.3	47.3
Alternative 1	43.3	43.9	44.6	45.2	49.8	51.5	53.2	53.2	53.2	53.2
Alternative 2	43.3	43.9	44.6	45.2	49.2	53.4	58.1	58.1	58.1	58.1
Alternative 3	43.3	43.9	44.6	45.2	50.2	55.8	62.0	62.0	62.0	62.0

Table V-2 – Estimated Required Average Fuel Economy (mpg), Light Truck Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	31.0	31.5	31.9	32.4	32.9	33.5	33.9	33.9	33.9	33.9
Alternative 1	31.0	31.5	31.9	32.4	36.4	37.7	39.0	39.0	39.0	39.0
Alternative 2	31.0	31.5	31.9	32.4	35.1	38.2	41.5	41.5	41.5	41.5
Alternative 3	31.0	31.5	31.9	32.4	35.9	39.9	44.3	44.3	44.3	44.3

Table V-3 – Estimated Required Average Fuel Economy (mpg), Total Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	35.4	36.0	36.8	37.4	38.1	38.7	39.4	39.4	39.5	39.5
Alternative 1	35.4	36.0	36.8	37.4	41.8	43.2	44.7	44.8	44.8	44.9
Alternative 2	35.4	36.0	36.8	37.4	40.7	44.2	48.1	48.1	48.2	48.2
Alternative 3	35.4	36.0	36.8	37.4	41.5	46.2	51.3	51.3	51.3	51.4

Manufacturers do not always comply exactly with each CAFE standard in each model year. To date, some manufacturers have tended to regularly exceed one or both requirements. Many manufacturers make use of EPCA's provisions allowing CAFE compliance credits to be applied when a fleet's CAFE level falls short of the corresponding requirement in a given model year. Some manufacturers have paid civil penalties (*i.e.,* fines) required under EPCA when a fleet falls short of a standard in a given model year and the manufacturer cannot provide compliance credits sufficient to address the compliance shortfall. As discussed in the accompanying PRIA and TSD, NHTSA simulates manufacturers' responses to each alternative given a wide range of input estimates (*e.g.,* technology cost and efficacy, fuel prices), and, per EPCA, setting aside the potential that any manufacturer would respond to CAFE standards in model years 2024–2026 by applying CAFE compliance credits or introducing new models of alternative fuel vehicles. Many of these inputs are subject to uncertainty and, in any event, as in all CAFE rulemakings, NHTSA's analysis merely illustrates one set of ways manufacturers could potentially respond to each regulatory alternative. At this time, NHTSA estimates that manufacturers' responses to standards defining each alternative could lead average fuel economy levels to increase through model year 2029 as summarized in the following three tables. Changes are shown to occur in MY 2023 even though NHTSA is not explicitly proposing to regulate that model year because NHTSA anticipates that manufacturers could make changes as early as that model year to affect future compliance positions (*i.e.,* multi-year planning).

Table V-4 – Estimated Achieved Average Fuel Economy (mpg), Passenger Car Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	41.7	43.6	46.6	48.3	50.4	51.5	52.4	52.8	53.0	53.4
Alternative 1	41.7	43.6	46.6	49.3	52.6	54.6	55.8	56.3	56.7	57.0
Alternative 2	41.7	43.6	46.6	49.7	53.9	57.1	59.6	60.5	61.3	61.4
Alternative 3	41.7	43.6	46.6	50.1	55.3	59.4	62.9	64.1	65.3	65.5

Table V-5 – Estimated Achieved Average Fuel Economy (mpg), Light Truck Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	30.2	31.5	33.1	34.4	35.5	36.0	37.0	37.2	37.4	37.7
Alternative 1	30.2	31.5	33.1	34.6	36.6	37.5	38.7	39.2	39.5	39.8
Alternative 2	30.2	31.5	33.1	34.8	36.5	37.9	40.2	40.7	41.1	41.4
Alternative 3	30.2	31.5	33.1	34.9	37.4	39.1	41.8	42.5	43.0	43.2

Table V-6 – Estimated Achieved Average Fuel Economy (mpg), Total Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	34.3	35.9	38.2	39.8	41.3	42.1	43.2	43.5	43.8	44.2
Alternative 1	34.3	35.9	38.2	40.3	42.8	44.1	45.5	46.0	46.4	46.8
Alternative 2	34.3	35.9	38.2	40.5	43.2	45.1	47.6	48.3	48.9	49.2
Alternative 3	34.3	35.9	38.2	40.7	44.2	46.6	49.7	50.6	51.4	51.7

While these increases in average fuel economy account for estimated changes in the composition of the fleet (*i.e.,* the relative shares of passenger cars and light trucks), they result almost wholly from the projected application of fuel-saving technology. As mentioned above, NHTSA's analysis merely illustrates one set of ways manufacturers could potentially respond to each regulatory alternative. Manufacturers' actual responses will almost assuredly differ from NHTSA's current estimates.

At this time, NHTSA estimates that manufacturers' application of advanced gasoline engines (*i.e.,* gasoline engines with cylinder deactivation, turbocharging, high or variable compression ratios) could increase through MY 2029 under the no-action alternative and through at least MY 2024 under each of the action alternatives. However, NHTSA also estimates that in MY 2024, reliance on advanced gasoline engines could begin to decline under the more stringent action alternatives, as manufacturers shift toward electrification.

Table V-7 – Estimated Advanced Gasoline Engine Penetration Rate, Passenger Car Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	53%	56%	61%	59%	64%	62%	61%	62%	61%	65%
Alternative 1	53%	56%	61%	59%	63%	62%	64%	64%	65%	69%
Alternative 2	53%	56%	61%	59%	66%	63%	62%	62%	62%	62%
Alternative 3	53%	56%	61%	58%	65%	58%	55%	52%	52%	52%

Table V-8 – Estimated Advanced Gasoline Engine Penetration Rate, Light Truck Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	55%	55%	56%	56%	57%	59%	61%	61%	63%	64%
Alternative 1	55%	55%	56%	57%	57%	57%	58%	57%	57%	56%
Alternative 2	55%	55%	56%	56%	56%	54%	53%	52%	52%	52%
Alternative 3	55%	55%	56%	56%	55%	53%	48%	46%	45%	45%

Table V-9 – Estimated Advanced Gasoline Engine Penetration Rate, Total Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	54%	55%	58%	58%	60%	60%	61%	62%	62%	65%
Alternative 1	54%	55%	58%	58%	60%	59%	61%	60%	61%	62%
Alternative 2	54%	55%	58%	58%	61%	58%	57%	57%	57%	57%
Alternative 3	54%	55%	58%	57%	60%	55%	51%	49%	48%	48%

The aforementioned estimated shift to electrification under the more stringent regulatory alternatives is the most pronounced for hybrid-electric vehicles (*i.e.,* ‘‘mild’’ ISG HEVs and ‘‘strong’’ P2 and Power-Split HEVs).

Table V-10 – Estimated Hybrid Electric Vehicle (HEV) Penetration Rate, Passenger Car Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	4%	4%	4%	4%	7%	7%	8%	8%	8%	8%
Alternative 1	4%	4%	4%	4%	7%	9%	9%	10%	11%	11%
Alternative 2	4%	4%	4%	4%	8%	10%	11%	12%	13%	13%
Alternative 3	4%	4%	4%	5%	11%	17%	20%	21%	23%	23%

Table V-11 – Estimated Hybrid Electric Vehicle (HEV) Penetration Rate, Light Truck Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	6%	9%	10%	12%	15%	15%	17%	17%	17%	17%
Alternative 1	6%	9%	10%	11%	20%	22%	26%	26%	28%	28%
Alternative 2	6%	9%	10%	12%	16%	19%	27%	27%	29%	30%
Alternative 3	6%	9%	10%	13%	19%	21%	29%	30%	32%	32%

Table V-12 – Estimated Hybrid Electric Vehicle (HEV) Penetration Rate, Total Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	5%	7%	7%	8%	11%	11%	13%	13%	13%	13%
Alternative 1	5%	7%	7%	8%	14%	16%	18%	18%	20%	20%
Alternative 2	5%	7%	7%	8%	12%	15%	19%	20%	21%	21%
Alternative 3	5%	7%	7%	9%	15%	19%	24%	26%	28%	28%

Under the more stringent action alternatives, NHTSA estimates that manufacturers could increase production of plug-in hybrid electric vehicles (PHEVs) well over current rates.

Table V-13 – Estimated Plug-In Hybrid Electric Vehicle (PHEV) Penetration Rate, Passenger Car Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	1%	1%	1%	1%	1%	1%	2%	2%	2%	1%
Alternative 1	1%	1%	1%	1%	2%	2%	3%	3%	3%	3%
Alternative 2	1%	1%	1%	1%	2%	5%	8%	8%	8%	8%
Alternative 3	1%	1%	1%	1%	2%	7%	10%	10%	10%	10%

Table V-14 – Estimated Plug-In Hybrid Electric Vehicle (PHEV) Penetration Rate, Light Truck Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	0%	0%	0%	0%	1%	1%	1%	1%	1%	1%
Alternative 1	0%	0%	0%	0%	2%	2%	2%	2%	2%	2%
Alternative 2	0%	0%	0%	0%	2%	4%	7%	7%	7%	7%
Alternative 3	0%	0%	0%	0%	4%	8%	12%	12%	12%	11%

Table V-15 – Estimated Plug-In Hybrid Electric Vehicle (PHEV) Penetration Rate, Total Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	0%	0%	0%	0%	1%	1%	1%	1%	1%	1%
Alternative 1	0%	0%	0%	0%	2%	2%	3%	3%	3%	2%
Alternative 2	0%	0%	0%	0%	2%	4%	7%	7%	7%	7%
Alternative 3	0%	0%	0%	0%	3%	8%	11%	11%	11%	11%

For this NPRM and accompanying PRIA, NHTSA's analysis excludes the introduction of new alternative fuel vehicle (AFV) models during MY 2024–2026 as a response to CAFE standards.[380] However, NHTSA's analysis does consider the potential that manufacturers might respond to CAFE standards by introducing new BEV models outside of MYs 2024–2026, and NHTSA's analysis does account for the potential that ZEV mandates could lead manufacturers to introduce new BEV models even during MYs 2024–2026. Also accounting for shifts in fleet mix, NHTSA projects increased production of BEVs through MY 2029.

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[380] The SEIS does not make this analytical exclusion.

Table V-16 – Estimated Battery Electric Vehicle (BEV) Penetration Rate, Passenger Car Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	4%	5%	6%	7%	7%	8%	8%	8%	8%	9%
Alternative 1	4%	5%	6%	8%	9%	9%	9%	10%	10%	10%
Alternative 2	4%	5%	6%	9%	9%	10%	10%	10%	11%	11%
Alternative 3	4%	5%	6%	9%	10%	10%	10%	11%	12%	12%

Table V-17 – Estimated Battery Electric Vehicle (BEV) Penetration Rate, Light Truck Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	0%	0%	1%	1%	2%	2%	2%	2%	2%	3%
Alternative 1	0%	0%	1%	2%	2%	2%	2%	2%	2%	3%
Alternative 2	0%	0%	1%	2%	2%	2%	3%	3%	3%	3%
Alternative 3	0%	0%	1%	2%	2%	3%	3%	3%	3%	3%

Table V-18 – Estimated Battery Electric Vehicle (BEV) Penetration Rate, Total Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	2%	2%	3%	4%	4%	5%	5%	5%	5%	6%
Alternative 1	2%	2%	3%	5%	5%	6%	6%	6%	6%	6%
Alternative 2	2%	2%	3%	5%	6%	6%	6%	6%	7%	7%
Alternative 3	2%	2%	3%	6%	6%	6%	6%	7%	7%	8%

The PRIA provides a wider-ranging summary of NHTSA's estimates of manufacturers' potential application of fuel-saving technologies (including other types of technologies, such as advanced transmissions, aerodynamic improvements, and reduced vehicle mass) in response to each regulatory alternative. Appendices I and II of the accompanying PRIA provide much more detailed and comprehensive results, and the underlying CAFE Model output files provide all information, including the specific combination of technologies estimated to be applied to every specific vehicle model/configuration in each of model years 2020–2050.[381]

NHTSA's analysis shows manufacturers' regulatory costs for CAFE standards, CO_2 standards, and ZEV mandates increasing through MY 2029, and (logically) increasing more under the more stringent alternatives. Accounting for fuel-saving technologies estimated to be added under each regulatory alternative (including air conditioning improvements and other off-cycle technologies), and also accounting for CAFE fines that NHTSA estimates some manufacturers could elect to pay rather than achieving full compliance with CAFE standards in some model years, NHTSA estimates that relative to the continued application of MY 2020 technologies, manufacturers' *cumulative* costs during MYs 2023–2029 could total $121b under the no-action alternative, and $166b, $208b, and $251b under alternatives 1, 2, and 3, respectively. The table below shows how these costs are estimated to vary among manufacturers, accounting for differences in the quantities of vehicles produced for sale in the U.S. Appendices I and II of the accompanying PRIA present results separately for each manufacturer's passenger car and light truck fleets in each model year under each regulatory alternative, and the underlying CAFE Model output files also show results specific to manufacturers' domestic and imported car fleets.

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[381] *See* Appendices I and II of the accompanying PRIA and the CAFE Model output files.

Table V-19 – Cumulative Costs ($b) During MYs 2023-2029

Manufacturer	Alternative 0	Alternative 1	Alternative 2	Alternative 3
BMW	4	4	5	6
Daimler	5	6	6	7
Stellantis (FCA)	18	21	23	25
Ford	18	22	27	33
General Motors	18	34	39	48
Honda	10	10	15	22
Hyundai	5	8	11	14
Kia	4	6	9	11
Jaguar - Land Rover	1	2	2	2
Mazda	3	4	5	5
Mitsubishi	1	1	1	2
Nissan	6	9	22	24
Subaru	6	9	10	10
Tesla	0	0	0	0
Toyota	12	19	22	29
Volvo	2	2	2	3
Volkswagen	9	8	9	10
Industry Total	121	166	208	251

As discussed in the TSD, these estimates reflect technology cost inputs that, in turn, reflect a ''markup'' factor that includes manufacturers' profits. In other words, if costs to manufacturers' are reflected in vehicle price increases as in the past, NHTSA estimates that the average costs to new vehicle purchasers could increase through MY 2029 as summarized in Table V–20 through Table V–22.

Table V-20 – Estimated Average Per Vehicle Regulatory Costs ($), Passenger Car Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	265	369	586	694	873	1,008	1,076	1,058	1,028	1,001
Alternative 1	265	369	586	896	1,242	1,455	1,550	1,507	1,473	1,426
Alternative 2	265	369	586	1,055	1,521	1,968	2,264	2,198	2,157	2,073
Alternative 3	265	369	586	1,147	1,748	2,327	2,733	2,649	2,607	2,506

Table V-21 – Estimated Average Per Vehicle Regulatory Costs ($), Light Truck Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	155	365	633	833	1,056	1,153	1,257	1,260	1,251	1,240
Alternative 1	155	365	633	888	1,456	1,616	1,748	1,715	1,717	1,684
Alternative 2	155	365	633	933	1,413	1,795	2,210	2,159	2,134	2,086
Alternative 3	155	365	633	980	1,760	2,255	2,810	2,730	2,687	2,619

Table V-22 – Estimated Average Per Vehicle Regulatory Costs ($), Total Fleet for Manufacturer (Total)

Model Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 0 (Baseline)	203	367	611	768	969	1,083	1,169	1,160	1,140	1,120
Alternative 1	203	367	611	892	1,354	1,539	1,653	1,614	1,598	1,557
Alternative 2	203	367	611	991	1,464	1,877	2,236	2,177	2,145	2,080
Alternative 3	203	367	611	1,058	1,754	2,289	2,773	2,692	2,649	2,565

Table V–23 shows how these costs could vary among manufacturers, suggesting that disparities could decrease as the stringency of standards increases.

Table V-23 – Average Manufacturer Per-Vehicle Costs by Alternative

Manufacturer	Alternative 0	Alternative 1	Alternative 2	Alternative 3
BMW	1,604	1,644	2,126	2,607
Daimler	1,583	2,062	2,412	2,741
Stellantis (FCA)	1,527	1,887	2,185	2,484
Ford	1,331	1,488	2,021	2,609
General Motors	1,056	2,014	2,591	3,160
Honda	965	972	1,515	2,107
Hyundai	846	1,516	2,320	2,859
Kia	850	1,295	2,006	2,595
Jaguar - Land Rover	1,168	1,829	2,137	2,479
Mazda	1,523	1,819	2,416	2,829
Mitsubishi	587	1,115	1,720	2,124
Nissan	737	1,134	2,679	3,147
Subaru	1,058	1,568	1,699	1,802
Tesla	47	47	47	47
Toyota	859	1,394	1,583	2,181
Volvo	1,867	2,578	2,855	3,201
Volkswagen	2,459	2,408	2,547	2,937
Industry Average	1,120	1,557	2,080	2,565

NHTSA estimates that although projected fuel savings under the more stringent regulatory alternatives could tend to increase new vehicles sales, this tendency could be outweighed by the opposing response to higher prices, such that new vehicle sales could decline slightly under the more stringent alternatives. The magnitude of these fuel savings and vehicle price increases depends on manufacturer compliance decisions, especially technology application. In the event that manufacturers select technologies with lower prices and/or higher fuel economy improvements, vehicle sales effects could differ. For example, in the case of the ''unconstrained'' SEIS results, manufacturer costs across alternatives are lower.

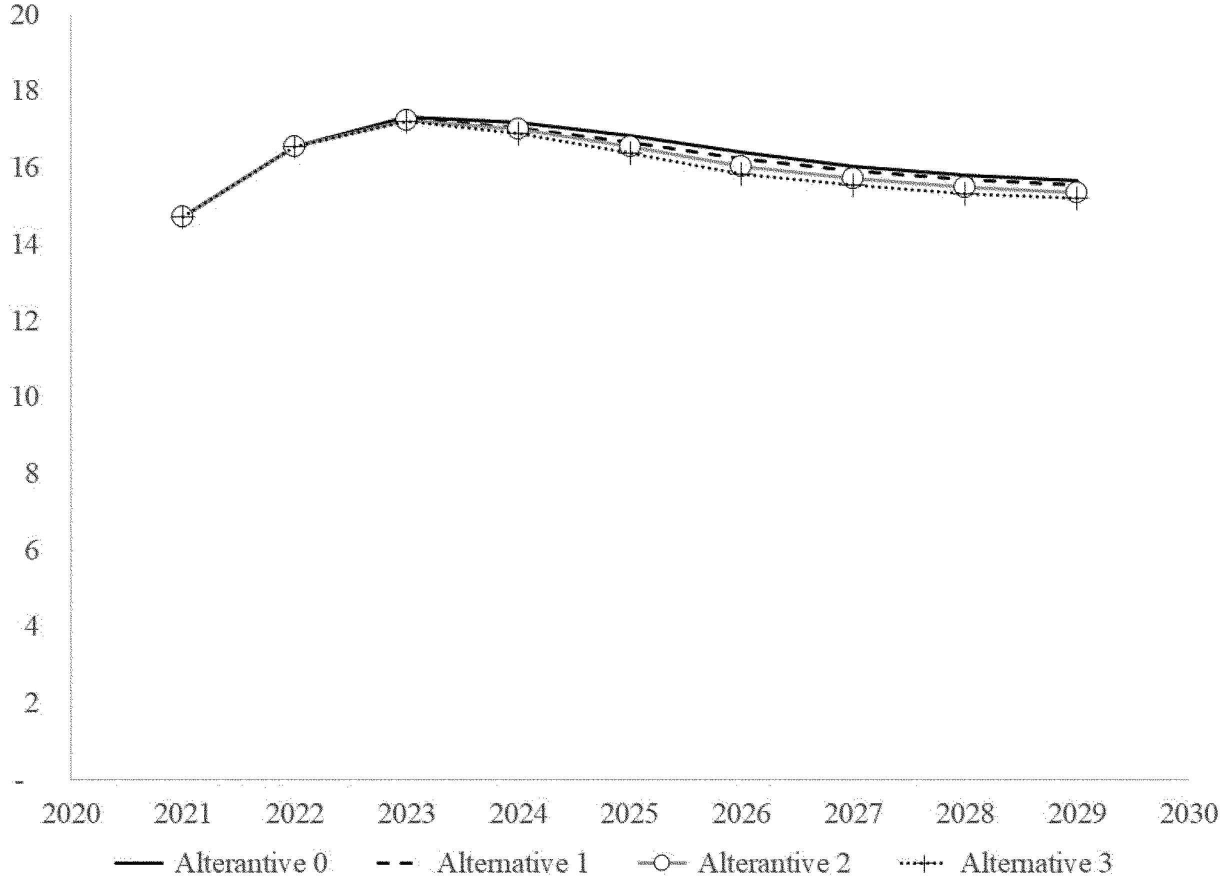

Figure V-1 – Estimated Annual New Vehicles Sales (Millions)

The TSD discusses NHTSA's approach to estimating new vehicle sales, including NHTSA's estimate that new vehicle sales could recover from 2020's aberrantly low levels.

While these slight reductions in new vehicles sales tend to slightly reduce projected automobile industry labor, NHTSA estimates that the cost increases could reflect an underlying increase in employment to produce additional fuel-saving technology, such that automobile industry labor could about the same under each of the four regulatory alternatives.

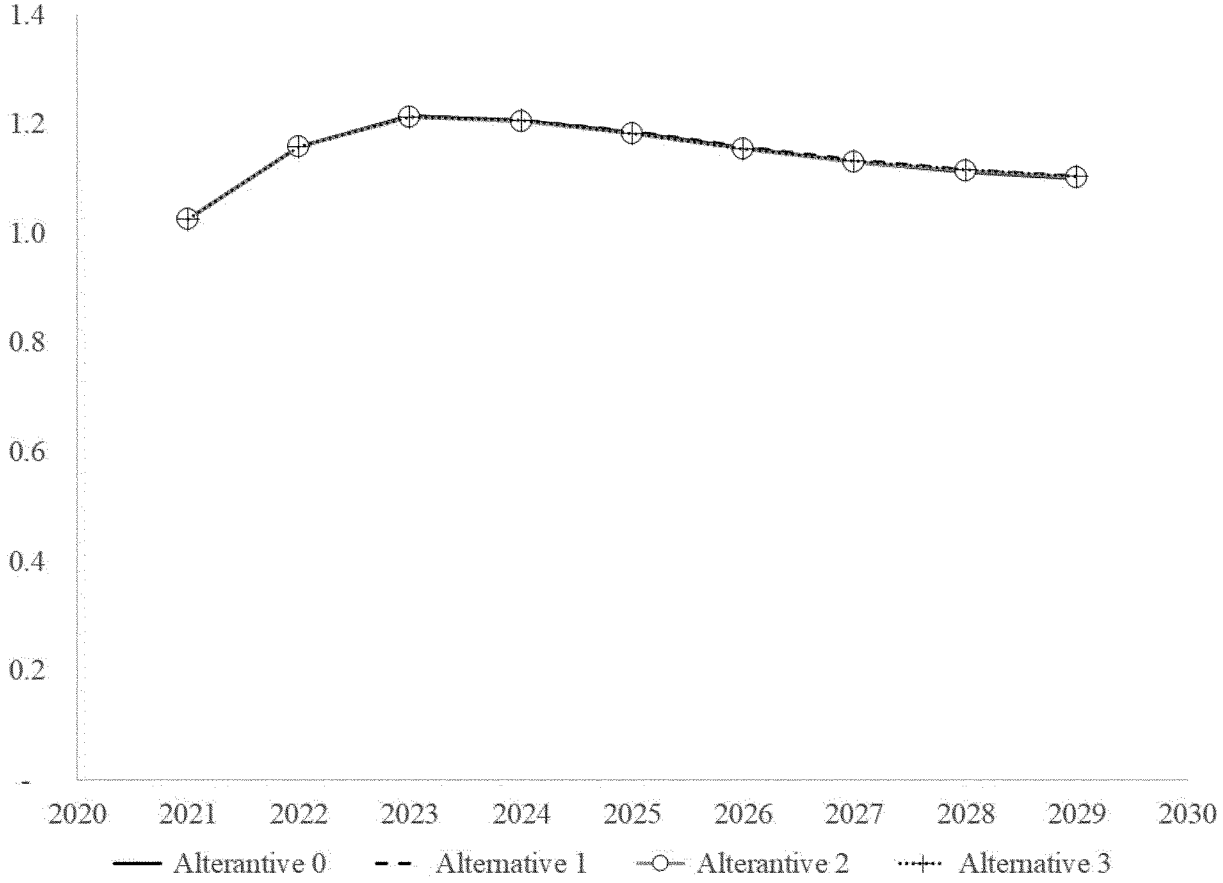

Figure V-2 – Estimated Automobile Industry Labor (as Millions of Full-Time-Equivalent Jobs)

The accompanying TSD discusses NHTSA's approach to estimating automobile industry employment, and the accompanying RIA (and its Appendices I and II) and CAFE Model output files provide more detailed results of NHTSA's analysis.

B. Effects on New Car and Truck Buyers

As discussed above, NHTSA estimates that the average fuel economy and purchase cost of new vehicles could increase between 2020 and 2029 and increase more quickly under each of the action alternatives than under the baseline No-Action Alternative. On one hand, buyers could realize the benefits of increase fuel economy: Spending less on fuel. On the other, buyers could pay more for new vehicles, for some costs tied directly to vehicle value (*e.g.,* sales taxes and collision insurance). Table V–24 reports sales-weighted MSRP values for the No-Action Alternative and relative increases in MSRP for the three regulatory alternatives.

Table V-24 – Sales-Weighted MSRP and Incremental Costs Under the Regulatory Alternatives by Regulatory Class, Undiscounted 2018$

Model Year	Light Truck				Passenger Car			
	Alt. 0	Relative to Alt. 0			Alt. 0	Relative to Alt. 0		
		Alt. 1	Alt. 2	Alt. 3		Alt. 1	Alt. 2	Alt. 3
2024	42,300	400	350	700	31,220	360	640	870
2025	42,400	460	640	1,100	31,360	440	950	1,300
2026	42,500	490	950	1,550	31,440	460	1,170	1,630
2027	42,500	460	900	1,470	31,430	440	1,120	1,550
2028	42,490	470	890	1,440	31,410	430	1,100	1,540
2029	42,480	450	850	1,380	31,390	410	1,040	1,460

Table V–25 through Table V–27 presents projected consumer costs and benefits along with net benefits for model year 2029 and 2039 vehicles under the proposed alternatives. Results are shown in 2018 dollars, without discounting and with benefits and costs discounted at annual rates of 3% and 7%. The TSD and PRIA accompanying this NPRM discuss underlying methods, inputs, and results in greater detail, and more detailed tables and underlying results are contained in the accompanying CAFE Data Book and CAFE Model output files. For all of the action alternatives, avoided outlays for fuel purchases account for most of the projected benefits to consumers, and increases in the cost to purchase new vehicles account for most of the projected costs.

Table V-25 – Average Per-Vehicle Consumer Benefits and Costs – Passenger Cars and Light Trucks, Undiscounted 2018$

	MY 2029				**MY 2039**			
	Alt. 0	**Relative to Alt. 0**			**Alt. 0**	**Relative to Alt. 0**		
		Alt. 1	**Alt. 2**	**Alt. 3**		**Alt. 1**	**Alt. 2**	**Alt. 3**
Consumer Costs								
Insurance cost	5,190	73	157	232	5,128	60	116	166
Financing cost	4,153	59	125	186	4,103	48	93	132
Taxes and fees	2,016	28	61	90	1,992	23	45	64
Regulatory cost	1,120	437	960	1,444	924	324	645	934
Foregone consumer sales surplus	0	1	7	17	0	0	1	3
Maintenance and repair cost	0	0	0	0	0	0	0	0
Implicit opportunity cost	0	0	0	0	0	0	0	0
Total consumer costs	**12,478**	**598**	**1,310**	**1,970**	**12,147**	**456**	**899**	**1,299**
Consumer Benefits								
Retail fuel outlay	19,703	-738	-1,186	-1,688	19,727	-818	-1,622	-2,351
Refueling time cost	1,046	-1	-2	-15	1,191	15	89	181
Drive value	693	125	160	219	779	137	162	204
Total consumer benefits	21,442	864	1,347	1,922	21,696	940	1,694	2,373
Net benefits	**8,964**	**266**	**37**	**-48**	**9,550**	**484**	**795**	**1,074**

Table V-26 – Average Per-Vehicle Consumer Benefits and Costs – Passenger Cars and Light Trucks, Discounted at 3% 2018$

	MY 2029				MY 2039			
	Alt. 0	Relative to Alt. 0			Alt. 0	Relative to Alt. 0		
		Alt. 1	Alt. 2	Alt. 3		Alt. 1	Alt. 2	Alt. 3
Consumer Costs								
Insurance cost	4,353	61	131	195	4,301	50	97	139
Financing cost	3,874	55	117	173	3,828	45	86	124
Taxes and fees	2,016	28	61	90	1,992	23	45	64
Regulatory cost	1,120	437	960	1,444	924	324	645	934
Foregone consumer sales surplus	0	1	7	17	0	0	1	3
Maintenance and repair cost	0	0	0	0	0	0	0	0
Implicit opportunity cost	0	0	0	0	0	0	0	0
Total consumer costs	**11,362**	**582**	**1,276**	**1,920**	**11,044**	**443**	**874**	**1,263**
Consumer Benefits								
Retail fuel outlay	15,510	-581	-937	-1,332	15,652	-648	-1,287	-1,866
Refueling time cost	834	0	-1	-12	951	13	72	145
Drive value	546	97	125	171	622	108	128	161
Total consumer benefits	16,890	679	1,063	1,516	17,226	743	1,343	1,882
Net benefits	**5,527**	**96**	**-213**	**-404**	**6,182**	**300**	**469**	**619**

Table V-27 – Average Per-Vehicle Consumer Benefits and Costs – Passenger Cars and Light Trucks, Discounted at 7% 2018$

	MY 2029				MY 2039			
	Alt. 0	Relative to Alt. 0			Alt. 0	Relative to Alt. 0		
		Alt. 1	Alt. 2	Alt. 3		Alt. 1	Alt. 2	Alt. 3
Consumer Costs								
Insurance cost	3,619	51	109	162	3,576	42	81	115
Financing cost	3,555	50	107	159	3,512	41	79	113
Taxes and fees	2,016	28	61	90	1,992	23	45	64
Regulatory cost	1,120	437	960	1,444	924	324	645	934
Foregone consumer sales surplus	0	1	7	17	0	0	1	3
Maintenance and repair cost	0	0	0	0	0	0	0	0
Implicit opportunity cost	0	0	0	0	0	0	0	0
Total consumer costs	**10,310**	**568**	**1,244**	**1,873**	**10,004**	**431**	**851**	**1,230**
Consumer Benefits								
Retail fuel outlay	12,001	-449	-726	-1,032	12,217	-503	-1,001	-1,453
Refueling time cost	654	0	-1	-9	747	10	56	115
Drive value	422	75	96	132	489	84	100	126
Total consumer benefits	13,077	524	823	1,173	13,453	578	1,045	1,464
Net benefits	**2,767**	**-44**	**-421**	**-700**	**3,449**	**147**	**194**	**234**

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C. Effects on Society

Table V–28 and Table V–29 describe the costs and benefits of increasing CAFE standards in each alternative, as well as the party to which they accrue. Manufacturers are directly regulated under the program and incur additional production costs when they apply technology to their vehicle offerings in order to improve their fuel economy. In this analysis, we assume that those costs are fully passed through to new car and truck buyers, in the form of higher prices. Other assumptions are possible, but we do not currently have data to support attempting to model cross-subsidization. We also assume that any civil penalties—paid by manufacturers for failing to comply with their CAFE standards—are passed through to new car and truck buyers and are included in the sales price. However, those civil penalties are paid to the U.S. Treasury, where they currently fund the general business of Government. As such, they are a transfer from new vehicle buyers to all U.S. citizens, who then benefit from the additional Federal revenue. While they are calculated in the analysis, and do influence consumer decisions in the marketplace, they do not contribute to the calculation of net benefits (and are omitted from the tables below).

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

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

In addition to private benefits and costs, there are purely external benefits and costs that can be attributed to increases in CAFE standards. These are benefits and costs that accrue to society more generally, rather than to the specific individuals who purchase a new vehicle that was produced under more stringent CAFE standards. Of the external costs, the largest is the loss in fuel tax revenue that occurs as a result of falling fuel consumption. While drivers of new vehicles (purchased in years where CAFE stringency is increasing) save fuel costs at retail prices, the rest of U.S. road users experience a welfare loss, in two ways. First, the revenue generated by fuel taxes helps to maintain roads and bridges, and improve infrastructure more generally, and that loss in fuel tax revenue is a social cost. And second, the additional driving that occurs as new vehicle buyers take advantage of lower per-mile fuel costs is a benefit to those drivers, but the congestion (and road noise) created by the additional travel impose a social cost to all road users.

Among the purely external benefits created when CAFE standards are increased, the largest is the reduction in damages resulting from greenhouse gas emissions. The estimates in Table V–28 assume a social cost of GHG emissions based on a 2.5% discount rate, and those in Table V–29 assume a social cost of GHG emissions based on a 3% discount rate. The associated benefits related to reduced health damages from conventional pollutants and the benefit of improved energy security are both significantly smaller than the associated change in GHG damages across alternatives. As the tables also illustrate, the overwhelming majority of both costs and benefits are private costs and benefits that accrue to buyers of new cars and trucks, rather than external welfare changes that affect society more generally. This has been consistently true in CAFE rulemakings.

The choice of discount rate also affects the resulting benefits and costs. As the tables show, net social benefits are positive for Alternative 1 and 2 at a 3% discount rate, but only for Alternative 1 when applying a 7% discount rate to benefits and costs. Alternative 3 has negative net benefits under both discount rates. As mentioned above, the benefits of the regulatory alternatives, but especially Alternative 3, are concentrated in later years where a higher discount rate has a greater contracting effect.

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Table V-28 – Incremental Benefits and Costs Over the Lifetimes of Total Fleet Produced Through 2029 (2018$ Billions), 3% Percent Discount Rate, by Alternative

Alternative:	1	2	3
Private Costs			
Technology Costs to Increase Fuel Economy	34.3	67.6	100.1
Increased Maintenance and Repair Costs	0.0	0.0	0.0
Sacrifice in Other Vehicle Attributes	0.0	0.0	0.0
Consumer Surplus Loss from Reduced New Vehicle Sales	0.1	0.6	1.3
Safety Costs Internalized by Drivers	6.2	8.2	11.2
Subtotal - Private Costs	40.6	76.4	112.6
External Costs			
Congestion and Noise Costs from Rebound-Effect Driving	7.3	10.1	13.5
Safety Costs Not Internalized by Drivers	7.5	15.8	23.2
Loss in Fuel Tax Revenue for the Highway Trust Fund	11.0	18.9	27.0
Subtotal - External Costs	25.8	44.8	63.7
Total Social Costs	**66.4**	**121.2**	**176.3**
Private Benefits			
Reduced Fuel Costs	47.9	73.0	103.8
Benefits from Additional Driving	12.3	15.3	20.8
Less Frequent Refueling	-0.5	-0.8	0.3
Subtotal - Private Benefits	59.7	87.5	124.9
External Benefits			
Reduction in Petroleum Market Externality	0.9	1.5	2.1
Reduced Climate Damages	20.3	32.0	45.6
Reduced Health Damages	1.7	0.4	0.3
Subtotal - External Benefits	22.9	33.9	48.0
Total Social Benefits	**82.6**	**121.4**	**172.9**
Net Social Benefits	**16.1**	**0.3**	**-3.4**

Table V-29 – Incremental Benefits and Costs Over the Lifetimes of Total Fleet Produced Through 2029 (2018$ Billions), 7% Percent Discount Rate, by Alternative

Alternative:	1	2	3
Private Costs			
Technology Costs to Increase Fuel Economy	28.1	55.0	81.4
Increased Maintenance and Repair Costs	0.0	0.0	0.0
Sacrifice in Other Vehicle Attributes	0.0	0.0	0.0
Consumer Surplus Loss from Reduced New Vehicle Sales	0.1	0.5	1.1
Safety Costs Internalized by Drivers	3.7	4.9	6.8
Subtotal - Private Costs	31.9	60.4	89.3
External Costs			
Congestion and Noise Costs from Rebound-Effect Driving	4.8	6.8	9.3
Safety Costs Not Internalized by Drivers	5.5	11.6	17.3
Loss in Fuel Tax Revenue	7.0	11.9	17.0
Subtotal - External Costs	17.3	30.3	43.6
Total Social Costs	**34.6**	**60.6**	**87.2**
Private Benefits			
Reduced Fuel Costs	29.7	44.9	63.7
Benefits from Additional Driving	7.5	9.3	12.7
Less Frequent Refueling	-0.4	-0.6	0.0
Subtotal - Private Benefits	36.8	53.6	76.4
External Benefits			
Reduction in Petroleum Market Externality	0.5	0.9	1.3
Reduced Climate Damages	13.3	21.0	29.9
Reduced Health Damages	0.9	0.1	-0.1
Subtotal - External Benefits	14.8	22.0	31.2
Total Social Benefits	**51.6**	**75.6**	**107.6**
Net Social Benefits	**2.3**	**-15.1**	**-25.2**

The following tables show the costs and benefits associated with external effects to society. As seen in Table V–28 and Table V–29, the external benefits are composed of reduced climate damages (Table V–30 and Table V–31), reduced health damages (Table V–32 and Table V–33), and reduced petroleum market externalities (Table V–36). The external costs to society include congestion and noise costs (Table V–34 and Table V–35) and safety costs (Table V–37). We show the costs and benefits by model year (1981–2029), in contrast to the tables above, which present incremental and net costs and benefits over the lifetimes of the entire fleet produced through 2029, beginning with model year 1981.

Table V-30 – Total and Incremental Costs of GHGs (2018$, billions), MY 1981-2029, 2.5% Discount Rate, by Alternative

Model Year	1981 - 2023	2024	2025	2026	2027	2028	2029	Total
Alternative 0/Baseline (Totals)								
CO_2	1,202.4	91.6	87.7	83.0	80.0	77.4	75.2	1,697.2
CH_4	40.4	3.2	3.1	2.9	2.9	2.8	2.7	58.0
N_2O	15.5	1.0	1.0	0.9	0.9	0.9	0.9	21.1
Alternative 1 (Relative to Baseline)								
CO_2	1.8	-3.0	-3.6	-3.7	-3.7	-3.7	-3.5	-19.4
CH_4	0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.6
N_2O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
Alternative 2 (Relative to Baseline)								
CO_2	4.5	-3.4	-5.2	-6.8	-6.7	-6.7	-6.3	-30.7
CH_4	0.2	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-1.0
N_2O	0.1	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.3
Alternative 3 (Relative to Baseline)								
CO_2	7.3	-5.2	-7.6	-9.8	-9.7	-9.7	-9.0	-43.8
CH_4	0.3	-0.2	-0.2	-0.3	-0.3	-0.3	-0.3	-1.4
N_2O	0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.4

Table V–30 and Table V–31 present the total costs of GHGs in the baseline scenario and the incremental costs relative to the baseline in the other three alternatives. Negative incremental values indicate a decrease in social costs of GHGs, while positive incremental values indicate an increase in costs relative to the baseline for the given model year. The GHG costs follow a similar pattern in all three alternatives, decreasing across all model years, with the largest reductions associated with 2025–2028 model years. The magnitude of CO_2 emissions is much higher than the magnitudes of CH_4 and N_2O emissions, which is why the total costs are so much larger for CO_2.

Table V-31 – Total and Incremental Costs of GHGs (2018$, billions), MY 1981-2029, 3% Discount Rate, by Alternative

Model Year:	1981 - 2023	2024	2025	2026	2027	2028	2029	Total
Alternative 0/Baseline (Totals)								
CO_2	796.4	60.2	57.6	54.4	52.4	50.6	49.0	1,120.5
CH_4	30.3	2.4	2.3	2.2	2.1	2.1	2.0	43.3
N_2O	10.4	0.7	0.7	0.6	0.6	0.6	0.6	14.0
Alternative 1 (Relative to Baseline)								
CO_2	1.2	-2.0	-2.4	-2.4	-2.4	-2.4	-2.3	-12.7
CH_4	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.5
N_2O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
Alternative 2 (Relative to Baseline)								
CO_2	3.0	-2.2	-3.4	-4.5	-4.4	-4.4	-4.1	-20.1
CH_4	0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.7
N_2O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
Alternative 3 (Relative to Baseline)								
CO_2	4.8	-3.4	-5.0	-6.5	-6.3	-6.3	-5.9	-28.6
CH_4	0.2	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-1.0
N_2O	0.1	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.3

The CAFE Model calculates health costs attributed to criteria pollutant emissions of NO_X, SO_X, and $PM_{2.5}$, shown in Table V–32 and Table V–33. These costs are directly related to the tons of each pollutant emitted from various upstream and downstream sources, including on-road vehicles, electricity generation, fuel refining, and fuel transportation and distribution. See Chapter 4 of the SEIS and Chapter 5.4 of the TSD for further information regarding the calculations used to estimate health impacts, and more details about the types of health effects. The following section of the preamble, V.D, discusses the changes in tons of emissions themselves across rulemaking alternatives, while the current section focuses on the changes in social costs associated with those emissions.

Criteria pollutant health costs (presented in Table V–32 and Table V–35) increase slightly in earlier model years (1981–2023), but those cost increases are offset by the decrease in health costs in later model years. In Table V–32 and Table V–33, the costs in alternatives 1–3 are shown in terms of percent of the baseline. For instance, the total decrease in SO_X costs in Alternative 2 is equivalent to 0.2% of the total baseline SO_X costs. The changes across alternatives relative to the baseline are relatively minor, although some impacts in later model years are more significant (*e.g.,* 7.5% decrease in $PM_{2.5}$ in 2028, Alternative 3). Since the health cost value per ton of emissions differs by pollutant, the pollutants that incur the highest costs are not necessarily those with the largest amount of emissions.

Table V-32 – Totals and Percent Changes in Health Costs of Criteria Pollutants (2018$, billions), MY 1981-2029, 3% Discount Rate, by Alternative

Model Year:	1981 - 2023	2024	2025	2026	2027	2028	2029	Total
Alternative 0/Baseline (Totals)								
NO_x	119.0	1.7	1.5	1.4	1.4	1.3	1.3	127.6
SO_x	168.7	11.6	11.0	10.3	9.8	9.3	8.9	229.7
$PM_{2.5}$	330.6	9.9	9.4	8.8	8.4	8.1	7.8	383.0
Alternative 1 (Relative to Baseline)								
NO_x	0.2%	-1.0%	-1.6%	-1.7%	-1.6%	-1.9%	-1.9%	0.1%
SO_x	0.2%	-1.7%	-2.5%	-2.6%	-2.6%	-2.9%	-2.9%	-0.5%
$PM_{2.5}$	0.2%	-2.1%	-2.6%	-2.8%	-2.8%	-2.9%	-2.8%	-0.2%
Alternative 2 (Relative to Baseline)								
NO_x	0.5%	-0.3%	-0.4%	0.1%	0.3%	0.2%	0.2%	0.5%
SO_x	0.4%	-1.3%	-2.1%	-2.2%	-2.0%	-2.2%	-2.1%	-0.2%
$PM_{2.5}$	0.5%	-2.3%	-3.7%	-5.0%	-4.9%	-5.1%	-4.9%	-0.1%
Alternative 3 (Relative to Baseline)								
NO_x	0.8%	-0.5%	-0.2%	0.0%	0.4%	0.3%	0.1%	0.7%
SO_x	0.7%	-2.0%	-2.6%	-3.2%	-2.9%	-3.0%	-3.0%	-0.2%
$PM_{2.5}$	0.8%	-3.5%	-5.5%	-7.4%	-7.3%	-7.5%	-7.3%	-0.2%

Table V-33 – Totals and Percent Changes in Health Costs of Criteria Pollutants (2018$, billions), MY 1981-2029, 7% Discount Rate, by Alternative

Model Year:	1981 - 2023	2024	2025	2026	2027	2028	2029	Total
Alternative 0/Baseline (Totals)								
NO$_x$	91.1	1.1	1.0	0.9	0.8	0.7	0.7	96.2
SO$_x$	125.8	7.5	6.8	6.2	5.6	5.2	4.8	161.9
PM$_{2.5}$	246.6	6.1	5.5	5.0	4.6	4.3	3.9	276.0
Alternative 1 (Relative to Baseline)								
NO$_x$	0.2%	-1.0%	-1.6%	-1.7%	-1.7%	-2.0%	-2.0%	0.1%
SO$_x$	0.2%	-1.8%	-2.5%	-2.7%	-2.7%	-2.9%	-2.9%	-0.4%
PM$_{2.5}$	0.2%	-2.2%	-2.7%	-2.9%	-2.8%	-2.9%	-2.9%	-0.1%
Alternative 2 (Relative to Baseline)								
NO$_x$	0.4%	-0.4%	-0.6%	-0.1%	0.1%	-0.1%	-0.1%	0.4%
SO$_x$	0.4%	-1.4%	-2.2%	-2.3%	-2.1%	-2.2%	-2.1%	-0.2%
PM$_{2.5}$	0.4%	-2.3%	-3.7%	-5.0%	-4.9%	-5.0%	-4.8%	-0.1%
Alternative 3 (Relative to Baseline)								
NO$_x$	0.6%	-0.6%	-0.4%	-0.3%	0.0%	-0.1%	-0.3%	0.6%
SO$_x$	0.6%	-2.1%	-2.8%	-3.3%	-3.0%	-3.0%	-3.1%	-0.2%
PM$_{2.5}$	0.7%	-3.6%	-5.5%	-7.4%	-7.3%	-7.4%	-7.2%	-0.1%

NHTSA estimates social costs of congestion and noise across regulatory alternatives, throughout the lifetimes of model years 1981–2029. Congestion and noise are functions of VMT and fleet mix, and the differences between alternatives are due mainly to differences in VMT (see Section V.D). Overall, congestion and noise costs increase relative to the baseline across all alternatives, but viewed from a model year perspective, the congestion and noise costs associated with later model years are negative relative to the baseline. It is important to note that the overall increases in congestion and noise costs are relatively small when compared to the total congestion and noise costs in the baseline (No-Action Alternative). For further details regarding congestion and noise costs, see Chapter 6.2.3 of the TSD and Chapter 6.5 of the PRIA.

Table V-34 – Total and Incremental Congestion and Noise Costs (2018$, billions), MY 1981-2029, 3% Discount Rate, by Alternative

Model Year:	1981 - 2023	2024	2025	2026	2027	2028	2029	Total
Alternative 0/Baseline (Totals)								
Congestion	4,003.4	347.5	331.3	314.3	298.9	285.9	274.8	5,856.1
Noise	28.5	2.5	2.3	2.2	2.1	2.0	1.9	41.6
Alternative 1 (Relative to the Baseline)								
Congestion	8.07	-0.83	-0.62	-0.42	0.10	0.38	0.59	7.28
Noise	0.06	-0.01	0.00	0.00	0.00	0.00	0.00	0.05
Alternative 2 (Relative to the Baseline)								
Congestion	17.61	-0.39	-1.61	-2.66	-1.61	-0.91	-0.44	9.98
Noise	0.13	0.00	-0.01	-0.02	-0.01	-0.01	0.00	0.07
Alternative 3 (Relative to the Baseline)								
Congestion	27.43	-0.92	-2.85	-4.42	-2.90	-1.88	-1.10	13.35
Noise	0.20	-0.01	-0.02	-0.03	-0.02	-0.01	-0.01	0.10

Table V-35 – Total and Incremental Congestion and Noise Costs (2018$, billions), MY 2020-2029, 7% Discount Rate, by Alternative

Model Year:	1981 - 2023	2024	2025	2026	2027	2028	2029	Total
Alternative 0/Baseline (Totals)								
Congestion	3,276.3	242.6	222.8	203.5	186.4	171.7	158.9	4,462.3
Noise	23.3	1.7	1.6	1.4	1.3	1.2	1.1	31.7
Alternative 1 (Relative to the Baseline)								
Congestion	5.62	-0.63	-0.47	-0.32	0.03	0.21	0.33	4.77
Noise	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Alternative 2 (Relative to the Baseline)								
Congestion	12.06	-0.39	-1.19	-1.81	-1.07	-0.58	-0.27	6.75
Noise	0.09	0.00	-0.01	-0.01	-0.01	0.00	0.00	0.05
Alternative 3 (Relative to the Baseline)								
Congestion	18.80	-0.83	-2.07	-2.98	-1.89	-1.17	-0.65	9.20
Noise	0.13	-0.01	-0.01	-0.02	-0.01	-0.01	0.00	0.07

The CAFE Model accounts for benefits of increased energy security by computing changes in social costs of petroleum market externalities. These social costs represent the risk to the U.S. economy incurred by exposure to price shocks in the global petroleum market that are not accounted for by oil prices and are a direct function of gallons of fuel consumed. Chapter 6.2.4 of the accompanying TSD describes the inputs involved in calculating these petroleum market externality costs. Petroleum market externality costs decrease relative to the baseline under all alternatives, regardless of the discount rate used. This pattern occurs due to the decrease in gallons of fuel consumed (see Section V.D) as the stringency of alternatives increases. Only the earlier model year cohorts (1981–2023) contribute to slight increases in petroleum market externality costs, but these are offset by the decreases from later model years.

Table V-36 – Total and Incremental Petroleum Market Externalities Costs (2018$, billions), MY 1981-2029, by Alternative

Model Year:	1981-2020	2021-2023	2024-2026	2027-2029
Discount rate	Alternative 0/Baseline (Totals)			
3%	35.31	10.9	10.3	9.3
7%	28.89	7.9	6.7	5.4
	Alternative 1 (Relative to Baseline)			
3%	0.08	-0.02	-0.45	-0.48
7%	0.06	-0.02	-0.29	-0.28
	Alternative 2 (Relative to Baseline)			
3%	0.18	-0.02	-0.72	-0.94
7%	0.13	-0.02	-0.47	-0.55
	Alternative 3 (Relative to Baseline)			
3%	0.28	-0.01	-1.06	-1.36
7%	0.19	-0.01	-0.69	-0.80

NHTSA estimates various monetized safety impacts across regulatory alternatives, including costs of fatalities, non-fatal crash costs, and property damage costs. Table V–37 presents these social costs across alternatives and discount rates. Safety effects are discussed at length in the PRIA accompanying this NPRM (see Chapter 5 of the PRIA).

Table V-37 – Total Social Costs of Safety Impacts (2018$, billions), MY 1981-2029, All Alternatives

	Alternative 1		Alternative 2		Alternative 3	
	3%	7%	3%	7%	3%	7%
Fatality Costs	7.8	5.2	14.5	9.9	21.1	14.7
Non-Fatal Crash Costs	4.9	3.3	8.0	5.6	11.1	7.9
Property Damage Crash Costs	1.0	0.7	1.6	1.1	2.2	1.5

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D. Physical and Environmental Effects

NHTSA calculates estimates for the various physical and environmental effects associated with the proposed standards. These include quantities of fuel and electricity consumption, tons of greenhouse gas (GHG) emissions and criteria pollutants, and health and safety impacts.

In terms of fuel and electricity usage, NHTSA estimates that the proposal would save about 50 billion gallons of gasoline and increase electricity consumption by about 275 TWh over the lives of vehicles produced prior to MY 2030, relative to the baseline standards (*i.e.,* the No-Action Alternative). From a calendar year perspective, NHTSA's analysis also estimates total annual consumption of fuel by the entire on-road fleet from calendar year 2020 through calendar year 2050. On this basis, gasoline and electricity consumption by the U.S. light-duty vehicle fleet evolves as shown in the following two graphs, each of which shows projections for the No-Action Alternative (Alternative 0, *i.e.,* the baseline), Alternative 1, Alternative 2 (the proposal), and Alternative 3.

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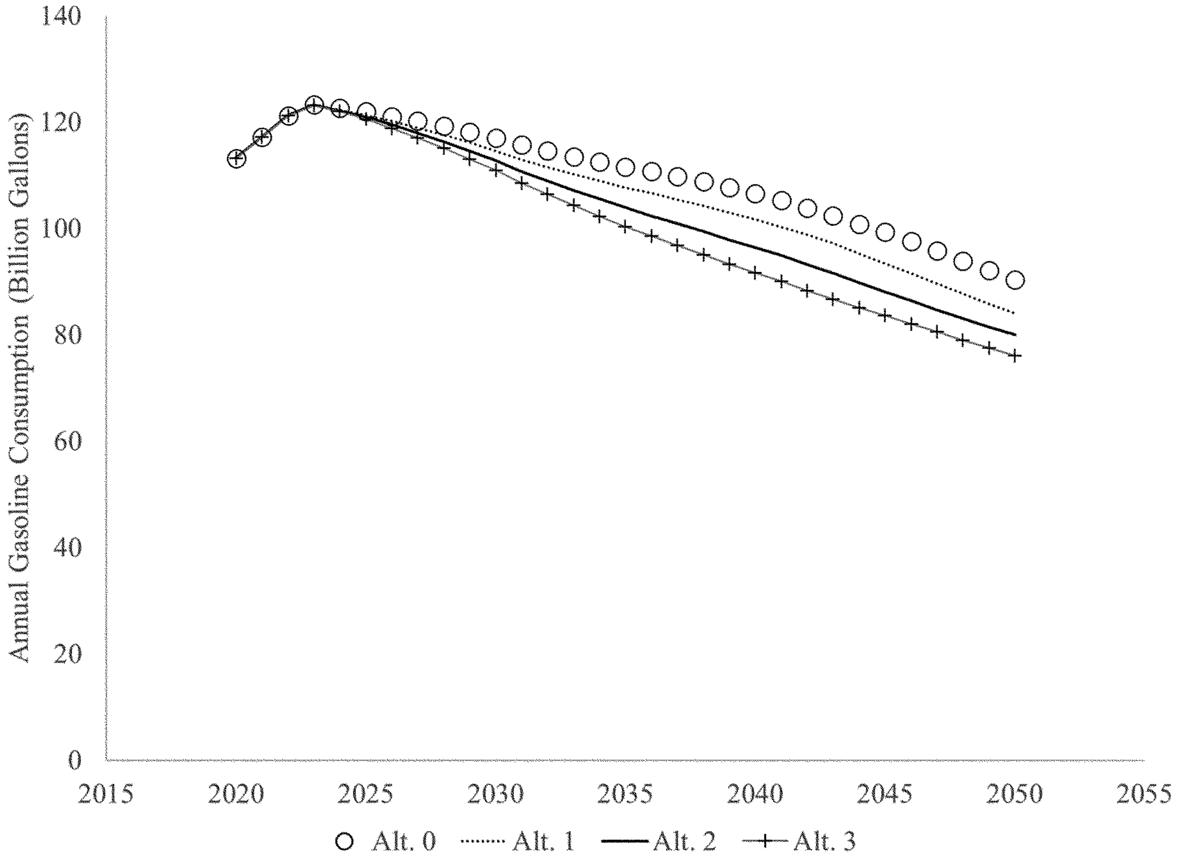

Figure V-3 – Estimated Annual Gasoline Consumption by Light-Duty On-Road Fleet

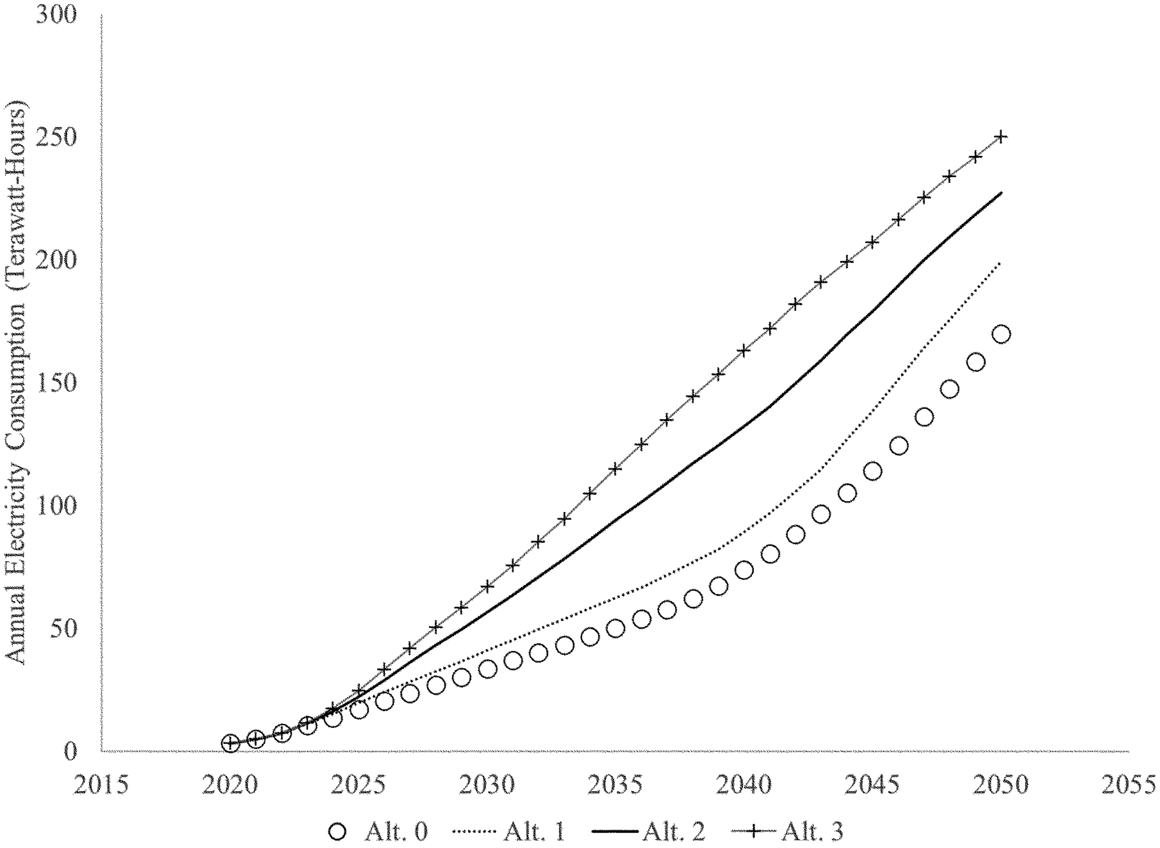

Figure V-4 – Estimated Electricity Consumption by Light-Duty On-Road Fleet

NHTSA estimates the greenhouse gas emissions (GHGs) attributable to the light-duty on-road fleet, from both vehicles and upstream energy sector processes (*e.g.,* petroleum refining, fuel transportation and distribution, electricity generation). Overall, NHTSA estimates that the proposed rule would reduce greenhouse gases by about 465 million metric tons of carbon dioxide (CO_2), about 500 thousand metric tons of methane (CH_4), and about 12 thousand tons of nitrous oxide (N_2O). The following three graphs (Figure V–5, Figure V–6, and Figure V–7) present NHTSA's estimate of how emissions from these three GHGs could evolve over the years. Note that these graphs include emissions from both vehicle and upstream processes. All three GHG emissions follow similar trends in the years between 2020–2050.

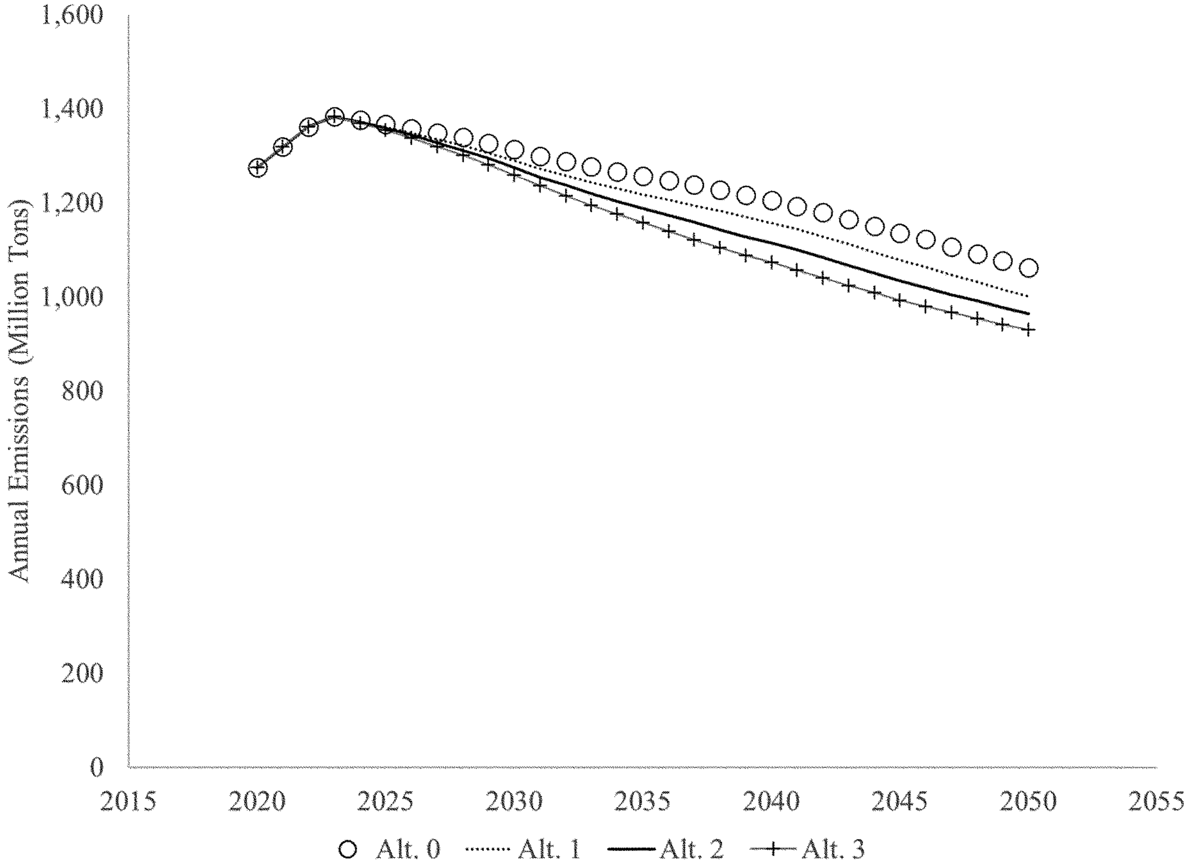

Figure V-5 – Estimated Annual CO_2 Emissions Attributable to Light-Duty On-Road Fleet

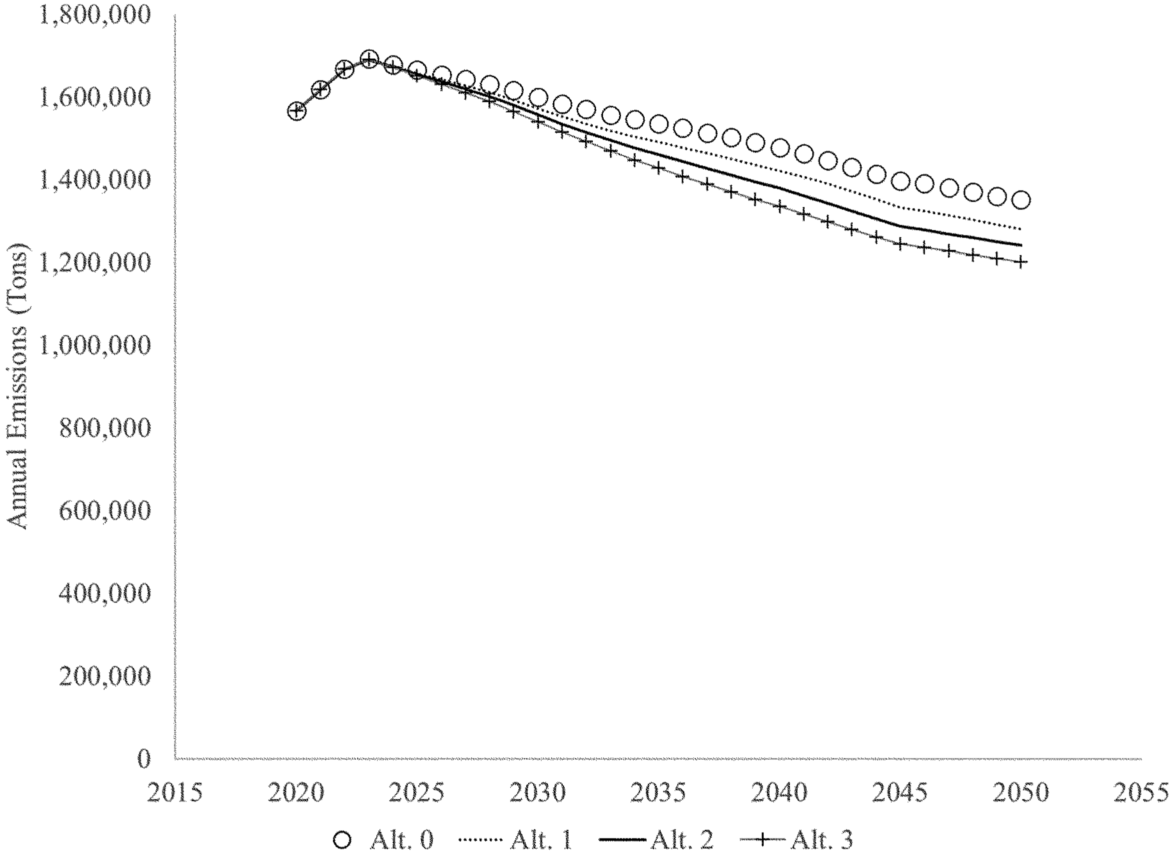

Figure V-6 – Estimated Annual CH_4 Emissions Attributable to Light-Duty On-Road Fleet

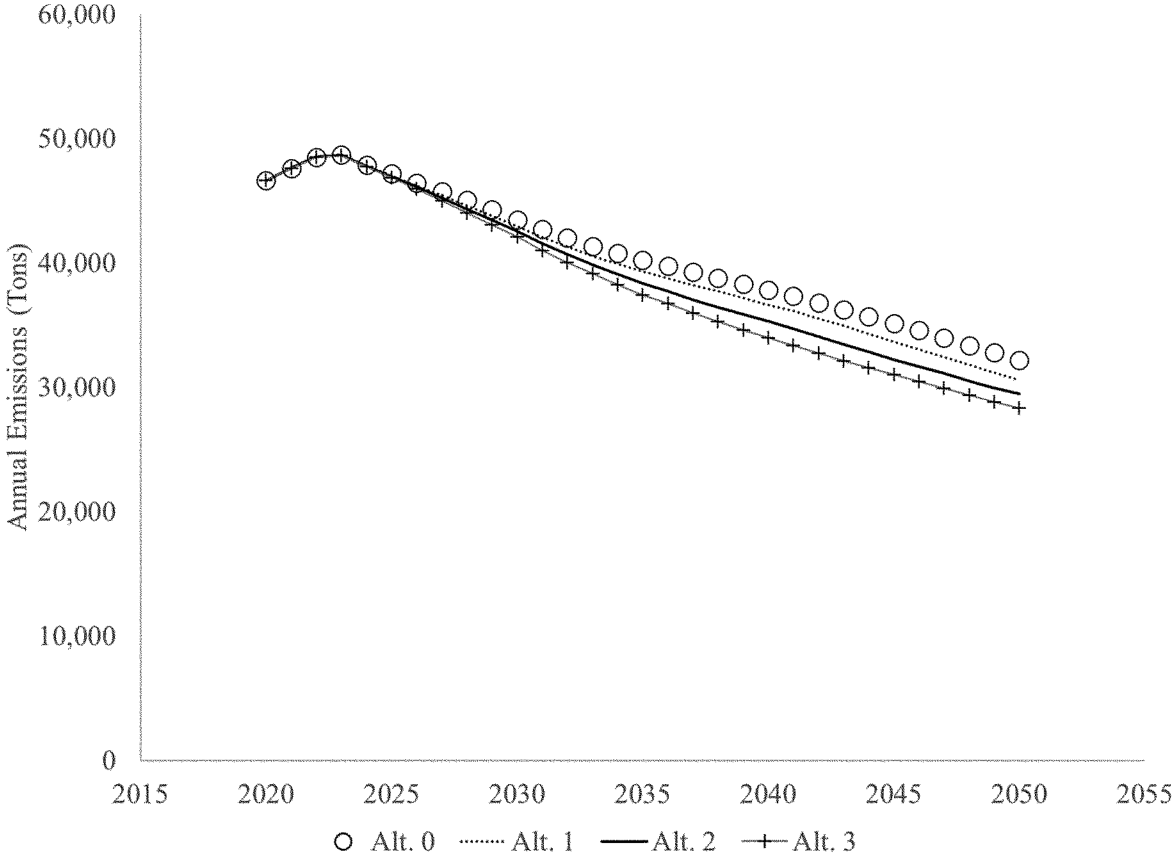

Figure V-7 – Estimated Annual N_2O Emissions Attributable to Light-Duty On-Road Fleet

The figures presented here are not the only estimates NHTSA has calculated regarding projected GHG emissions in future years. As discussed in Section II, the accompanying SEIS uses an ''unconstrained'' analysis as opposed to the ''standard setting'' analysis presented in this NPRM and PRIA. For more information regarding projected GHG emissions, as well as model-based estimates of corresponding impacts on several measures of global climate change, see the SEIS.

NHTSA also estimates criteria pollutant emissions resulting from vehicle and upstream processes attributable to the light-duty on-road fleet. NHTSA includes estimates for all of the criteria pollutants for which EPA has issued National Ambient Air Quality Standards. Under each regulatory alternative, NHTSA projects a dramatic decline in annual emissions of carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxide (NO_X), and fine particulate matter ($PM_{2.5}$) attributable to the light-duty on-road fleet between 2020 and 2050. As exemplified in Figure V–8, emissions in any given year could be very nearly the same under each regulatory alternative.

On the other hand, as discussed in the PRIA and SEIS accompanying this NPRM, NHTSA projects that annual SO_2 emissions attributable to the light-duty on-road fleet could increase modestly under the action alternatives, because, as discussed above, NHTSA projects that each of the action alternatives could lead to greater use of electricity (for PHEVs and BEVs). The adoption of actions—such as actions prompted by President Biden's Executive order directing agencies to develop a Federal Clean Electricity and Vehicle Procurement Strategy—to reduce electricity generation emission rates beyond projections underlying NHTSA's analysis (discussed in the TSD) could dramatically reduce SO_2 emissions under all regulatory alternatives considered here.[382]

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[382] E.O. 14008, 86 FR 7619 (Feb. 1, 2021), *https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/,* accessed June 17, 2021.

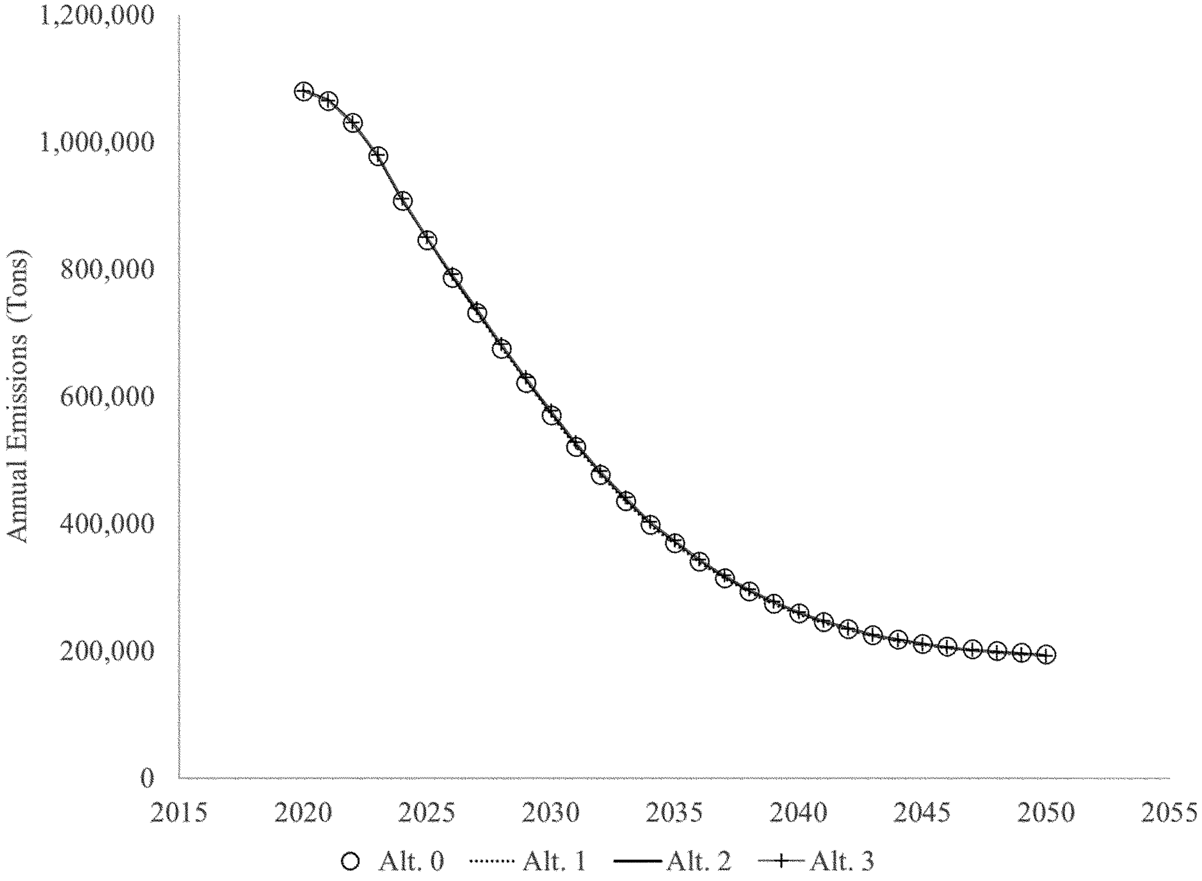

Figure V-8 – Estimated Annual NOx Emissions Attributable to Light-Duty On-Road Fleet

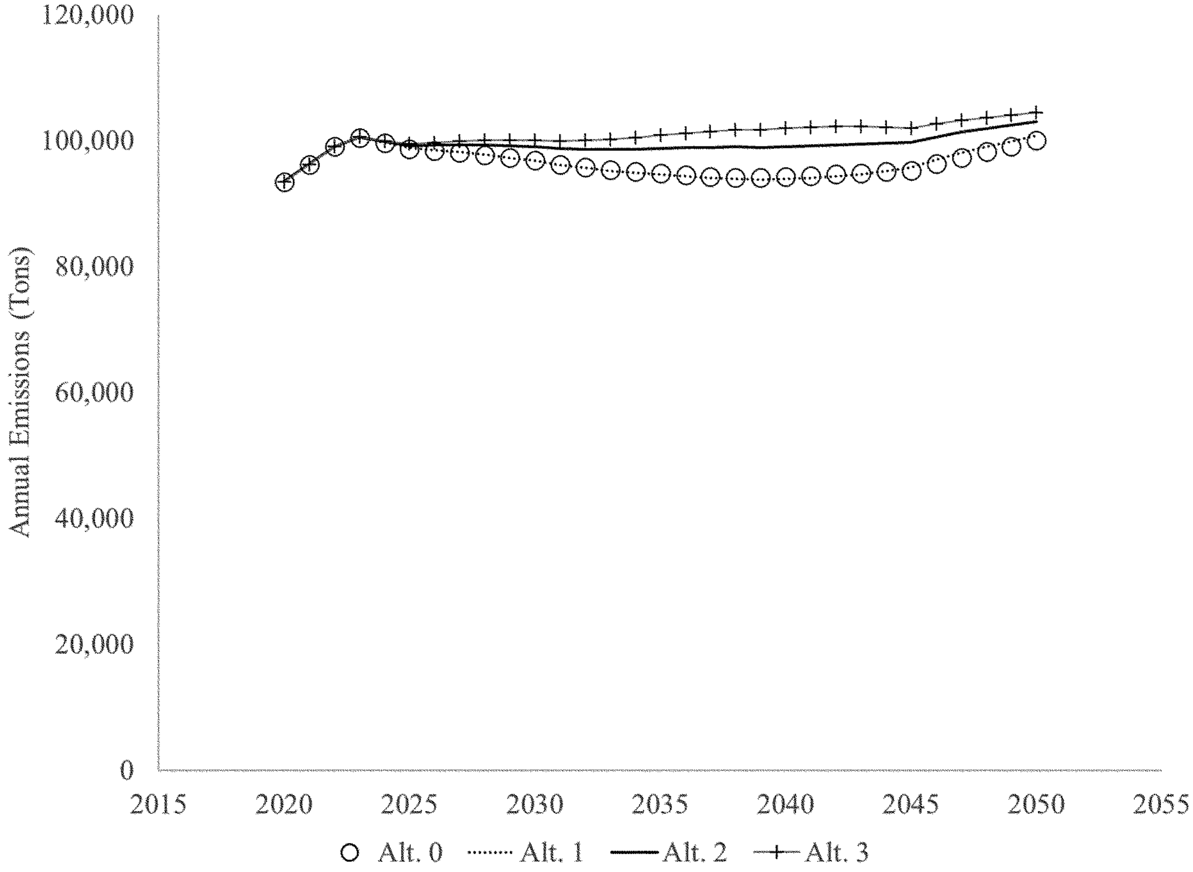

Figure V-9 – Estimated Annual SO_2 Emissions Attributable to Light-Duty On-Road Fleet

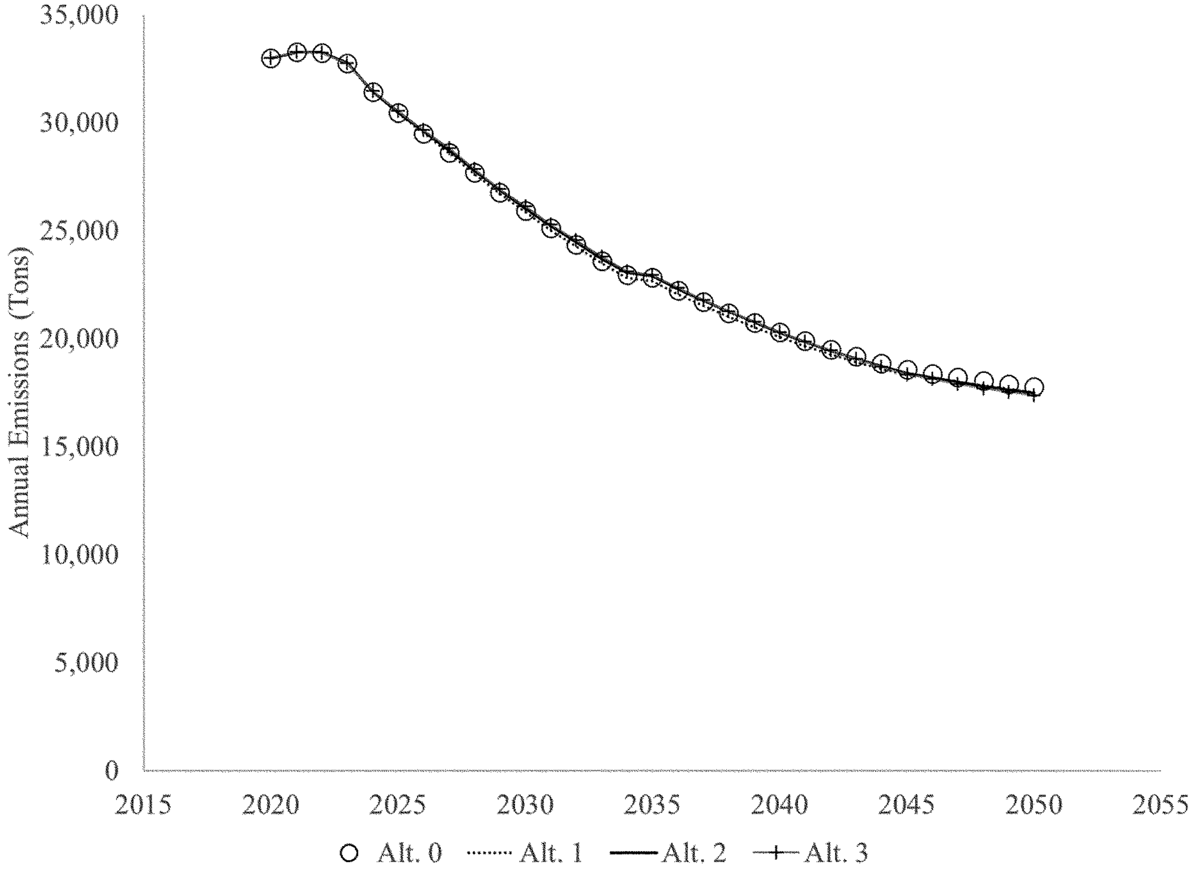

Figure V-10 – Estimated Annual $PM_{2.5}$ Emissions Attributable to Light-Duty On-Road Fleet

Health impacts quantified by the CAFE Model include various instances of hospital visits due to respiratory problems, minor restricted activity days, non-fatal heart attacks, acute bronchitis, premature mortality, and other effects of criteria pollutant emissions on health. Figure V–11 shows the differences in select health impacts relative to the baseline, across alternatives 1–3. These changes are split between calendar year decades, with the largest differences between the baseline and alternatives occurring between 2041–2050. The magnitude of the differences relates directly to the changes in tons of criteria pollutants emitted. See Chapter 5.4 of the TSD for information regarding how the CAFE Model calculates these health impacts.

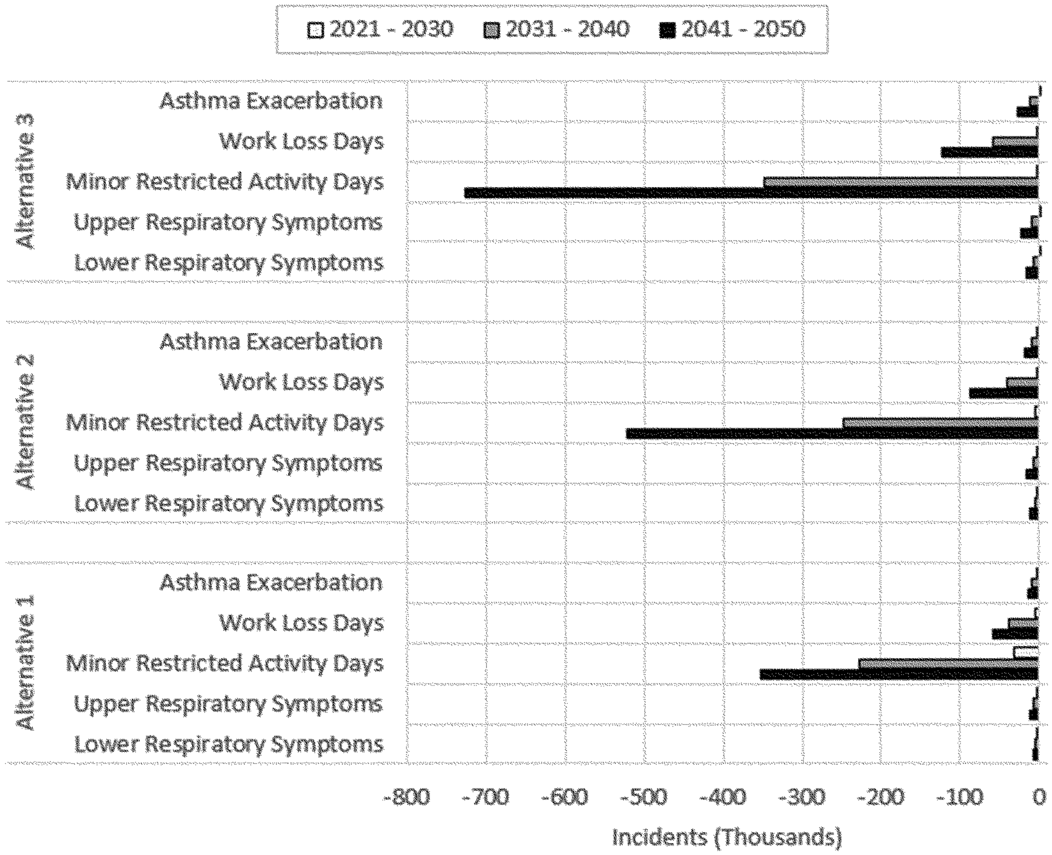

Figure V-11 – Changes in Cumulative Emission Health Impacts Relative to the Baseline

Lastly, NHTSA also quantifies safety impacts in its analysis. These include estimated counts of fatalities, non-fatal injuries, and property damage crashes occurring over the lifetimes of the light-duty on-road vehicles considered in the analysis. Chapter 5 in the PRIA accompanying this NPRM contains an in-depth discussion on the effects of the various alternatives on these safety measures, and TSD Chapter 7 contains information regarding the construction of the safety estimates.

E. Sensitivity Analysis

The analysis conducted to support this proposal consists of data, estimates, and assumptions, all applied within an analytical framework, the CAFE Model. Just like in all past CAFE rulemakings, NHTSA recognizes that many analytical inputs are uncertain, and some inputs are very uncertain. Of those uncertain inputs, some are likely to exert considerable influence over specific types of estimated impacts, and some are likely to do so for the bulk of the analysis. Yet making assumptions in the face of that uncertainty is necessary, if we are going to try to analyze meaningfully the effects of something that will happen in the future—*i.e.,* the regulatory alternatives being considered, that represent different possible CAFE standards for MYs 2024–2026. To get a sense of the effect that these assumptions have on the analytical findings, we conducted additional model runs with alternative assumptions, which explored a range of potential inputs and the sensitivity of estimated impacts to changes in model inputs. Sensitivity cases in this analysis span assumptions related to technology applicability and cost, economic conditions, consumer preferences, externality values, and safety assumptions, among others.[383] A sensitivity analysis can identify two critical pieces of information: *How big an influence* does each parameter exert on the analysis, and *how sensitive are the model results* to that assumption?

That said, influence is different from likelihood. NHTSA does not mean to suggest that any one of the sensitivity cases presented here is inherently more likely than the collection of assumptions that represent the reference case in the figures and tables that follow. Nor is this sensitivity analysis intended to suggest that only one of the many assumptions made is likely to prove off-base with the passage of time or new observations. It is more likely that, when assumptions are eventually contradicted by future observation (*e.g.,* deviations in observed and predicted fuel prices are nearly a given), there will be *collections* of assumptions, rather than individual parameters, that simultaneously require updating. For this reason, we do not interpret the sensitivity analysis as necessarily providing justification for alternative regulatory scenarios to be preferred. Rather, the analysis simply provides an indication of which assumptions are most critical, and the extent to which future deviations from central analysis

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[383] In contrast to an uncertainty analysis, where many assumptions are varied simultaneously, the sensitivity analyses included here vary a single assumption and provide information about the influence of each individual factor, rather than suggesting that an alternative assumption would have justified a different preferred alternative.

assumptions could affect costs and benefits of this proposal.

Table V–38 lists and briefly descries the cases that we examined in the sensitivity analysis.

Table V-38 – Cases Included in Sensitivity Analysis

Sensitivity Case	Description
Reference case (RC)	Reference case with 2.5% SCC discount rate
RC w/ 7% social DR, 3% SC-GHG DR	Reference case with 3% SCC discount rate (DR) (for 7% social discount rate)
RC w/ 7% social DR, 5% SC-GHG DR	Reference case with 5% SCC discount rate
RC w/ 95th pctile SC-GHG DR	Reference case with 95th percentile SCC discount rate
2020 SCC	Social cost of carbon values at 2020 Final Rule levels
One-year redesign cadence	Vehicles redesigned every year
MR5/6 skip (>100k)	MR5 and MR6 skipped for platforms with 100k or more units
MR5/6 skip (>2k)	MR5 and MR6 skipped for platforms with 2k or more units
No MR5/6 skip	No MR5 or MR6 application applied without SKIP restriction
2020 Final Rule MR5/6 costs	Cost values for MR5 and MR6 at levels from 2020 Final Rule
No HCR skip	HCR engine applicable for all OEMs and technology classes
Flat AC/OC	No additional AC or OC credit accumulation after MY 2021 levels
Reduced MDPCS stringency	Minimum domestic passenger car standard reduced as described in Section VI of the preamble
60-month payback period	60-month payback period
Battery direct costs (-20%)	Battery direct manufacturing cost decreased by 20%, reference battery learning cost
Battery direct costs (+20%)	Battery direct manufacturing cost increased by 20%, reference battery learning cost
Battery learning costs (-20%)	Battery learning cost decreased by 20%, reference direct manufacturing cost
Battery learning costs (+20%)	Battery learning cost increased by 20%, reference direct manufacturing cost
Rebound (10%)	Ten percent rebound effect
Rebound (20%)	Twenty percent rebound effect
Mass-size-safety (low)	The lower bound of the 95% CI for all model coefficients
Mass-size-safety (high)	The upper bound of the 95% CI for all model coefficients
Crash avoidance (low effectiveness)	Lower-bound estimate of effectiveness for 6 current crash avoidance technologies at avoiding fatal, injury, and property damage
Crash avoidance (high effectiveness)	Upper-bound estimate of effectiveness for 6 current crash avoidance technologies at avoiding fatal, injury, and property damage
Sales-scrappage response (-20%)	Sales-scrappage elasticity decreased by 20%
Sales-scrappage response (+20%)	Sales-scrappage elasticity increased by 20%
Low GDP	Low economic growth (AEO2021)
High GDP	High economic growth (AEO2021)
Oil price (EIA low)	Input oil price series based on EIA low forecast
Oil price (Global Insight)	Input oil price series based on Global Insight forecast
Oil price (EIA high)	Input oil price series based on EIA high forecast

Complete results for the sensitivity cases are summarized in Chapter 7 of the accompanying PRIA, and detailed model inputs and outputs for curious readers are available on NHTSA's website.[384] For purposes of this preamble, Figure V–12 below illustrates the relative change of the sensitivity effect of selected inputs on the costs and benefits that we estimate for the proposal.

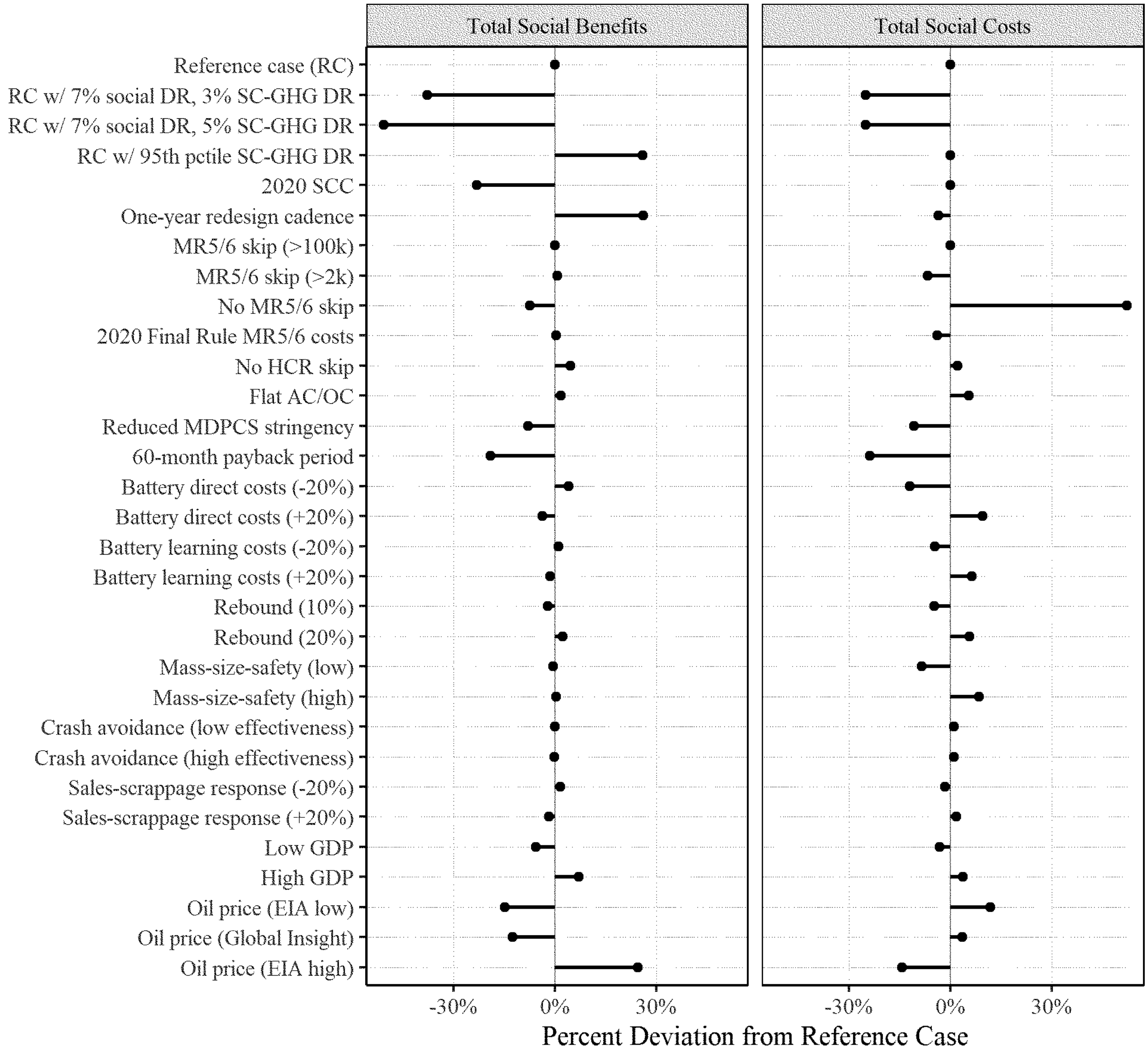

Figure V-12 – Relative Change in Total Costs and Total Benefits from Reference Case

While Figure V–12 does not show precise values, it gives us a sense of which inputs are ones for which a different assumption would have a much different effect on analytical findings, and which ones would not have much effect. Assuming a more-discounted or lower social cost of carbon would have a relatively large effect, as would assuming a different oil price, or doubling the assumed "payback period." Making very high levels of mass reduction unavailable in the modeling appears to have a (relatively) very large effect on costs, but this is to some extent an artifact of the "standard setting" runs used for the preamble and PRIA analysis, where electrification is limited due to statutory restrictions. On the other hand, assumptions about which there has been significant disagreement in the past, like the rebound effect or the sales-scrappage response, appear to cause only relatively small changes in net benefits. Chapter 7 of the PRIA provides a much fuller discussion of these findings, and presents net benefits estimated under each of the cases included in the sensitivity analysis, including the subset for which impacts are summarized in Figure V–13.

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[384] *https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy.*

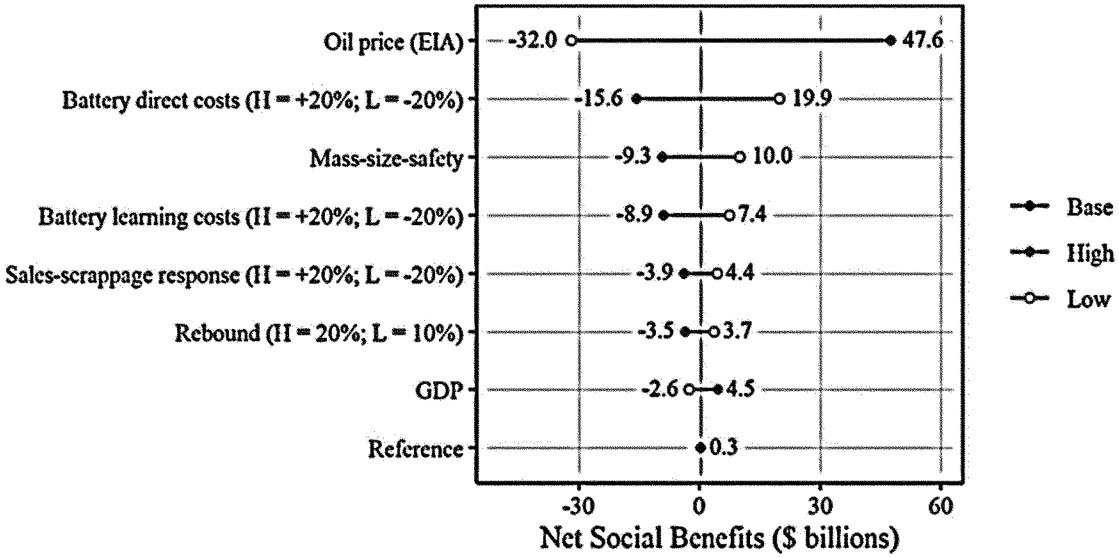

Figure V-13 – Relative Magnitude of Sensitivity Effect on Net Benefits

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The results presented in the earlier subsections of Section V and discussed in Section VI reflect the agency's best judgments regarding many different factors, and the sensitivity analysis discussed here is simply to illustrate the obvious, that differences in assumptions can lead to differences in analytical outcomes, some of which can be large and some of which may be smaller than expected. Policy-making in the face of future uncertainty is inherently complex. Section VI explains how NHTSA proposes to balance the statutory factors in light of the analytical findings, the uncertainty that we know exists, and our Nation's policy goals, to determine the CAFE standards that NHTSA tentatively concludes are maximum feasible for MYs 2024–2026.

VI. Basis for NHTSA's Tentative Conclusion That the Proposed Standards Are Maximum Feasible

In this section, NHTSA discusses the factors, data, and analysis that the agency has considered in the tentative selection of the proposed CAFE standards for MYs 2024–2026. The primary purpose of EPCA, as amended by EISA, and codified at 49 U.S.C. chapter 329, is energy conservation, and fuel economy standards help to conserve energy by requiring automakers to make new vehicles travel a certain distance on a gallon of fuel.[385] The goal of the CAFE standards is to conserve energy, while taking into account the statutory factors set forth at 49 U.S.C. 32902(f), as discussed below.

The provision at 49 U.S.C. 32902(f) states that when setting maximum feasible CAFE standards for new passenger cars and light trucks, the Secretary of Transportation[386] "shall consider technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy." In previous rulemakings, including the 2012 final rule issued during the Obama Administration and the recent 2020 final rule, NHTSA considered technological feasibility, including the availability of various fuel-economy-improving technologies to be applied to new vehicles in the timeframe of the standards depending on the ultimate stringency levels, and also considered economic practicability, including the differences between a range of regulatory alternatives in terms of effects on per-vehicle costs, the ability of both the industry and individual manufacturers to comply with standards at various levels, as well as effects on vehicle sales, industry employment, and consumer demand. NHTSA also considered how compliance with other motor vehicle standards of the Government might affect manufacturers' ability to meet CAFE standards represented by a range of regulatory alternatives, and how the need of the U.S. to conserve energy could be more or less addressed under a range of regulatory alternatives, in terms of considerations like costs to consumers, the national balance of payments, environmental implications like climate and smog effects, and foreign policy effects such as the likelihood that U.S. military and other expenditures could change as a result of more or less oil consumed by the U.S. vehicle fleet. These elements are discussed in detail throughout this analysis. As will be explained in greater detail below, while NHTSA is considering all of the same factors in proposing revised CAFE standards for MYs 2024–2026 that it considered in previous rulemakings, the agency's balancing of those factors has shifted, and NHTSA is therefore choosing to set CAFE standards at a different level from what both the 2012 final rule and the 2020 final rule set forth. Besides the factors specified in 32902(f), NHTSA has also historically considered the safety effects of potential CAFE standards, and additionally considers relevant case law.

NHTSA and EPA have coordinated in setting standards, and many of the factors that NHTSA considers to set maximum feasible standards complement factors that EPA considers under the Clean Air Act. The balancing of competing factors by both EPA and NHTSA are consistent with each agency's statutory authority and recognize the statutory obligations the Supreme Court pointed to in *Massachusetts* v. *EPA.* NHTSA also

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[385] While individual vehicles need not meet any particular mpg level, as discussed elsewhere in this preamble, fuel economy standards do require vehicle manufacturers' fleets to meet certain compliance obligations based on fuel economy levels target curves set forth by NHTSA in regulation.

[386] By delegation, the NHTSA Administrator.

considers the Ninth Circuit's decision in *Center for Biological Diversity* v. *NHTSA,* which remanded NHTSA's 2006 final rule establishing standards for MYs 2008–2011 light trucks and underscored that ''the overarching purpose of EPCA is energy conservation.''[387]

This proposal contains a range of regulatory alternatives for MYs 2024–2026, from retaining the 1.5 percent annual increases set in 2020, up to a stringency increase of 10 percent annually. The analysis supported this range of alternatives based on factors relevant to NHTSA's exercise of its 32902(f) authority, such as fuel saved and emissions reduced, the technologies available to meet the standards, the costs of compliance for automakers and their abilities to comply by applying technologies, the impact on consumers with respect to cost, fuel savings, and vehicle choice, and effects on safety, among other things.

NHTSA's tentative conclusion, after consideration of the factors described below and information in the administrative record for this action, is that 8 percent increases in stringency for MYs 2024–2026 (Alternative 2 of this analysis) are maximum feasible. The Biden Administration is deeply committed to working aggressively to improve energy conservation, and higher standards appear increasingly likely to be economically practicable given almost-daily announcements by major automakers about forthcoming new high-fuel-economy vehicle models, as described below. Despite only one year having passed since the 2020 final rule, enough has changed in the U.S. and the world that revisiting the CAFE standards for MYs 2024–2026, and raising their stringency considerably, is both appropriate and reasonable.

The following sections discuss in more detail the statutory requirements and considerations involved in NHTSA's tentative determination of maximum feasible CAFE standards, and NHTSA's explanation of its balancing of factors for this tentative determination.

A. EPCA, as Amended by EISA

EPCA, as amended by EISA, contains a number of provisions regarding how NHTSA must set CAFE standards. DOT (by delegation, NHTSA)[388] must establish separate CAFE standards for passenger cars and light trucks[389] for each model year,[390] and each standard must be the maximum feasible that the Secretary (again, by delegation, NHTSA) believes the manufacturers can achieve in that model year.[391] In determining the maximum feasible levels of CAFE standards, EPCA requires that NHTSA consider four statutory factors: Technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy.[392] In addition, NHTSA has the authority to consider (and typically does consider) other relevant factors, such as the effect of CAFE standards on motor vehicle safety and consumer preferences. The ultimate determination of what standards can be considered maximum feasible involves a weighing and balancing of factors, and the balance may shift depending on the information before NHTSA about the expected circumstances in the model years covered by the rulemaking. The agency's decision must also be guided by the overarching purpose of EPCA, energy conservation, while balancing these factors.[393]

Besides the requirement that the standards be maximum feasible for the fleet in question and the model year in question, EPCA/EISA also contain several other requirements, as follow.

1. Lead Time

EPCA requires that NHTSA prescribe new CAFE standards at least 18 months before the beginning of each model year.[394] For amendments to existing standards (as this NPRM proposes), EPCA requires that if the amendments make an average fuel economy standard more stringent, at least 18 months of lead time must be provided.[395] Thus, if the first year for which NHTSA is proposing to amend standards in this NPRM is MY 2024, NHTSA interprets this provision as requiring the agency to issue a final rule covering MY 2024 standards no later than April 2022.

2. Separate Standards for Cars and Trucks, and Minimum Standards for Domestic Passenger Cars

As mentioned above, EPCA requires NHTSA to set separate standards for passenger cars and light trucks for each model year.[396] NHTSA has long interpreted this requirement as preventing the agency from setting a single combined CAFE standard for cars and trucks together, based on the plain language of the statute. Congress originally required separate CAFE standards for cars and trucks to reflect the different fuel economy capabilities of those different types of vehicles, and over the history of the CAFE program, has never revised this requirement. Even as many cars and trucks have come to resemble each other more closely over time—many crossover and sport-utility models, for example, come in versions today that may be subject to either the car standards or the truck standards depending on their characteristics—it is still accurate to say that vehicles with truck-like characteristics such as 4-wheel drive, cargo-carrying capability, etc., currently consume more fuel per mile than vehicles without these characteristics.

EPCA, as amended by EISA, also requires another separate standard to be set for domestically-manufactured[397] passenger cars. Unlike the generally-applicable standards for passenger cars and light trucks described above, the compliance obligation of the minimum domestic passenger car standard (MDPCS for brevity) is identical for all manufacturers. The statute clearly states that any manufacturer's domestically manufactured passenger car fleet must meet the greater of either 27.5 mpg on average, or 92 percent of the average fuel economy projected by the Secretary for the combined domestic and non-domestic passenger automobile fleets manufactured for sale in the United States by all manufacturers in the model year, which projection shall be published in the **Federal Register** when the standard for that model year is promulgated in accordance with 49 U.S.C. 32902(b).[398]

Since that requirement was promulgated, the ''92 percent'' has always been greater than 27.5 mpg, and foreseeably will continue to be so in the future. While NHTSA published 92 percent MDPCSs for MYs 2024–2026 at 49 CFR 531.5(d) as part of the 2020 final rule, the statutory language is clear that

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[387] 538 F.3d 1172 (9th Cir. 2008).

[388] EPCA and EISA direct the Secretary of Transportation to develop, implement, and enforce fuel economy standards (*see* 49 U.S.C. 32901 *et seq.*), which authority the Secretary has delegated to NHTSA at 49 CFR 1.95(a).

[389] 49 U.S.C. 32902(b)(1) (2007).

[390] 49 U.S.C. 32902(a) (2007).

[391] *Id.*

[392] 49 U.S.C. 32902(f) (2007).

[393] Center for Biological Diversity v. NHTSA, 538 F.3d 1172, 1197 (9th Cir. 2008) (''Whatever method it uses, NHTSA cannot set fuel economy standards that are contrary to Congress's purpose in enacting the EPCA—energy conservation.'').

[394] 49 U.S.C. 32902(a) (2007).

[395] 49 U.S.C. 32902(g)(2) (2007).

[396] 49 U.S.C. 32902(b)(1) (2007).

[397] In the CAFE program, ''domestically-manufactured'' is defined by Congress in 49 U.S.C. 32904(b). The definition roughly provides that a passenger car is ''domestically manufactured'' as long as at least 75 percent of the cost to the manufacturer is attributable to value added in the United States, Canada, or Mexico, unless the assembly of the vehicle is completed in Canada or Mexico *and* the vehicle is imported into the United States more than 30 days after the end of the model year.

[398] 49 U.S.C. 32902(b)(4) (2007).

the MDPCS must be determined at the time an overall passenger car standards is promulgated and published in the **Federal Register**. Thus, any time NHTSA establishes or changes a passenger car standard for a model year, the MDPCS must also be evaluated or re-evaluated and established accordingly.

As in the 2020 final rule, NHTSA recognizes industry concerns that actual total passenger car fleet standards have differed significantly from past projections, perhaps more so when the agency has projected significantly into the future. In that final rule, because the compliance data showed that the standards projected in 2012 were consistently more stringent than the actual standards, by an average of 1.9 percent. NHTSA stated that this difference indicated that in rulemakings conducted in 2009 through 2012, NHTSA's and EPA's projections of passenger car vehicle footprints and production volumes, in retrospect, underestimated the production of larger passenger cars over the MYs 2011 to 2018 period.[399]

Unlike the passenger car standards and light truck standards which are vehicle-attribute-based and automatically adjust with changes in consumer demand, the MDPCS are *not* attribute-based, and therefore do not adjust with changes in consumer demand and production. They are instead fixed standards that are established at the time of the rulemaking. As a result, by assuming a smaller-footprint fleet, on average, than what ended up being produced, the MYs 2011–2018 MDPCS ended up being more stringent and placing a greater burden on manufacturers of domestic passenger cars than was projected and expected at the time of the rulemakings that established those standards. In the 2020 final rule, therefore, NHTSA agreed with industry concerns over the impact of changes in consumer demand (as compared to what was assumed in 2012 about future consumer demand for greater fuel economy) on manufacturers' ability to comply with the MDPCS and in particular, manufacturers that produce larger passenger cars domestically. Some of the largest civil penalties for noncompliance in the history of the CAFE program have been paid for noncompliance with the MDPCS. NHTSA also expressed concern that consumer demand may shift even more in the direction of larger passenger cars if fuel prices continue to remain low. Sustained low oil prices can be expected to have real effects on consumer demand for additional fuel economy, and consumers may foreseeably be even more interested in 2WD crossovers and passenger-car-fleet SUVs (and less interested in smaller passenger cars) than they are at present.

Therefore, in the 2020 final rule, to help avoid similar outcomes in the 2021–2026 timeframe to what had happened with the MDPCS over the preceding model years, NHTSA determined that it was reasonable and appropriate to consider the recent projection errors as part of estimating the total passenger car fleet fuel economy for MYs 2021–2026. NHTSA therefore projected the total passenger car fleet fuel economy using the central analysis value in each model year, and applied an offset based on the historical 1.9 percent difference identified for MYs 2011–2018.

For this proposal, recognizing that we are proposing to increase stringency considerably over the baseline standards and that civil penalties have also recently increased, NHTSA remains concerned that the MDPCS may pose a significant challenge to certain manufacturers. To that end, NHTSA is proposing to retain the 1.9 percent offset for the MDPCS for MYs 2024–2026, which we have appropriately recalculated based on the current projections for passenger cars based on the current analysis fleet. Table VI–1 shows the calculation values used to determine the total passenger car fleet fuel economy value for each model year for the preferred alternative.

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Table VI-1 – Calculation of the Projected Total Passenger Car Fleet Standard and the Minimum Domestic Passenger Car Standard (92 Percent of the Total Passenger Car Standard) for the Preferred Alternative

	2024	2025	2026
Projected Total PC Fleet Standard – Central Analysis (mpg)	49.2	53.4	58.1
Offset: Average Historical Difference Between Regulatory Analyses and Actual Total PC Fleet Standard (percent)	-1.9	-1.9	-1.9
Offset: Average Historical Difference Between Regulatory Analyses and Actual Total PC Fleet Standard (mpg)	-0.92	-1.00	-1.08
Projected Total PC Standard Accounting for Historical Offset (mpg)	48.2	52.4	57.0
Minimum Domestic Passenger Car Standard = 92% of Projected Total PC Standard Accounting for Historical Offset (mpg)	44.4	48.2	52.4

Using this approach, the MDPCS under each regulatory alternative would thus be as shown in Table VI–2.

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[399] *See* 85 FR at 25127 (Apr. 30, 2020).

Table VI-2 – Proposed MDPCS for Each Regulatory Alternative, Calculated per 1.9 Percent Offset

Alternative	MY 2024	MY 2025	MY 2026
No Action	41.4	42.1	42.7
Alternative 1	44.9	46.5	48.0
Alternative 2 (Preferred)	44.4	48.2	52.4
Alternative 3	45.4	50.4	56.0

NHTSA is also seeking comment on another approach to offsetting the MDPCS. Recognizing that the analysis supporting this proposal does not attempt to project how vehicle footprints may change in the future, nor how that might affect the average fuel economy of passenger cars sold in the U.S., NHTSA could instead attempt to make such a projection explicitly.

Examination of the average footprints of passenger cars sold in the U.S. from 2008, when EPA began reporting footprint data, to 2020 indicates a clear and statistically significant trend of gradually increasing average footprint (Figure VI–1). The average annual increase in passenger car footprint, estimated by ordinary least squares, indicates that the passenger car footprints increased by an average of 0.1206 square feet annually over the 2008–2020 period. The estimated average increase is statistically significant at the 0.000001 level, with a 95 percent confidence interval of (0.0929, 0.1483).

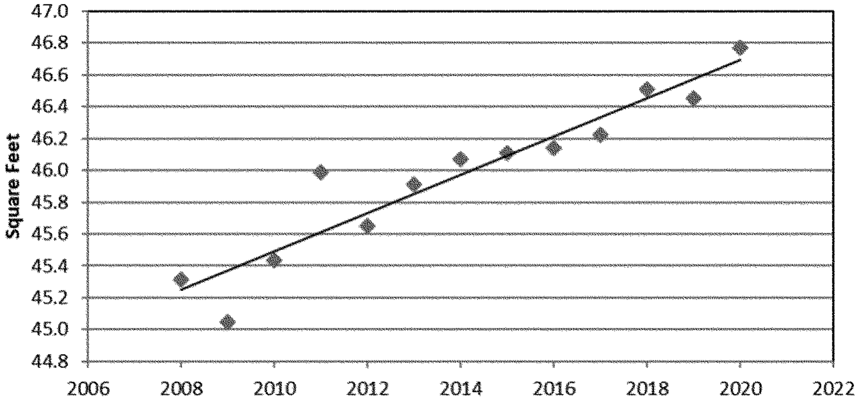

Figure VI-1 – Trend in Passenger Car Footprint, 2008-2020 (Source: EPA 2020 Automotive Trends Report)

The alternate method for calculating an offset to the MDPCS would be three steps, as follows:

1. Starting from the average footprint of passenger cars in 2020 as reported by EPA, add 0.1206 square feet per year through 2026.
2. Calculate the estimated fuel economy of passenger cars using the average projected footprint numbers calculated in step 1 and the footprint functions that are the passenger car standards for the corresponding model year, which then become "the Secretary's projected passenger car fuel economy numbers."
3. Apply the 92 percent factor to calculate the MDPCS for 2024, 2025, and 2026.

The results of this approach are shown in Table VI–3.

Table VI-3 – Alternate Approach to Offsetting MDPCS, on Which NHTSA Seeks Comment

Alternative	MY 2024	MY 2025	MY 2026
No Action	41.6	42.2	42.7
Alternative 1	45.1	46.5	48.0
Alternative 2 (Preferred)	44.6	48.3	52.4
Alternative 3	45.5	50.5	56.0

Comparing all of these, Table VI–4 shows (1) the unadjusted 92 percent MDPCS for MYs 2024–2026, (2) the proposed 1.9 percent-offset MDPCS for MYs 2024–2026, and (3) the alternate approach offset MDPCS for MYs 2024–2026.

Table VI-4 – Comparing the Required mpg Levels for the MDPCS by Regulatory Alternative and Offset Approach

Alternative	MY 2024	MY 2025	MY 2026
No Action			
Unadjusted 92%	42.2	42.9	43.5
1.9% offset	41.4	42.1	42.7
Alternate approach offset	41.6	42.2	42.7
Alternative 1			
Unadjusted 92%	45.8	47.3	48.9
1.9% offset	44.9	46.5	48.0
Alternate approach offset	45.1	46.5	48.0
Alternative 2 (Preferred)			
Unadjusted 92%	45.2	49.2	53.4
1.9% offset	44.4	48.2	52.4
Alternate approach offset	44.6	48.3	52.4
Alternative 3			
Unadjusted 92%	50.2	55.8	62.0
1.9% offset	45.4	50.4	56.0
Alternate approach offset	45.5	50.5	56.0

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While the CAFE Model analysis underlying this proposal, the PRIA, and the Draft SEIS does not reflect an offset to the unadjusted 92 percent MDPCS, separate analysis that does reflect the change demonstrates that doing so does not change estimated impacts of any of the regulatory alternatives under consideration, despite the mpg values being slightly different as shown in Table VI–4.

NHTSA seeks comment on the discussion above. To be clear, the agency also seeks comment on whether to apply the MDPCS without any modifier.

3. Attribute-Based and Defined by a Mathematical Function

EISA requires NHTSA to set CAFE standards that are ‘‘based on 1 or more attributes related to fuel economy and express[ed] . . . in the form of a mathematical function.’’ [400] Historically, NHTSA has based standards on vehicle footprint, and proposes to continue to do so for the reasons described in Section III.B of this preamble and Chapter 1 of the accompanying TSD. As in previous rulemakings, NHTSA is proposing to define the standards in the form of a constrained linear function that generally sets higher (more stringent) targets for smaller-footprint vehicles and lower (less stringent) targets for larger-footprint vehicles. These footprint curves are discussed in more detail in Section III.B and TSD Chapter 1. NHTSA seeks comment in Section III.B both on the continued use of footprint as the relevant attribute and on the continued use of the constrained linear curve shapes.

4. Number of Model Years for Which Standards May Be Set at a Time

EISA also states that NHTSA shall ‘‘issue regulations under this title prescribing average fuel economy standards for at least 1, but not more than 5, model years.’’ [401] In this NPRM, NHTSA is proposing to set CAFE standards for three model years, MYs 2024–2026. This proposal fits squarely within the plain language of the statute.

5. Maximum Feasible Standards

As discussed above, EPCA requires NHTSA to consider four factors in determining what levels of CAFE standards would be maximum feasible. NHTSA presents in the sections below its understanding of the meanings of those four factors.

(a) Technological Feasibility

‘‘Technological feasibility’’ refers to whether a particular method of improving fuel economy is available for deployment in commercial application in the model year for which a standard is being established. Thus, NHTSA is not limited in determining the level of new standards to technology that is already being applied commercially at the time of the rulemaking. For this proposal, NHTSA has considered a wide range of technologies that improve fuel economy, while considering the need to account for which technologies have already been applied to which vehicle model/configuration, as well as the need to estimate realistically the cost and fuel

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[400] 49 U.S.C. 32902(b)(3)(A) (2007).

[401] 49 U.S.C. 32902(b)(3)(B) (2007).

economy impacts of each technology as applied to different vehicle models/configurations. NHTSA has not, however, attempted to account for every technology that might conceivably be applied to improve fuel economy, nor does NHTSA believe it is necessary to do so given that many technologies address fuel economy in similar ways.[402]

NHTSA notes that the technological feasibility factor allows NHTSA to set standards that force the development and application of new fuel-efficient technologies, but this factor does not *require* NHTSA to do so.[403] In the 2012 final rule, NHTSA stated that ''[i]t is important to remember that technological feasibility must also be balanced with the other of the four statutory factors. Thus, while 'technological feasibility' can drive standards higher by assuming the use of technologies that are not yet commercial, 'maximum feasible' is also defined in terms of economic practicability, for example, which might caution the agency against basing standards (even fairly distant standards) *entirely* on such technologies.'' [404] NHTSA further stated that ''. . . as the 'maximum feasible' balancing may vary depending on the circumstances at hand for the model year in which the standards are set, the extent to which technological feasibility is simply met or plays a more dynamic role may also shift.'' [405] For purposes of this proposal covering standards for MYs 2024–2026, NHTSA is certain that sufficient technology exists to meet the standards—even for the most stringent regulatory alternative. As will be discussed further below, for this proposal, the question is more likely rather, given that the technology exists, how much of it should be required to be added to new cars and trucks in order to conserve more energy, and how to balance that objective against the additional cost of adding that technology.

(b) Economic Practicability

''Economic practicability'' has consistently referred to whether a standard is one ''within the financial capability of the industry, but not so stringent as to'' lead to ''adverse economic consequences, such as a significant loss of jobs or unreasonable elimination of consumer choice.'' [406] In evaluating economic practicability, NHTSA considers the uncertainty surrounding future market conditions and consumer demand for fuel economy alongside consumer demand for other vehicle attributes. There is not necessarily a bright-line test for whether a regulatory alternative is economically practicable, but there are several metrics that we discuss below that we find can be useful for making this assessment. In determining whether standards may or may not be economically practicable, NHTSA considers:

Application rate of technologies—whether it appears that a regulatory alternative would impose undue burden on manufacturers in either or both the near and long term in terms of how much and which technologies might be required. This metric connects to the next two metrics, as well.

Other technology-related considerations—related to the application rate of technologies, whether it appears that the burden on several or more manufacturers might cause them to respond to the standards in ways that compromise, for example, vehicle safety, or other aspects of performance that may be important to consumer acceptance of new products.

Cost of meeting the standards—even if the technology exists and it appears that manufacturers can apply it consistent with their product cadence, if meeting the standards will raise per-vehicle cost more than we believe consumers are likely to accept, which could negatively impact sales and employment in this sector, the standards may not be economically practicable. While consumer acceptance of additional new vehicle cost associated with more stringent CAFE standards is uncertain, NHTSA still finds this metric useful for evaluating economic practicability. Elsewhere in this preamble, we seek comment specifically on consumer valuation of fuel economy.

Sales and employment responses—as discussed above, sales and employment responses have historically been key to NHTSA's understanding of economic practicability.

Uncertainty and consumer acceptance[407] *of technologies*—considerations not accounted for expressly in our modeling analysis, but important to an assessment of economic practicability given the timeframe of this rulemaking. Consumer acceptance can involve consideration of anticipated consumer responses not just to increased vehicle cost and consumer valuation of fuel economy, but also the way manufacturers may change vehicle models and vehicle sales mix in response to CAFE standards.

Over time, NHTSA has tried different methods to account for economic practicability. Many years ago, prior to the MYs 2005–2007 rulemaking under the non-attribute-based (fixed value) CAFE standards, NHTSA sought to ensure the economic practicability of standards in part by setting them at or near the capability of the ''least capable manufacturer'' with a significant share of the market, *i.e.,* typically the manufacturer whose fleet mix was, on average, the largest and heaviest, generally having the highest capacity and capability so as not to limit the availability of those types of vehicles to consumers. NHTSA rejected the ''least capable manufacturer'' approach several rulemakings ago and no longer believes that it is consistent with our root interpretation of economic practicability. Economic practicability focuses on the capability of the *industry* and seeks to avoid adverse consequences such as (*inter alia*) a significant loss of jobs or unreasonable elimination of consumer choice. If the overarching purpose of EPCA is energy conservation, it seems reasonable to expect that maximum feasible standards may be harder for some automakers than for others, and that they need not be keyed to the capabilities of the *least* capable manufacturer.

NHTSA has also sought to account for economic practicability by applying marginal cost-benefit analysis since the first rulemakings establishing attribute-based standards, considering both overall societal impacts and overall consumer impacts. Whether the standards maximize net benefits has thus been a significant, but not dispositive, factor in the past for NHTSA's consideration of economic practicability. Executive Order 12866, as amended by Executive Order 13563, states that agencies should ''select, in choosing among alternative regulatory approaches, those approaches that maximize net benefits . . .'' In practice, however, agencies, including NHTSA, must consider that the modeling of net benefits does not capture all considerations relevant to economic practicability. Therefore, as in past rulemakings, NHTSA is considering net societal impacts, net consumer impacts,

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[402] For example, NHTSA has not considered high-speed flywheels as potential energy storage devices for hybrid vehicles; while such flywheels have been demonstrated in the laboratory and even tested in concept vehicles, commercially-available hybrid vehicles currently known to NHTSA use chemical batteries as energy storage devices, and the agency has considered a range of hybrid vehicle technologies that do so.

[403] *See* 77 FR at 63015 (Oct. 12, 2012).

[404] *Id.*

[405] *Id.*

[406] 67 FR 77015, 77021 (Dec. 16, 2002).

[407] *See, e.g., Center for Auto Safety* v. *NHTSA* (CAS), 793 F.2d 1322 (D.C. Cir. 1986) (Administrator's consideration of market demand as component of economic practicability found to be reasonable).

and other related elements in the consideration of economic practicability. That said, it is well within the agency's discretion to deviate from the level at which modeled net benefits are maximized if the agency concludes that the level would not represent the maximum feasible level for future CAFE standards. Economic practicability is complex, and like the other factors must be considered in the context of the overall balancing and EPCA's overarching purpose of energy conservation.

(c) The Effect of Other Motor Vehicle Standards of the Government on Fuel Economy

''The effect of other motor vehicle standards of the Government on fuel economy'' involves analysis of the effects of compliance with emission, safety, noise, or damageability standards on fuel economy capability and thus on average fuel economy. In many past CAFE rulemakings, NHTSA has said that it considers the adverse effects of other motor vehicle standards on fuel economy. It said so because, from the CAFE program's earliest years [408] until recently, the effects of such compliance on fuel economy capability over the history of the CAFE program have been negative ones. For example, safety standards that have the effect of increasing vehicle weight thereby lower fuel economy capability, thus decreasing the level of average fuel economy that NHTSA can determine to be feasible. NHTSA has also accounted for EPA's ''Tier 3'' standards for criteria pollutants in its estimates of technology effectiveness in this proposal, and State emissions standards (like California's) that address the tailpipe NO_X, NMOG, and CO emissions that occur during cold start.[409]

In other cases, the effect of other motor vehicle standards of the Government may be neutral, or positive. Since the Obama administration, NHTSA has considered the GHG standards set by EPA as ''other motor vehicle standards of the Government.'' In the 2012 final rule, NHTSA stated that ''To the extent the GHG standards result in increases in fuel economy, they would do so almost exclusively as a result of inducing manufacturers to install the same types of technologies used by manufacturers in complying with the CAFE standards.'' [410] NHTSA concluded in 2012 that ''no further action was needed'' because ''the agency had already considered EPA's [action] and the harmonization benefits of the National Program in developing its own [action].'' [411] In the 2020 final rule, NHTSA reinforced that conclusion by explaining that a textual analysis of the statutory language made it clear that EPA's CO_2 standards applicable to light-duty vehicles are literally ''other motor vehicle standards of the Government,'' because they are standards set by a Federal agency that apply to motor vehicles. NHTSA and EPA are obligated by Congress to exercise their own independent judgment in fulfilling their statutory missions, even though both agencies' regulations affect both fuel economy and CO_2 emissions. There are differences between the two agencies' programs that make NHTSA's CAFE standards and EPA's GHG standards not perfectly one-to-one (even besides the fact that EPA regulates other GHGs besides CO_2, EPA's CO_2 standards also differ from NHTSA's in a variety of ways, often because NHTSA is bound by statute to a certain aspect of CAFE regulation). NHTSA endeavors to create standards that meet our statutory obligations and still avoid requiring manufacturers to build multiple fleets of vehicles for the U.S. market.[412] As in 2020, NHTSA has continued to do all of these things with this proposal.

Similarly, NHTSA has considered and accounted for California's ZEV mandate (and its adoption by the other Section 177 states) in developing the baseline for this proposal. As discussed above, NHTSA has not expressly accounted for California's GHG standards for the model years subject to this rulemaking in the baseline analysis for this proposal,[413] but seeks comment on this approach for the final rule. NHTSA notes again that no final decision has yet been made on the CAA waiver for California.

(d) The Need of the U.S. To Conserve Energy

NHTSA has consistently interpreted ''the need of the United States to conserve energy'' to mean ''the consumer cost, national balance of payments, environmental, and foreign policy implications of our need for large quantities of petroleum, especially imported petroleum.'' [414]

(1) Consumer Costs and Fuel Prices

Fuel for vehicles costs money for vehicle owners and operators, so all else equal, consumers benefit from vehicles that need less fuel to perform the same amount of work. Future fuel prices are a critical input into the economic analysis of potential CAFE standards because they determine the value of fuel savings both to new vehicle buyers and to society; the amount of fuel economy that the new vehicle market is likely to demand in the absence of regulatory action; and they inform NHTSA about the ''consumer cost . . . of our need for large quantities of petroleum.'' For this proposal, NHTSA relied on fuel price projections from the U.S. Energy Information Administration's (EIA) Annual Energy Outlook (AEO) for 2021. Federal government agencies generally use EIA's price projections in their assessment of future energy-related policies.

In previous CAFE rulemakings, discussions of fuel prices have always been intended to reflect the price of motor gasoline. However, a growing set of vehicle offerings that rely in part, or entirely, on electricity suggests that gasoline prices are no longer the only fuel prices relevant to evaluations of proposed CAFE standards. In the analysis supporting this proposal, NHTSA considers the energy consumption and resulting emissions from the entire on-road fleet, which already contains a number of plug-in hybrid and fully electric vehicles. Higher CAFE standards encourage manufacturers to improve fuel economy; concurrently, manufacturers will foreseeably seek to continue to maximize profit (or minimize compliance cost), and some reliance on electrification is a viable strategy for some manufacturers, even though NHTSA does not consider it in determining maximum feasible CAFE

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[408] 43 FR 63184, 63188 (Dec. 15, 1977). *See also* 42 FR 33534, 33537 (Jun. 30, 1977).

[409] For most ICE vehicles on the road today, the majority of tailpipe NO_X, NMOG, and CO emissions occur during ''cold start,'' before the three-way catalyst has reached the very high temperature (*e.g.,* 900–1000 °F) at which point it is able to convert (through oxidation and reduction reactions) those emissions into less harmful derivatives. By limiting the amount of those emissions, tailpipe smog standards require the catalyst to be brought to temperature extremely quickly, so modern vehicles employ cold start strategies that intentionally release fuel energy into the engine exhaust to heat the catalyst to the right temperature as quickly as possible. The additional fuel that must be used to heat the catalyst is typically referred to as a ''cold-start penalty,'' meaning that the vehicle's fuel economy (over a test cycle) is reduced because the fuel consumed to heat the catalyst did not go toward the goal of moving the vehicle forward. The Autonomie work employed to develop technology effectiveness estimates for this proposal accounts for cold-start penalties, as discussed in the Autonomie model documentation.

[410] 77 FR 62624, 62669 (Oct. 15, 2012).

[411] *Id.*

[412] *Massachusetts* v. *EPA,* 549 U.S. 497, 532 (2007) (''[T]here is no reason to think that the two agencies cannot both administer their obligations and yet avoid inconsistency.'').

[413] As discussed elsewhere, however, NHTSA has sought to account in the baseline for the California Framework Agreement with BMW, Ford, Honda, VWA, and Volvo.

[414] 42 FR 63184, 63188 (Dec. 15, 1977).

stringency. Under the more stringent CAFE alternatives in this proposal, we see a greater reliance on electrification technologies in the analysis in the years following the explicitly-regulated model years, even though internal combustion engines continue to be the most common powertrain across the industry in the action years of this proposal.

While the current national average electricity price is significantly higher than that of gasoline, on an energy equivalent basis ($/MMBtu),[415] electric motors convert energy into propulsion much more efficiently than internal combustion engines. This means that, even though the energy-equivalent prices of electricity are higher, electric vehicles still produce fuel savings for their owners. EIA also projects rising real gasoline prices over the next three decades, while projecting real electricity prices to remain relatively flat. As the reliance on electricity grows in the light-duty fleet, NHTSA will continue to monitor the trends in electricity prices and their implications for CAFE standards. Even if NHTSA is prohibited from considering electrification as a technology during the model years covered by the rulemaking, the consumer (and social) cost implications of manufacturers otherwise switching to electrification may remain relevant to the agency's considerations.

For now, gasoline is still the dominant fuel used in light-duty transportation. As such, consumers, and the economy more broadly, are subject to fluctuations in price that impact the cost of travel and, consequently, the demand for mobility. Over the last decade, the U.S. has become a stabilizing force in the global oil market and our reliance on imported petroleum has decreased steadily. The most recent Annual Energy Outlook, AEO 2021, projects the U.S. to be a net exporter of petroleum and other liquids through 2050 in the Reference Case. Over the last decade, EIA projections of real fuel prices have generally flattened in recognition of the changing dynamics of the oil market and slower demand growth, both in the U.S. and in developing markets. For example, the International Energy Agency projects that global demand for gasoline is unlikely to ever return to its 2019 level (before the pandemic).[416] However, vehicles are long-lived assets and the long-term price uncertainty of petroleum still represents a risk to consumers, albeit one that has decreased in the last decade. Continuing to reduce the amount of money consumers spend on vehicle fuel thus remains an important consideration for the need of the U.S. to conserve energy.

(2) National Balance of Payments

NHTSA has consistently included consideration of the ''national balance of payments'' as part of the need of the U.S. to conserve energy because of concerns that importing large amounts of oil created a significant wealth transfer to oil-exporting countries and left the U.S. economically vulnerable.[417] As recently as 2009, nearly half the U.S. trade deficit was driven by petroleum,[418] yet this concern has been less critical in more recent CAFE actions, in part because other factors besides petroleum consumption have been playing a bigger role in the U.S. trade deficit.[419] While transportation demand is expected to increase as the economy recovers from the pandemic, it is foreseeable that the trend of trade in consumer goods and services continuing to dominate the national balance of payments, as compared to petroleum, will continue during the rulemaking timeframe.

That said, the U.S. continues to rely on oil imports, and NHTSA continues to recognize that reducing the vulnerability of the U.S. to possible oil price shocks remains important. This proposal aims to improve fleet-wide fuel efficiency and to help reduce the amount of petroleum consumed in the U.S., and therefore aims to improve this part of the U.S. balance of payments.

(3) Environmental Implications

Higher fleet fuel economy reduces U.S. emissions of CO_2 as well as various other pollutants by reducing the amount of oil that is produced and refined for the U.S. vehicle fleet, but can also potentially increase emissions by reducing the cost of driving, which can result in increased vehicle miles traveled (*i.e.,* the rebound effect). Thus, the net effect of more stringent CAFE standards on emissions of each pollutant depends on the relative magnitudes of its reduced emissions in fuel refining and distribution and increases in its emissions from vehicle use. Fuel savings from CAFE standards also necessarily result in lower emissions of CO_2, the main greenhouse gas emitted as a result of refining, distribution, and use of transportation fuels.

NHTSA has considered environmental issues, both within the context of EPCA and the context of the National Environmental Policy Act (NEPA), in making decisions about the setting of standards since the earliest days of the CAFE program. As courts of appeal have noted in three decisions stretching over the last 20 years,[420] NHTSA defined ''the need of the United States to conserve energy'' in the late 1970s as including, among other things, environmental implications. In 1988, NHTSA included climate change concepts in its CAFE NPRMs and prepared its first environmental assessment addressing that subject.[421] It cited concerns about climate change as one of the reasons for limiting the extent of its reduction of the CAFE standard for MY 1989 passenger cars.[422]

NHTSA also considers environmental justice issues as part of the environmental considerations under the need of the U.S. to conserve energy, per Executive Order 12898, ''Federal Actions to Address Environmental Justice in Minority Populations'' [423] and DOT Order 5610.2(c), ''U.S. Department of Transportation Actions to Address Environmental Justice in Minority Populations and Low-Income Populations.'' [424] The affected environment for environmental justice is nationwide, with a focus on areas that

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[415] Source: AEO 2021, Table 3.

[416] International Energy Agency, Oil 2021, (p. 30), *https://iea.blob.core.windows.net/assets/1fa45234-bac5–4d89-a532-768960f99d07/Oil_2021-PDF.pdf.*

[417] For the earliest discussion of this topic, *see* 42 FR 63184, 63192 (Dec. 15, 1977) (''A major reason for this need [to reduce petroleum consumption] is that the importation of large quantities of petroleum creates serious balance of payments and foreign policy problems. The United States currently spends approximately $45 billion annually for imported petroleum. But for this large expenditure, the current large U.S. trade deficit would be a surplus.'').

[418] *See, Today in Energy: Recent improvements in petroleum trade balance mitigate U.S. trade deficit,* U.S. Energy Information Administration (July 21, 2014). Available at *https://www.eia.gov/todayinenergy/detail.php?id=17191* and in the docket for this rulemaking, NHTSA–2021–0053.

[419] Consumer products are the primary drivers of the trade deficit. In 2020, the U.S. imported $2.4 trillion in consumer goods, versus $116.4 billion of petroleum, which is the lowest amount since 2002. The 2020 goods deficit of $904.9 billion was the highest on record, while the 2020 petroleum *surplus* of $18.1 billion was the first annual surplus on record. *See* U.S. Census Bureau, ''Annual 2020 Press Highlights,'' at *census.gov/foreign-trade/statistics/highlights/AnnualPressHighlights.pdf,* and available in the docket for this rulemaking. While 2020 was an unusual year for U.S. transportation demand, given the global pandemic, this is consistent with existing trends in which consumer products imports significantly outweigh oil imports.

[420] CAS, 793 F.2d 1322, 1325 n. 12 (D.C. Cir. 1986); Public Citizen, 848 F.2d 256, 262–63 n. 27 (D.C. Cir. 1988) (noting that ''NHTSA itself has interpreted the factors it must consider in setting CAFE standards as including environmental effects''); CBD, 538 F.3d 1172 (9th Cir. 2007).

[421] 53 FR 33080, 33096 (Aug. 29, 1988).

[422] 53 FR 39275, 39302 (Oct. 6, 1988).

[423] 59 FR 629 (Feb. 16, 1994).

[424] Department of Transportation Updated Environmental Justice Order 5610.2(c) (May 14, 2021).

could contain minority and low-income communities who would most likely be exposed to the environmental and health effects of oil production, distribution, and consumption, or the impacts of climate change. This includes areas where oil production and refining occur, areas near roadways, coastal flood-prone areas, and urban areas that are subject to the heat island effect.

Numerous studies have found that some environmental hazards are more prevalent in areas where minority and low-income populations represent a higher proportion of the population compared with the general population. In terms of effects due to criteria pollutants and air toxics emissions, the body of scientific literature points to disproportionate representation of minority and low-income populations in proximity to a range of industrial, manufacturing, and hazardous waste facilities that are stationary sources of air pollution, although results of individual studies may vary. While the scientific literature specific to oil refineries is limited, disproportionate exposure of minority and low-income populations to air pollution from oil refineries is suggested by other broader studies of racial and socioeconomic disparities in proximity to industrial facilities generally. Studies have also consistently demonstrated a disproportionate prevalence of minority and low-income populations that are living near mobile sources of pollutants (such as roadways) and therefore are exposed to higher concentrations of criteria air pollutants in multiple locations across the United States. Lower-positioned socioeconomic groups are also differentially exposed to air pollution and differentially vulnerable to effects of exposure.

In terms of exposure to climate change risks, the literature suggests that across all climate risks, low-income communities, some communities of color, and those facing discrimination are disproportionately affected by climate events. Communities overburdened by poor environmental quality experience increased climate risk due to a combination of sensitivity and exposure. Urban populations experiencing inequities and health issues have greater susceptibility to climate change, including substantial temperature increases. Some communities of color facing cumulative exposure to multiple pollutants also live in areas prone to climate risk. Indigenous peoples in the United States face increased health disparities that cause increased sensitivity to extreme heat and air pollution. Together, this information indicates that climate impacts disproportionately affect minority and low-income populations because of socioeconomic circumstances, histories of discrimination, and inequity. Furthermore, high temperatures can exacerbate poor air quality, further compounding the risk to overburdened communities. Finally, health-related sensitivities in low-income and minority populations increase risk of damaging impacts from poor air quality under climate change, underscoring the potential benefits of improving air quality to communities overburdened by poor environmental quality.

In the SEIS, Chapters 3, 4, 5, and 8 discuss the connections between oil production, distribution, and consumption, and their health and environmental impacts.

All of the action alternatives considered in this proposal reduce carbon dioxide emissions and, thus, the effects of climate change, as compared to the baseline. Effects on criteria pollutants and air toxics emissions are somewhat more complicated, for a variety of reasons, as discussed in Section VI.C, although over time and certainly over the lifetimes of the vehicles that would be subject to this proposal, these emissions are currently forecast to fall significantly.

As discussed above, while the majority of light-duty vehicles will continue to be powered by internal combustion engines in the near- to mid-term under all regulatory alternatives, the more stringent alternatives do appear in the analysis to lead to greater electrification in the mid- to longer-term. While NHTSA is prohibited from considering electric vehicles in determining maximum feasible CAFE levels, electric vehicles (which appear both in the agency's baseline and which may be produced in model years following the period of regulation as an indirect effect of more stringent standards, or in response to other standards or to market demand) produce few to zero tailpipe emissions, and thus contribute meaningfully to the decarbonization of the transportation sector, in addition to having environmental, health, and economic development benefits, although these benefits may not yet be equally distributed across society. They also present new environmental (and social) questions, like those associated with reduced tailpipe emissions, upstream electricity production, minerals extraction for battery components, and ability to charge an electric vehicle. The upstream environmental effects of extraction and refining for petroleum are well-recognized; minerals extraction and refining can also have significant downsides. As one example of documentation of these effects, the United Nations Conference on Trade and Development issued a report in July 2020 describing acid mine drainage and uranium-laced dust associated with cobalt mines in the DRC, along with child labor concerns; considerable groundwater consumption and dust issues that harm miners and indigenous communities in the Andes; issues with fine particulate matter causing human health effects and soil contamination in regions near graphite mines; and so forth.[425] NHTSA's SEIS discusses these and other effects (such as production and end-of-life issues) in more detail, and NHTSA will continue to monitor these issues going forward insofar as CAFE standards may increase electrification levels even if NHTSA does not expressly consider electrification in setting those standards, because NHTSA does not control what technologies manufacturers use to meet those standards, and because NHTSA is required to consider the environmental effects of its standards under NEPA.

NHTSA carefully considered the environmental effects of this proposal, both quantitative and qualitative, as discussed in the SEIS and in Sections VI.C and VI.D.

(4) Foreign Policy Implications

U.S. consumption and imports of petroleum products impose costs on the domestic economy that are not reflected in the market price for crude petroleum or in the prices paid by consumers for petroleum products such as gasoline. These costs include (1) higher prices for petroleum products resulting from the effect of U.S. oil demand on world oil prices; (2) the risk of disruptions to the U.S. economy caused by sudden increases in the global price of oil and its resulting impact of fuel prices faced by U.S. consumers, and (3) expenses for maintaining the strategic petroleum reserve (SPR) to provide a response option should a disruption in commercial oil supplies threaten the U.S. economy, to allow the U.S. to meet part of its International Energy Agency obligation to maintain emergency oil stocks, and to provide a national defense fuel reserve. Reducing U.S. consumption of crude oil or refined petroleum products (by reducing motor

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[425] UNCTAD, ''Commodities at a Glance: Special issue on strategic battery raw materials,'' No. 13, Geneva, 2020, at 46. *Available at https://unctad.org/system/files/official-document/ditccom2019d5_en.pdf* and in the docket for this rulemaking, NHTSA–2021–0053.

fuel use) can reduce these external costs.[426]

Stephen Brown, who has published extensively on price shock and foreign policy risks associated with U.S. oil consumption, stated in a recent paper that:

> Over the past few years, world oil market conditions have changed considerably (with the United States importing much less oil), new estimates of the probabilities of world oil supply disruptions have become available, and new estimates of the response of U.S. real GDP to oil supply shocks and the short-run elasticity of oil demand have become available. These developments suggest that it is time to update the estimates of the security costs of U.S. oil consumption. The new estimates of the oil security premiums suggest that U.S. oil security may have become less of an issue than it was in the past, mostly as a result of new estimates of the short-run elasticity of demand and the response of U.S. real GDP to oil price shocks.[427]

Brown notes that ''Because we have not observed a modern economy with large oil supply disruptions, we have no reliable method to quantify the effects of these disruptions,'' and ''The result could be an average of old and new results or estimation problems and a poor fit.''[428] Geopolitical risk can still affect global oil prices, of course, because oil is a global market, and thus can affect U.S. oil prices, although possibly by less than in the past.[429] The U.S. still maintains a military presence in certain parts of the world to help secure global access to petroleum supplies. Chapter 6.2.4 of the TSD discusses this topic in more detail. Brown concludes that:

> Nonetheless, only the highest estimates of the oil security premiums suggest that U.S. oil security is nearly an equally important issue to the environmental costs of oil use. The mid-estimates from the model that may best represent how the world oil market and the U.S. economy will respond to world oil supply disruptions of various sizes . . . find U.S. consumption of imported or domestic oil does yield important security costs, but those costs are much lower than the estimated environmental costs of oil use. Consistent with Brown and Huntington (2013), the substitution of domestic oil for imported oil only slightly improves U.S. oil security. Oil conservation is more effective than increased domestic oil production at improving U.S. oil security.[430]

NHTSA agrees both that oil conservation improves U.S. oil security, and that the environmental costs of oil use are intertwined with the security costs of oil use in some ways as climate change destabilizes traditional geopolitical power structures over time. The effect of climate change on natural resources inevitably has security implications—population changes and shifts have already been forced in some countries, which can create social and security effects at all geopolitical levels—local, national, regional, and global. CAFE standards over the last few decades have conserved significant quantities of oil, and the petroleum intensity of the U.S. fleet has decreased significantly. Continuing to improve energy conservation and reduce U.S. oil consumption by raising CAFE standards further has the potential to continue to help with all of these considerations.

As standards and market demand move the U.S. light-duty vehicle fleet toward electrification, different potential foreign policy implications arise. Most vehicle electrification is enabled by lithium-ion batteries. Lithium-ion battery global value chains have several phases: Sourcing (mining/extraction); processing/refining; cell manufacturing; battery manufacturing; installation in an EV; and recycling.[431] Because lithium-ion battery materials have a wide global diversity of origin, accessing them can pose varying geopolitical challenges.[432] The U.S. International Trade Commission (USITC) recently summarized 2018 data from the U.S. Geological Survey on the production/sourcing of the four key lithium-ion battery materials, as shown in Table VI–5.

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[426] A 2006 report by the Council on Foreign Relations identified six foreign policy costs that it said arose from U.S. consumption of imported oil. These costs include (1) the adverse effect that significant disruptions in oil supply will have for political and economic conditions in the U.S. and other importing countries; (2) the fears that the current international system is unable to ensure secure oil supplies when oil is seemingly scarce and oil prices are high; (3) political realignment from dependence on imported oil that limits U.S. alliances and partnerships; (4) the flexibility that oil revenues give oil-exporting countries to adopt policies that are contrary to U.S. interests and values; (5) an undermining of sound governance by the revenues from oil and gas exports in oil-exporting countries; and (6) an increased U.S. military presence in the Middle East that results from the strategic interest associated with oil consumption. Council on Foreign Relations, National Security Consequences of U.S. Oil Dependency, Independent Task Force Report No. 58, October 2006. *Available at https://cdn.cfr.org/sites/default/files/report_pdf/0876093659.pdf* and in the docket for this rulemaking, NHTSA–2021–0053. Brown and Huntington (2015) find that these six costs are either implicitly incorporated in the welfare-theoretic analysis, are not externalities, or cannot be quantified. Brown, Stephen and Hillard Huntington, Evaluating U.S. oil security and import reliance, Energy Policy 108, 2015, at 512–523. *Available at https://www.sciencedirect.com/science/article/abs/pii/S0301421515000026* and for hard copy review at DOT headquarters. To the extent that these costs are externalities that cannot be quantified, the measured security costs of U.S. reliance on imported oil will be understated.

[427] Brown, Stephen. ''New Estimates of the security costs of U.S. oil consumption,'' *Energy Policy,* Vol. 113, Feb. 2018, at 172. *Available at https://www.sciencedirect.com/science/article/abs/pii/S0301421517307413* and for hard copy review at DOT headquarters.

[428] *Id.* at 181.

[429] Also in 2018, Beccue, Huntington, Leiby, and Vincent reported on their findings of an expert panel on oil market disruption risks and likelihoods, and stated that based on these findings, during the period of 2016–2025, ''It is very likely that a disruption greater than 2 MMBD will occur (81%). However, it is unlikely that disruptions greater than 15 MMBD will occur (1%).'' They further state that ''. . . experts in the current study expect that both gross shocks and excess capacity will be lower than before, resulting in similar net disruptions [to what was estimated in 2005]. Although turmoil remains high in these countries with the ongoing Iraq war, tensions between Iran and its Arab neighbors, and concern over the ability of terrorists to cut oil supply facilities, these conditions do not produce larger oil market disruptions.'' They conclude that ''In general, this panel of energy security experts has concluded that current world events and energy markets have increased the likelihood of oil disruptions since 1996 but demonstrated a similar risk profile compared to the 2005 period. Moreover, their assessments indicate that lower oil price paths make net disruptions of any given size more likely.'' Beccue *et al.,* ''An updated assessment of oil market disruption risks,'' *Energy Policy,* Vol. 115, Apr. 2018, at 456. *Available at https://www.sciencedirect.com/science/article/abs/pii/S0301421517308285* and for hard copy review at DOT headquarters.

[430] Brown, 2018, at 182.

[431] Scott, Sarah, and Robert Ireland, ''Lithium-Ion Battery Materials for Electric Vehicles and their Global Value Chains,'' Office of Industries Working Paper ID–068, U.S. International Trade Commission, June 2020, at 7. *Available at https://www.usitc.gov/publications/332/working_papers/gvc_overview_scott_ireland_508_final_061120.pdf* and in the docket for this rulemaking, NHTSA–2021–0053.

[432] *Id.* at 8.

Table VI-5 – Lithium-ion Battery Materials Mining Production, 2018[433]

Lithium-ion Battery Material Ores and Concentrates	Countries with Largest Mining Production (Share of Global Total)	U.S. Mining Production (Share of Global Total)
Lithium	Australia (60 percent), Chile (19 percent), China (9 percent), Argentina (7 percent)	USITC staff estimates less than 1 percent
Cobalt	Democratic Republic of Congo (64 percent), Cuba (4 percent), Russia (4 percent), Australia (3 percent)	Less than 0.5 percent
Graphite (natural)	China (68 percent), Brazil (10 percent), India (4 percent)	0 percent
Nickel	Indonesia (24 percent), Philippines (15 percent), Russia (9 percent)	Less than 1 percent

Of these sources, the USITC notes that while ''lithium has generally not faced political instability risks,'' ''Because of the [Democratic Republic of Congo's] ongoing political instability, as well as poor labor conditions, sourcing cobalt faces significant geopolitical challenges.''[434] Nickel is also used extensively in stainless steel production, and much of what is produced in Indonesia and the Philippines is exported to China for stainless steel manufacturing.[435] Obtaining graphite for batteries does not currently pose geopolitical obstacles, but the USITC notes that Turkey has great potential to become a large graphite producer, which would make stability there a larger concern.[436]

For materials processing and refining, China is the largest importer of unprocessed lithium, which it then transforms into processed or refined lithium,[437] the leading producer of refined cobalt (with Finland a distant second),[438] one of the leading producers of primary nickel products (along with Indonesia, Japan, Russia, and Canada) and one of the leading refiners of nickel into nickel sulfate, the chemical compound used for cathodes in lithium-ion batteries,[439] and one of the leading processors of graphite intended for use in lithium-ion batteries as well.[440] In all regions, increasing attention is being given to vertical integration in the lithium-ion battery industry from material extraction, mining and refining, battery materials, cell production, battery systems, reuse, and recycling. The United States is lagging in upstream capacity; although the U.S. has some domestic lithium deposits, it has very little capacity in mining and refining any of the key raw materials. As mentioned elsewhere, however, there can be benefits and drawbacks in terms of environmental consequences associated with increased mining, refining, and battery production.

China and the European Union (EU) are also major consumers of lithium-ion batteries, along with Japan, Korea, and others. Lithium-ion batteries are used not only in light-duty vehicles, but in many ubiquitous consumer goods, and are likely to be used eventually in other forms of transportation as well. Thus, securing sufficient batteries to enable large-scale shifts to electrification in the U.S. light-duty vehicle fleet may face new issues as vehicle companies compete with other new sectors. NHTSA will continue to monitor these issues going forward.

President Biden has already issued an Executive Order on ''America's Supply Chains,'' aiming to strengthen the resilience of America's supply chains, including those for automotive batteries.[441] Reports are to be developed within one year of issuance of the Executive Order, and NHTSA will monitor these findings as they develop.

(e) Factors That NHTSA Is Prohibited From Considering

EPCA also provides that in determining the level at which it should set CAFE standards for a particular model year, NHTSA may not consider the ability of manufacturers to take advantage of several EPCA provisions that facilitate compliance with CAFE standards and thereby reduce the costs of compliance.[442] NHTSA cannot consider compliance credits that manufacturers earn by exceeding the CAFE standards and then use to achieve compliance in years in which their measured average fuel economy falls below the standards. NHTSA also cannot consider the use of alternative fuels by dual fueled automobiles, nor the fuel economy (*i.e.,* the availability) of dedicated alternative fueled automobiles—including battery-electric vehicles—in any model year. EPCA encourages the production of alternative fuel vehicles by specifying that their fuel economy is to be determined using a special calculation procedure that results in those vehicles being assigned a higher equivalent fuel economy level than they actually achieve.

The effect of the prohibitions against considering these statutory flexibilities in setting the CAFE standards is that the flexibilities remain voluntarily-employed measures. If NHTSA were instead to assume manufacturer use of those flexibilities in setting new standards (as NHTSA does in the ''EIS analysis,'' but not the ''standard setting analysis''), compliance with higher standards would appear more cost-effective and, potentially, more feasible, which would thus effectively require manufacturers to use those flexibilities if NHTSA determined that standards should be more stringent. By keeping NHTSA from including them in our stringency determination, the provision ensures that those statutory credits

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[433] *Id.,* citing U.S. Geological Survey, Mineral Commodity Summaries, Feb. 2019.

[434] *Id.* at 8, 9.

[435] *Id* at 9.

[436] *Id.*

[437] *Id.*

[438] *Id.* at 10.

[439] *Id.*

[440] *Id.*

[441] Executive Order 14017, ''America's Supply Chains,'' Feb. 24, 2021. 86 FR 11849 (Mar. 1, 2021).

[442] 49 U.S.C. 32902(h).

remain true compliance flexibilities. However, the flip side of the effect described above is that preventing NHTSA from assuming use of dedicated alternative fuel vehicles for compliance makes it more difficult for the CAFE program to facilitate a complete transition of the U.S. light-duty fleet to full electrification.

In contrast, for the non-statutory fuel economy improvement value program that NHTSA developed by regulation, NHTSA does not consider these fuel economy adjustments subject to the 32902(h) prohibition on considering flexibilities. The statute is very clear as to which flexibilities are not to be considered. When the agency has introduced additional flexibilities such as A/C efficiency and ''off-cycle'' technology fuel improvement values, NHTSA has considered those technologies as available in the analysis. Thus, this analysis includes assumptions about manufacturers' use of those technologies, as detailed in Chapter 3.8 of the accompanying TSD.

NHTSA notes that one of the recommendations in the 2021 NAS Report was for Congress to ''amend the statute to delete the [32902(h)] prohibition on considering the fuel economy of dedicated alternative fueled vehicles in setting CAFE standards.'' [443] Recognizing that changing statutory text is Congress' affair and not NHTSA's, the committee further recommended that if Congress does not change the statute, NHTSA should consider adding another attribute to the fuel economy standard function, like ''the expected market share of ZEVs in the total U.S. fleet of new light-duty vehicles—such that the standards increase as the share of ZEVs in the total U.S. fleet increases.'' [444] NHTSA discusses this recommendation further in Section III.B.

While NHTSA does not consider the prohibited items in its standard-setting analysis or for making its tentative decision about what levels of standards would be maximum feasible, NHTSA notes that it is informed by the ''EIS'' analysis presented in the PRIA. The EIS analysis does not contain these restrictions, and therefore accounts for credit availability and usage, and manufacturers' ability to employ alternative fueled vehicles, for purpose of conformance with E.O. 12866 and NEPA regulations. Under the EIS analysis, compliance generally appears less costly. For example, this EIS analysis shows manufacturers' costs averaging about $1,070 in MY 2029 under the proposed standards, as compared to the $1,175 shown by the standard setting analysis. Again, however, for purposes of tentatively determining maximum feasible CAFE levels, NHTSA considers only the standard setting analysis shown in the NPRM, consistent with Congress' direction.

(f) Other Considerations in Determining Maximum Feasible CAFE Standards

NHTSA has historically considered the potential for adverse safety effects in setting CAFE standards. This practice has been upheld in case law.[445] In this proposal, NHTSA has considered the safety effects discussed in Section V of this preamble and in Chapter 5 of the accompanying PRIA. NHTSA discusses its consideration of these effects in Section VI.D.

B. Administrative Procedure Act

The Administrative Procedure Act governs agency rulemaking generally and provides the standard of judicial review for agency actions. To be upheld under the ''arbitrary and capricious'' standard of judicial review under the APA, an agency rule must be rational, based on consideration of the relevant factors, and within the scope of the authority delegated to the agency by statute. The agency must examine the relevant data and articulate a satisfactory explanation for its action including a ''rational connection between the facts found and the choice made.'' [446]

Statutory interpretations included in an agency's rule are subject to the two-step analysis of *Chevron, U.S.A.* v. *Natural Resources Defense Council.*[447] Under step one, where a statute ''has directly spoken to the precise question at issue,'' *id.* at 842, the court and the agency ''must give effect to the unambiguously expressed intent of Congress.'' [448] If the statute is silent or ambiguous regarding the specific question, the court proceeds to step two and asks ''whether the agency's answer is based on a permissible construction of the statute.'' [449] The APA also requires that agencies provide notice and comment to the public when proposing regulations,[450] as NHTSA is doing in this proposal.

NHTSA recognizes that this proposal, like the 2020 final rule, is reconsidering standards previously promulgated. NHTSA, like any other Federal agency, is afforded an opportunity to reconsider prior views and, when warranted, to adopt new positions. Indeed, as a matter of good governance, agencies *should* revisit their positions when appropriate, especially to ensure that their actions and regulations reflect legally sound interpretations of the agency's authority and remain consistent with the agency's views and practices. As a matter of law, ''an Agency is entitled to change its interpretation of a statute.'' [451] Nonetheless, ''[w]hen an Agency adopts a materially changed interpretation of a statute, it must in addition provide a 'reasoned analysis' supporting its decision to revise its interpretation.'' [452]

''Changing policy does not, on its own, trigger an especially 'demanding burden of justification.' '' [453] Providing a reasoned explanation ''would ordinarily demand that [the Agency] display awareness that it *is* changing position.'' [454] Beyond that, however, ''[w]hen an agency changes its existing position, it 'need not always provide a more detailed justification than what would suffice for a new policy created on a blank slate.' '' [455] While the agency ''must show that there are good reasons for the new policy,'' the agency ''need not demonstrate to a court's satisfaction that the reasons for the new policy are

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[443] 2021 NAS Report, Summary Recommendation 5.

[444] *Id.*

[445] As courts have recognized, ''NHTSA has always examined the safety consequences of the CAFE standards in its overall consideration of relevant factors since its earliest rulemaking under the CAFE program.'' *Competitive Enterprise Institute* v. *NHTSA,* 901 F.2d 107, 120 n. 11 (D.C. Cir. 1990) (''CEI–I'') (citing 42 FR 33534, 33551 (Jun. 30, 1977). Courts have consistently upheld NHTSA's implementation of EPCA in this manner. *See, e.g., Competitive Enterprise Institute* v. *NHTSA,* 956 F. 2d 321, 322 (D.C. Cir. 1992) (''CEI–II'') (in determining the maximum feasible standard, ''NHTSA has always taken passenger safety into account) (citing CEI–I, 901 F.2d at 120 n. 11); *Competitive Enterprise Institute* v. *NHTSA,* 45 F.3d 481, 482–83 (D.C. Cir. 1995) (CEI–III) (same); *Center for Biological Diversity* v. *NHTSA,* 538 F.3d 1172, 1203–04 (9th Cir. 2008) (upholding NHTSA's analysis of vehicle safety issues associated with weight in connection with the MYs 2008–2011 light truck CAFE rulemaking).

[446] *Burlington Truck Lines, Inc.* v. *United States,* 371 U.S. 156, 168 (1962).

[447] 467 U.S. 837 (1984).

[448] *Id.* at 843.

[449] *Id.*

[450] 5 U.S.C. 553.

[451] *Phoenix Hydro Corp.* v. *FERC,* 775 F.2d 1187, 1191 (D.C. Cir. 1985).

[452] *Alabama Educ. Ass'n* v. *Chao,* 455 F.3d 386, 392 (D.C. Cir. 2006) (quoting Motor Vehicle Mfrs. *Ass'n of U.S., Inc.* v. *State Farm Mut. Auto. Ins. Co.,* 463 U.S. 29, 57 (1983)); *see also Encino Motorcars, LLC* v. *Navarro,* 136 S Ct. 2117, 2125 (2016) (''Agencies are free to change their existing policies as long as they provide a reasoned explanation for the change.'') (citations omitted).

[453] *See Mingo Logan Coal Co.* v. *EPA,* 829 F.3d 710, 718 (D.C. Cir. 2016) (quoting *Ark Initiative* v. *Tidwell,* 816 F.3d 119, 127 (D.C. Cir. 2016)).

[454] *FCC* v. *Fox Television Stations, Inc.* 556 U.S. 502, 515 (2009) (emphasis in original) (''An agency may not, for example, depart from a prior policy *sub silentio* or simply disregard rules that are still on the books.'').

[455] Encino Motorcars, LLC, 136 S Ct. at 2125–26 (quoting Fox Television Stations, Inc. 556 U.S. at 515).

better than the reasons for the old one.''[456] ''[I]t suffices that the new policy is permissible under the statute, that there are good reasons for it, and that the Agency *believes* it to be better, which the conscious change of course adequately indicates.''[457] For instance, ''evolving notions'' about the appropriate balance of varying policy considerations constitute sufficiently good reasons for a change in position.[458] Moreover, it is ''well within an Agency's discretion'' to change policy course even when no new facts have arisen: Agencies are permitted to conduct a ''reevaluation of which policy would be better in light of the facts,'' without ''rely[ing] on new facts.''[459]

To be sure, providing ''a more detailed justification'' is appropriate in some cases. ''Sometimes [the agency] must [provide a more detailed justification than what would suffice for a new policy created on a blank slate]—when, for example, its new policy rests upon factual findings that contradict those which underlay its prior policy; or when its prior policy has engendered serious reliance interests that must be taken into account.''[460] This preamble, and the accompanying TSD and PRIA, all provide extensive detail on the agency's updated analysis, and Section VI.D contains the agency's explanation of how the agency has considered that analysis and other relevant information in tentatively determining that the proposed CAFE standards are maximum feasible for MYs 2024–2026 passenger cars and light trucks.

C. National Environmental Policy Act

As discussed above, EPCA requires NHTSA to determine the level at which to set CAFE standards for each model year by considering the four factors of technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy. The National Environmental Policy Act (NEPA) directs that environmental considerations be integrated into that process.[461] To explore the potential environmental consequences of this rulemaking action, NHTSA has prepared a Supplemental Environmental Impact Statement (''SEIS'') for this proposal.[462] The purpose of an EIS is to ''provide full and fair discussion of significant environmental impacts and [to] inform decisionmakers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the human environment.''[463]

When preparing an EIS, NEPA requires an agency to compare the potential environmental impacts of its proposed action and a reasonable range of alternatives. In the SEIS, NHTSA analyzed a No Action Alternative and three action alternatives. The alternatives represent a range of potential actions the agency could take, and they are described more fully in Section IV of this preamble, Chapter 1 of the TSD, and Chapter 2 of the PRIA. The environmental impacts of these alternatives, in turn, represent a range of potential environmental impacts that could result from NHTSA's setting maximum feasible fuel economy standards for passenger cars and light trucks.

To derive the direct and indirect impacts of the action alternatives, NHTSA compared each action alternative to the No Action Alternative, which reflects baseline trends that would be expected in the absence of any further regulatory action. More specifically, the No Action Alternative in the SEIS assumed that the CAFE standards set in the 2020 final rule for MYs 2021–2026 passenger cars and light trucks would remain in effect. In addition, the No Action Alternative also includes several other actions that NHTSA believes will occur in the absence of further regulatory action, as discussed in more detail in Section IV above: (1) California's ZEV mandate; (2) the ''Framework Agreements'' between California and BMW, Ford, Honda, VWA, and Volvo, which NHTSA implemented by including EPA's baseline GHG standards (*i.e.,* those set in the 2020 final rule) and introducing more stringent GHG target functions for those manufacturers; and (3) the assumption that manufacturers will also make any additional fuel economy improvements estimated to reduce owners' estimated average fuel outlays during the first 30 months of vehicle operation by more than the estimated increase in new vehicle price. The No Action Alternative provides a baseline against which to compare the environmental impacts of other alternatives presented in the SEIS.[464]

For the SEIS, NHTSA analyzed three action alternatives, Alternatives 1 through 3, which ranged from increasing CAFE stringency for MY 2024 by 9.14 percent for passenger cars and 11.02 percent for light trucks, and increase stringency in MYs 2025 and 2026 by 3.26 percent per year for both passenger cars and light trucks (Alternative 1) to increasing CAFE stringency for each year, for each fleet, at 10 percent per year (Alternative 3). The range of action alternatives, as well as the No Action Alternative, encompass a spectrum of possible standards NHTSA could determine was maximum feasible based on the different ways the agency could weigh EPCA's four statutory factors. Throughout the SEIS, estimated impacts were shown for all of these action alternatives, as well as for the No Action Alternative. For a more detailed discussion of the environmental impacts associated with the alternatives, see Chapters 3–6 of the SEIS, as well as Section V of this preamble.

NHTSA's SEIS describes potential environmental impacts to a variety of resources, including fuel and energy use, air quality, climate, land use and development, hazardous materials and regulated wastes, historical and cultural resources, noise, and environmental justice. The SEIS also describes how climate change resulting from global greenhouse gas emissions (including CO_2 emissions attributable to the U.S. light-duty transportation sector under the alternatives considered) could affect certain key natural and human resources. Resource areas are assessed qualitatively and quantitatively, as appropriate, in the SEIS, and the findings of that analysis are summarized here.[465]

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[456] Fox Television Stations, Inc., 556 U.S. at 515 (emphasis in original).

[457] *Id.* (emphasis in original).

[458] *N. Am.'s Bldg. Trades Unions* v. *Occupational Safety & Health Admin.,* 878 F.3d 271, 303 (D.C. Cir. 2017) (quoting the agency's rule).

[459] *Nat'l Ass'n of Home Builders* v. *EPA,* 682 F.3d 1032, 1037–38 (D.C. Cir. 2012).

[460] *See* Fox Television Stations, Inc., 556 U.S. at 515 (2009).

[461] NEPA is codified at 42 U.S.C. 4321–47. The Council on Environmental Quality (CEQ) NEPA implementing regulations are codified at 40 CFR parts 1500–08.

[462] Because this proposal revises CAFE standards established in the 2020 final rule, NHTSA chose to prepare a SEIS to inform that amendment of the MYs 2024–2026 standards. *See* the SEIS for more details.

[463] 40 CFR 1502.1.

[464] *See* 40 CFR 1502.2(e), 1502.14(d). CEQ has explained that ''[T]he regulations require the analysis of the no action alternative even if the agency is under a court order or legislative command to act. This analysis provides a benchmark, enabling decision makers to compare the magnitude of environmental effects of the action alternatives [*See* 40 CFR 1502.14(c).] . . . Inclusion of such an analysis in the EIS is necessary to inform Congress, the public, and the President as intended by NEPA. [*See* 40 CFR 1500.1(a).]'' Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, 46 FR 18026 (Mar. 23, 1981).

[465] The impacts described in this section come from NHTSA's SEIS, which is being publicly issued simultaneously with this NPRM. As described above, the SEIS is based on ''unconstrained'' modeling rather than ''standard setting'' modeling.

Continued

As the stringency of the alternatives increases, total U.S. passenger car and light truck fuel consumption for the period of 2020 to 2050 decreases. Total light-duty vehicle fuel consumption from 2020 to 2050 under the No Action Alternative is projected to be 3,510 billion gasoline gallon equivalents (GGE). Light-duty vehicle fuel consumption from 2020 to 2050 under the action alternatives is projected to range from 3,409 billion GGE under Alternative 1 to 3,282 billion GGE under Alternative 3. Under Alternative 2, light-duty vehicle fuel consumption from 2020 to 2050 is projected to be 3,344 billion GGE. All of the action alternatives would decrease fuel consumption compared to the No-Action Alternative, with fuel consumption decreases that range from 100 billion GGE under Alternative 1 to 227 billion GGE under Alternative 3.

The relationship between stringency and criteria and air toxics pollutant emissions is less straightforward, reflecting the complex interactions among the tailpipe emissions rates of the various vehicle types (passenger cars and light trucks, ICE vehicles and EVs, older and newer vehicles, etc.), the technologies assumed to be incorporated by manufacturers in response to CAFE standards, upstream emissions rates, the relative proportions of gasoline, diesel, and electricity in total fuel consumption, and changes in VMT from the rebound effect. In general, emissions of criteria and toxic air pollutants increase very slightly in the short term, and then decrease dramatically in the longer term, across all action alternatives, with some exceptions. In addition, the action alternatives would result in decreased incidence of $PM_{2.5}$-related health impacts in most years and alternatives due to the emissions decreases. Decreases in adverse health outcomes include decreased incidences of premature mortality, acute bronchitis, respiratory emergency room visits, and work-loss days.

The air quality analysis in the SEIS identified the following impacts on criteria air pollutants.

For all criteria pollutants in 2025, emissions increase slightly under the action alternatives compared to the No-Action Alternative. The emission increases generally get larger (although they are still small) from Alternative 1 through Alternative 3 (the most stringent alternative in terms of required miles per gallon). This temporary increase is largely due to new vehicle prices increasing in the short-term, which slightly slows new-vehicle sales and encourages consumers to buy used vehicles instead or retain existing vehicles for longer. As the analysis timeframe progresses, the new, higher fuel-economy vehicles become used vehicles, and the impacts of the standards change direction. In 2025, across all criteria pollutants and action alternatives, the smallest increase in emissions is 0.01 percent for VOCs under Alternative 2; the largest increase is 0.6 percent and occurs for SO_2 under Alternative 3. We underscore that these are fractions of a single percent.

In 2035 and 2050, emissions of CO, NO_X, $PM_{2.5}$, and VOCs generally decrease under the action alternatives compared to the No-Action Alternative, except for CO in 2035 under Alternative 1 (0.07 percent increase) and NO_X in 2035 under Alternative 3 (0.5 percent increase) (again, these are fractions of a single percent), with the more stringent alternatives having the largest decreases, except for NO_X and $PM_{2.5}$ in 2035 (emissions decrease less or increase with more stringent alternatives) and NO_X in 2050 (emissions increase under Alternative 3 relative to Alternative 2, due primarily to slightly higher upstream emissions associated with greater electrification rates). SO_2 emissions generally increase under the action alternatives compared to the No-Action Alternative (except in 2035 under Alternative 1), with the more stringent alternatives having the largest increases. SO_2 increases are largely due to higher upstream emissions associated with electricity use by greater numbers of electrified vehicles being produced in response to the standards. In 2035 and 2050, across all criteria pollutants and action alternatives, the smallest decrease in emissions is 0.03 percent and occurs for NO_X under Alternative 2; the largest decrease is 11.9 percent and occurs for VOCs under Alternative 3. The smallest increase in emissions is 0.07 percent and occurs for CO under Alternative 1; the largest increase is 4.8 percent and occurs for SO_2 under Alternative 3.

The air quality analysis identified the following impacts on toxic air pollutants.

Under each action alternative in 2025 compared to the No-Action Alternative, increases in emissions would occur for all toxic air pollutants by as much as 0.5 (half of 1) percent, except for DPM, for which emissions would decrease by as much as 0.5 percent. For 2025, the largest relative increases in emissions would occur for benzene and 1,3-butadiene, for which emissions would increase by as much as 0.5 percent. Percentage increases in emissions of acetaldehyde, acrolein, and formaldehyde would be even smaller.

Under each action alternative in 2035 and 2050 compared to the No-Action Alternative, decreases in emissions would occur for all toxic air pollutants, except for acetaldehyde, acrolein, and 1,3-butadiene in 2035 under Alternative 1 where emissions would increase by 0.2 (one-fifth of 1), 0.01, and 0.1 percent, respectively, with the more stringent alternatives having the largest decreases, except for benzene (emissions increase in 2035 under Alternative 3 relative to Alternative 2). The largest relative decreases in emissions would occur for formaldehyde, for which emissions would decrease by as much as 10.3 percent. Percentage decreases in emissions of acetaldehyde, acrolein, benzene, 1,3-butadiene, and DPM would be less.

The air quality analysis identified the following health impacts.

In 2025, Alternative 3 would result in slightly increased adverse health impacts (mortality, acute bronchitis, respiratory emergency room visits, and other health effects) nationwide compared to the No-Action Alternative as a result of increases in emissions of NO_X, $PM_{2.5}$, and SO_2. Alternative 2 would also result in slightly increased adverse health impacts from mortality and non-fatal heart attacks due to increases in NO_X, $PM_{2.5}$, and SO_2 emissions, while Alternative 1 would result in decreased adverse health impacts. The more stringent alternatives are associated with the largest increases in adverse health impacts, or the smallest decreases in impacts, relative to the No-Action Alternative. Again, in the short-term, these slight changes in health impacts are projected under the action alternatives as the result of increases in the prices of new vehicles slightly delaying sales of new vehicles and encouraging more VMT in older vehicles instead, but this trend shifts over time as higher fuel-economy new vehicles become used vehicles and older vehicles are removed from the fleet.

In 2035 and 2050, all action alternatives would result in decreased

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NHTSA conducts modeling both ways in order to reflect the various statutory requirements of EPCA/EISA and NEPA. The preamble employs the ‘‘standard setting’’ modeling in order to aid the decision-maker in avoiding consideration of the prohibited items in 49 U.S.C. 32902(h) in determining maximum feasible standards, but as a result, the impacts reported here may differ from those reported elsewhere in this preamble. However, NHTSA considers the impacts reported in the SEIS, in addition to the other information presented in this preamble, the TSD, and the PRIA, as part of its decision-making process.

adverse health impacts nationwide compared to the No-Action Alternative as a result of general decreases in emissions of NO_X, $PM_{2.5}$, and DPM. The decreases in adverse health impacts get larger from Alternative 1 to Alternative 3.

In terms of climate effects, all action alternatives would decrease U.S. passenger car and light truck fuel consumption compared with the No-Action Alternative, resulting in reductions in the anticipated increases in global CO_2 concentrations, temperature, precipitation, and sea level, and increases in ocean pH that would otherwise occur. The impacts of the action alternatives on global mean surface temperature, precipitation, sea level, and ocean pH would be small in relation to global emissions trajectories. Although these effects are small, they occur on a global scale and are long lasting; therefore, in aggregate, they can have large consequences for health and welfare and can make an important contribution to reducing the risks associated with climate change.

The alternatives would have the following impacts related to GHG emissions.

Passenger cars and light trucks are projected to emit 89,600 million metric tons of carbon dioxide ($MMTCO_2$) from 2021 through 2100 under the No-Action Alternative. Alternative 1 would decrease these emissions by 5 percent through 2100. Alternative 3 would decrease these emissions by 10 percent through 2100. Emissions would be highest under the No-Action Alternative, and emission reductions would increase from Alternative 1 to Alternative 3.

Compared with total projected CO_2 emissions of 984 $MMTCO_2$ from all passenger cars and light trucks under the No-Action Alternative in the year 2100, the action alternatives are expected to decrease CO_2 emissions from passenger cars and light trucks in the year 2100 from 6 percent under Alternative 1 to 12 percent under Alternative 3.

The emission reductions in 2025 compared with emissions under the No-Action Alternative are approximately equivalent to the annual emissions from 1,284,000 vehicles under Alternative 1 to 2,248,000 vehicles under Alternative 3. For scale, a total of 253,949,000 passenger cars and light trucks are projected to be on the road in 2025 under the No-Action Alternative.

CO_2 emissions affect the concentration of CO_2 in the atmosphere, which in turn affects global temperature, sea level, precipitation, and ocean pH. For the analysis of direct and indirect impacts, NHTSA used the Global Change Assessment Model Reference Scenario to represent the Reference Case emissions scenario (*i.e.,* future global emissions assuming no comprehensive global actions to mitigate GHG emissions).

Estimated CO_2 concentrations in the atmosphere for 2100 would range from 788.33 pollutant per million parts (ppm) under Alternative 3 to approximately 789.11 ppm under the No-Action Alternative, indicating a maximum atmospheric CO_2 decrease of approximately 0.77 ppm compared to the No-Action Alternative. Atmospheric CO_2 concentration under Alternative 1 would decrease by 0.37 ppm compared with the No-Action Alternative.

Global mean surface temperature is projected to increase by approximately 3.48 °C (6.27 °F) under the No-Action Alternative by 2100. Implementing the most stringent alternative (Alternative 3) would decrease this projected temperature rise by 0.003 °C (0.006 °F), while implementing Alternative 1 would decrease projected temperature rise by 0.002 °C (0.003 °F).

Projected sea-level rise in 2100 ranges from a high of 76.28 centimeters (30.03 inches under the No-Action Alternative to a low of 76.22 centimeters (30.01 inches) under Alternative 3. Alternative 3 would result in a decrease in sea-level rise equal to 0.06 centimeter (0.03 inch) by 2100 compared with the level projected under the No-Action Alternative compared to a decrease under Alternative 1 of 0.03 centimeter (0.01 inch) compared with the No-Action Alternative.

Global mean precipitation is anticipated to increase by 5.85 percent by 2100 under the No-Action Alternative. Under the action alternatives, this increase in precipitation would be reduced by 0.00 to 0.01 percent.

Ocean pH is anticipated to be 8.2180 under Alternative 3, about 0.0004 more than the No-Action Alternative. Under Alternative 1, ocean pH in 2100 would be 8.2178, or 0.0002 more than the No-Action Alternative.

The action alternatives would reduce the impacts of climate change that would otherwise occur under the No-Action Alternative. Although the projected reductions in CO_2 and climate effects are small compared with total projected future climate change, they are quantifiable and directionally consistent and would represent an important contribution to reducing the risks associated with climate change.

Although NHTSA does quantify the changes in monetized damages that can be attributable to each action alternative, many specific impacts of climate change on health, society, and the environment cannot be estimated quantitatively. Therefore, NHTSA provides a qualitative discussion of these impacts by presenting the findings of peer-reviewed panel reports including those from the Intergovernmental Panel on Climate Change (IPCC), U.S. Global Change Research Program (GCRP), the U.S. Climate Change Science Program (CCSP), the National Research Council, and the Arctic Council, among others. While the action alternatives would decrease growth in GHG emissions and reduce the impact of climate change across resources relative to the No-Action Alternative, they would not themselves prevent climate change and associated impacts. Long-term climate change impacts identified in the scientific literature are briefly summarized below, and vary regionally, including in scope, intensity, and directionality (particularly for precipitation). While it is difficult to attribute any particular impact to emissions that could result from this proposal, the following impacts are likely to be beneficially affected to some degree by reduced emissions from the action alternatives:

- Impacts on freshwater resources could include changes in rainfall and streamflow patterns, warming temperatures and reduced snowpack, changes in water availability paired with increasing water demand for irrigation and other needs, and decreased water quality from increased algal blooms. Inland flood risk could increase in response to increasing intensity of precipitation events, drought, changes in sediment transport, and changes in snowpack and the timing of snowmelt.
- Impacts on terrestrial and freshwater ecosystems could include shifts in the range and seasonal migration patterns of species, relative timing of species' life-cycle events, potential extinction of sensitive species that are unable to adapt to changing conditions, increases in the occurrence of forest fires and pest infestations, and changes in habitat productivity due to increased atmospheric concentrations of CO_2.
- Impacts on ocean systems, coastal regions, and low-lying areas could include the loss of coastal areas due to inundation, submersion, or erosion from sea-level rise and storm surge, with increased vulnerability of the built environment and associated economies. Changes in key habitats (*e.g.,* increased temperatures, decreased oxygen, decreased ocean pH, increased

salinization) and reductions in key habitats (*e.g.,* coral reefs) may affect the distribution, abundance, and productivity of many marine species.

- Impacts on food, fiber, and forestry could include increasing tree mortality, forest ecosystem vulnerability, productivity losses in crops and livestock, and changes in the nutritional quality of pastures and grazing lands in response to fire, insect infestations, increases in weeds, drought, disease outbreaks, or extreme weather events. Increased concentrations of CO_2 in the atmosphere can also stimulate plant growth to some degree, a phenomenon known as the CO_2 fertilization effect, but the impact varies by species and location. Many marine fish species could migrate to deeper or colder water in response to rising ocean temperatures, and global potential fish catches could decrease. Impacts on food and agriculture, including yields, food processing, storage, and transportation, could affect food prices, socioeconomic conditions, and food security globally.
- Impacts on rural and urban areas could affect water and energy supplies, wastewater and stormwater systems, transportation, telecommunications, provision of social services, incomes (especially agricultural), air quality, and safety. The impacts could be greater for vulnerable populations such as lower-income populations, historically underserved populations, some communities of color and tribal and Indigenous communities, the elderly, those with existing health conditions, and young children.
- Impacts on human health could include increases in mortality and morbidity due to excessive heat and other extreme weather events, increases in respiratory conditions due to poor air quality and aeroallergens, increases in water and food-borne diseases, increases in mental health issues, and changes in the seasonal patterns and range of vector-borne diseases. The most disadvantaged groups such as children, the elderly, the sick, those experiencing discrimination, historically underserved populations, some communities of color and tribal and Indigenous communities, and low-income populations are especially vulnerable and may experience disproportionate health impacts.
- Impacts on human security could include increased threats in response to adversely affected livelihoods, compromised cultures, increased or restricted migration, increased risk of armed conflicts, reduction in adequate essential services such as water and energy, and increased geopolitical rivalry.

In addition to the individual impacts of climate change on various sectors, compound events may occur more frequently. Compound events consist of two or more extreme weather events occurring simultaneously or in sequence when underlying conditions associated with an initial event amplify subsequent events and, in turn, lead to more extreme impacts. To the extent the action alternatives would result in reductions in projected increases in global CO_2 concentrations, this rulemaking would contribute to reducing the risk of compound events.

NHTSA has considered the SEIS carefully in arriving at its tentative conclusion that Alternative 2 is maximum feasible, as discussed below. We seek comment on the SEIS associated with this NPRM.

D. Evaluating the EPCA Factors and Other Considerations To Arrive at the Proposed Standards

Despite only one year having passed since the 2020 final rule, enough has changed in the United States and in the world that revisiting the CAFE standards for MYs 2024–2026 is reasonable and appropriate. The global coronavirus pandemic, with all of its tragedy, also demonstrated what happens to U.S. and global oil consumption (and CO_2 and other pollutant emissions) when driving demand plummets. The Biden Administration committed itself in its earliest moments to improving energy conservation and tackling climate change. Nearly all auto manufacturers have announced forthcoming new advanced technology, high-fuel-economy vehicle models, making strong public commitments that mirror those of the Administration. Five major manufacturers voluntarily bound themselves to stricter GHG national-level requirements as part of the California Framework agreement. While some facts on the ground remain similar to what was before NHTSA in the prior analysis—gas prices remain relatively low in the U.S., for example, and while light-duty vehicle sales fell sharply in MY 2020, the vehicles that *did* sell tended to be, on average, larger, heavier, and more powerful, all factors which increase fuel consumption—again, enough has changed that a rebalancing of the EPCA factors is appropriate for model years 2024–2026.

In the 2020 final rule, NHTSA interpreted the need of the U.S. to conserve energy as less important than in previous rulemakings. This was in part because of structural changes in global oil markets as a result of shale oil drilling in the U.S., but also because in the context of environmental effects, NHTSA interpreted the word ''conserve'' as ''to avoid waste.'' NHTSA concluded then that the ultimate difference to the climate (among the regulatory alternatives) of thousandths of a degree Celsius in 2100 did not represent a ''wasteful'' use of energy, given the other considerations involved in the balancing of factors.

One of those factors was consumer demand for vehicles with higher fuel economy levels. In the 2020 final rule, NHTSA expressed concern that low gasoline prices and apparent consumer preferences for larger, heavier, more powerful vehicles would make it exceedingly difficult for manufacturers to achieve higher standards without negative consequences to sales and jobs, and would cause consumer welfare losses. Since then, however, more and more manufacturers are announcing more and more vehicle models with advanced engines and varying levels of electrification. It is reasonable to conclude that manufacturers (who are all for-profit companies) would not be announcing plans to offer these types of vehicles if they did not expect to be able to sell them,[466] and thus that manufacturers are more sanguine about consumer demand for fuel efficiency and the market for fully electric vehicles going forward than they have been previously.

Additionally, NHTSA no longer believes that it is reasonable or appropriate to focus only on ''avoiding waste'' in evaluating the need of the U.S. to conserve energy. EPCA's overarching purpose is energy conservation. The need of the U.S. to conserve energy may be reasonably interpreted as continuing to push the balancing toward greater stringency.

The following sections will walk through the four statutory factors in more detail and discuss NHTSA's decision-making process more thoroughly. To be clear at the outset, however, the fundamental balancing of factors for this proposal is different from the 2020 final rule because the evidence suggests that manufacturers believe there is a market for advanced technology vehicles with higher fuel economy, and CAFE standards are likely to be maximum feasible if they are set at levels that reflect that evidence.

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[466] To the extent that manufacturers are offering these vehicles in response to expected regulations, NHTSA still believes that they would not do so if they believed the vehicles were unsaleable or unmanageably detrimental to profits. Vehicle manufacturers are sophisticated corporate entities well able to communicate their views to regulatory agencies.

We may begin with the need of the U.S to conserve energy, which as stated is being considered more holistically in this proposal as compared to in the 2020 final rule. According to the analysis presented in Section V and in the accompanying PRIA and SEIS, Alternative 3 would save consumers the most in fuel costs, and would achieve the greatest reductions in climate change-causing CO_2 emissions. Alternative 3 would also maximize fuel consumption reductions, better protecting consumers from international oil market instability and price spikes. As discussed above, for now, gasoline is still the dominant fuel used in light-duty transportation. As such, consumers, and the economy more broadly, are subject to fluctuations in price that impact the cost of travel and, consequently, the demand for mobility. Vehicles are long-lived assets and the long-term price uncertainty of petroleum still represents a risk to consumers. By increasing the fuel economy of vehicles in the marketplace, more stringent CAFE standards better insulate consumers against these risks over longer periods of time. Fuel economy improvements that reduce demand for oil are a more certain hedging strategy against price volatility than increasing U.S. energy production. Continuing to reduce the amount of money consumers spend on vehicle fuel thus remains an important consideration for the need of the U.S. to conserve energy.

Additionally, the SEIS finds that overall, projected changes in both upstream and downstream emissions of criteria and toxic air pollutants are mixed, with emissions of some pollutants remaining constant or increasing and emissions of some pollutants decreasing. These increases are associated with both upstream and downstream sources, and therefore, may disproportionately affect minority and low-income populations that reside in proximity to these sources. However, the magnitude of the change in emissions relative to the No-Action alternative is minor for all action alternatives, and would not be characterized as high or adverse; over time, adverse health impacts are projected to decrease nationwide under each of the action alternatives.

For the other considerations that contribute to the need of the U.S. to conserve energy, it follows reasonably that reducing fuel consumption more would improve our national balance of payments more, and our energy security, as discussed above. It is therefore likely that Alternative 3 best meets the need of the U.S. to conserve energy.

During interagency review, the Department of Energy urged NHTSA to propose Alternative 3, on the basis that ‘‘a faster transition to battery electric vehicles (BEVs) is feasible,’’ because a variety of market analysts and the National Academies of Sciences, Engineering, and Medicine find that BEVs will reach cost parity with ICE vehicles by or before 2025. DOE further commented that new BEV prices would drop over time because ‘‘DOE has set aggressive technology targets for battery costs and electric drive technologies, . . . And DOE has a consistent track record in meeting its technology targets: DOE met or exceeded its technology cost and performance goals for battery and electric drive technologies every year between 2012 and 2018.’’ [citation omitted] While NHTSA appreciates this comment from DOE, as stated repeatedly throughout this proposal, NHTSA is statutorily prohibited from considering the fuel economy of dedicated alternative fuel vehicles during the rulemaking time frame when determining what levels of standards would be maximum feasible. NHTSA believes that Alternative 3 could potentially end up being maximum feasible in the final rule depending on a variety of factors, but NHTSA would be prohibited from basing such a finding exclusively on the date by which DOE estimates that BEVs will achieve cost parity with ICEs.

We next evaluate how the regulatory alternatives fare in terms of economic practicability. NHTSA recognizes that the amount of lead time available before MY 2024 is less than what was provided in the 2012 rule. As will be discussed further below, NHTSA believes that the evidence suggests that the proposed standards are still economically practicable, and not out of reach for a significant portion of the industry. CAFE standards can help support industry by requiring ongoing improvements even if demand for more fuel economy flags unexpectedly.

For the proposed standards, the annual rates of increase in the passenger car and light truck standards represent increases over the required levels in MY 2023 and are as shown in Table VI–6.

Table VI-6 – Annual Rate of Increase in Proposed CAFE Stringency for Each Model Year from 2024 to 2026

Model year	Passenger Car (percent)	Light Truck (percent)
2024	8	8
2025	8	8
2026	8	8

Part of the way that we try to evaluate economic practicability, and thus where the tipping point in the balancing of factors might be, is through a variety of metrics, examined in more detail below. If the amounts of technology or per-vehicle cost increases required to meet the standards appear to be beyond what we believe the market could bear; or sales and employment appear to be unduly impacted, the agency may decide that the standards under consideration may not be economically practicable. We underscore again, as throughout this preamble, that the modeling analysis does not dictate the ‘‘answer,’’ it is merely one source of information among others that aids the agency's balancing of the standards. We similarly underscore that there is no single bright line beyond which standards might be economically practicable, and that these metrics are not intended to suggest one; they are simply ways to think about the information before us.

Economic practicability may be evaluated in terms of how much technology manufacturers would have to apply to meet a given regulatory alternative. Technology application can be considered as ''which technologies, and when''—both the technologies that NHTSA's analysis suggests would be used, and how that application occurs given manufacturers' product redesign cadence. While the need of the U.S. to conserve energy may encourage the agency to be more technology-forcing in its balancing, and while technological feasibility is not limiting in this rulemaking given the state of technology in the industry, regulatory alternatives that require extensive application of very advanced technologies (that may have known or unknown consumer acceptance issues) or that require manufacturers to apply additional technology in earlier model years, in which meeting the standards is already challenging, may not be economically practicable, and may thus be beyond maximum feasible.

The first issue is timing of technology application. While the MY 2024 standards provide less lead time for an increase in stringency than was provided by the standards set in 2012, NHTSA believes that the standards for MYs 2021–2023 should provide a relative ''break'' for compliance purposes. NHTSA does not believe that significant additional technology application would be required by the CAFE standards in the years immediately preceding the rulemaking time frame. That said, NHTSA is aware of, and has accounted for, several manufacturers voluntarily agreeing with CARB to increase their fuel economy during those model years. Manufacturers would have to apply more technology than would be required by the MYs 2021–2023 CAFE standards alone to meet those higher fuel economy levels. Again, NHTSA interprets these agreements as evidence that the participating companies believe that applying that additional technology is practicable, because for-profit companies can likely be relied upon to make decisions that maximize their profit. Companies who did not agree with CARB to meet higher targets may not increase their fuel economy levels by as much over MYs 2021–2023, but they, too, will get the relative ''break'' in CAFE obligations mentioned above, and have additional time to plan for the higher stringency increases in subsequent years. Those manufacturers can opt to employ more modest technologies to improve fuel economy (beyond their standard) to generate credits to carry forward into more challenging years, or concentrate limited research and development resources on the next generation of higher fuel economy vehicles that will be needed to meet the proposed standards in MYs 2024–2026 (and beyond), rather investing in more modest improvements in the near-term.

NHTSA's analysis estimates manufacturers' product ''cadence,'' representing them in terms of estimated schedules for redesigning and ''freshening'' vehicles, and assuming that significant technology changes will be implemented during vehicle redesigns—as they historically have been. Once applied, a technology will be carried forward to future model years until superseded by a more advanced technology. NHTSA does not consider model years in isolation in the analysis, because that is not consistent with how industry responds to standards, and thus would not accurately reflect practicability. If manufacturers are already applying technology widely and intensively to meet standards in earlier years, requiring them to add yet more technology in the model years subject to the rulemaking may be less economically practicable; conversely, if the preceding model years require less technology, more technology during the rulemaking time frame may be more economically practicable. The tables below illustrate how the agency has modeled that process of manufacturers applying technologies in order to comply with different alternative standards. The technologies themselves are described in detail in Chapters 2 and 3 of the accompanying TSD.

Table VI-7 – Estimated Market Share (%) of Selected Technologies, Passenger Cars, Alternative 2 and Alternative 3, Standard Setting Analysis

Tech	Alt	2020	2023	2024	2025	2026
PHEV (all types)	2	< 1	< 1	2	5	8
BEV (all ranges)	2	4	9	9	10	10
Advanced AERO[1]	2	8	48	71	82	87
Strong Hybrid (all types)	2	3	3	5	5	6
MR4[2]	2	5	12	28	36	44
Advanced Engine[3]	2	13	29	46	50	50
PHEV (all types)	3	< 1	< 1	2	7	10
BEV (all ranges)	3	4	9	10	10	10
Advanced AERO	3	8	48	76	87	92
Strong Hybrid (all types)	3	3	4	7	8	8
MR4	3	5	12	30	38	46
Advanced Engine	3	13	29	46	51	52

[1] Combined penetration of 15% and 20% aerodynamic improvement

[2] Reduce glider weight by 15%

[3] Combined penetration of advanced cylinder deactivation, advanced turbo, variable compression ratio, high compression ratio and diesel engines

Table VI-8 – Estimated Market Share (%) of Selected Technologies, Light Trucks, Alternative 2 and Alternative 3, Standard Setting Analysis

Tech	Alt	2020	2023	2024	2025	2026
PHEV (all types)	2	< 1	< 1	2	4	7
BEV (all ranges)	2	< 1	2	2	2	3
Advanced AERO[1]	2	16	38	55	64	75
Strong Hybrid (all types)	2	2	4	7	9	9
MR4[2]	2	11	12	16	21	28
Advanced Engine[3]	2	15	32	37	42	50
PHEV (all types)	3	< 1	< 1	4	8	12
BEV (all ranges)	3	< 1	2	2	3	3
Advanced AERO	3	16	38	55	64	74
Strong Hybrid (all types)	3	2	5	9	9	9
MR4	3	11	12	16	21	29
Advanced Engine	3	15	32	36	40	51

[1] Combined penetration of 15% and 20% aerodynamic improvement

[2] Reduce glider weight by 15%

[3] Combined penetration of advanced cylinder deactivation, advanced turbo, variable compression ratio, high compression ratio and diesel engines

Although NHTSA's analysis is intended to estimate ways manufacturers *could* respond to new standards, not to predict how manufacturers *will* respond to new standards, manufacturers have indicated in meetings with the agency and in public announcements (including the CARB Framework Agreements) that they do intend to increase technology application over the coming years, and specifically electrification technology which NHTSA does not model as part of its standard-setting analysis, considered for decision-making, due to the 49 U.S.C. 32902(h) restrictions for MYs 2024–2026.

As the tables illustrate, both Alternative 2 and Alternative 3 appear to require rapid deployment of fuel efficiency technology across a variety of vehicle systems—body improvements due to weight reduction and improved aerodynamic drag, engine advancements, and electrification.[467] The aggressive application that is simulated to occur between MY 2020 (which NHTSA observed and is the starting point of this analysis) and MY 2023 occurs in all of the alternatives, for both cars and light trucks. This reflects both the task presented to signatories by the California Framework and existing compliance positions (in some fleets) across the industry to improve fuel economy in the near-term. In general, technology market shares for Alternative 3 look similar to those for Alternative 2, with the notable exception of plug-in hybrids which differ by only a couple of percent for cars and about 5 percent for light trucks. While still relatively small differences on their own, the market share of plug-in hybrids is currently less than one percent in total. While manufacturers could certainly choose to produce fully electric vehicles instead of PHEVs, fully electric vehicles are projected to grow by multiples of their current market share as well. The market for high levels of electrification is likely to continue growing but NHTSA acknowledges that consumer demand, especially in the near-term, remains somewhat unclear. If policy decisions are made to extend or expand incentives for electric vehicle purchases, NHTSA could potentially consider the greater reliance on electrification in Alternative 3 to be a smaller risk.

NHTSA's analysis seeks to account for manufacturers' capital and resource constraints in several ways—through the restriction of technology application to refreshes and redesigns, through the phase-in caps applied to certain technologies, and through the explicit consideration of vehicle components (like powertrains) and technologies (like platforms based on advanced materials) that are shared by models throughout a manufacturer's portfolio. NHTSA is aware that there is a significant difference in the level of capital and resources required to implement one or more new technologies on a single vehicle model, and the level of capital and resources required to implement those same technologies across the entire vehicle fleet. NHTSA realizes that it would not be economically practicable to expand some of the most advanced technologies to every vehicle in the fleet within the rulemaking time frame, although it should be possible to increase the application of advanced technologies across the fleet in a progression that accounts for those resource constraints. That is what NHTSA's analysis tries to do.

Another consideration for economic practicability is the extent to which new standards could increase the average cost to acquire new vehicles, because even insofar as the underlying application of technology leads to reduced outlays for fuel over the useful lives of the affected vehicles, these per-vehicle cost increases provide both a measure of the degree of effort faced by manufacturers, and also the degree of adjustment, in the form of potential vehicle price increases, that will ultimately be required of vehicle

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[467] While these technology pathways reflect NHTSA's statutory restrictions under EPCA/EISA, it is worth noting that they represent only one possible solution. In the simulations that support the SEIS, PHEV market share grows by less, and is mostly offset by an increase in BEV market share.

purchasers. Table VI–9 and Table VI–10 show the agency's estimates of average cost increase under the Preferred Alternative for passenger cars and light trucks, respectively. Because our analysis includes estimates of manufacturers' indirect costs and profits, as well as civil penalties that some manufacturers (as allowed under EPCA/EISA) might elect to pay in lieu of achieving compliance with CAFE standards, we report cost increases as estimated average increases in vehicle price (as MSRP). These are average values, and the agency does not expect that the prices of every vehicle would increase by the same amount; rather, the agency's underlying analysis shows unit costs varying widely between different vehicle models. For example, a small SUV that replaces an advanced internal combustion engine with a plug-in hybrid system may incur additional production costs in excess of $10,000, while a comparable SUV that replaces a basic engine with an advanced internal combustion engine incurs a cost closer to $2,000. While we recognize that manufacturers will distribute regulatory costs throughout their fleet to maximize profit, we have not attempted to estimate strategic pricing, having insufficient data (which would likely be confidential business information (CBI)) on which to base such an attempt. To provide an indication of potential price increases relative to today's vehicles, we report increases relative to the market forecast using technology in the MY 2020 fleet—the most recent actual fleet for which we have information sufficient for use in our analysis. We provide results starting in MY 2023 in part to illustrate the cost impacts in the first model year that we believe manufacturers might actually be able to change their products in preparation for compliance with standards in MYs 2024–2026.

Table VI-9 – Estimated Total (vs. MY 2020 Technology) Average MSRP Increases During MYs 2023-2026 Under Preferred Alternative, Passenger Cars

Manufacturer	2023	2024	2025	2026
BMW	1,133	1,468	2,125	2,769
Daimler	1,180	2,422	2,789	3,204
FCA (Stellantis)	2,697	3,031	3,404	3,740
Ford	3,699	3,402	3,421	3,310
GM	848	1,339	2,065	2,474
Honda	685	829	1,332	1,757
Hyundai Kia-H	623	978	1,661	2,357
Hyundai Kia-K	411	997	1,371	1,880
JLR	609	1,532	1,837	2,256
Mazda	2,288	2,427	3,285	3,401
Mitsubishi	822	1,342	1,815	1,785
Nissan	1,349	2,054	2,871	2,856
Subaru	909	2,055	2,265	2,748
Tesla	48	47	49	49
Toyota	364	934	1,075	1,179
VWA	1,102	1,397	1,743	4,523
Volvo	943	2,761	2,829	3,006
Total, Average	1,055	1,521	1,968	2,264

Table VI-10 – Estimated Total (vs. MY 2020 Technology) Average MSRP Increases During MYs 2023-2026 Under Preferred Alternative, Light Trucks

Manufacturer	2023	2024	2025	2026
BMW	1,282	1,379	1,404	1,431
Daimler	634	657	1,358	1,935
FCA (Stellantis)	1,114	1,325	1,643	1,973
Ford	938	1,187	1,219	1,912
GM	738	1,311	2,309	2,935
Honda	527	1,183	1,705	1,674
Hyundai Kia-H	638	764	883	3,117
Hyundai Kia-K	599	2,416	2,414	2,421
JLR	822	1,311	1,850	2,247
Mazda	492	594	1,370	1,664
Mitsubishi	363	841	1,862	1,832
Nissan	1,133	2,249	2,327	2,824
Subaru	1,121	1,267	1,441	1,434
Tesla	82	81	79	78
Toyota	1,239	1,921	1,925	2,331
VWA	2,210	2,222	2,467	2,482
Volvo	901	2,010	2,392	2,628
Total, Average	933	1,413	1,795	2,210

Relative to current vehicles (again, as represented here by technology in the MY 2020 fleet, the most recent for which NHTSA has adequate data), NHTSA judges these cost increases to be significant, but not impossible for the market to bear. Cost increases will be partially offset by fuel savings, which consumers will experience eventually, if not concurrent with the upfront increase in purchase price. And as discussed previously, nearly every manufacturer has already indicated their intent to continue introducing advanced technology vehicles between now and MY 2026. Again, NHTSA believes that manufacturers introduce new vehicles (and technologies) expecting that there is a market for them—if not immediately, then in the near future. For-profit companies cannot afford to lose money indefinitely. This trend suggests that manufacturers believe that at least some cost increases should be manageable for consumers.

Relative to the Preferred Alternative, however, NHTSA notes significant further cost increases for several major manufacturers under Alternative 3. Table VI–11 and Table VI–12 show additional technology costs estimated to be incurred under Alternative 3 as compared to the Preferred Alternative.

Table VI-11 – Estimated Difference Between Estimated Average MSRP Increase under Preferred Alternative and Alternative 3 for Passenger Cars

Manufacturer	2023	2024	2025	2026
BMW	48	207	631	693
Daimler	45	292	407	546
FCA (Stellantis)	(0)	122	265	379
Ford	(0)	11	(239)	78
GM	115	139	367	428
Honda	498	555	516	534
Hyundai Kia-H	4	206	462	617
Hyundai Kia-K	-	111	696	670
JLR	(2)	125	292	463
Mazda	(0)	266	542	534
Mitsubishi	-	119	602	576
Nissan	16	308	427	573
Subaru	(0)	(0)	147	468
Tesla	-	-	-	-
Toyota	56	326	383	441
VWA	(0)	47	129	160
Volvo	(12)	(216)	(131)	337
Total, Average	92	227	360	469

Table VI-12 – Estimated Difference Between Estimated Average MSRP Increase under Preferred Alternative and Alternative 3 for Light Trucks

Manufacturer	2023	2024	2025	2026
BMW	24	23	44	143
Daimler	(8)	43	168	331
FCA (Stellantis)	0	83	187	318
Ford	66	521	605	847
GM	-	283	622	798
Honda	312	1,036	1,046	1,037
Hyundai Kia-H	-	17	29	671
Hyundai Kia-K	0	719	693	672
JLR	16	122	214	363
Mazda	-	17	96	387
Mitsubishi	0	128	355	340
Nissan	0	27	58	181
Subaru	0	0	47	(0)
Tesla	-	-	-	-
Toyota	53	652	622	798
VWA	653	624	599	597
Volvo	10	369	490	573
Total, Average	46	347	461	600

For example, Honda's light truck fleet appears to hit an inflection point in cost where much more aggressive technology application is required in order to comply with Alternative 3. In general, light truck fleets appear to be pressed harder to comply with Alternative 3 than passenger car fleets across the industry. For example, Ford's passenger car compliance costs are estimated to increase minimally between Alternative 2 and Alternative 3, but light truck compliance costs increase by over 40 percent (in most years). A number of other manufacturers are pushed in both fleets (Honda, Toyota, and Kia, for example), and make significant additional investments in fuel economy technology to reach compliance with the standards in Alternative 3.

Changes in costs for new vehicles are not the only costs that NHTSA considers in balancing the statutory factors—fuel costs for consumers are relevant to the need of the U.S. to conserve energy, and NHTSA believes that consumers themselves weigh expected fuel savings against increases in purchase price for vehicles with higher fuel economy. Fuel costs (or savings) continue to be the largest source of benefits for CAFE standards, and GHG reduction benefits, which are also part of the need of the U.S. to conserve energy, are also increasing. E.O. 12866 and Circular A–4 also direct agencies to consider maximizing net benefits in rulemakings whenever possible and consistent with applicable law. Thus, because it can be relevant to balancing the statutory factors and because it is directed by E.O. 12866 and OMB guidance, NHTSA also considers the net benefits attributable to the different regulatory alternatives, as shown in Table VI–13.

Table VI-13 – Summary of Cumulative Benefits and Costs for Model Years through MY 2029, by Alternative and Discount Rate

		Alternative 1	Alternative 2	Alternative 3
3% Rate	Total Benefits	82.6	121.4	172.9
	Total Costs	66.5	121.1	176.3
	Net Benefits	16.1	0.3	-3.4
7% Rate	Total Benefits	51.6	75.6	107.6
	Total Costs	49.3	90.7	132.8
	Net Benefits	2.3	-15.1	-25.2

While maximizing net benefits is a valid decision criterion for choosing among alternatives, it is not the only reasonable decision perspective. When NHTSA recognizes that the need of the U.S. to conserve fuel weighs importantly in the overall balancing of factors, it is reasonable to consider choosing the regulatory alternative that produces the largest reduction in fuel consumption, while remaining net beneficial. The benefit-cost analysis is not the sole factor that NHTSA considers in determining the maximum feasible stringency, though it supports NHTSA's tentative conclusion that Alternative 2 is the maximum feasible stringency. While Alternative 1 produces higher net benefits, it also continues to allow fuel consumption that could have been avoided in a cost-beneficial manner. And while Alternative 3 achieves greater reductions in fuel consumption than Alternative 2, it shows relatively high negative net benefits under both discount rates.

While NHTSA estimates that new vehicle sales will be slightly lower under Alternative 2 than under the No-Action Alternative, as a consequence of the higher retail prices that result from additional technology application, the difference is only about 1 percent over the entire period covered by MYs 2020–2026. NHTSA does not believe that this estimated change in new vehicle sales over the period covered by the rule is a persuasive reason to choose another regulatory alternative. Similarly, the estimated labor impacts within the automotive industry provide no evidence that another alternative should be preferred. While the change in sales is estimated to decrease industry employment over the period, the decrease is even smaller than the impact on new vehicle sales (about 0.1 percent). As NHTSA explained earlier in defining economic practicability, standards simply should avoid a *significant* loss of jobs, and may still be economically practicable even though they appear to show a negative impact (here, a very slight impact) on sales and employment.

As with any analysis of sufficient complexity, there are a number of critical assumptions here that introduce uncertainty about manufacturer compliance pathways, consumer responses to fuel economy improvements and higher vehicle prices, and future valuations of the consequences from higher CAFE standards. While NHTSA considers dozens of sensitivity cases to measure the influence of specific parametric assumptions and model relationships, only a small number of them demonstrate meaningful impacts to net benefits under the proposed standards.

Looking at these cases more closely, the majority of both costs and benefits that occur under the proposed standards accrue to buyers of new cars and trucks, rather than society in general. It then follows that the assumptions that exert the greatest influence over private costs and benefits also exert the greatest influence over net benefits—chief among these is the assumed trajectory of future fuel prices, specifically gasoline. NHTSA considers the ''High Oil Price'' and ''Low Oil Price'' cases from AEO 2021 as bounding cases, though they are asymmetrical (while the low case is only about 25 percent lower than the Reference case on average, the high case is almost 50 percent higher on average). The sensitivity cases suggest that fuel prices exert considerable influence on net benefits—where higher and lower prices not only determine the dollar value of each gallon saved, but also how market demand responds to higher levels of fuel economy in vehicle offerings. Under the low case, net benefits become negative and exceed $30 billion, but increase to almost (positive) $50 billion in the high case (the largest increase among any sensitivity cases run for this proposal). This suggests that the net benefits resulting from this proposal are dependent upon the future price of gasoline being at least as high as the AEO 2021 Reference Case projects.

Another critical uncertainty that affects private benefits is the future cost of advanced electrification technologies, specifically batteries. These emerging technologies provide both the greatest fuel savings to new car buyers and impose the highest technology costs (at the moment). While the cost to produce large vehicle batteries has been rapidly declining for years, they are still expensive relative to advancements in internal combustion engines and transmissions. However, the analysis projects continued cost learning over time and shows battery electric vehicles reaching price parity with conventional vehicles in the 2030s for most market segments—after which market adoption of BEVs accelerates—although other estimates show price parity occurring sooner and we seek comment on whether and how to use those estimates in our analysis for the final rule. Electrification is also a viable compliance strategy, as partially or fully electric vehicles benefit from generous compliance incentives that improve their estimated fuel economy relative to measured energy consumption. As such, the assumption about future battery costs has the ability to influence compliance costs to manufacturers and prices to consumers, the rate of electric vehicle adoption in the market, and thus the emissions associated with their operation. NHTSA considered two different mechanisms to affect battery costs: Higher/lower direct costs, and faster/slower cost learning rates. The two mechanisms that reduce cost (whether by faster cost learning or lower direct costs) both increase net benefits relative to the central case, though lowering initial direct costs by 20 percent had a greater effect than increasing the learning rate by 20 percent. Increasing cost (though either mechanism) by 20 percent produced a similar effect, but in the opposite direction (reducing net benefits). However, none of those cases exerted a level of influence that compares to alternative fuel price assumptions.

There is one assumption that affects the analysis without influencing the benefits and costs that accrue to new car buyers: The social cost of damages attributable to greenhouse gas emissions. While there is no feedback in either the analysis or the policy between the assumed social cost of GHGs and metric tons of GHGs emitted (or gallons of fuel consumed), it directly controls the valuation of each metric ton saved over time. The central analysis assumes a SC–GHG cost based on the 2.5 percent discount rate for the 3 percent social discount rate, and a SC–GHG cost based on the 3 percent discount rate in the 7 percent social discount rate case. However, this assumption directly scales total benefits by increasing (or decreasing) the value of each ton saved. Using the highest SCC–GHG, based on the 95th percentile estimate, pushes net benefits above $30 billion under Alternative 2. NHTSA does not independently develop the SC–GHG assumptions used in this proposal but takes them from the interagency working group on the social cost of GHGs. If future analyses by that group determine that the SC–GHG should be different from what it currently is, NHTSA will consider those values and whether to include them in subsequent analyses. As the sensitivity cases illustrate, their inclusion could exert enough influence on net benefits to suggest that a different alternative could represent the maximum feasible stringency—at least based on the decision criteria described in this section. As mentioned above, NHTSA is seeking comment on the methodology employed by that group for determining the SC–GHG.

Based on all of the above, NHTSA tentatively concludes that while all of the action alternatives are technologically feasible, Alternative 3 may be too costly to be economically practicable in the rulemaking timeframe, even if choosing it could result in greater fuel savings. NHTSA interprets the need of the U.S. to conserve energy as pushing the balancing toward greater stringency—consumer savings on fuel costs are estimated to be higher under Alternative 3 than under Alternative 2, but the additional technology cost required to meet Alternative 3 (as evidenced by the negative net benefits at both discount rates) may yet make Alternative 3 too stringent for these model years. Changes in criteria pollutants, health effects, and vehicle safety effects are relatively minor under all action alternatives, and thus not dispositive. NHTSA has considered the effect of other motor vehicle standards of the Government by incorporating the fuel economy effects of California's ZEV program into its baseline, and calculating the costs and benefits of CAFE standards as above and beyond those baseline costs and benefits. The additional costs of the proposed standards are, on average, not far from what NHTSA estimated in the 2012 final rule for standards in a similar timeframe; the additional benefits are lower, but this is due to a variety of factors, including significant addition of fuel-economy-improving technology to new vehicles between then and now (including the growing market for electric vehicles), and lower fuel price projections from EIA. To the extent that higher prices for new vehicles as a result of the technology required by the standards could translate to decreases in new vehicle sales, we note that those effects appear small, as discussed above. Moreover, improving the fuel efficiency of new vehicles has effects over time, not just at point of first sale, on consumer fuel savings. Somewhat-more-expensive-but-more-efficient new vehicles eventually become more-efficient used vehicles, which may be purchased by consumers who may be put off by higher new vehicle prices. The benefits have the potential to continue across the fleet and over time, for all consumers regardless of their current purchasing power.

NHTSA recognizes, again, that lead time for this proposal is less than past rulemakings have provided, and that the economy and the country are in the process of recovering from a global pandemic. NHTSA also recognizes that at least parts of the industry are nonetheless making announcement after announcement of new forthcoming advanced technology, high-fuel-economy vehicle models, and does not believe that they would be doing so if they thought there was no market at all for them. Perhaps some of the introductions are driven by industry perceptions of future regulation, but the fact remains that the introductions are happening. CAFE standards can help to buttress this momentum by continuing to require the fleets as a whole to improve their fuel economy levels steadily over the coming years, so that a handful of advanced technology vehicles do not inadvertently allow backsliding in the majority of the fleet that will continue to be powered by internal combustion for likely the next 5–10 years. CAFE standards that increase steadily may help industry make this transition more smoothly.

And finally, if the purpose of EPCA is energy conservation, and NHTSA is interpreting the need to conserve energy to be largely driven by fuel savings, energy security, and environmental concerns, then it makes sense to interpret EPCA's factors as asking the agency to push stringency as far as possible before benefits become negative. The energy conservation benefits of Alternative 3 appear, under the current analysis, to be highest, as discussed in the SEIS and in Section VI.C above, and better protect consumers from international oil market instability and price spikes. By increasing the fuel economy of vehicles in the marketplace, more stringent CAFE standards better insulate consumers against these risks over longer periods of time. Fuel economy improvements that reduce demand for oil are a more certain hedging strategy against price volatility than increasing U.S. energy production. However, with negative net benefits for Alternative 3 under both discount rates, it may be that for the moment, the costs of achieving those benefits are more than the market is willing to bear. NHTSA thus aims to help bolster the industry's trajectory toward higher future standards, by keeping stringency high in the mid-term, but not so high as to be economically impracticable.

NHTSA therefore proposes that Alternative 2 is maximum feasible for MYs 2024–2026. We seek comment on this tentative conclusion.

VII. Compliance and Enforcement

A. Introduction

1. Overview of the NHTSA Compliance Program

A manufacturer's fleet is divided into three compliance categories of automobiles: Passenger vehicles manufactured domestically, passenger vehicles not manufactured domestically; and non-passenger automobiles.[468] Each category has its own CAFE fleet mpg standard that a manufacturer is required to meet. The CAFE standard is determined for each model year by a combination of the production volume of vehicles produced for sale, the footprint of those vehicles, and the requisite CAFE footprint-based fuel economy target curves.

For each compliance category, manufacturers self-report data at the end of each MY in the form of a Final Model Year Report, and once these data are verified by EPA, NHTSA determines final compliance. Using EPA's final verified data, a manufacturer fleet is determined to be compliant if the 2-cycle CAFE performance of their fleet with the addition of the Alternative Motor Fuels Act (AMFA) and AC/OC incentives are equal to or greater than the CAFE fleet mpg standard. The manufacturer fleet is out of compliance if its fleet mpg falls below the CAFE mpg standard, in which case the manufacturer may resolve the shortfall through civil penalties or the use of flexibilities. Resolving a shortfall through flexibilities may include the application of CAFE credits through trade, carry-forward, carry-back, or transfer from within the manufacturer's fleet accounts or from another manufacturer's fleet accounts.

The following sections provide a brief overview how CAFE standards and compliance values are derived, what compliance flexibilities and incentives are available to manufacturers, and the revisions to the CAFE program NHTSA is proposing in this rulemaking. In summary, NHTSA is proposing to: (1) Increase and clarify flexibilities for its off-cycle program; (2) revive incentives for hybrid and electric full-size pickup trucks through MY 2025; (3) modify its standardized templates for CAFE reporting and credit transactions; and (4) add a new template for manufacturers to report information on the monetary and non-monetary costs associated with credit trades.

2. How Manufacturers' Target and Achieved Performances Are Calculated

Compliance begins each model year with manufacturers testing vehicles on a dynamometer in a laboratory over pre-defined test cycles and controlled conditions.[469] EPA and manufacturers use two different dynamometer test procedures—the Federal Test Procedure (FTP) and the Highway Fuel Economy Test (HFET) to determine fuel economy. These procedures originated in the early 1970s and were intended to generally represent city and highway driving conditions, respectively. These two tests are commonly referred to as the ''2-cycle'' test procedures for CAFE. A machine is connected to the vehicle's tailpipe while it performs the test cycle, which collects and analyzes exhaust gases, such as CO_2 quantities.[470] Fuel economy is determined from relating a derived emissions factor to the amount of observed CO_2 using a reference test fuel.[471] Manufacturers continue to test vehicles over the course of the model year and will test enough vehicles to cover approximately 90 percent of the subconfigurations within each model type. Manufacturers self-report this information to EPA as part of their end-of-the-model year reports, which are due 90 days after the model year is completed. After manufacturers submit their reports, EPA confirms and validates those results by testing a random sample of vehicles at the National Vehicle and Fuel Emissions Laboratory (NVFEL) in Ann Arbor, Michigan.

A manufacturer's fleet fuel economy performance (hereafter referenced as Base CAFE) for a given model year is calculated through the following steps:

- Each vehicle model's mile per gallon (mpg) performance in the city and highway test cycles are calculated based off the carbon emitted during dynamometer testing. The vehicle's mpg performance is combined at 55 percent city and 45 percent highway. Measurement incentives for alternative fuel vehicles (such as for electricity, counting 15 percent of the actual energy used to determine the gasoline equivalent mpg) are applied as part of these procedures;
- Performance improvements not fully captured through 2-cycle dynamometer testing, such as eligible A/C and off-cycle technologies are then added to the vehicle's mpg performance. Incentives for full-size pickup trucks with mild or strong HEV technology or other technologies that perform significantly better than the vehicle's target value are also applied.
- The quantity of vehicles produced of each model type within a manufacturer's fleet is divided by its respective fuel economy performance (mpg) including any flexibility/incentive increases; The resulting numbers for each model type are summed;
- The manufacturer's total production volume is then divided by the summed value calculated in the previous step; and

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[468] *See* 49 U.S. Code 32903.6. Passenger vehicles not manufactured domestically are referenced as import passenger cars and non-passenger automobiles as light trucks.

[469] For readers unfamiliar with this process, the test is similar to running a car on a treadmill following a program—or more specifically, two programs. 49 U.S.C. 32904(c) states that, in testing for fuel economy, EPA must ''use the same procedures for passenger automobiles [that EPA] used for model year 1975 (weighted 55 percent urban cycle and 45 percent highway cycle), or procedures that give comparable results.'' Thus, the ''programs'' are the ''urban cycle,'' or Federal Test Procedure (abbreviated as ''FTP'') and the ''highway cycle,'' or Highway Fuel Economy Test (abbreviated as ''HFET''), and they have not changed substantively since 1975. Each cycle is a designated speed trace (of vehicle speed versus time) that vehicles must follow during testing—the FTP is meant roughly to simulate stop and go city driving, and the HFET is meant roughly to simulate steady flowing highway driving at about 50 mph. The 2-cycle dynamometer test results differ somewhat from what consumers will experience in the real-world driving environment because of the lack of high speeds, rapid accelerations, and hot and cold temperatures evaluations with the A/C operation. These added conditions are more so reflected in the EPA 5-cycle test results listed on each vehicle's fuel economy label and on the *fueleconomy.gov* website.

[470] Vehicles without tailpipe emissions, such as battery electric vehicles, have their performance measured differently, as discussed below.

[471] Technically, for the CAFE program, carbon-based tailpipe emissions (including CO_2, CH_4, and CO) are measured, and fuel economy is calculated using a carbon balance equation. EPA uses carbon-based emissions (CO_2, CH_4, and CO, the same as for CAFE) to calculate the tailpipe CO_2 equivalent for the tailpipe portion of its standards. CO_2 is by far the largest carbon-based exhaust constituent.

- That number, which is the harmonic average of the fleet's fuel economy, is rounded to the nearest tenth of an mpg and represents the manufacturer's achieved fuel economy.

The Base CAFE of each fleet is compared to the manufacturer's unique fleet compliance obligation, which is calculated using the same approach as the Base CAFE performance, except that the fuel economy target value (based on the unique footprint of each vehicle within a model type) is used instead of the measured fuel economy performance values. The fuel economy target values of the model types within each fleet and production volumes are used to derive the manufacturer's fleet standard (also known as the obligation) which is the harmonic average of these values.

To further illustrate how Base CAFE and fuel economy targets are calculated, assume that a manufacturer produces two models of cars—a hatchback and a sedan. Figure VII–1 shows the two vehicle models imposed onto a fuel economy target function. From Figure VII–1, we can see that the target function extends from about 30 mpg for the largest cars to about 41 mpg for the smallest cars.

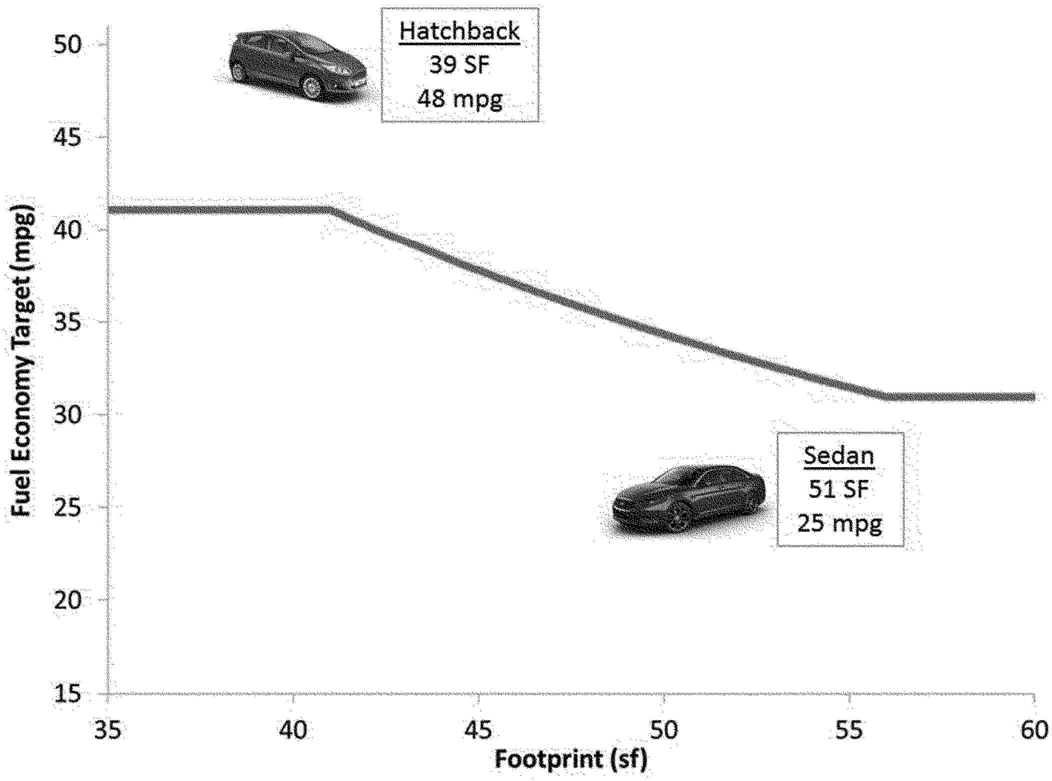

Figure VII-1 – Illustration of Vehicle Models vs. Fuel Economy Targets

The manufacturer's required CAFE obligation would be determined by calculating the production-weighted harmonic average of the fuel economy target values applicable at the hatchback and sedan footprints (from the curve, about 41 mpg for the hatchback and about 33 mpg for the sedan). The manufacturer's achieved Base CAFE level is determined by calculating the production-weighted harmonic average of the hatchback and sedan fuel economy levels (in this example the values shown in the boxes in Figure VII–1, 48 mpg for the hatchback and 25 mpg for the sedan). Depending on the relative mix of hatchbacks and sedans produced, the manufacturer's fleet Base CAFE may be equal to the standard, perform better than the standard (if the required fleet CAFE is less than the achieved fleet Base CAFE) and thereby earn credits, or perform worse than the standard (if the required fleet CAFE is greater than achieved fleet Base CAFE) and thereby earn a credit shortfall which would need to be made up using CAFE credits, otherwise the manufacturer would be subject to civil penalties.

As illustrated by the example, the CAFE program's use of sales-weighted harmonic averages makes compliance more intricate than comparing a model to its target as not every model type needs to precisely meet its target for a manufacturer to achieve compliance. Consequently, if a manufacturer finds itself producing large numbers of vehicles that fall well-short of its targets, a manufacturer can attempt to equally balance its compliance by producing vehicles that are excessively over-compliant. However, NHTSA understands that several factors determine the ability of manufacturers to change their fleet-mix mid-year. In response, the CAFE program is structured to provide relief to manufacturers in offsetting any shortfalls by offering several compliance flexibilities. Many manufacturers use these flexibilities to avoid civil penalties.

3. The Use for CAFE Compliance Flexibilities and Incentives

The CAFE program offers several compliance flexibilities which expand options for compliance, and incentives which encourage manufacturers to build vehicles with certain technologies to achieve longer range policy objectives. For example, since MY 2017, manufacturers have had the flexibility to earn credits for air conditioning

(A/C) systems with improved efficiency. These fuel economy improvements are added to the 2-cycle performance results of the vehicle and increases the calculation of a manufacturer's fleet Base CAFE in determining compliance relative to standards.[472]

Some CAFE flexibilities and incentives are codified by statute in EPCA or EISA, while others have been implemented by the NHTSA through regulations, consistent with the statutory scheme. Compliance flexibilities and incentives have a great deal of theoretical attractiveness: If designed properly, they can help reduce the overall regulatory costs, while maintaining or improving programmatic benefits. If designed poorly, they may create significant potential for market distortion. Consequently, creating or revising compliance flexibilities and incentives requires proper governmental and industry collaboration for understanding upcoming technological developments and for determining whether a technology is economically feasible for compliance. When designing these programmatic elements, the agency must be mindful to ensure flexibilities and incentives are provided with long term benefits to the CAFE program while avoiding unintended windfalls for only certain manufacturers or technologies.

Compliance incentives and flexibilities are structured to encourage implementation of technology that will further increase fuel savings. Some incentives are designed to encourage the development of technologies that may have high initial costs but offer promising fuel efficiency benefits in the long-term. Others are designed to bring low cost technologies uniformly into the market that improve fuel economy in the real-world but may be missed by the 2-cycle test, such as the cost-effective off-cycle menu technologies included by EPA for CAFE compliance.

Below is a summary of all the current and proposed changes to the flexibilities and incentives for the CAFE and CO_2 programs in Table VII–1 through Table VII–4. Note that this proposal only covers the CAFE program; the EPA program is listed here to demonstrate the congruencies between the two programs. NHTSA is proposing to maintain the bulk of its current program with a few modifications. One of the changes raised in this proposal is to increase the off-cycle flexibility technology benefit cap along with new technology definitions as shown in the table. NHTSA is also proposing to reinstate incentives for full-size hybrid and game changing advanced technology pickup trucks for model years 2022 through 2026. NHTSA believes that these incentives will increase the production of environmentally beneficial technologies and help achieve economies of scale to reduce costs that will enable more stringent CAFE standards in the future. These proposals are explained in further detail in Section VII.B.

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[472] NHTSA characterizes any programmatic benefit manufacturers can use to comply with CAFE standards that fully accounts for fuel use as a "flexibility" (*e.g.,* credit trading) and any benefit that counts less than the full fuel use as an "incentive" (*e.g.,* adjustment of alternative fuel vehicle fuel economy). NHTSA flexibilities and incentives are discussed further in Section VII.B.3.a).

Table VII-1 – Statutory Flexibilities for Over-compliance with Standards

Regulatory Item	**NHTSA**		**EPA**	
	Authority	**Current Program**	**Authority**	**Current and *Proposed* Program**
Credit Earning	49 U.S.C. 32903(a)	Denominated in tenths of a mpg	CAA 202(a)	Denominated in g/mi
Credit "Carry-forward"	49 U.S.C. 32903(a)(2)	5 MYs into the future	CAA 202(a)	5 MYs into the future (except for MYs 2010-2015 = credits may be carried forward through MY 2021) ***EPA proposes to extend credit expiration for MY 2016 by 2 years, and for MYs 2017-2020 by 1 year***
Credit "Carryback" (AKA "deficit carry-forward")	49 U.S.C. 32903(a)(1)	3 MYs into the past	CAA 202(a)	3 MYs into the past
Credit Transfer	49 U.S.C. 32903(g)	Up to 2 mpg per fleet; transferred credits may not be used to meet MDPCS	CAA 202(a)	Unlimited
Credit Trade	49 U.S.C. 32903(f)	Unlimited quantity; traded credits may not be used to meet MDPCS	CAA 202(a)	Unlimited

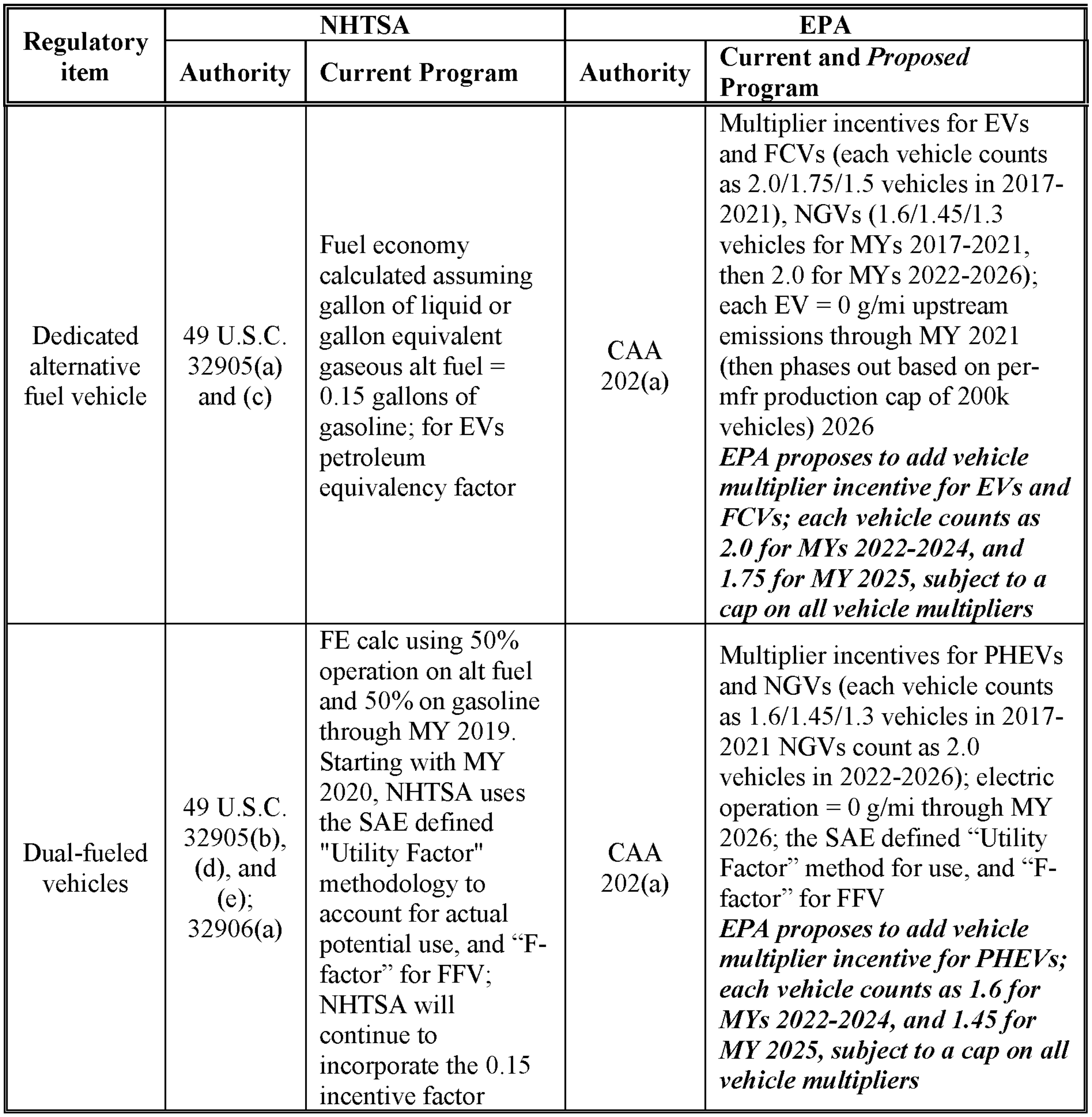
Table VII-2 – Current and Proposed Flexibilities that Address Gaps in Compliance Test Procedures

Regulatory Item	NHTSA		EPA	
	Authority	Current and *Proposed* Program	Authority	Current and *Proposed* Program
A/C efficiency	49 U.S.C. 32904	Allows mfrs to earn "fuel consumption improvement values" (FCIVs) equivalent to EPA credits starting in MY 2017	CAA 202(a)	"Credits" for A/C efficiency improvements up to caps of 5.0 g/mi for cars and 7.2 g/mi for trucks
Off-cycle	49 U.S.C. 32904	Allows mfrs to earn "fuel consumption improvement values" (FCIVs) equivalent to EPA credits starting in MY 2017 ***For MY 2020 and beyond, NHTSA proposes to implement CAFE provisions equivalent to the EPA proposed changes***	CAA 202(a)	"Menu" of pre-approved credits (~10), up to cap of 10 g/mi for MY 2014 and beyond; other pathways require EPA approval through either 5-cycle testing or through public notice and comment ***EPA proposes to revise the definitions for passive cabin ventilation and active engine and transmission warm-up beginning in MY 2023; for MY 2020-2022, the cap is 15 g/mi if the revised definitions are met (if these technologies are used). In MY 2023 and later, the cap is increased to 15 g/mile***

Table VII-3 – Incentives that Encourage Application of Technologies

Regulatory item	NHTSA		EPA	
	Authority	*Proposed* Program	Authority	Current and *Proposed* Program
Full-size pickup trucks with HEV or overperforming target	49 U.S.C. 32904	Allows mfrs to earn FCIVs equivalent to EPA credits for MYs 2017-2021 ***NHTSA proposes to reinstate incentives for strong hybrid OR overperforming target by 20% for MYs 2022-2025***	CAA 202(a)	10 g/mi for full-size pickups with mild hybrids OR overperforming target by 15% (MYs 2017-2021); 20 g/mi for full-size pickups with strong hybrids OR overperforming target by 20% (MYs 2017-2021); requires 10% or more of full-size pickup production volume ***EPA proposes to reinstate incentives for strong hybrid OR overperforming by 20% for MYs 2022-2025***

Table VII-4 – Incentives that Encourage Alternative Fuel Vehicles



Regulatory item	NHTSA		EPA	
	Authority	Current Program	Authority	Current and *Proposed* Program
Dedicated alternative fuel vehicle	49 U.S.C. 32905(a) and (c)	Fuel economy calculated assuming gallon of liquid or gallon equivalent gaseous alt fuel = 0.15 gallons of gasoline; for EVs petroleum equivalency factor	CAA 202(a)	Multiplier incentives for EVs and FCVs (each vehicle counts as 2.0/1.75/1.5 vehicles in 2017-2021), NGVs (1.6/1.45/1.3 vehicles for MYs 2017-2021, then 2.0 for MYs 2022-2026); each EV = 0 g/mi upstream emissions through MY 2021 (then phases out based on per-mfr production cap of 200k vehicles) 2026 ***EPA proposes to add vehicle multiplier incentive for EVs and FCVs; each vehicle counts as 2.0 for MYs 2022-2024, and 1.75 for MY 2025, subject to a cap on all vehicle multipliers***
Dual-fueled vehicles	49 U.S.C. 32905(b), (d), and (e); 32906(a)	FE calc using 50% operation on alt fuel and 50% on gasoline through MY 2019. Starting with MY 2020, NHTSA uses the SAE defined "Utility Factor" methodology to account for actual potential use, and "F-factor" for FFV; NHTSA will continue to incorporate the 0.15 incentive factor	CAA 202(a)	Multiplier incentives for PHEVs and NGVs (each vehicle counts as 1.6/1.45/1.3 vehicles in 2017-2021 NGVs count as 2.0 vehicles in 2022-2026); electric operation = 0 g/mi through MY 2026; the SAE defined "Utility Factor" method for use, and "F-factor" for FFV ***EPA proposes to add vehicle multiplier incentive for PHEVs; each vehicle counts as 1.6 for MYs 2022-2024, and 1.45 for MY 2025, subject to a cap on all vehicle multipliers***

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4. Light Duty CAFE Compliance Data for MYs 2011–2020

NHTSA uses compliance data in part to identify industry trends. For this proposal, NHTSA examined CAFE compliance data for model years 2011 through 2020 using final compliance data for MYs 2011 through 2017,[473] projections from end-of-the-model year reports submitted by manufacturers for MYs 2018 and 2019,[474] and projections from manufacturers' mid model year reports for MY 2020.[475] Projections from the mid-year and end-of-the-model year reports may differ from EPA-verified final CAFE values either because of differing test results or final sales-volume figures. MY 2011 was selected as the start of the data because it represents the first compliance model year for which manufacturers were permitted to trade and transfer credits.[476] The data go up to MY 2020, because this was the most recent year compliance reports were available.

Figure VII–2 through Figure VII–5 provide a graphical overview of the actual and projected compliance data for MYs 2011 to 2020.[477]

In the figures, an overview is provided for the total fuel economy performance of the industry (the combination of all passenger cars and light trucks produced for sale during the

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[473] Final compliance data have been verified by EPA and are published on the NHTSA's Public Information Center (PIC) site. MY 2017 is currently the most-recent model year verified by EPA.

[474] MY 2018 data come from information received in manufacturers' final reports submitted to EPA according to 40 CFR 600.512–12.

[475] Manufacturers' mid-model year CAFE reports are submitted to NHTSA in accordance with 49 CFR part 537. At the time of the analysis, end of the model year data had not yet been submitted for MY 2020.

[476] 49 CFR 535.6(c).

[477] As mentioned previously, the figures include estimated values for certain model years based on the most up to date information provided to NHTSA from manufacturers.

model year) as a single fleet, and for each of the three CAFE compliance fleets: Domestic passenger car, import passenger car, and light truck fleets. For each of the graphs, a sale-production weighting is applied to determine the average total or fleet Base CAFE performances.[478] [479] [480] The graphs do not include adjustments for full-size pickup trucks because manufactures have yet to bring qualifying products into production.

The figures also show how many credits remain in the market each model year. One complicating factor for presenting credits is that the mpg-value of a credit is contingent where it was earned and applied. Therefore, the actual use of the credits for MYs 2018 and beyond will be uncertain until compliance for those model years is completed. Also, since credits can be retained for up to 6 MYs after they were earned or applied retroactively to the previous 3 model years, it is impossible to know the final application of credits for MY 2020 until MY 2023 compliance data are finalized. Instead of attempting to project how credits would be generated and used, the agency opted to value each credit based on its actual value when earned, by estimating the value when applied assuming it was applied to the overall average fleet and across all vehicles. In the figures, two different approaches were used to represent the mpg value of credits used to offset shortages (shown as CAFE after credit allocation in the figures). The mpg shortages for MYs 2011 to 2017 are based upon actual compliance values from EPA and the credit allocations or fines manufacturers instructed NHTSA to adjust and apply to resolve compliance shortages. For MYs 2018 to 2020, NHTSA used a different approach for representing the mpg shortages, deriving them from projected estimates adjusted for fuel savings calculated from the projected fleet average performances and standards for each model year and fleet. To represent the mpg value of manufacturers' remaining banked credits in the figures (shown as Credits in the Market) the same weighting approach was also applied to these credits based upon the fleet averages. For MYs 2011–2017, the remaining banked credits include those currently existing in manufacturers' credit accounts adjusted for fuel savings and subtracting any expired credits for each year. This approach was taken to represent these credits for the actual value that would likely exist if the credits were applied for compliance purposes. Without adjusting the banked credits, it would provide an unrealistic value of the true worth of these credits when used for compliance. For MYs 2018–2020, the mpg value of the remaining banked credits is shown slightly differently where the value represents the difference between the adjusted credits carried forward from previous model years (minus expiring credits) and the projected earned credits minus any expected credit shortages. Since all the credits in these model years were adjusted using the same approach it was possible to subtract the credit amounts. However, readers are reminded that for MYs 2018–2020 since the final CAFE reports have yet to be issued, the credit allocation process has not started, and the data shown in the graphs are a projection of potential overall compliance. Consequently, the credits included for MYs 2018–2020 are separated from earlier model years by a dashed line to highlight that there is a margin of uncertainty in the estimated values. Projecting how and where credits will be used is difficult for a number of reasons such as not knowing which flexibilities manufacturers will utilize and the fact that credits are not valued the same across different fleets. As such, the agency reminds readers that the projections may not align with how manufacturers will actually approach compliance for these years.

Table VII–5 provides the numerical CAFE performance values and standards for MYs 2011–2020 as shown in the figures.

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[478] In the figures, the label ''2-Cycle CAFE'' represents the maximum increase each year in the average fuel economy set to the limitation ''cap'' for manufacturers attributable to dual-fueled automobiles as prescribed in 49 U.S.C. 32906. The label ''AC/OC contribution'' represents the increase in the average fuel economy adjusted for A/C and off-cycle fuel consumption improvement values as prescribed by 40 CFR 600.510–12.

[479] Consistent with applicable law, NHTSA established provisions starting in MY 2017 allowing manufacturers to increase compliance performance based on fuel consumption benefits gained by technologies not accounted for during normal 2-cycle EPA compliance testing (called ''off-cycle technologies'' for technologies such as stop-start systems) as well as for A/C systems with improved efficiencies and for hybrid or electric full-size pickup trucks.

[480] Adjustments for earned credits include those that have been adjusted for fuel saving using the manufacturers CAFE values for the model years in which they were earned and adjusted to the average CAFE values for the fleets they exist within.

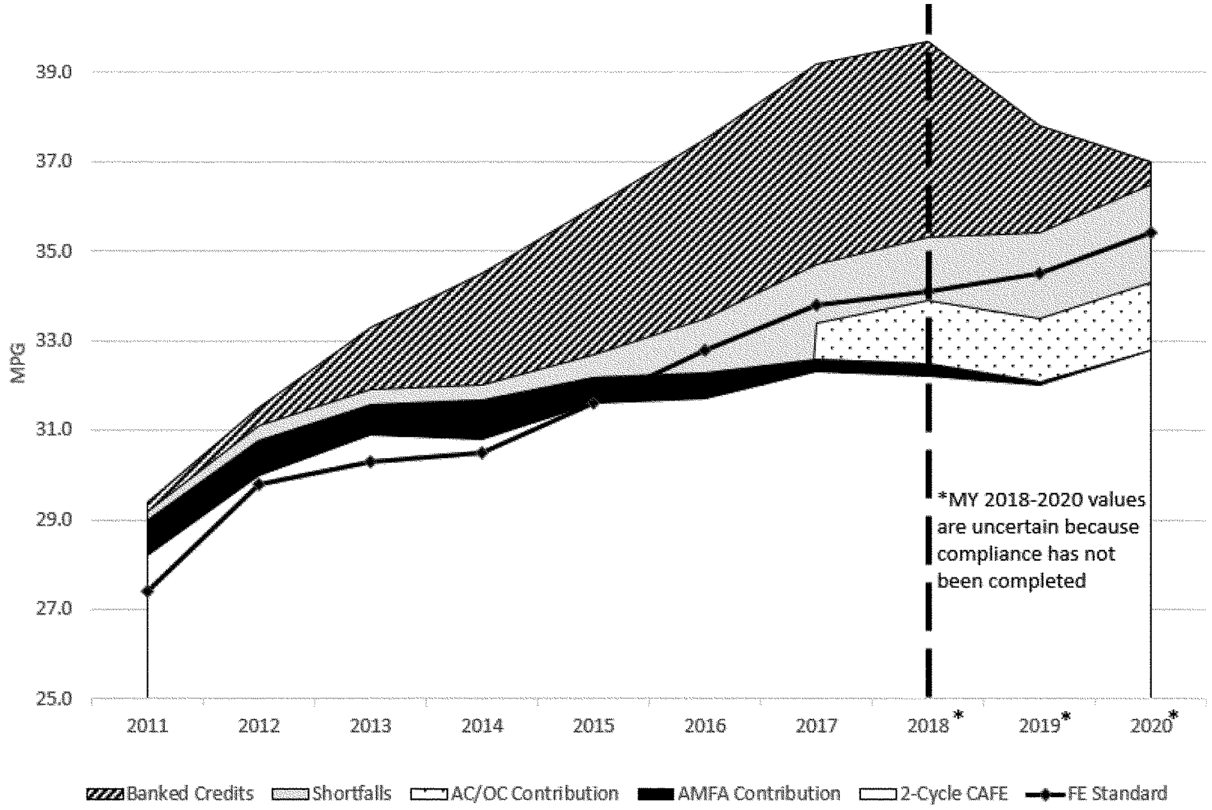

Figure VII-2 – Total Fleet Compliance Overview for MYs 2011 to 2020

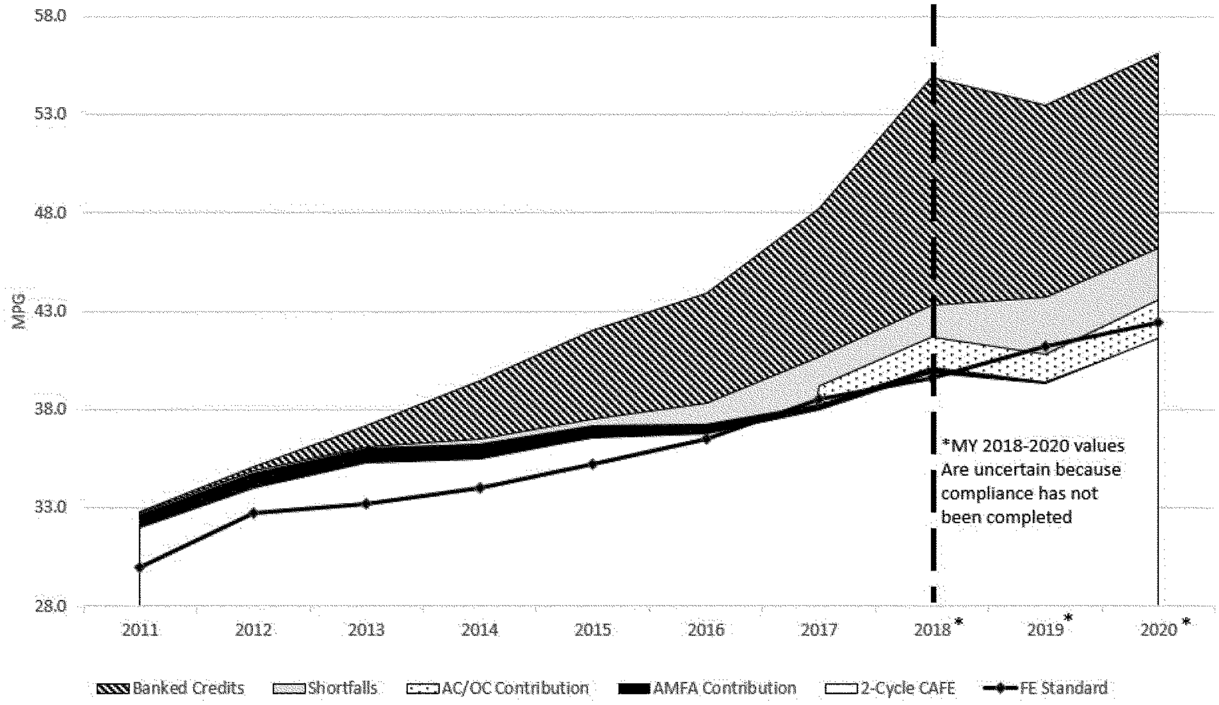

Figure VII-3 – Domestic Passenger Car Compliance Overview for MYs 2011 to 2020

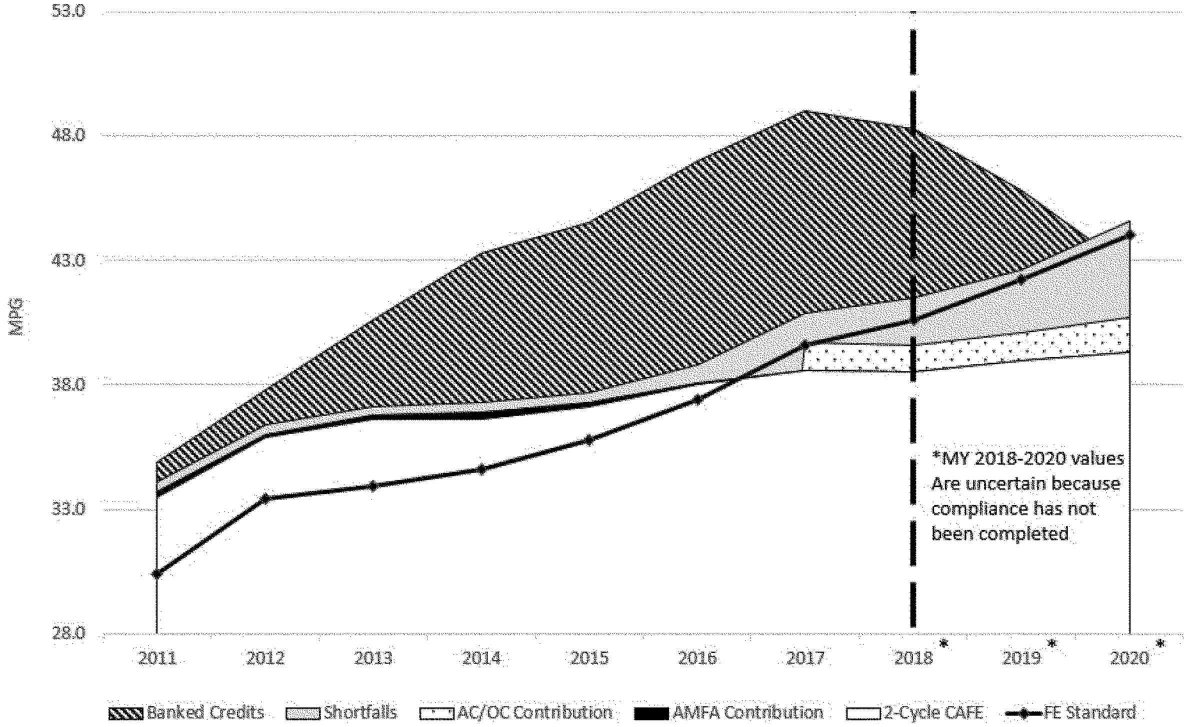

Figure VII-4 – Import Passenger Car Compliance Overview for MYs 2011 to 2020

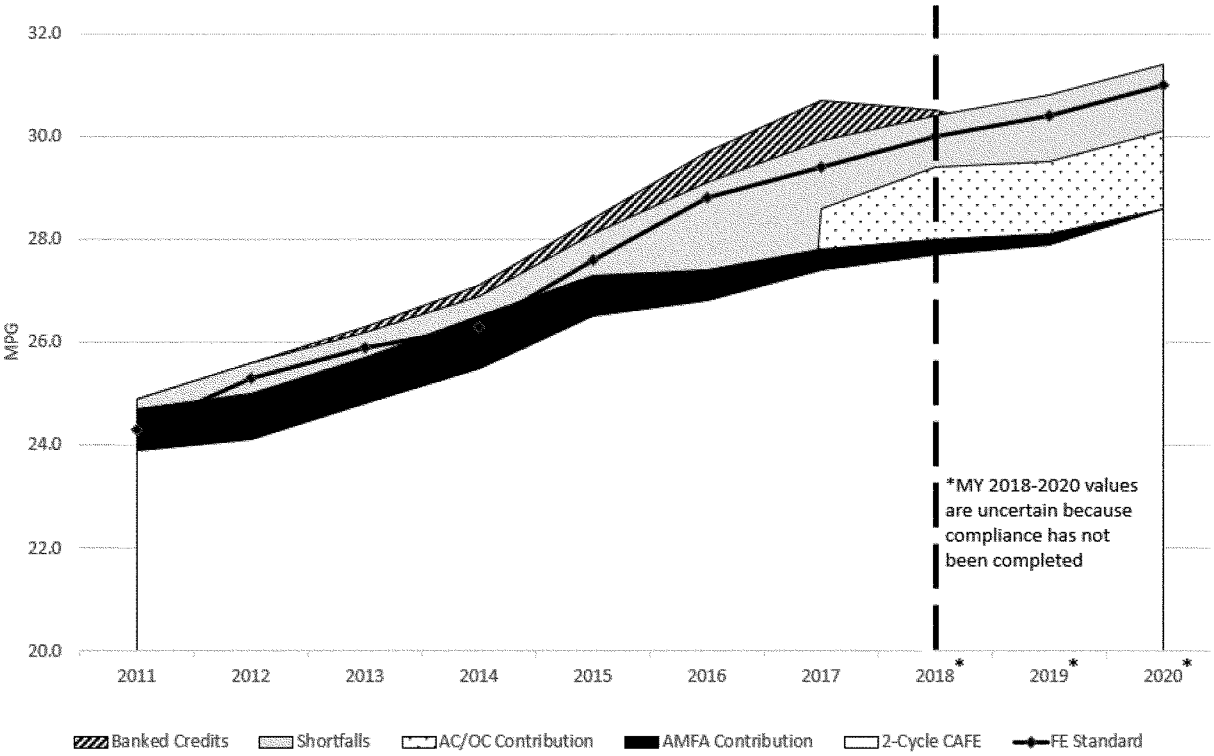

Figure VII-5 – Light Truck Compliance Overview for MYs 2011 to 2020

Table VII-5 – CAFE Performance and Standards for MYs 2011 to 2020

Model Year	Domestic Passenger Car		Import Passenger Car		Light Truck		Total Fleet	
	CAFE (mpg)	Standard (mpg)	CAFE (mpg)	Standard (mpg)	CAFE (mpg)	Standard (mpg)	CAFE (mpg)	Standard (mpg)
2020	43.6	42.4	40.7	44	30.1	31	34.3	35.4
2019	40.8	41.2	40.1	42.2	29.5	30.4	33.5	34.5
2018	41.7	39.6	39.6	40.6	29.4	30	33.9	34.1
2017	39.2	38.5	39.7	39.6	28.6	29.4	33.4	33.8
2016	37.3	36.5	38.1	37.4	27.4	28.8	32.3	32.8
2015	37.2	35.2	37.3	35.8	27.3	27.6	32.2	31.6
2014	36.3	34	36.9	34.6	26.5	26.3	31.7	30.5
2013	36.1	33.2	36.8	33.9	25.7	25.9	31.6	30.3
2012	34.8	32.7	36	33.4	25	25.3	30.8	29.8
2011	32.7	30	33.7	30.4	24.7	24.3	29	27.4

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As shown in Figure VII–2, manufacturers' fuel economy performance (2-cycle CAFE plus AMFA) for the total fleet was better than the fleet-wide target through MY 2015. On average, the total fleet exceeded the standards by approximately 0.9 mpg for MYs 2011 to 2015. As shown in Figure VII–3 through Figure VII–5, domestic and import passenger cars exceeded standards on average by 2.1 mpg and 2.3 mpg, respectively. By contrast, light truck manufacturers on average fell below the standards by 0.3 mpg over the same time period.

For MYs 2016 through 2020, Figure VII–2 shows that the total fleet Base CAFE (including 2-Cycle CAFE plus A/C and OC benefits) falls below and appears to remain below the fleet CAFE standards for these model years.[481] The projected compliance shortfall (*i.e.* the difference between CAFE performance values and the standards) remains constant and reaches its greatest difference between MYs 2019 and 2020. Compliance becomes even more complex when observing individual compliance fleets over these years. Only domestic passenger car fleets collectively appear to exceed CAFE standards while import passenger car fleets appear to have the greatest compliance shortages. In MY 2020, the import passenger car fleet appear to reach its highest compliance shortfall equal to 3.3 mpg.

The graphs provide an overall representation of the average values for each fleet, although they are less helpful for evaluating compliance with the minimum domestic passenger car standards given statutory prohibitions on manufacturers using traded or transferred credits to meet those standards.[482] Consequently, in MY 2020, domestic passenger car manufacturers may improve their performance by adding more AC/OC technology, allowing the domestic passenger car fleet to once again exceed CAFE standards. However, NHTSA notes that several manufacturers have already reported insufficient earned credits and may have to make fine payments if they fail to reach the minimum domestic passenger car standards.

In summary, MY 2016 is the last compliance model year that passenger cars complied with CAFE standards relying solely on Base CAFE performance. Prior to this timeframe, passenger car manufacturers especially those building domestic fleets could substantially exceed CAFE standards. MY 2016 marked the first time in the history of the CAFE program where compliance for passenger car manufacturers fell below standards thereby increasing shortfalls and forcing the need for manufacturers to rely heavily upon credit flexibilities. Despite higher shortfalls, domestic passenger car manufacturers have continued to generate credits and increase their total credit holdings. The projections show that for MYs 2018–2020, domestic passenger car fleets will transition from generating to using credits but will maintain sizable amounts of banked credits sufficient to sustain compliance shortfalls in other regulatory fleets. Figure VII–4 shows residual available banked credits even as far as MY 2020. Domestic passenger car credits and their off-cycle credits will play an important role in sustaining manufacturers in complying with CAFE standards.

From the projections, it appears that based on the number of remaining domestic passenger credits in the market and the rate at which they are being used, there will be insufficient credits to cover the shortfalls in other compliance fleets in years following MY 2020. Figure VII–2 shows that the total remaining combined credits for the industry is expected to decline starting in MY 2018. Import passenger cars and light truck fleets will play a major role in the decline and possible depletion of all available credits to resolve shortfalls after MY 2020. Several factors exist that could produce this outcome. First, increasing credit shortages are occurring in the import passenger car and light truck fleets especially since the reduction and then termination of AMFA incentives in MY 2019 (a major contributor for light trucks). Next, residual banked credits for the light truck fleet are expected to be exhausted starting in MY 2018 and for import

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[481] Until MY 2023 compliance, the last year where earned credits can be retroactively applied to MY 2020, NHTSA will be unable to make a determination about the fleet's overall compliance over this timespan.

[482] In accordance with 49 CFR 536.9(c), transferred or traded credits may not be used, pursuant to 49 U.S.C. 32903(g)(4) and (f)(2), to meet the domestically manufactured passenger automobile minimum standard specified in 49 U.S.C. 32902(b)(4) and in 49 CFR 531.5(d).

passenger cars in MY 2020. Finally, the use of AC/OC benefits for import passenger cars and lights trucks is not a significant factor for these fleets in complying with CAFE standards. Manufacturers will need to change their production strategies or introduce substantially more fuel saving technologies to sustain compliance in the future.

Figure VII–6 provides a historical overview of the industry's use of CAFE credit flexibilities and fine payments for addressing compliance shortfalls.[483] As mentioned, MY 2017 is the last model year for which CAFE compliance determinations are completed, and credit application and civil penalty payment determinations finalized. As shown in the figure, for MYs 2011–2015, manufacturers generally resolved credit shortfalls by carrying forward earned credits from previous years. However, since 2011, the rise in manufacturers executing credit trades has become increasingly common and, in MY 2017, credit trades were the most frequently used flexibility for achieving compliance. Credit transfers have also become increasingly more prevalent for manufacturers. As a note to readers, credit trades in the figures can also involve credit transfers but are aggregated in the figure as credit trades to simplify results. In MY 2016, credit transfers constituted the highest contributor to credit flexibilities but are starting to decline signifying that manufacturers are currently exhausting credit transfers within their own fleets. Manufacturers only occasionally carry back credits to resolve performance shortfalls. NHTSA believes that trading credits between manufacturers and to some degree transferring traded credit across fleets will be the most commonly used flexibility in complying with future CAFE standards as started in MY 2017.

Credit trading has generally replaced civil penalty payments as a compliance mechanism. Only a handful of manufacturers have made civil penalty payments since the implementation of the credit trading program. As previously shown, NHTSA believes that manufacturers have sufficient credits to resolve any import passenger car and light truck performance shortfalls expected through MY 2020. As of recent, the only fine payments being made or expected in the future are those directly resulting from manufacturers failing to comply with the minimum domestic passenger car standards.[484] There were two fine payments made in MYs 2016 and 2017 which fit this exact case. By statute, manufacturers cannot use traded or transferred credits to address performance shortfalls for failing to meet the minimum domestic passenger car standards.[485] Because of this limitation, the fine payments made in MY 2016 and 2017 came from one manufacturer that had exhausted all of its earned domestic passenger credits and could not carryback future credits.[486] The same condition will occur for other manufacturers in the future. NHTSA calculates that six manufacturers will meet this same condition and have to make substantial civil penalty payments for failing to comply with the minimum domestic passenger cars standards in MYs 2018 through 2020.

In Figure VII–8, additional information is provided on the credit flexibilities exercised and fine payments made by manufacturers for MYs 2011–2017. The figure includes the gasoline gallon equivalent for these credit flexibilities or for paying civil penalties. The figure shows that manufacturers used carrying forward credits most often to resolve shortfalls. Credit trades were the second leading benefit to manufacturers in using credit flexibilities and then followed by credit transfers. In summary, manufacturers used these flexibilities amounting to the equivalent of 2,952,856 gallons of fuel by carrying forward credits in 2017 and 583,720 gallons of fuel by trading credits in 2017.

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[483] The Figure includes all credits manufacturers have used in credit transactions to date. Credits contained in carryback plans yet to be executed or in pending enforcement actions are not included in the Figure.

[484] Six manufacturers have paid CAFE civil penalties since credit trading began in 2011. Fiat Chrysler paid the largest civil penalty total over the period, followed by Jaguar Land Rover and then Volvo. *See* Summary of CAFE Civil Penalties Collected, CAFE Public Information Center, *https://one.nhtsa.gov/cafe_pic/CAFE_PIC_Fines_LIVE.html.*

[485] Congress prescribed minimum domestic passenger car standards for domestic passenger car manufacturers and unique compliance requirements for these standards in 49 U.S.C. 32902(b)(4) and 32903(f)(2).

[486] Fiat Chrysler paid $77,268,702.50 in civil penalties for MY 2016 and $79,376,643.50 for MY 2017 for failing to comply with the minimum domestic passenger car standards for those MYs.

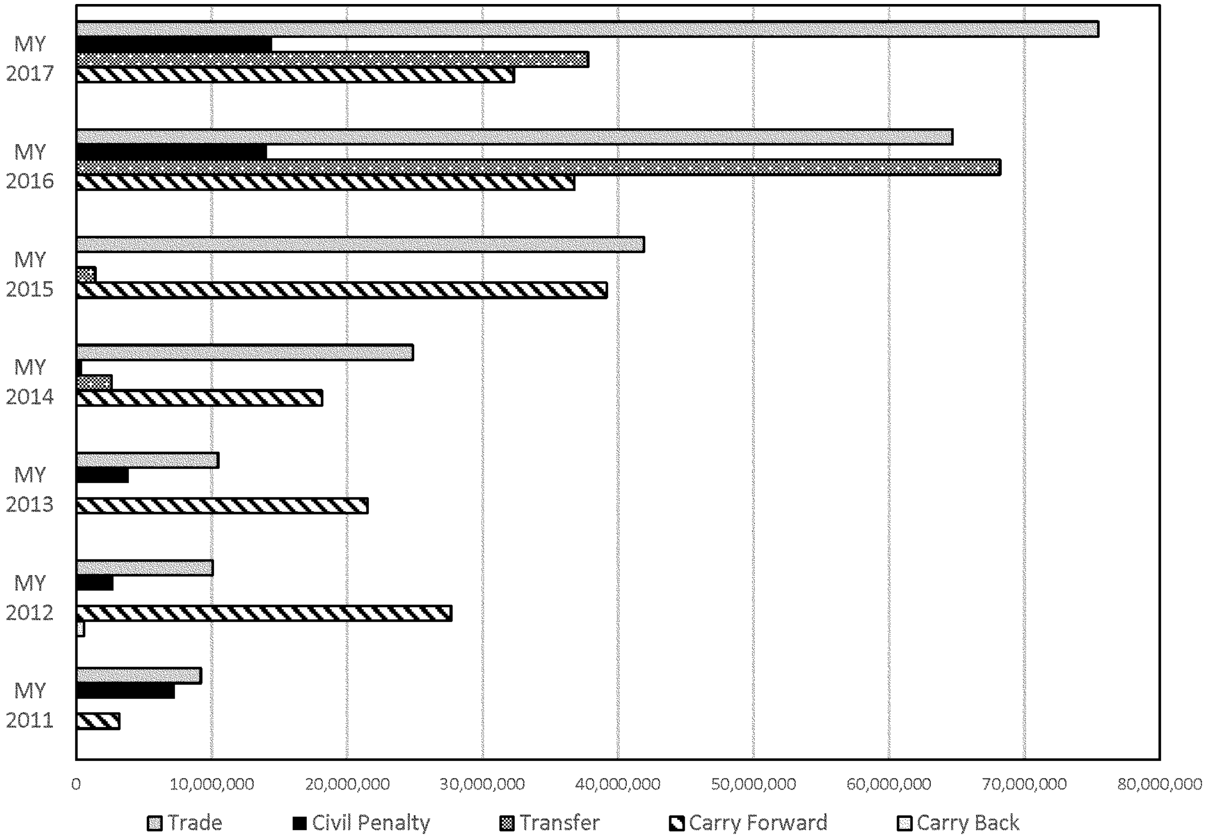

Figure VII-6 – Industry Use of Compliance Flexibilities and Civil Penalty Payments[487]

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[487] For Figure VII–6; in each year some flexibilities were not utilized by manufacturers. For example, carry backed credits were not utilized in 2011, 2013, 2014, 2015, 2016, or 2017. Transfer credits were not used in 2011, 2012 or 2013. No civil penalties were paid in 2015.

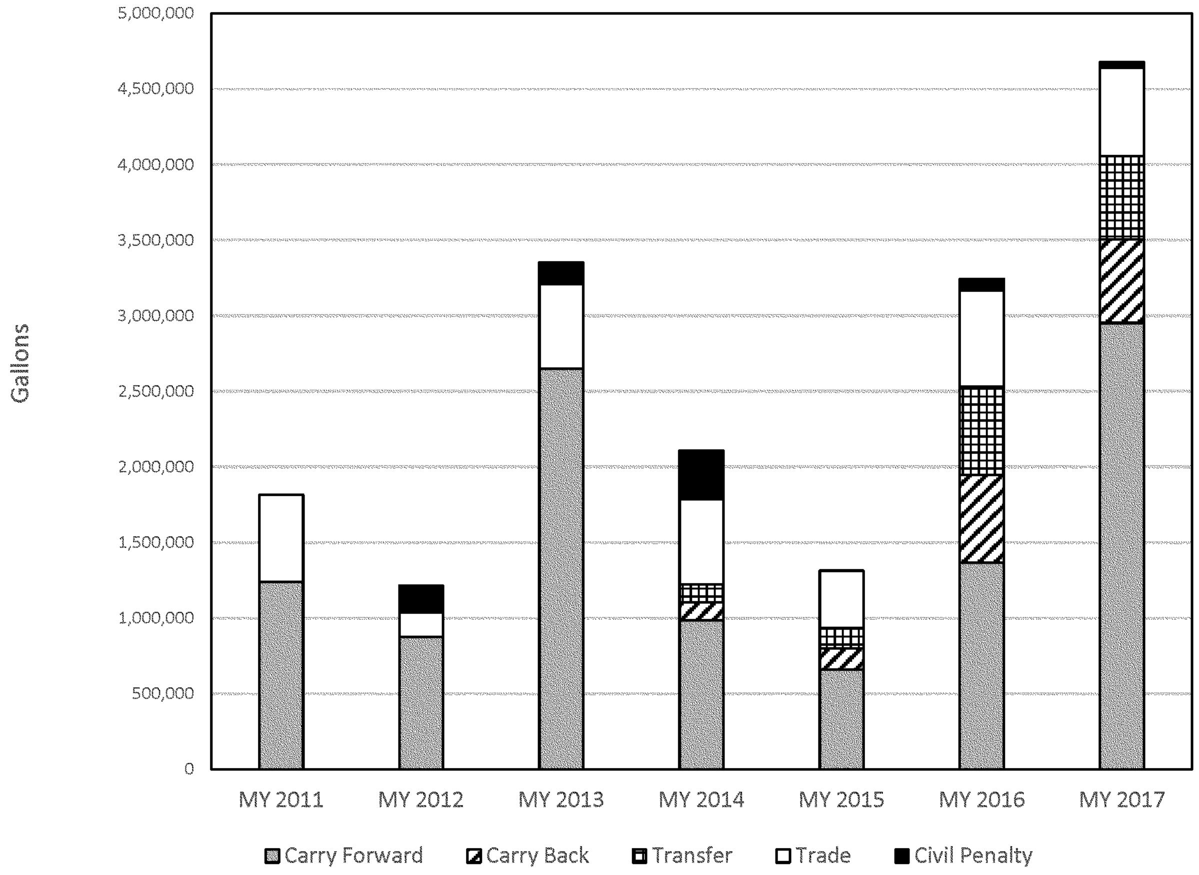

Figure VII-7 – Value of Applied Credit Flexibilities and Civil Penalty Payments in Gallons

Despite this compliance picture, NHTSA's analysis supporting this NPRM shows some amount of overcompliance in the baseline/No-Action Alternative for the model years subject to this proposal. This modeled overcompliance occurs due to assumptions about a variety of factors, including (1) a number of manufacturers voluntarily binding themselves to the California Framework Agreements, (2) expected manufacturer compliance with California's ZEV program, (3) expected manufacturer compliance with the EPA GHG and NHTSA CAFE standards finalized in 2020, (4) a small amount of market demand for increased fuel economy (due mostly to projected fuel prices), (5) the projected affordability of applying certain technologies that are eligible for compliance boosts (like off-cycle adjustments), and so on. If these assumptions do not come to pass in the real world, the difference between the compliance picture over the last several model years and the one shown in the analysis for the next several years would accordingly be smaller. Overcompliance with the regulatory alternatives is much lower than what was shown in the NPRM that preceded the 2020 final rule and is highly manufacturer-dependent. NHTSA seeks comment on the amount of overcompliance with the regulatory alternatives shown, if any, in light of how the agency has described its modeling approach for this proposal.

5. Shift in Sales Production From Passenger Cars to Light Trucks

The apparent stagnant growth in the automotive industry's CAFE performance is likely related to a relative decrease in the share of passenger cars, where manufacturers made the most gains in fuel economy performance combined with an increase in the relative share of light trucks purchased beginning with MY 2013. Light trucks experienced sharp increases in sales, increasing by a total of 5 percent from MYs 2013 to 2014. In MY 2014, light trucks comprised approximately 41 percent of the total sales production volume of automobiles and has continued to grow ever since. In comparison, for model year 2014, domestic passenger cars represented 36 percent of the total fleet and import passenger cars represented 23 percent. Both domestic and import passenger car sales have continued to fall every year since MY 2013. Figure VII–8 shows the sales production volumes of light trucks and domestic and import passenger cars for MYs 2004 to 2020. Historically, light truck fleets have fallen below their associated CAFE standards and have had larger performance shortages than either import and domestic passenger car fleets. For MY 2020, NHTSA expects even greater CAFE performance shortages in the light truck and import passenger car fleets than in prior model years, based upon manufacturer's mid-model year (MMY) reports. MY 2020 light trucks are expected to comprise approximately 53 percent of the total. As mentioned previously, the combined effect of these fuel economy shortages will likely require manufacturers to rely on compliance flexibilities or pay civil penalties.

Out of 25 vehicle types listed in the EPA database, 5 vehicle types—namely compact cars, midsize cars, small and standard SUVs with 4WD, and standard pickup trucks with 4WD have the highest volumes of vehicles produced for sale in MYs 2012 to 2017. From 2012 to 2020, there was a drastic decrease of 24% and 17% in the production of compact cars and midsize cars, respectively. On the other side, there was a significant increase in the production of 4WD small and standard equaling approximately 41% collectively of all sales. Standard pickup trucks with 4WD experienced little change in the production volume throughout the years. As shown in Figure VII–9, small SUVs, with 4WD and 2WD drivetrains, have surpassed the sales production volumes of all other vehicle types over these the given model years. The number of small and standard SUVs sold in the U.S. for MY 2017 nearly doubled compared to sales in the U.S. for MY 2012. During that same period, passenger car sales production as a total of vehicle sales production decreased by approximately 11 percent. The combination of low gas prices and the increased utility that SUVs provide, along with aggressive manufacturer marketing, may explain the shift in sales production. Nonetheless, if the sales of these small SUVs and pickup trucks continue to increase, there may be continued stagnation in the CAFE performance of the overall fleet unless manufacturers respond with greater adoption of fuel economy technology in the SUV and pickup truck portion of their fleets.

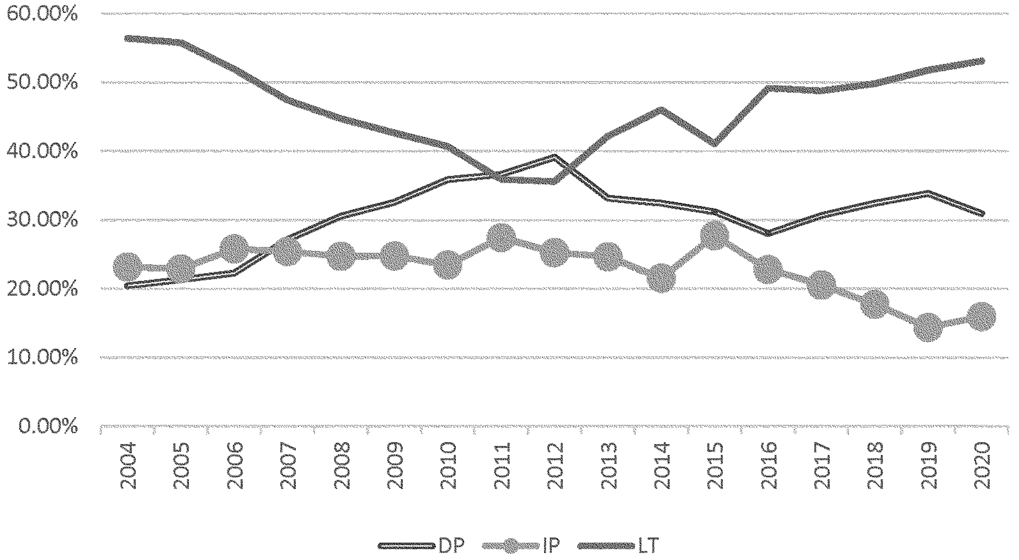

Figure VII-8 – Sales Production Volumes for MYs 2004 to 2020

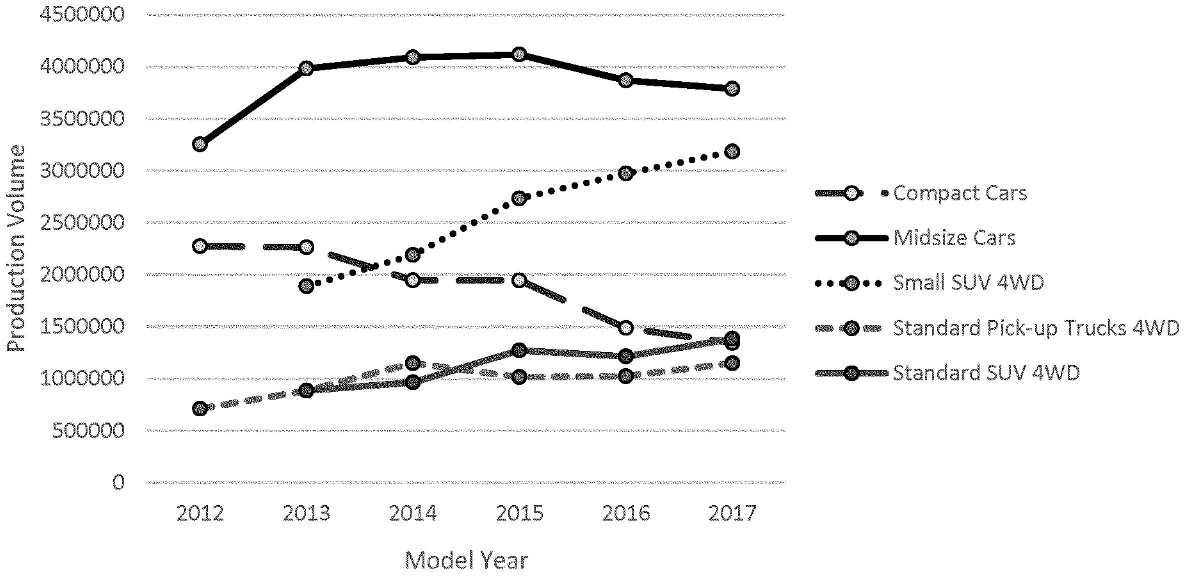

Figure VII-9 – Change in Major Vehicle Type Production from 2012-2017

6. Electrification

According to data submitted to EPA and NHTSA for MYs 2012 through 2017, the population of electrified vehicles in the passenger car fleet has steadily increased. The percentage of petroleum-based passenger cars in the market has decreased. While the nominal amount of electric light trucks has increased, the percentage of electric light trucks has decreased due to petroleum-based light trucks growing at a faster rate. All electric passenger cars account for up to 3 percent of the total production of light-duty vehicles each year. In comparison, all electric light trucks account for about 0.2 percent of the total fleet each year. The number of passenger cars using alternative fuels has also steadily increased while the population of alternative fuel light trucks has become non-existent. However, comparing the total fleet, the population of electric and hybrid vehicles is steadily increasing each year on average.

Table VII-6 – Production Volumes by Fuel Usage for MYs 2012 to 2017[488,489,490,491]

PV number		**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Petroleum	PC	8,200,856	9,120,467	8,718,892	9,095,073	8,627,914	8,375,973
Flexible Fuel Vehicle	PC	3,307	514	746	372	845	3,521
Electricity/Hybrid	PC	453,447	624,584	486,844	505,846	365,314	614,755
Petroleum	LT	4,770,297	5,428,215	6,283,680	7,115,971	7,211,930	7,928,617
Flexible Fuel Vehicle	LT	216	82	337	0	0	0
Electricity/Hybrid	LT	18,061	23,300	22,216	21,561	65,278	97,980
PV percentage		**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Petroleum	PC	60.99%	60.01%	56.20%	54.34%	53.03%	49.21%
Alternative	PC	0.02%	0.00%	0.00%	0.00%	0.01%	0.02%
Electricity/Hybrid	PC	3.37%	4.11%	3.14%	3.02%	2.25%	3.61%
Petroleum	LT	35.48%	35.72%	40.51%	42.51%	44.32%	46.58%
Flexible Fuel Vehicle	LT	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Electricity/Hybrid	LT	0.13%	0.15%	0.14%	0.13%	0.40%	0.58%
PV percentage		**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Petroleum	Total	96.47%	95.73%	96.71%	96.85%	97.35%	95.79%
Flexible Fuel Vehicle	Total	0.03%	0.00%	0.01%	0.00%	0.01%	0.02%
Electricity/Hybrid	Total	3.51%	4.26%	3.28%	3.15%	2.65%	4.19%

Despite the small market share currently for electric and hybrid trucks, manufacturers are making a strong effort to grow this market. Starting in 2020, several manufacturers introduced several new models of hybrid and PEV SUVs and crossovers.

NHTSA is considering new CAFE compliance strategies for electric pickup trucks in this rulemaking. EPA and NHTSA previously provided flexibilities for hybrid and electric pickup trucks adopted under the 2017–2025 CAFE and GHG final rule issued in 2012. These flexibilities would have provided manufacturers with an incentive through MY 2025 to build additional electric pickup trucks but in the 2020 final rule, NHTSA and EPA decided to terminate these incentives early. Further discussion of NHTSA's and EPA's incentive programs for hybrid and electric pickup trucks is presented in Section B.3.e)(1). As a part of the section, a new proposal is also included for EPA and NHTSA to reconsider extending the incentives for pickup trucks back to their original effective date ending in MY 2025.

7. Vehicle Classification

Vehicle classification, for purposes of the light-duty CAFE program, refers to whether an automobile qualifies as a passenger automobile (car) or a non-passenger automobile (light truck). Passenger cars and light trucks are subject to different fuel economy standards as required by EPCA/EISA and consistent with their different capabilities.

Vehicles are designated as either passenger automobiles or non-passenger automobiles. Vehicles ''capable of off-highway operation'' are, by statute, non-passenger automobiles.[492] Determining ''off-highway operation'' was left to NHTSA, and currently is a two-part inquiry: First, does the vehicle either have 4-wheel drive or over 6,000 pounds gross vehicle weight rating (GVWR), and second, does the vehicle have a significant feature designed for

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[488] 49 U.S. Code 538 discusses Flexible Fuel Vehicle.

[489] Definition of Electricity/Hybrids can be found in 49 U.S. Code 523.2.

[490] If the fuel type is marked as Hybrid, for this table the vehicles are automatically counted as Hybrid no matter what type of fuel category they have. Flexible Fuel Vehicle is everything else except where the fuel type is gasoline and electric/hybrid.

[491] Complete data is only available through MY 2017.

[492] 49 U.S. Code 32902.

off-highway operation.[493] NHTSA's regulation on vehicle classification contain requirements for vehicles to be classified as light trucks either on the basis of off-highway capability or on the basis of having ''truck-like characteristics.'' Over time, NHTSA has refined the light truck vehicle classification by revising its regulations and issuing legal interpretations. However, based on the increase in crossover SUVs and advancements in vehicle design trends, NHTSA has become aware of vehicle designs that complicate classification determinations for the CAFE program. Throughout the past decade, NHTSA has identified these changes in compliance testing, data analysis, and has discussed the trend in rulemakings, publications, and with stakeholders.

NHTSA believes that an objective procedure for classifying vehicles is paramount to the agency's continued oversight of the CAFE program. When there is uncertainty as to how vehicles should be classified, inconsistency in determining manufacturers' compliance obligations can result, which is detrimental to the predictability and fairness of the program. In the 2020 final rule, NHTSA attempted to resolve several classification issues and committed to continuing research to resolve others. NHTSA notified the public of its plans to develop a compliance test procedure for verifying manufacturers' submitted classification data. An objective standard would help avoid manufacturers having to reclassify their vehicles, improve consistency and fairness across the industry, and introduce areas within the criteria where uncertainties existed and research could be conducted in the near future to resolve.

In this rulemaking, NHTSA is providing additional classification guidance and seeking comments on several unknown aspects needed to develop its compliance test procedure. Based upon the comments received to this NPRM, NHTSA plans to release its draft test procedure later this year. No changes are being made in this rulemaking that will change how vehicles are classified.

(a) Clarifications for Classifications Based Upon ''Off-Road Capability''

For a vehicle to qualify as off-highway (off-road) capable, in addition to either having 4WD or a GVWR more than 6,000 pounds. The vehicle must have four out of five characteristics indicative of off-highway operation. These characteristics are:

- An approach angle of not less than 28 degrees
- A breakover angle of not less than 14 degrees
- A departure angle of not less than 20 degrees
- A running clearance of not less than 20 centimeters
- Front and rear axle clearances of not less than 18 centimeters each

(1) Production Measurements

NHTSA's regulations require manufacturers to measure vehicle characteristics when a vehicle is at its curb weight, on a level surface, with the front wheels parallel to the automobile's longitudinal centerline, and the tires inflated to the manufacturer's recommended cold inflation pressure.[494] NHTSA clarified in the 2020 final rule that 49 CFR part 537 requires manufacturers to classify vehicles for CAFE based upon their physical production characteristics. The agency verifies reported values by measuring production vehicles. Manufacturers must also use physical vehicle measurements as the basis for values reported to the agency for purposes of vehicle classification. It may be possible for certain vehicles within a model type to qualify as light trucks while others would not because of their production differences. Since issuing the 2020 final rule, NHTSA has met with manufacturers to reinforce the use of production measurements and clarifying here that manufacturers are only required to report classification information for those physical measurements used for qualification and can omit other measurements.

In the previous rulemaking, NHTSA also identified that certain vehicle designs incorporate rigid (*i.e.,* inflexible) air dams, valance panels, exhaust pipes, and other components, equipped as manufacturers' standard or optional equipment (*e.g.,* running boards and towing hitches), that likely do not meet the 20-centimeter running clearance requirement. Despite these rigid features, some manufacturers are not taking these components into consideration when making classification decisions. Additionally, other manufacturers provide dimensions for their base vehicles without considering optional or various trim level components that may reduce the vehicle's ground clearance. Consistent with our approach to other measurements, NHTSA believes that ground clearance, as well as all the other off-highway criteria for a light truck determination, should use the measurements from vehicles with all standard and optional equipment installed, at the time vehicles are shipped to dealerships. These views were shared by manufacturers in response to the previous CAFE rulemaking.

The agency reiterates that the characteristics listed in 49 CFR 523.5(b)(2) are characteristics indicative of off-highway capability. A fixed feature—such as an air dam that does not flex and return to its original state or an exhaust that could detach—inherently interferes with the off-highway capability of these vehicles. If manufacturers seek to classify vehicles as light trucks under 49 CFR 523.5(b)(2) and the vehicles have a production feature that does not meet the four remaining characteristics to demonstrate off-highway capability, they must be classified as passenger cars. NHTSA also clarifies that vehicles that have adjustable ride height, such as air suspension, and permit variable on-road or off-road running clearances should be classified based upon the mode most commonly used or the off-road mode for those with this feature. NHTSA seeks comments on how to define the mode most commonly used for any adjustable suspensions. For the test procedure, would it be more appropriate to allow manufacturers to define the mode setting for vehicles with adjustable suspensions?

(2) Testing for Approach, Breakover, and Departure Angles

Approach angle, breakover angle, and departure angle are relevant to determine off-highway capability. Large approach and departure angles ensure the front and rear bumpers and valance panels have sufficient clearance for obstacle avoidance while driving off-road. The breakover angle ensures sufficient body clearance from rocks and other objects located between the front and rear wheels while traversing rough terrain. Both the approach and departure angles are derived from a line tangent to the front (or rear) tire static loaded radius arc extending from the ground near the center of the tire patch to the lowest contact point on the front or rear of the vehicle. The term ''static loaded radius arc'' is based upon the definitions in SAE J1100 and J1544.[495] The term is defined as the distance from wheel axis of rotation to the supporting surface (ground) at a given load of the vehicle and stated inflation pressure of

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[493] 49 U.S. Code 523.5(A)(5)(ii)(b).

[494] 49 U.S. Code 523.5(A)(5).

[495] *See* SAE J1100 published on May 26, 2012 and SAE J1544 published on Oct 25, 2011.

the tire (manufacturer's recommended cold inflation pressure).

The static loaded radius arc is easy to measure, but the imaginary line tangent to the static loaded radius arc is difficult to ascertain in the field. The approach and departure angles are the angles between the line tangent to the static loaded radius arc and the level ground on which the test vehicle rests. For the compliance test procedure, a substitute measurement will be used. A measurement that provides a good approximation of the approach and departure angles involve using a line tangent to the outside diameter or perimeter of the tire and extends to the lowest contact point on the front or rear of the vehicle. This approach provides an angle slightly greater than the angle derived from the true static loaded radius arc. The approach also has the advantage to allow measurements to be made quickly for measuring angles in the field to verify data submitted by the manufacturers used to determine light truck classification decisions. In order to comply, the vehicle measurement must be equal to or greater than the required measurements to be considered as compliant and if not, the reported value will require an investigation which could lead to the manufacturer's vehicle becoming reclassified as a passenger car.

(3) Running Clearance

NHTSA regulations define ''running clearance'' as ''the distance from the surface on which an automobile is standing to the lowest point on the automobile, excluding unsprung weight.'' Unsprung weight includes the components (*e.g.,* suspension, wheels, axles, and other components directly connected to the wheels and axles) that are connected and translate with the wheels. Sprung weight, on the other hand, includes all components fixed underneath the vehicle that translate with the vehicle body (*e.g.,* mufflers and subframes). To clarify these requirements, NHTSA previously issued a letter of interpretation stating that certain parts of a vehicle—such as tire aero deflectors that are made of flexible plastic, bend without breaking, and return to their original position—would not count against the 20-centimeter running clearance requirement. The agency explained that this does not mean a vehicle with less than 20 centimeters running clearance could be elevated by an upward force that bends the deflectors and still be considered compliant with the running clearance criterion, as it would be inconsistent with the conditions listed in the introductory paragraph of 49 CFR 523.5(b)(2). Further, NHTSA explained that without a flexible component installed, the vehicle must meet the 20-centimeter running clearance requirement along its entire underside. This 20-centimeter clearance is required for all sprung weight components. For its compliance test procedure, NHTSA will include a list of the all the components under the vehicle considered as unsprung components. NHTSA will update the list of unsprung components as the need arises.

(4) Front and Rear Axle Clearance

NHTSA regulations state that front and rear axle clearances of not less than 18 centimeters are another criterion that can be used for designating a vehicle as off-highway capable.[496] The agency defines ''axle clearance'' as the vertical distance from the level surface on which an automobile is standing to the lowest point on the axle differential of the automobile.

The agency believes this definition may be outdated because of vehicle design changes, including axle system components and independent front and rear suspension components. In the past, traditional light trucks with and without 4WD systems had solid rear axles with center-mounted differential on the axle. For these trucks, the rear axle differential was closer to the ground than any other axle or suspension system component. This traditional axle design still exists today for some trucks with a solid chassis (also known as body-on-frame configuration). Today, however, many SUVs and CUVs that qualify as light trucks are constructed with a unibody frame and have unsprung (*e.g.,* control arms, tie rods, ball joints, struts, shocks, etc.) and sprung components (*e.g.,* the axle subframes) connected together as a part of the axle assembly. These unsprung and sprung components are located under the axles, making them lower to the ground than the axles and the differential, and were not contemplated when NHTSA established the definition and the allowable clearance for axles. The definition also did not originally account for 2WD vehicles with GVWRs greater than 6,000 pounds that had one axle without a differential, such as the model year 2018 Ford Expedition. Vehicles with axle components that are low enough to interfere with the vehicle's ability to perform off-road would seem inconsistent with the regulation's intent of ensuring off-highway capability.

In light of these issues, for the compliance test procedure, NHTSA will ask manufacturers to identify those axle components that are sprung or unsprung and provide sufficient justification as a part of the testing setup request forms sent to manufacturers before testing. In addition, for vehicles without a differential, NHTSA will request the location each manufacturer used to establish its axle clearance qualification. NHTSA will validate the location specified by the manufacturer but will challenge any location on the vehicle's axle found to be located at a lower elevation to the ground than the designed location of its axle clearance measurement.

(5) 49 CFR 571.3 MPV Definition

The definition for multipurpose passenger vehicle (MPV) is defined as a ''a motor vehicle with motive power, except a low-speed vehicle or trailer, designed to carry 10 persons or less which is constructed either on a truck chassis or with special features for occasional off-road operation.''[497] The regulation is silent, however, in defining special features for occasional off-road operation are qualified. In a letter of interpretation dated May 31, 1979, the agency responded to a question from Subaru requesting the agency's opinion whether a four-wheel drive hatchback sedan could be classified as an MPV. NHTSA responded stating that the agency interprets the definition as requiring that the vehicle contain more than a single feature designed for off-road use and that four-wheel drive would be useful in snow on public streets, roads and highways, so this feature cannot be determinative of the vehicle's classification if there are no features for off-road use. The interpretation also stated that Subaru needed to provide additional information (including, but not limited to, pictures or drawings of the vehicle) concerning other special features of the vehicle that would make it suitable for off-road operation. Finally, the interpretation referenced 49 CFR 523.5(b)(2) for a description of some of the characteristics that would be considered ''special features'' for off-road operation although that section relates primarily related to fuel economy. Considering that the definition for MPVs does not list the ''special features,'' NHTSA is seeking comment on whether manufacturers use ''special features'' other than those in 49 CFR 523.5(b)(2) to qualify vehicles as MPVs. Should NHTSA link the definition of MPV in 49 CFR 571.3 (as it relates to special features for occasional off-road operation) to 49 CFR

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[496] 49 U.S. Code 523.5(b)(2).

[497] 49 CFR 571.3.

523.5(b)(2)? What drawbacks exist in linking both provisions? Using the longstanding off-road features for fuel economy provides could clarify the means for certifying that a vehicle meets the definition for MPV in 571.3 when manufacturers may otherwise be uncertain as to how to classify a vehicle.

B. Complying With the NHTSA CAFE Program

1. Annual Compliance Process

Manufacturers' production decisions drive the mixture of automobiles on the road. Manufacturers largely produce a mixture of vehicles both to influence and meet consumer demand and address compliance with CAFE standards though the application of fuel economy improving technologies to those vehicles, and by using compliance flexibilities and incentives that are available in the CAFE program. As discussed earlier in this NPRM, each vehicle manufacturer is subject to separate CAFE standards for passenger cars and light trucks, and for the passenger car standards, a manufacturer's domestically-manufactured and imported passenger car fleets are required to comply separately.[498] Additionally, domestically-manufactured passenger cars are subject to a statutory minimum standard. Some CAFE program flexibilities are described by statute. Other flexibilities are established by NHTSA through regulation in accordance with the EPCA and EISA, such as fuel economy improvements for air conditioning efficiency, off-cycle, and pickup truck advanced technologies that are not expressly specified by CAFE statute, but are implemented consistent with EPCA's provisions regarding the calculation of fuel economy authorized for EPA.

Compliance with the CAFE program begins each year with manufacturers submitting required reports to NHTSA in advance and during the model year that contain information, specifications, data, and projections about their fleets.[499] Manufacturers report early product projections to NHTSA describing their efforts to comply with CAFE standards per EPCA's reporting requirements.[500] Manufacturers' early projections are required to identify any of the flexibilities and incentives manufacturers plan to use for air-conditioning (A/C) efficiency, off-cycle and, through MY 2021, which this action proposes to extend through MY 2026, full-size pickup truck advanced technologies. EPA consults with NHTSA when reviewing and considering manufacturers' requests for fuel consumption improvement values for A/C and off-cycle technologies that improve fuel economy. NHTSA evaluates and monitors the performance of the industry using compliance data. NHTSA also audits manufacturers' projected data for conformance and verifies vehicle conformance through measurements (*e.g.,* vehicle footprints) to ensure manufacturers are complying. After the model year ends, manufacturers submit final reports to EPA, that include final information on all the flexibilities and incentives allowed or approved for the given model year.[501] EPA then verifies manufacturers' reported information and values and calculates the final fuel economy level of each fleet produced by each manufacturer, and transmits that information to NHTSA.[502]

In previous years, the normal processes for CAFE compliance between NHTSA and EPA have been effective at administering the CAFE program for decades. EPA sends NHTSA its final CAFE results usually between November to December after the given model year. In recent years, this process has been disrupted by manufacturers submitting requests for A/C and off-cycle benefits during the model year and at times well after the end of the model year. As EPA cannot finalize CAFE results until all A/C and off-cycle credits for a model year are accounted for, the belated submissions have significantly delayed NHTSA receiving final CAFE results for many manufacturers. Late submissions place significant burdens on the agencies and complicate administering the CAFE program, including delaying the exchange and use of credits. In the following sections, NHTSA discusses the adverse impacts on the CAFE program resulting from late and retro-active A/C and off-cycle requests and proposes regulatory modifications to mitigate late submissions and help expedite processes for future off-cycle requests.

After receiving EPA's final reports, NHTSA completes the remainder of its compliance processes for manufacturers usually one to three months after receiving EPA's final reports. The process starts with NHTSA using EPA's final verified information to determine the CAFE standard for each of the manufacturer's fleets, and each fleet's compliance level. Those results are then used to determine credits, credit shortfalls and credit balances, and NHTSA sends letters to manufacturers stating the outcome of that assessment. Credit shortfall letters specify the obligated credit deficiency a manufacturer must resolve to comply with the applicable CAFE standard for the given model year. Credit balance letters specify the official balance of credits NHTSA has allotted to the manufacturer in each of its credit accounts and a ledger of the credit transactions the manufacturer has executed. Upon receipt of NHTSA's compliance letters, manufacturers are required to submit plans explaining how they plan to resolve any shortfalls. NHTSA periodically releases data and reports to the public through its CAFE Public Information Center (PIC) based on information in the EPA final reports for the given compliance model year and based on the projections manufacturers provide to NHTSA for the next two model years.[503]

Some flexibilities are defined, and sometimes limited by statute—for example, while Congress allowed manufacturers to transfer credits earned for over-compliance from their car fleet to their truck fleet and vice versa, Congress also limited the amount by which manufacturers could increase their CAFE levels using those transfers.[504] Consistent with the limits Congress placed on certain statutory flexibilities and incentives, NHTSA crafted and implemented credit transfer and trading regulations authorized by EISA ensure that total fuel savings are preserved when manufacturers exercise statutory compliance flexibilities required by statute.

NHTSA and EPA have previously developed other compliance flexibilities and incentives for the CAFE program consistent with the statutory provisions regarding EPA's calculation of manufacturers' fuel economy levels. As discussed previously, NHTSA finalized in the 2012 final rule an approach for manufacturers' "credits" under EPA's program to be applied as fuel economy

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[498] 49 U.S.C. 32904(b).

[499] 49 U.S.C. 32907(a); 49 CFR 537.7.

[500] 49 U.S.C. 32907(a).

[501] For example, alternative fueled vehicles get special calculations under EPCA (49 U.S.C. 32905–06), and fuel economy levels can also be adjusted to reflect air conditioning efficiency and "off-cycle" improvements.

[502] 49 U.S.C. 32904(c)–(e). EPCA granted EPA authority to establish fuel economy testing and calculation procedures; EPA uses a two-year early certification process to qualify manufacturers to start selling vehicles, coordinates manufacturer testing throughout the model year, and validates manufacturer-submitted final test results after the close of the model year.

[503] The NHTSA Public Information Center (PIC) is located at *https://one.nhtsa.gov/cafe_pic/CAFE_PIC_Home.htm.*

[504] *See* 49 U.S.C. 32903(g).

''adjustments'' or ''improvement values'' under NHTSA's program for: (1) Technologies that cannot be measured or cannot be fully measured on the 2-cycle test procedure, *i.e.,* ''off-cycle'' technologies; and (2) A/C efficiency improvements that also improve fuel economy but cannot be measured on the 2-cycle test procedure. Additionally, both agencies' programs give manufacturers compliance incentives through MY 2021, and proposed to be extended to MY 2026 in this NPRM, for utilizing specified technologies on full-size pickup trucks, such as hybridization, or full-size pickup trucks that overperform their fuel economy stringency target values by greater than a specified amount.

The following sections outline how NHTSA determines whether manufacturers are in compliance with CAFE standards for each model year, and how manufacturers may use compliance flexibilities, or alternatively address noncompliance through civil penalties. Moreover, it explains how manufacturers submit data and information to the agency. This includes a detailed discussion of NHTSA's standardized CAFE reporting template adopted as a part of the 2020 final rule, and the standardized template for reporting credit transactions. In the 2020 final rule, NHTSA also adopted requirements for manufacturers to provide information on terms of credit trades. In this rulemaking, NHTSA is proposing to make changes to its reporting and credit templates and to issue a new template to clarify the required reporting information for credit trades. These new requirements were intended to streamline reporting and data collection from manufacturers, in addition to helping the agency use the best available data to inform CAFE program decision makers.

2. How does NHTSA determine compliance?

(a) Manufacturers Submit Data to NHTSA and EPA and the Agencies Validate Results

EPCA, as amended by EISA, in 49 U.S.C. 32907, requires manufacturers to submit reports to the Secretary of Transportation explaining how they will comply with the CAFE standards for the model year for which the report is made; the actions a manufacturer has taken or intends to take to comply with the standard; and other information the Secretary requires by regulation.[505] A manufacturer must submit a report containing this information during the 30-day period before the beginning of each model year, and during the 30-day period beginning the 180th day of the model year.[506] When a manufacturer determines it is unlikely to comply with a CAFE standard, the manufacturer must report additional actions it intends to take to comply and include a statement about whether those actions are sufficient to ensure compliance.[507]

To implement these reporting requirements, NHTSA issued 49 CFR part 537, ''Automotive Fuel Economy Reports,'' which specifies three types of CAFE reports that manufacturers must submit.[508] A manufacturer must first submit a pre-model year (PMY) report containing the manufacturer's projected compliance information for that upcoming model year. By regulation, the PMY report must be submitted in December of the calendar year prior to the corresponding model year.[509] Manufacturers must then submit a mid-model year (MMY) report containing updated information from manufacturers based upon actual and projected information known midway through the model year. By regulation, the MMY report must be submitted by the end of July for the applicable model year.[510] Finally, manufacturers must submit a supplementary report to supplement or correct previously submitted information, as specified in NHTSA's regulation.[511]

If a manufacturer wishes to request confidential treatment for a CAFE report, it must submit both a confidential and redacted version of the report to NHTSA. CAFE reports submitted to NHTSA contain estimated sales production information, which may be protected as confidential until the termination of the production period for that model year.[512] NHTSA protects each manufacturer's competitive sales production strategies for 12 months, but does not permanently exclude sales production information from public disclosure. Sales production volumes are part of the information NHTSA routinely makes publicly available through the CAFE PIC.

The manufacturer reports provide information on light-duty automobiles such as projected and actual fuel economy standards, fuel economy performance, and production volumes, as well as information on vehicle design features (*e.g.,* engine displacement and transmission class) and other vehicle attribute characteristics (*e.g.,* track width, wheelbase, and other off-road features for light trucks). Beginning with MY 2017, to obtain credit for fuel economy improvement values attributable to additional technologies, manufacturers must also provide information regarding A/C systems with improved efficiency, off-cycle technologies (*e.g.,* stop-start systems, high-efficiency lighting, active engine warm-up), and full-size pickup trucks with hybrid technologies or with fuel economy performance that is better than footprint-based targets by specified amounts. This includes identifying the makes and model types equipped with each technology, the compliance category those vehicles belong to, and the associated fuel economy improvement value for each technology.[513] In some cases, NHTSA may require manufacturers to provide supplementary information to justify or explain the benefits of these technologies and their impact on fuel consumption or to evaluate the safety implication of the technologies. These details are necessary to facilitate NHTSA's technical analyses and to ensure the agency can perform enforcement audits as appropriate.

NHTSA uses manufacturer-submitted PMY, MMY, and supplementary reports to assist in auditing manufacturer compliance data and identifying potential compliance issues as early as possible. Additionally, as part of its footprint validation program, NHTSA conducts vehicle testing throughout the model year to confirm the accuracy of the track width and wheelbase measurements submitted in the reports.[514] These tests help the agency better understand how manufacturers may adjust vehicle characteristics to change a vehicle's footprint measurement, and ultimately its fuel economy target. NHTSA also includes a summary of manufacturers' PMY and MMY data in an annual fuel economy performance report made publicly available on its PIC.

As mentioned, NHTSA uses EPA-verified final-model year (FMY) data to evaluate manufacturers' compliance with CAFE program requirements and draw conclusions about the performance of the industry. After

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[505] 49 U.S.C. 32907(a).

[506] *Id.*

[507] *Id.*

[508] *See* 47 FR 34986, Aug. 12, 1982.

[509] 49 CFR 537.5(b).

[510] *Id.*

[511] 49 CFR 537.8.

[512] 49 CFR part 512, appx. B(2).

[513] NHTSA collects model type information based upon the EPA definition for ''model type'' in 40 CFR 600.002.

[514] U.S. Department of Transportation, NHTSA, Laboratory Test Procedure for 49 CFR part 537, Automobile Fuel Economy Attribute Measurements (Mar. 30, 2009), *available at http://www.nhtsa.gov/DOT/NHTSA/Vehicle%20Safety/Test%20Procedures/Associated%20Files/TP-537-01.pdf.*

manufacturers submit their FMY data, EPA verifies the information, accounting for NHTSA and EPA testing, and subsequently forwards the final verified data to NHTSA.

(b) New CAFE Reporting Templates Adopted in the 2020 Final Rule

NHTSA adopted changes to its CAFE reporting requirements in the 2020 final rule with the intent of streamlining data collection and reporting for manufacturers while helping the agency obtain the best available data to inform CAFE program decision-makers. The agency adopted two new standardized reporting templates for manufacturers. NHTSA's goal was to adopt standardized templates to assist manufacturers in providing the agency with all the necessary data to ensure they comply with CAFE regulations.

The first template was designed for manufacturers to simplify reporting CAFE credit transactions starting in model year 2021. The template's purpose was to reduce the burden on credit account holders, encourage compliance, and facilitate quicker NHTSA credit transaction approval. Before the template, manufacturers would inconsistently submit information required by 49 CFR 536.8, creating difficulties in processing credit transactions. Using the template simplifies CAFE compliance aspects of the credit trading process and helps to ensure that trading parties follow the requirements for a credit transaction in 49 CFR 536.8(a).[515]

The second template was designed to standardize reporting for CAFE PMY and MMY information, as specified in 49 CFR 537.7(b) and (c), as well as supplementary information required by 49 CFR 537.8. The template organizes the required data in a manner consistent with NHTSA and EPA regulations and simplifies the reporting process by incorporating standardized responses consistent with those provided to EPA. The template collects the relevant data, calculates intermediate and final values in accordance with EPA and NHTSA methodologies, and aggregates all the final values required by NHTSA regulations in a single summary worksheet. Thus, NHTSA believes that the standardized templates will benefit both the agency and manufacturers by helping to avoid reporting errors, such as data omissions and miscalculations, and will ultimately simplify and streamline reporting. Manufacturers are required to use the standardized template for all PMY, MMY, and supplementary CAFE reports starting in MY 2023. The template also allowed manufacturers to enter information to generate the required confidential versions of CAFE reports specified in 49 CFR part 537 and to produce automatically the required non-confidential versions by clicking a button within the template.

The standardized CAFE reporting templates were made available on the NHTSA website and through the DOT docket. Since then, manufacturers have downloaded the templates and met with NHTSA to share recommendations for changes, such as allowing the PMY and MMY reporting templates to accommodate different types of alternative fueled vehicles and to clarify and correct the methods for calculating CAFE values. The proposed changes are discussed in the following sections. NHTSA plans to host a series of workshops to implement the templates and to provide an open dialogue for manufacturers to identify any further problems and seek clarifications. NHTSA plans to announce the workshops through the **Federal Register** later this year.

(1) Changes to the CAFE Reporting Template

The changes to the CAFE Reporting Template include several general improvements made to simply the use and the effectiveness for manufacturers. These include, but are not limited to; wording changes, corrections to calculations and codes, and auto-populating fields previously requiring manual entry.

More specifically, NHTSA is proposing to modify the CAFE Reporting Template by adding filters and sorting functions to help manufacturers connect the data definitions to the location of each of the required data fields in the template. Additional information from other parts of the CAFE Reporting Template would be pulled forward to display on the summary tab. For the information that must be included pursuant to 49 CFR 537.7(b)(2), manufacturers can also compare the values the template calculates to their own internally calculated CAFE values. Additionally, we are proposing to expand the CAFE Reporting Template to include more of the required information regarding vehicle classification, and guidance provided to ease manufacturers reporting burden by having them report only the data used for each vehicle's qualification pathway ignoring other possible light truck classification information.

NHTSA is also proposing that the CAFE Reporting Template be modified to combine the footprint attribute information and model type sub-configuration data for the purposes of matching. NHTSA uses this information to match test data directly to fuel economy footprint values for the purposes of modeling fuel economy standards. Features were added to auto-populate redundant information from one worksheet to another. The data gathered and the formulas coded within the proposed worksheets have also been updated for the calculation of fuel economy based on 40 CFR 600.510–12. The changes to the data and formulas will allow data to more accurately represent the fuel economy of electric and other vehicles using alternative fuels. NHTSA considers this information critically important to forming a more complete picture of the performances of dual fuel and alternative fuel vehicles.

We are also proposing several corrections so that manufacturers will submit CAFE data at each of the different sub-configuration levels they test and will combine CO_2 and fuel economy data. As mentioned, manufacturers test approximately 90-percent of their vehicles within each model type. Each sub-configuration variant within a model type has a unique CO_2 and CAFE value. Manufacturers combine other vehicles at the configuration, base level and then finally at the model type level for determining CAFE performance. The CAFE performance data for the sub-configurations have been added to the proposed template. NHTSA determined that this level of data was needed to verify manufacturers reported CAFE values.

Finally, we are proposing corrections to the CAFE Reporting Template to collect information on off-cycle technologies. The proposed changes match the format of the data with the EPA off-cycle database system. For example, manufacturers report to EPA high efficiency lighting as combination packages, so NHTSA is proposing to change its form to reflect this same level of information.

Version 2.21 of the template is available on NHTSA's Public Information Center (PIC) site.

(2) Credit Transactions Reporting Template

NHTSA established mandatory use of the CAFE credit template starting on January 1, 2021. However, manufacturers identified several calculation errors in the version of the credit reporting template available on

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[515] Submitting a properly completed template and accompanying transaction letter will satisfy the trading requirements in 49 CFR part 536.

the PIC site. Those calculation errors have been corrected and a new version of the template is available for download on the NHTSA PIC. Starting January 1, 2022, NHTSA will only accept its credit template as the sole source for executing CAFE credit transactions. Until that time, manufacturers can deviate from the generated language in the NHTSA credit trade confirmation by adding qualifications but, at a minimum, must include the core information generated by the template.

(3) Monetary and Non-Monetary Credit Trade Information

Credit trading became permissible in MY 2011.[516] To date, NHTSA has received numerous credit trades from entities, but has only made limited information publicly available.[517] As discussed earlier, NHTSA maintains an online CAFE database with manufacturer and fleetwide compliance information that includes year-by-year accounting of credit balances for each credit holder. While NHTSA maintains this database, the agency's regulations currently state that it will not publish information on individual transactions, and NHTSA has not previously required trading entities to submit information regarding the compensation (whether financial, or other items of value) exchanged for credits.[518] [519] Thus, NHTSA's PIC offers sparse information to those looking to determine the value of a credit.

The lack of information regarding credit transactions means entities wishing to trade credits have little, if any, information to determine the value of the credits they seek to buy or sell. Historically we have assumed that the civil penalty for noncompliance with CAFE standards largely determines the upper value of a credit, because it is logical to assume that manufacturers would not purchase credits if it cost less to pay civil penalties instead, but it is unknown how other factors affect the value. For example, a credit nearing the end of its five-model-year lifespan would theoretically be worth less than a credit within its full five-model-year lifespan. In the latter case, the credit holder would likely value the credit more, as it can be used for compliance purposes for a longer period of time.

NHTSA adopted requirements in the 2020 final rule requiring manufacturers to submit all credit trade contracts, including cost and transactional information, to the agency starting January 1, 2021. NHTSA also adopted requirements allowing manufacturers to submit the information confidentially, in accordance with 49 CFR part 512.[520] As stated in the final rule, NHTSA intended to use this information to determine the true cost of compliance for all manufacturers. This information would allow NHTSA to better assess the impact of its regulations on the industry and provide more insightful information in developing future rulemakings. This confidential information would be held by secure electronic means in NHTSA's database systems. As for public information, NHTSA would include more information on the PIC on aggregated credit transactions, such as the combined flexibilities all manufacturers used for compliance as shown in Figure VII–6, or information comparable to the credit information EPA makes available to the public. In the future, NHTSA will consider what information, if any, can be meaningfully shared with the public on credit transactional details or costs, while accounting for the concerns raised by the automotive industry for protecting manufacturers' competitive sources of information.

However, manufacturers continue to argue that disclosing trading terms may not be as simple as a spot purchase at a given price. As stated in the 2020 final rule, manufacturers contend a number of transactions for both CAFE and CO_2 credits involve a range of complexity due to numerous factors that are reflective of the marketplace, such as the volume of credits, compliance category, credit expiration date, a seller's compliance strategy, and even the CAFE penalty rate in effect at that time. In addition, automakers have a range of partnerships and cooperative agreements with their own competitors. Credit transactions can be an offshoot of these broader relationships, and difficult to price separately and independently.

Since then, NHTSA has identified a series of non-monetary factors that it believes to be important to the costs associated with credit trading in the CAFE program.[521] The agency believes this information will allow for a better assessment of the true costs of compliance. NHTSA further notes that greater government oversight is needed over the CAFE credit market and it needs to understand the full range of complexity in transactions, monetary and non-monetary, in addition to the range of partnerships and cooperative agreements between credit account holders—which may impact the price of credit trades.[522] Therefore, using the identified series of non-monetary factors, NHTSA has developed a new CAFE Credit Reporting Template (Form 1621) for capturing the monetary and non-monetary terms of credit trading contracts. NHTSA proposes that manufacturers start using the new template starting September 1, 2022. The draft template can be viewed and downloaded from the NHTSA PIC site.

3. What compliance flexibilities and incentives are currently available under the CAFE program and how do manufacturers use them?

Generating, trading, transferring, and applying CAFE credits is governed by statute.[523] Program credits are generated when a vehicle manufacturer's fleet over-complies with its standard for a given model year, meaning its vehicle fleet achieved a higher corporate average fuel economy value than the amount required by the CAFE program for that fleet in that model year. Conversely, if the fleet average CAFE level does not meet the standard, the fleet incurs debits (also referred to as a shortfall or deficit). A manufacturer whose fleet generates a credit shortfall in a given model year can resolve its shortfall using any one or combination of several credits flexibilities, including credit carryback, credit carry-forward, credit transfers, and credit trades, and if all credit flexibilities have been exhausted, then the manufacturer must resolve its shortfall by making civil penalty payments.[524]

NHTSA has also promulgated compliance flexibilities and incentives consistent with EPCA's provisions regarding calculation of fuel economy levels for individual vehicles and for fleets.[525] These compliance flexibilities and incentives, which were first adopted in the 2012 rule for MYs 2017 and later, include A/C efficiency improvement and off-cycle adjustments,

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[516] 49 CFR 536.6(c).

[517] Manufacturers may generate credits, but non-manufacturers may also hold or trade credits. Thus, the word "entities" is used to refer to those that may be a party to a credit transaction.

[518] 49 CFR 536.5(e)(1).

[519] NHTSA understands that not all credits are exchanged for monetary compensation. The proposal that NHTSA is adopting in this proposed rule requires entities to report compensation exchanged for credits and is not limited to reporting monetary compensation.

[520] *See also* 49 U.S.C. 32910(c).

[521] UCS, Detailed Comments, NHTSA–2018–0067–12039; Jason Schwartz, Detailed Comments, NHTSA–2018–0067–12162.

[522] Honda, Detailed Comments, NHTSA–2018–0067–11819.

[523] 49 U.S.C. 32903.

[524] Manufacturers may elect to pay civil penalties rather than utilizing credit flexibilities at their discretion. For purposes of the analysis, we assume that manufacturers will only pay penalties when all flexibilities have been exhausted.

[525] 49 U.S.C. 32904.

and adjustments for advanced technologies in full-size pickup trucks, including adjustments for mild and strong hybrid electric full-size pickup trucks and performance-based incentives in full-size pickup trucks. The fuel consumption improvement benefits of these technologies measured by various testing methods can be used by manufacturers to increase the CAFE performance of their fleets.

(a) Available Credit Flexibilities

Under NHTSA regulations, credit holders (including, but not limited to manufacturers) have credit accounts with NHTSA where they can, hold credits, and use them to achieve compliance with CAFE standards, by carrying forward, carrying back, or transferring credits across compliance categories, subject to several restrictions. Manufacturers with excess credits in their accounts can also trade credits to other manufacturers, who may use those credits to resolve a shortfall currently or in a future model year. A credit may also be cancelled before its expiration date if the credit holder so chooses. Traded and transferred credits are subject to an ''adjustment factor'' to ensure total oil savings are preserved.[526]

Credit ''carryback'' means that manufacturers are able to use recently earned credits to offset a deficit that had accrued in a prior model year, while credit ''carry-forward'' means that manufacturers can bank credits and use them towards compliance in future model years. EPCA, as amended by EISA, allows manufacturers to carryback credits for up to three model years, and to carry-forward credits for up to five model years.[527] Credits expire the model year after which the credits may no longer be used to achieve compliance with fuel economy regulations.[528] Manufacturers seeking to use carryback credits must submit a carryback plan to NHTSA, for NHTSA's review and approval, demonstrating their ability to earn sufficient credits in future MYs that can be carried back to resolve the current MY's credit shortfall.

Credit ''trading'' refers to the ability of manufacturers or persons to sell credits to, or purchase credits from, one another while credit ''transfer'' means the ability to transfer credit between a manufacturer's compliance fleets to resolve a credit shortfall. EISA gave NHTSA discretion to establish by regulation a CAFE credit trading program, to allow credits to be traded between vehicle manufacturers, now codified at 49 CFR part 536.[529] EISA prohibits manufacturers from using traded credits to meet the minimum domestic passenger car CAFE standard.[530]

(b) Fuel Savings Adjustment Factor

Under NHTSA's credit trading regulations, a fuel savings adjustment factor is applied when trading occurs between manufacturers and those credits are used, or when a manufacturer transfers credits between its compliance fleets and those credits are used, but not when a manufacturer carries credits forward or backwards within the same fleet.[531]

NHTSA is including in this proposal a restoration of certain definitions that are part of the adjustment factor equation that had been inadvertently deleted in the 2020 final rule. The 2020 final rule had intended to add a sentence to the adjustment factor term in 49 CFR 536.4(c), simply to make clear that the figure should be rounded to four decimal places. While the 2020 final rule implemented this change, the amendatory instruction for doing so unintentionally deleted several other definitions from that paragraph. NHTSA had not intended to modify or delete those definitions, so they are simply being added back into the paragraph.

(c) VMT Estimates for Fuel Savings Adjustment Factor

NHTSA uses VMT estimates as part of its fuel savings adjustment equation. Including VMT is important as fuel consumption is directly related to vehicle use, and in order to ensure trading credits between fleets preserves oil savings, VMT must be considered.[532] For MYs 2017 and later, NHTSA finalized VMT values of 195,264 miles for passenger car credits, and 225,865 miles for light truck credits.[533]

(d) Fuel Economy Calculations for Dual and Alternative Fueled Vehicles

As discussed at length in prior rulemakings, EPCA, as amended by EISA, encouraged manufacturers to build alternative-fueled and dual- (or flexible-) fueled vehicles by providing special fuel economy calculations for ''dedicated'' (that is, 100 percent) alternative fueled vehicles and ''dual-fueled'' (that is, capable of running on either the alternative fuel or gasoline/diesel) vehicles.

Dedicated alternative-fuel automobiles include electric, fuel cell, and compressed natural gas vehicles, among others. The statutory provisions for dedicated alternative fuel vehicles in 49 U.S.C. 32905(a) state that the fuel economy of any dedicated automobile manufactured after MY 1992 shall be measured ''based on the fuel content of the alternative fuel used to operate the automobile. A gallon of liquid alternative fuel used to operate a dedicated automobile is deemed to contain 0.15 gallon of fuel.'' There are no limits or phase-out for this special fuel economy calculation within the statute.

EPCA's statutory incentive for dual-fueled vehicles at 49 U.S.C. 32906 and the measurement methodology for dual-fueled vehicles at 49 U.S.C. 32905(b) and (d) expired after MY 2019. In the 2012 final rule, NHTSA and EPA concluded that it would be inappropriate and contrary to the intent of EPCA/EISA to measure duel-fueled vehicles' fuel economy like that of conventional gasoline vehicles with no recognition of their alternative fuel capability. The agencies determined that for MY 2020 and later vehicles, the general statutory provisions authorizing EPA to establish testing and calculation procedures provide discretion to set the CAFE calculation procedures for those vehicles. The methodology for EPA's approach is outlined in the 2012 final rule for MYs 2017 and later at 77 FR 63128 (Oct. 15, 2012).

(e) Flexibilities for Air-Conditioning Efficiency, Off-Cycle Technologies, and Full-Size Pickup Trucks

(1) Incentives for Advanced Technologies in Full-Size Pickup Trucks

Under its EPCA authority for CAFE and under its CAA authority for GHGs, EPA established fuel consumption improvement values (FCIVs) for manufacturers that hybridize a significant quantity of their full-size pickup trucks, or that use other technologies that significantly reduce fuel consumption of these full-sized pickup trucks. More specifically, CAFE FCIVs were made available to manufacturers that produce full-size pickup trucks with Mild HEV or Strong HEV technology, provided the percentage of production with the technology is greater than specified percentages.[534] In addition, CAFE FCIVs were made available for manufacturers that produce full-size pickups with other technologies that enable full-size

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[526] *See* Section VII.B.3.b) for details.

[527] 49 U.S.C. 32903(a).

[528] 49 CFR 536.3(b).

[529] 49 U.S.C. 32903(f).

[530] 49 U.S.C. 32903(f)(2).

[531] *See* Section III.C for details about carry forward and back credits.

[532] *See* 49 CFR 536.4(c).

[533] 77 FR 63130 (Oct. 15, 2012).

[534] 77 FR 62651 (Oct. 15, 2012).

pickup trucks to exceed their CAFE targets based on footprints by specified amounts (*i.e.,* electric vehicles and other electric components).[535] These performance-based incentives create a technology-neutral path (as opposed to the other technology-encouraging path) to achieve the CAFE FCIVs, which would encourage the development and application of new technological approaches.

Large pickup trucks represent a significant portion of the overall light duty vehicle fleet and generally have higher levels of fuel consumption and GHG emissions than most other light duty vehicles. Improvements in the fuel economy and GHG emissions of these vehicles can have significant impact on the overall light-duty fleet fuel use and GHG emissions. NHTSA believes that offering incentives could encourage the deployment of technologies that can significantly improve the efficiency of these vehicles and that also will foster production of those technologies at levels that will help achieve economies of scale, would promote greater fuel savings overall and make these technologies more cost effective and available in the future model years to assist in compliance with CAFE standards.

EPA and NHTSA also established limits on the eligibility for these pickup trucks to qualify for incentives. A truck was required to meet minimum criteria for bed size and towing or payload capacities and meet minimum production thresholds (in terms of a percentage of a manufacturer's full-size pickup truck fleet) in order to qualify for these incentives. Under the provisions, Mild HEVs are eligible for a per-vehicle CO_2 credit of 10 g/mi (equivalent to 0.0011 gallon/mile for a gasoline-fueled truck) during MYs 2017–2021. To be eligible a manufacturer would have to show that the Mild HEV technology is utilized in a specified portion of its truck fleet beginning with at least 20 percent of a company's full-size pickup production in MY 2017 and ramping up to at least 80 percent in MY 2021. Strong HEV pickup trucks are eligible for a 20 g/mi credit (0.0023 gallon/mile) during MYs 2017–2021, and in this rulemaking proposed to be extended through MY 2026, if the technology is used on at least 10 percent of a company's full-size pickups in that model year. EPA and NHTSA also adopted specific definitions for Mild and Strong HEV pickup trucks, based on energy flow to the high-voltage battery during testing.

Furthermore, to incentivize other technologies that can provide significant reductions in GHG emissions and fuel consumption for full-size pickup trucks, EPA also adopted, a performance-based fuel consumption improvement value for full-size pickup trucks. Eligible pickup trucks certified as performing 15 percent better than their applicable CO_2 target receive a 10 g/mi credit (0.0011 gallon/mile), and those certified as performing 20 percent better than their target receive a 20 g/mi credit (0.0023 gallon/mile). The 10 g/mi performance-based credit is available for MYs 2017 to 2021 and, once qualifying; a vehicle model will continue to receive the credit through MY 2021, provided its CO_2 emissions level does not increase. To be eligible a manufacturer would have to show that the technology is utilized in a specified portion of its truck fleet beginning with at least 20 percent of a company's full-size pickup production in MY 2017 and ramping up to at least 80 percent in MY 2021. The 20 g/mi performance-based credit was available for a vehicle model for a maximum of 5 years within the 2017 to 2021 model year period, and in this rulemaking proposed to be extended through MY 2026, provided its CO_2 emissions level does not increase. To be eligible, the technology must be applied to at least 10 percent of a company's full-size pickups in for the model year.

The agencies designed a definition for full-size pickup truck based on minimum bed size and hauling capability, as detailed in 40 CFR 86.1866–12(e). This definition ensured that the larger pickup trucks, which provide significant utility with respect to bed access and payload and towing capacities, are captured by the definition, while smaller pickup trucks with more limited capacities are not covered. A full-size pickup truck is defined as meeting requirements (1) and (2) below, as well as either requirement (3) or (4) below.

(1) Bed Width—The vehicle must have an open cargo box with a minimum width between the wheelhouses of 48 inches. And—

(2) Bed Length—The length of the open cargo box must be at least 60 inches. And—

(3) Towing Capability—the gross combined weight rating (GCWR) minus the gross vehicle weight rating (GVWR) must be at least 5,000 pounds. Or—

(4) Payload Capability—the GVWR minus the curb weight (as defined in 40 CFR 86.1803) must be at least 1,700 pounds.

In the 2020 CAFE rule, the agencies ended the incentives for full-size pickup trucks after the end of model year 2021 believing expanded incentives would likely not result in any further emissions benefits or fuel economy improvements since an increase in sales volume was unanticipated. At the time, no manufacturer had qualified to use the full-size pickup truck incentives since they went into effect in MY 2017. One vehicle manufacturer introduced a mild hybrid pickup truck in MY 2019 but was ineligible for the FCIV because it did not meet the minimum production threshold. Other manufacturers had announced potential collaborations or started designing future hybrid or electric models, but none were expected to meet production requirements within the time period of eligibility for these incentives.

Since the 2020 final rule, many manufacturers have publicly announced several new model types of full-size electric pickup trucks starting in MY 2022. NHTSA notes that historically its goal has always been to promote electric vehicles due to their exceptional fuel saving benefits. For this reason, even given the discontinuation in MY 2019 of AMFA incentives for dual fueled vehicles, NHTSA retained its benefits for alternative dedicated fueled vehicles to focus on the growth of electric vehicles in the market. Therefore, after the careful consideration of this new information and the potential role incentives could play in increasing the production of these technologies, and the associated beneficial impacts on fuel consumption, the agency is proposing to extend the full-size pickup truck incentive through MY 2025 for strong hybrids and for full-size pickup trucks performing 20-percent better than their target. Also, understanding the importance of electric vehicles in the market, NHTSA is proposing to allow manufacturers to combine both the incentives for alternative fueled vehicles and full-size pickup trucks FCIVs when complying with the CAFE program.

(2) Flexibilities for Air Conditioning Efficiency

A/C systems are virtually standard automotive accessories, and more than 95 percent of new cars and light trucks sold in the U.S. are equipped with mobile A/C systems. A/C system usage places a load on an engine, which results in additional fuel consumption; the high penetration rate of A/C systems throughout the light-duty vehicle fleet means that more efficient systems can significantly impact the total energy consumed. A/C systems also have non-CO_2 emissions associated with

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[535] *Id.*

refrigerant leakage.[536] Manufacturers can improve the efficiency of A/C systems though redesigned and refined A/C system components and controls.[537] That said, such improvements are not measurable or recognized using 2-cycle test procedures since A/C is turned off during 2-cycle testing. Any A/C system efficiency improvements that reduce load on the engine and improve fuel economy is therefore not measurable on those tests.

The CAFE program includes flexibilities to account for the real-world fuel economy improvements associated with improved A/C systems and to include the improvements for compliance.[538] The total A/C efficiency credits is calculated by summing the individual credit values for each efficiency improving technology used on a vehicle, as specified in the A/C credit menu. The total A/C efficiency credit sum for each vehicle is capped at 5.0 grams/mile for cars and 7.2 grams/mile for trucks. Additionally, the off-cycle credit program contains credit earning opportunities for technologies that reduce the thermal loads on a vehicle from environmental conditions (solar loads or parked interior air temperature).[539] These technologies are listed on a thermal control menu that provides a predefined improvement value for each technology. If a vehicle has more than one thermal load improvement technology, the improvement values are added together, but subject to a cap of 3.0 grams/mile for cars and 4.3 grams/mile for trucks. Under its EPCA authority for CAFE, EPA calculates equivalent FCIVs and applies them for the calculation of manufacturer's fleet CAFE values. Manufacturers seeking credits beyond the regulated caps must request the added benefit for A/C technology under the off-cycle program discussed in the next section. The agency is not proposing to change its A/C efficiency flexibility and will retain its provisions in its current form.

(3) Flexibilities for Off-Cycle Technologies

''Off-cycle'' technologies are those that reduce vehicle fuel consumption in the real world, but for which the fuel consumption reduction benefits cannot be fully measured under the 2-cycle test procedures (city, highway or correspondingly FTP, HFET) used to determine compliance with the fleet average standards. The cycles are effective in measuring improvements in most fuel economy improving technologies; however, they are unable to measure or underrepresent certain fuel economy improving technologies because of limitations in the test cycles. For example, off-cycle technologies that improve emissions and fuel economy at idle (such as ''stop start'' systems) and those technologies that improve fuel economy to the greatest extent at highway speeds (such as active grille shutters which improve aerodynamics) receive less than their real-world benefits in the 2-cycle compliance tests.

In the CAFE rule for MYs 2017–2025, EPA, in coordination with NHTSA, established regulations extending the off-cycle technology flexibility to the CAFE program starting with MY 2017. For the CAFE program, EPA calculates off-cycle fuel consumption improvement values (FCIVs) that are equivalent to the EPA CO_2 credit values, and applies them in the calculation of manufacturer's CAFE compliance values for each fleet instead of treating them as separate credits as for the EPA GHG program.

For determining benefits, EPA created three compliance pathways for the off-cycle program. The first approach allows manufacturers to gain credits using a predetermined approach or ''menu'' of credit values for specific off-cycle technologies which became effective starting in MY 2014 for EPA.[540] [541] This pathway allows manufacturers to use credit values established by EPA for a wide range of off-cycle technologies, with minimal or no data submittal or testing requirements.[542] Specifically, EPA established a menu with a number of technologies that have real-world fuel consumption benefits not measured, or not fully measured, by the two-cycle test procedures, and those benefits were reasonably quantified by the agencies at that time. For each of the pre-approved technologies on the menu, EPA established a menu value or approach that is available without testing verifications. Manufacturers must demonstrate that they are in fact using the menu technology, but not required to submit test results to EPA to quantify the technology's effects, unless they wish to receive a credit larger than the default value. The default values for these off-cycle credits were largely determined from research, analysis, and simulations, rather than from full vehicle testing, which would have been both cost and time prohibitive. EPA generally used conservative predefined estimates to avoid any potential credit windfall.[543]

For off-cycle technologies not on the pre-defined technology list, EPA created a second pathway which allows manufacturers to use 5-cycle testing to demonstrate off-cycle improvements.[544] Starting in MY 2008, EPA developed the ''five-cycle'' test methodology to measure fuel economy for the purpose of improving new car window stickers (labels) and giving consumers better information about the fuel economy they could expect under real-world driving conditions.[545] As learned through development of the ''five-cycle'' methodology and prior rulemakings, there are technologies that provide real-world fuel consumption improvements,

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[536] Notably, manufacturers cannot claim CAFE-related benefits for reducing A/C leakage or switching to an A/C refrigerant with a lower global warming potential. While these improvements reduce GHG emissions consistent with the purpose of the CAA, they generally do not impact fuel economy and, thus, are not relevant to the CAFE program.

[537] The approach for recognizing potential A/C efficiency gains is to utilize, in most cases, existing vehicle technology/componentry, but with improved energy efficiency of the technology designs and operation. For example, most of the additional A/C-related load on an engine is because of the compressor, which pumps the refrigerant around the system loop. The less the compressor operates, the less load the compressor places on the engine resulting in less fuel consumption. Thus, optimizing compressor operation with cabin demand using more sophisticated sensors, controls, and control strategies is one path to improving the efficiency of the A/C system.

[538] *See* 40 CFR 86.1868–12.

[539] *See* 40 CFR 86.1869–12(b).

[540] *See* 40 CFR 86.1869–12(b). The first approach requires some technologies to derive their pre-determined credit values through EPA's established testing. For example, waste heat recovery technologies require manufacturers to use 5-cycle testing to determine the electrical load reduction of the waste heat recovery system.

[541] EPA implemented its off-cycle GHG program starting in MY 2012.

[542] The Technical Support Document (TSD) for the 2012 final rule for MYs 2017 and beyond provides technology examples and guidance with respect to the potential pathways to achieve the desired physical impact of a specific off-cycle technology from the menu and provides the foundation for the analysis justifying the credits provided by the menu. The expectation is that manufacturers will use the information in the TSD to design and implement off-cycle technologies that meet or exceed those expectations in order to achieve the real-world benefits of off-cycle technologies from the menu.

[543] While many of the assumptions made for the analysis were conservative, others were ''central.'' For example, in some cases, an average vehicle was selected on which the analysis was conducted. In that case, a smaller vehicle may presumably deserve fewer credits whereas a larger vehicle may deserve more. Where the estimates are central, it would be inappropriate for the agencies to grant greater credit for larger vehicles, since this value is already balanced by smaller vehicles in the fleet. The agencies take these matters into consideration when applications are submitted for credits beyond those provided on the menu.

[544] *See* 40 CFR 86.1869–12(c). EPA proposed a correction for the 5-cycle pathway in a separate technical amendments rulemaking. *See* 83 FR 49344 (Oct. 1, 2019). EPA is not approving credits based on the 5-cycle pathway pending the finalization of the technical amendments rule.

[545] *https://www.epa.gov/vehicle-and-fuel-emissions-testing/dynamometer-drive-schedules.*

but those improvements are not fully reflected on the ''two-cycle'' test. EPA established this alternative for a manufacturer to demonstrate the benefits of off-cycle technologies using 5-cycle testing. The additional emissions test allows emission benefits to be demonstrated over some elements of real-world driving not captured by the two-cycle CO_2 compliance tests including high speeds, rapid accelerations, hot temperatures, and cold temperatures. Under this pathway, manufacturers submit test data to EPA, and EPA determines whether there is sufficient technical basis to approve the off-cycle credits. No public comment period is required for manufacturers seeking credits using the EPA menu or using 5-cycle testing.

The third pathway allows manufacturers to seek EPA review, through a notice and comment process, to use an alternative methodology other than the menu or 5-cycle methodology for determining the off-cycle technology CO_2 credits.[546] Manufacturers must provide supporting data on a case-by-case basis demonstrating the benefits of the off-cycle technology on their vehicle models. Manufacturers may also use the third pathway to apply for credits and FCIVs for menu technologies where the manufacturer is able to demonstrate credits and FCIVs greater than those provided by the menu.

(a) The Off-Cycle Process

In meetings with EPA and manufacturers, NHTSA examined the processes for bringing off-cycle technologies into market. Two distinct processes were identified: (1) The manufacturer's off-cycle pre-production process, and; (2) the manufacturer's regulatory compliance process. During the pre-production process, the off-cycle program for most manufacturers begins as early as four to 6 years in advance of the given model year. Manufacturers' design teams or suppliers identify technologies to develop capable of qualifying for off-cycle credits after careful considering of the possible benefits. Manufacturer then identify the opportunities for the technologies finding the most optimal condition for equipping the technology given the availability in the production cycle of either new or multiple platforms capitalizing on any commonalities to increase sales volumes and reduce costs. After establishing their new or series platform development plans, manufacturers have two processes for off-cycle technologies on the pre-defined menu list or using 5-cycle testing and for those for which benefits are sought using the alternative approval methodology. For those on the menu list or 5-cycle testing, technologies whose credit amounts are defined by EPA regulation, manufacturers confirm that: (1) New candidate technologies meet regulatory definitions; and (2) for qualifying technologies, there is real fuel economy (FE) benefit based on good engineering judgement and/or testing. For these technologies, manufacturers conduct research and testing independently without communicating with EPA or NHTSA. For non-menu technologies, those not defined by regulation, manufacturers pre-production processes include: (1) Determining the credit amounts based on the effectiveness of the technologies; (2) developing suitable test procedures; (3) identifying any necessary studies to support effectiveness; (4) and identifying the necessary equipment or vehicle testing using good engineer judgement to confirm the vehicle platform benefits of the technology.

While for the regulatory compliance process, the first step for manufacturers begins by providing EPA with early notification in their pre-model year GHG reports (*e.g.,* 2025MY Pre-GHG are due in 2023CY) of their intention to generate any off-cycle credits in accordance with 40 CFR 600.514–12. Next, manufacturers present a brief overview of the technology concept and planned model types for their off-cycle technologies as a part of annual pre-certification meetings with EPA. Manufacturers typical hold their pre-certification meetings with EPA somewhere between September through November two years in advance of each model year. These meetings are designed to give EPA a holistic overview of manufacturers planned product offerings for the upcoming compliance model year and since 2012 information on the A/C and off-cycle programs. Thus, a manufacturer complying in the 2023 compliance model year would arrange its pre-certification meeting with EPA in September 2021 and would be required to share information on the A/C and off-cycle technologies its plans to equip during the model year. After this, manufacturers report projected information on off-cycle technologies as a part of their CAFE reports to NHTSA in accordance with 49 CFR part 537 CAFE due by December 31st before the end of the model year.

According to EPA and NHTSA regulations, eligibility to gain benefits for off-cycle technologies only require manufacturers to reporting information in advance of the model year notifying the agencies of a manufacturer's intent to claim credits. More specifically, manufacturers must notify EPA in their pre-model year reports, and in their applications for certification, of their intention to generate any A/C and off-cycle credits before the model year, regardless of the methodology for generating credits. Similarly, for NHTSA, manufacturers are also required to provide data in their pre-model year reports required by 49 CFR part 537 including projected information on A/C, off-cycle, and full-size pickup truck incentives. These regulations require manufacturers to report information on factors such as the approach for determining the benefit of the technology, projected production information and the planned model types for equipping the off-cycle technology.

If a manufacturer is pursuing credits for a non-menu off-cycle technology, EPA also encourages manufacturers to seek early reviews for the eligibility of a technology, the test procedure, and the model types for testing in advance of the model year. EPA emphasizes the critical importance for manufacturers to seek these reviews prior to conducting testing or any analytical work. Yet, some manufacturers have decided not to seek EPA's early reviews which resulted in significant delays in the process as EPA has had to identify and correct multiple testing and analytical errors after the fact. Consequently, EPA's goal is to provide approvals for manufacturers as early as possible to ensure timely processing of their credit requests. NHTSA shares the same goals and views as EPA for manufacturers submissions but to-date neither agency has created any required deadlines for these reviews. For NHTSA, its only requirement is for manufacturers to submit copies of all information sent to EPA at the same time.

The next step in the credit review process is for manufacturers to submit an analytical plan defining the required testing to derive the exact benefit of a non-menu off-cycle technology before the model year begins and then to start testing. It is noted that some manufacturers failed to seek EPA's early reviews which delayed finalizing their analytical plans and then the start of their testing. These delays had greater impacts depending upon the required testing for the technology. For example, some manufacturers were required to conduct a four-season testing methodology lasting almost a year to evaluate the performance of a technology during all environmental conditions.

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[546] *See* 40 CFR 86.1869–12(d).

After completing testing, manufacturers are required to prepare an official application requesting a certain amount of off-cycle credits for the technology. In accordance with EPA regulations, the official application request must include final testing data, details on the methodology used to determine the off-cycle credit value, and the official benefit value requested. EPA anticipated that these submissions would be made prior to the end of the model year where the off-cycle technology was applied.

Each manufacturers' application to EPA must then undergo a public notice and comment process if the manufacturer uses a methodology to derive the benefit of a technology not previously approved by EPA. Once a methodology for a specific off-cycle technology has gone through the public notice and comment process and is approved for one manufacturer, other manufacturers may follow the same methodology to collect data on which to base their off-cycle credits. Other manufacturers are only required to submit applications citing the approved methodology, but those manufacturers must provide their own necessary test data, modeling, and calculations of credit value specific to their vehicles, and any other vehicle-specific details pursuant to that methodology, to assess an appropriate credit value. This is similar to what occurred with the advanced A/C compressor, where one manufacturer applied for credits with data collected through bench testing and vehicle testing, and subsequent to the first manufacturer being approved, other manufacturers applied for credits following the same methodology by submitting test data specific for their vehicle models. Consequently, as long as the testing is conducted using the previously-approved methodology, EPA will evaluate the credit application and issue a decision with no additional notice and comment, since the first application that established the methodology was subject to notice and comment. EPA issues a decision document regarding the manufacturer's official application upon resolution of any public comments to the its **Federal Register** notice and after consultation with NHTSA. Finally, manufacturers submit information after the model year ends on off-cycle technologies and the equipped vehicles in their final CAFE reports due by March 30th and then in their final GHG Averaging, Banking, and Trading (AB&T) reports due to EPA by April 30th.

During the 2020 rulemaking, the agencies and manufacturers both agreed that responding to petitions before the end of a model year is beneficial to manufacturers and the government. It allows manufacturers to have a better idea of what credits they will earn, and for the government, a timely and less burdensome completion of manufacturers' end-of-the-year final compliance processes. EPA structured the A/C and off-cycle programs to make it possible to complete the processes by the end of the model year so manufacturers could submit their final reports within the required deadline—90 days after the calendar year, when CAFE final reports are due from manufacturers.[547]

However, at the time of the previous rulemaking, manufacturers were submitting retroactive off-cycle petitions for review causing significant delays to review and approval of novel technologies and issuances of **Federal Register** notices seeking public comments, where applicable. As a result, the agencies set a one-time allowance that ended in May 2020 for manufacturers to ask for retroactive credits or FCIVs for off-cycle technologies equipped on previously-manufactured vehicles after the model year had ended. After that time, the agencies denied manufacturers' late submissions requesting retroactive credits. However, manufacturers who properly submitted information ahead of time were allowed to make corrections to resolve inadvertent errors during or after the model year.

Both EPA and NHTSA regulations fail to include specific deadlines for manufacturers to meet in finalizing their off-cycle analytical plans or the official applications to the agencies. The agencies believed that enforcing the existing submission requirements would be the most efficient approach to expedite approvals and set aside adding any new regulatory deadlines or additional requirements in the previous rulemaking. There were also concerns to provide manufacturers with maximum flexibility and due to the uncertainties existing with the non-menu off-cycle process. However, the agencies anticipated that any timeliness problems would resolve themselves as the off-cycle program reached maturity and more manufacturers began requesting benefits for previously approved off-cycle technologies.

Despite the agencies expectations, the lack of deadlines for test results or the official application has significantly delayed approvals for non-menu off-cycle requests. In many cases, EPA has received off-cycle non-menu application requests either late in the model year or after the model year. This falls outside the agencies planned strategy for the off-cycle non-menu review process whereas manufacturers would seek approval and submit their official application requests either in advance of the model year or early enough in the model year to allow the agency to approve a manufacturer's credits before the end of the model year.

(b) Proposed Changes to the Off-Cycle Program

(i) Review Process

The current review process for off-cycle technologies is causing significant challenges in finalizing end-of-the-year compliance processes for the agencies. The backlog of retro-active and pending late off-cycle requests have delayed EPA from recalculating NHTSA's MY 2017 finals and from completing those for MYs 2018 and 2019. Fifty-four off-cycle non-menu requests have been submitted to EPA to date. Nineteen of the requests were submitted late and another seven apply retroactively to previous model years starting as early as model year 2015. Since these requests represent potential credits or adjustments that will influence compliance figures, CAFE final results cannot be finalized until all off-cycle requests have been disposed. These factors have so far delayed MY 2017 final CAFE compliance by 28 months, MY 2018 by 15 months, and MY 2019 by 4 months.

These late reports amount to more than just a mere accounting nuisance for the agencies; they are actively chilling the credit market. Until EPA verifies final compliance numbers, manufacturers are uncertain about either how many credits they have available to trade or, conversely, how many credits are necessary for them to cover any shortfalls.

For MY 2017, NHTSA will void manufacturers previous credit trades pending the revised final calculations. Second, until late requests are approved, credit sellers are unable to make trades with buyers having pending approvals or credits are sold whereas the final balance of credits is unknown. Because credit trades and transfers must be adjusted for fuel savings anytime a change occurs in a manufacturer's CAFE values, the resulting earned or purchased credits must be recalculated. These recalculations are significantly burdensome on the government to administer and places an undue risk on manufacturers involved in CAFE credit trade transactions.

NHTSA met with EPA and manufacturers to better understand the process for reviewing off-cycle non-menu technologies. From these

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[547] 40 CFR 600.512(12).

discussions, NHTSA identified several issues that may be influencing late submissions. First, non-menu requests are becoming more complex and are requiring unique reviews. Previously approved technologies are also becoming more complex and are requiring either new testing, test procedures or have evolved beyond the definitions which at one time previously qualified them. Next, manufacturers identified the lack of standardized test procedures approved by EPA or certainty from EPA on which model types need to be tested as major sources for delays in submitting their analytical plans. In addition, manufacturers claimed there is significant uncertainty surrounding the necessary data sources to substantiate the benefit of the technology. For example, the data sources necessary to substantiate the usage rates certain technologies in the market. Testing or extrapolating test results for variations in model types can also be difficult and a source of delay. Manufacturers are typically uncertain as to what configurations within a model type must be tested and believe further guidance may be needed by EPA. Manufacturers further claim that it is challenging to coordinate the required testing identified by EPA for off-cycle in coordination with other required certification and emissions testing. Several of these issues were addressed in the 2020 final rule. In that rulemaking, the agencies stated that developing a standardized test procedure ''toolbox'' may not be possible due to the development of new and emerging technologies, and manufacturers' different approaches for evaluating the benefits of the technologies. However, the agencies committed to considering additional guidance, if feasible, as the programs further matures in the review process of technologies and, if possible, identify consistent methodologies that may help manufacturers analyze off-cycle technologies.

Part of the issue is that the review process begins significantly later than the development of technology. Typically, EPA only learns about a new off-cycle technology during manufacturers' precertification meetings, months or even years after manufacturers started to develop the technology. NHTSA seeks comments on whether opportunities exist during the initial development of off-cycle technologies for manufacturers to start discussions with the agencies to identify suitable test procedures or approval of the initial concept of a new technology. After certification meetings, NHTSA also identified that in many cases, manufacturers do not communicate with EPA seeking approvals for their test procedures, test vehicles or credit calculations until anywhere from 3–6 months after the initial development of the technology. Delays in approving a suitable test procedure extends the manufacturers ability to perform testing or to submit its formal request for benefits until after the model year has ended. As mentioned, testing can take up to 12 months after a suitable test procedure and identifying which subconfigurations must be tested.

One manufacturer also stated that set submission deadlines are impossible, agency approvals are variable based on OEM need and reply timing is driven by the EPA. When questioned whether any deadlines could be imposed manufacturers responded believing any deadlines would need to be negotiated between the manufacturer and the government. Please comment on any drawbacks associated with negotiating and enforcing off-cycle process deadlines with manufacturers.

NHTSA is proposing to modify the eligibility requirements for non-menu off-cycle technologies in the CAFE program starting in model year 2024. Manufacturers will be required to finalize their analytical plans by December before the model years and their final official technology credit requests by September during the model year. Manufacturers will also be required to meet the proposed deadlines or be subject an enforcement action. Unless an extension is granted by NHTSA for good cause, a manufacturer will be precluded from claiming any off-menu items not timely submitted. Failure to request extensions or meet negotiated deadlines will be subject to enforcement action in compliance with 49 U.S.C. 32912(a).

To further streamline the process of reviews, NHTSA also proposes to work with EPA to create a quicker process for adding off-cycle technologies to the predetermined menu list if widely approved for multiple manufacturers. For example, the agencies added high-efficiency alternators and advanced A/C compressors to the menu allowing manufacturers to select the menu credit rather than continuing to seek credits through the public approval process. High-efficiency alternators were added to the off-cycle credits menu, and advanced A/C compressors with a variable crankcase valve were added to the menu for A/C efficiency credits. The credit levels are based on data previously submitted by multiple manufacturers through the off-cycle credits application process. The high efficiency alternator credit is scalable with efficiency, providing an increasing credit value of 0.16 grams/mile CO_2 per percent improvement as the efficiency of the alternator increases above a baseline level of 67 percent efficiency. The advanced A/C compressor credit value is 1.1 grams/mile for both cars and light trucks.[548]

(ii) Safety Assessment

In the 2016 heavy-duty fuel economy rule (81 FR 73478, October 25, 2016), NHTSA adopted provisions preventing manufacturers from receiving credits for technology that impair safety—whether due to a defect, negatively affecting a FMVSS, or other safety reasons.[549] Additionally, NHTSA clarified that technologies that do not provide fuel savings as intended will also be stripped of credits. To harmonize the light-duty and heavy-duty off-cycle programs, NHTSA is proposing to adopt these provisions for the light-duty CAFE program. While the agency encourages fuel economy innovations, safety remains NHTSA's primary mission and any technology applied for CAFE-purposes should not impair safety. Furthermore, adopting these requirements for the light-duty fleet will harmonize it with the heavy-duty regulations.

(iii) Menu Credit Cap

Due to the uncertainties associated with combining menu technologies and the fact that some uncertainty is introduced because off-cycle credits are provided based on a general assessment of off-cycle performance, as opposed to testing on the individual vehicle models, EPA established caps that limit the amount of credits a manufacturer may generate using the EPA menu list. Off-cycle technology is capped at 10 grams/mile per year on a combined car and truck fleet-wide average basis. In its concurrent proposal for MYs 2023–2026 GHG standards (86 FR 43726, August 10, 2021), EPA is proposing to increase the off-cycle menu cap from 10 grams CO_2/mile to 15 grams CO_2/mile beginning with MY 2023. EPA also proposes to revise the definitions for passive cabin ventilation and active engine and transmission warm-up beginning in MY 2023, as discussed in the next following sections. Furthermore, EPA is proposing, for MYs

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[548] For additional details regarding the derivation of these credits, *see* EPA's Memorandum to Docket EPA–HQ–OAR–2018–0283 (''Potential Off-cycle Menu Credit Levels and Definitions for High Efficiency Alternators and Advanced Air Conditioning Compressors'').

[549] *See* 49 CFR 535.7(f)(2)(iii).

2020–2022, to allow manufacturers to use the cap of 15 g/mi if the revised definitions are met for these technologies. NHTSA is proposing to adopt these same provisions for the CAFE programs as a part of this rulemaking. No caps were established for technologies gaining credits through the petitioning or 5-cycle approval methodologies and the agency are not proposing to add caps in these areas.

(iv) Proposal To Update the Menu Technology Definitions

(a) Passive Cabin Ventilation

Some manufacturers have claimed off-cycle credits for passive ventilation cabin technologies based on the addition of software logic to their HVAC system that sets the dash vent to the open position when the power to vehicle is turned off at higher ambient temperatures. The manufacturers have indicated that the opening of the vent allows for the flow of ambient temperature air into the cabin. While ensuring that the interior of the vehicle is open for flow into the cabin, by only opening the dash vent no other action is taken to improve the flow of heated air out of the vehicle. This technology relies on the pressure in the cabin to reach a sufficient level for the heated air in the interior to flow out through body leaks or the body exhausters open and vent heated air out of the cabin.

The credits for passive cabin ventilation were determined based on an National Renewable Energy Laboratory (NREL) study that strategically opened a sunroof to allow for the unrestricted flow of heated air to exit the interior of the vehicle while combined with additional floor openings to provide a minimally restricted entry for cooler ambient air to enter the cabin.[550] The modifications NREL performed on the vehicle reduced the flow restrictions for both heated cabin air to exit the vehicle and cooler ambient air to enter the vehicle, creating a convective airflow path through the vehicle cabin.

Analytical studies performed by manufacturers to evaluate the performance of the open dash vent demonstrate that while the dash vent may allow for additional airflow of ambient temperature air entering the cabin, it does not reduce the existing restrictions on heated cabin air exiting the vehicle. Opening the dash vent primarily relies on body leaks and occasional venting of the heated cabin air through the body exhausters for the higher temperature cabin air to be vented from the vehicle. While this does provide some reduction in cabin temperatures this technology is not as effective as the combination of vents used by the NREL researchers to allow additional ambient temperature air to enter the cabin and also to reduce the restriction of heated air exiting the cabin.

As noted in the Joint Technical Support Document: Final Rulemaking for 2017–2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards,[551] pg. 584, ''For passive ventilation technologies, such as opening of windows and/or sunroofs and use of floor vents to supply fresh air to the cabin (which enhances convective airflow), (1.7 grams/mile for LDVs and 2.3 grams/mile for LDTs) a cabin air temperature reduction of 5.7 °C can be realized.'' The passive cabin ventilation credit values were based on achieving the 5.7 °C cabin temperature reduction.

EPA and NHTSA have decided to revise the passive cabin ventilation definition to make it consistent with the technology used to generate the credit value. NHTSA supports EPA's proposal to revise the definition of passive cabin ventilation to only include methods which create and maintain convective airflow through the body's cabin by opening windows or a sunroof, or equivalent means of creating and maintaining convective airflow, when the vehicle is parked outside in direct sunlight.

Current systems claiming the passive ventilation credit by opening the dash vent would no longer meet the updated definition. Manufacturers seeking to claim credits for the open dash vent system will be eligible to petition the agency for credits for this technology using the alternative EPA approved method outlined in § 86.1869–12(d).

(b) Active Engine and Transmission Warmup

NHTSA, in coordination with EPA, is proposing to revise the menu definitions of active engine and transmission warm-up to no longer allow systems that capture heat from the coolant circulating in the engine block prior to the opening of the thermostat to qualify for the Active Engine and Active Transmission warm-up menu credits. The agency would allow credit for coolant systems that capture heat from a liquid-cooled exhaust manifold if the system is segregated from the coolant loop in the engine block. The agency would also allow system design that captures and routes waste heat from the exhaust to the engine or transmission as this was the basis for these two credits as originally proposed in the NPRM to the 2017 to 2025 GHG rulemaking (76 FR 74854, Dec. 1, 2011).

Manufacturers seeking to utilize their existing systems that capture coolant heat before the engine is fully warmed-up and transfer this heat to the engine oil and transmission fluid would remain eligible to seek credits through the alternative method application process outlined in § 86.1869–12(d). These technologies may provide some benefit, however, as noted above as these system designs remove heat that is needed to warmup the engine may be less effective than those that capture and utilize exhaust waste heat.

VIII. Public Participation

NHTSA requests comments on all aspects of this NPRM. This section describes how you can participate in this process.

How do I prepare and submit comments?

Your comments must be written and in English.[552] To ensure that your comments are correctly filed in the docket, please include the docket number NHTSA–2021–0053 in your comments. Your comments must not be more than 15 pages long.[553] NHTSA established this limit to encourage you to write your primary comments in a concise fashion. However, you may attach necessary additional documents to your comments, and there is no limit on the length of the attachments. If you are submitting comments electronically as a PDF (Adobe) file, we ask that the documents please be scanned using the Optical Character Recognition (OCR) process, thus allowing NHTSA to search and copy certain portions of your submissions.[554] Please note that pursuant to the Data Quality Act, in order for substantive data to be relied upon and used by the agency, it must meet the information quality standards set forth in the OMB and DOT Data Quality Act guidelines. Accordingly, we encourage you to consult the guidelines in preparing your comments. OMB's

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[550] Rugh, J., Chaney, L., Lustbader, J., and Meyer, J., ''Reduction in Vehicle Temperatures and Fuel Use from Cabin Ventilation, Solar-Reflective Paint, and a New Solar-Reflective Glazing,'' SAE Technical Paper 2007–01–1194, 2007.

[551] ''Final Rulemaking for 2017–2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards'' August 2012. NHTSA and EPA. *https://www.nhtsa.gov/sites/nhtsa.gov/files/joint_final_tsd.pdf.* Last Accessed June 6, 2021.

[552] 49 CFR 553.21.

[553] *Id.*

[554] Optical character recognition (OCR) is the process of converting an image of text, such as a scanned paper document or electronic fax file, into computer-editable text.

guidelines may be accessed at *https://www.gpo.gov/fdsys/pkg/FR-2002-02-22/pdf/R2-59.pdf.* DOT's guidelines may be accessed at *https://www.transportation.gov/dot-information-dissemination-quality-guidelines.*

Tips for Preparing Your Comments

When submitting comments, please remember to:

- Identify the rulemaking by docket number and other identifying information (subject heading, **Federal Register** date and page number).
- Explain why you agree or disagree, suggest alternatives, and substitute language for your requested changes.
- Describe any assumptions and provide any technical information and/or data that you used.
- If you estimate potential costs or burdens, explain how you arrived at your estimate in sufficient detail to allow for it to be reproduced.
- Provide specific examples to illustrate your concerns and suggest alternatives.
- Explain your views as clearly as possible, avoiding the use of profanity or personal threats.
- Make sure to submit your comments by the comment period deadline identified in the **DATES** section above.

How can I be sure that my comments were received?

If you submit your comments to NHTSA's docket by mail and wish DOT Docket Management to notify you upon receipt of your comments, please enclose a self-addressed, stamped postcard in the envelope containing your comments. Upon receiving your comments, Docket Management will return the postcard by mail.

How do I submit confidential business information?

If you wish to submit any information any information under a claim of confidentiality, you should submit three copies of your complete submission, including the information you claim to be confidential business information, to the Chief Counsel, NHTSA, at the address given above under **FOR FURTHER INFORMATION CONTACT**. When you send a comment containing confidential business information, you should include a cover letter setting forth the information specified in 49 CFR part 512.

In addition, you should submit a copy from which you have deleted the claimed confidential business information to the Docket by one of the methods set forth above.

Will NHTSA consider late comments?

NHTSA will consider all comments received before the close of business on the comment closing date indicated above under **DATES**. To the extent practicable, we will also consider comments received after that date. If interested persons believe that any information that the agency places in the docket after the issuance of the NPRM affects their comments, they may submit comments after the closing date concerning how the agency should consider that information for the final rule. However, the agency's ability to consider any such late comments in this rulemaking will be limited due to the time frame for issuing a final rule.

If a comment is received too late for us to practicably consider in developing a final rule, we will consider that comment as an informal suggestion for future rulemaking action.

How can I read the comments submitted by other people?

You may read the materials placed in the dockets for this document (*e.g.,* the comments submitted in response to this document by other interested persons) at any time by going to *https://www.regulations.gov.* Follow the online instructions for accessing the dockets. You may also read the materials at the DOT Docket Management Facility by going to the street address given above under **ADDRESSES**.

How do I participate in the public hearings?

NHTSA will hold one virtual public hearing during the public comment period. The agency will announce the specific date and web address for the hearing in a supplemental **Federal Register** notification. The agency will accept oral and written comments to the rulemaking documents and will also accept comments to the Supplemental Environmental Impact Statement (SEIS) at this hearing. The hearing will start at 9 a.m. Eastern standard time and continue until everyone has had a chance to speak.

NHTSA will conduct the hearing informally, and technical rules of evidence will not apply. We will arrange for a written transcript of each hearing to be posted in the dockets as soon as it is available and keep the official record of the hearing open for 30 days following the hearing to allow you to submit supplementary information.

The Draft Supplemental Environmental Impact Statement (SEIS) associated with this proposal has a unique public docket number and is available in Docket No. NHTSA–2021–0054.

Comments on the Draft SEIS can be submitted electronically at *http://www.regulations.gov,* in Docket No. NHTSA–2021–0054. You may also mail or hand deliver comments to Docket Management, U.S. Department of Transportation, 1200 New Jersey Avenue SE, Room W12–140, Washington, DC 20590 (referencing Docket No. NHTSA–2021–0054), between 9 a.m. and 5 p.m., Monday through Friday, except on Federal holidays. To be sure someone is there to help you, please call (202) 366–9322 before coming. All comments and materials received, including the names and addresses of the commenters who submit them, will become part of the administrative record and will be posted on the web at *http://www.regulations.gov.*

IX. Regulatory Notices and Analyses

A. Executive Order 12866, Executive Order 13563

Executive Order 12866, ''Regulatory Planning and Review'' (58 FR 51735, Oct. 4, 1993), as amended by Executive Order 13563, ''Improving Regulation and Regulatory Review'' (76 FR 3821, Jan. 21, 2011), provides for making determinations whether a regulatory action is ''significant'' and therefore subject to the Office of Management and Budget (OMB) review process and to the requirements of the Executive Order. Under these Executive orders, this action is an ''economically significant regulatory action'' because it is likely to have an annual effect on the economy of $100 million or more. Accordingly, NHTSA submitted this action to OMB for review and any changes made in response to OMB recommendations have been documented in the docket for this action. The benefits and costs of this proposal are described above and in the Preliminary Regulatory Impact Analysis (PRIA), which is located in the docket and on NHTSA's website.

B. DOT Regulatory Policies and Procedures

This proposal is also significant within the meaning of the Department of Transportation's Regulatory Policies and Procedures. The benefits and costs of the proposal are described above and in the PRIA, which is located in the docket and on NHTSA's website.

C. Executive Order 13990

Executive Order 13990, ''Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis'' (86 FR 7037, Jan. 25, 2021), directed the immediate review of ''The Safer Affordable Fuel-Efficient (SAFE)

Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks'' (the 2020 final rule) by July 2021. The Executive order directed that ''In considering whether to propose suspending, revising, or rescinding that rule, the agency [*i.e.,* NHTSA] should consider the views of representatives from labor unions, States, and industry.''

This proposal follows the review directed in this Executive order. Promulgated under NHTSA's statutory authorities, it proposes new CAFE standards for the model years covered by the 2020 final rule for which there is still available lead time to change, and it accounts for the views provided by labor unions, States, and industry.

D. Environmental Considerations

1. National Environmental Policy Act (NEPA)

Concurrently with this NPRM, NHTSA is issuing a Supplemental Environmental Impact Statement (SEIS), pursuant to the National Environmental Policy Act, 42 U.S.C. 4321–4347, and implementing regulations issued by the Council on Environmental Quality (CEQ), 40 CFR part 1500, and NHTSA, 49 CFR part 520. NHTSA prepared the SEIS to analyze and disclose the potential environmental impacts of the proposed CAFE standards and a range of alternatives. The SEIS analyzes direct, indirect, and cumulative impacts and analyzes impacts in proportion to their significance.

The SEIS describes potential environmental impacts to a variety of resources, including fuel and energy use, air quality, climate, land use and development, hazardous materials and regulated wastes, historical and cultural resources, noise, and environmental justice. The SEIS also describes how climate change resulting from global carbon dioxide emissions (including CO_2 emissions attributable to the U.S. light-duty transportation sector under the alternatives considered) could affect certain key natural and human resources. Resource areas are assessed qualitatively and quantitatively, as appropriate, in the SEIS.

NHTSA has considered the information contained in the SEIS as part of developing this proposal. The SEIS is available for public comment; instructions for the submission of comments are included inside the document. NHTSA will simultaneously issue the Final Environmental Impact Statement and Record of Decision, pursuant to 49 U.S.C. 304a(b), unless it is determined that statutory criteria or practicability considerations preclude simultaneous issuance. For additional information on NHTSA's NEPA analysis, please see the SEIS.

2. Clean Air Act (CAA) as Applied to NHTSA's Proposal

The CAA (42 U.S.C. 7401 *et seq.*) is the primary Federal legislation that addresses air quality. Under the authority of the CAA and subsequent amendments, EPA has established National Ambient Air Quality Standards (NAAQS) for six criteria pollutants, which are relatively commonplace pollutants that can accumulate in the atmosphere as a result of human activity. EPA is required to review each NAAQS every five years and to revise those standards as may be appropriate considering new scientific information.

The air quality of a geographic region is usually assessed by comparing the levels of criteria air pollutants found in the ambient air to the levels established by the NAAQS (taking into account, as well, the other elements of a NAAQS: Averaging time, form, and indicator). Concentrations of criteria pollutants within the air mass of a region are measured in parts of a pollutant per million parts (ppm) of air or in micrograms of a pollutant per cubic meter ($\mu g/m^3$) of air present in repeated air samples taken at designated monitoring locations using specified types of monitors. These ambient concentrations of each criteria pollutant are compared to the levels, averaging time, and form specified by the NAAQS in order to assess whether the region's air quality is in attainment with the NAAQS.

When the measured concentrations of a criteria pollutant within a geographic region are below those permitted by the NAAQS, EPA designates the region as an attainment area for that pollutant, while regions where concentrations of criteria pollutants exceed Federal standards are called nonattainment areas. Former nonattainment areas that are now in compliance with the NAAQS are designated as maintenance areas. Each State with a nonattainment area is required to develop and implement a State Implementation Plan (SIP) documenting how the region will reach attainment levels within time periods specified in the CAA. For maintenance areas, the SIP must document how the State intends to maintain compliance with the NAAQS. When EPA revises a NAAQS, each State must revise its SIP to address how it plans to attain the new standard.

No Federal agency may ''engage in, support in any way or provide financial assistance for, license or permit, or approve'' any activity that does not ''conform'' to a SIP or Federal Implementation Plan after EPA has approved or promulgated it.[555] Further, no Federal agency may ''approve, accept, or fund'' any transportation plan, program, or project developed pursuant to title 23 or chapter 53 of title 49, U.S.C., unless the plan, program or project has been found to ''conform'' to any applicable implementation plan in effect.[556] The purpose of these conformity requirements is to ensure that Federally sponsored or conducted activities do not interfere with meeting the emissions targets in SIPs, do not cause or contribute to new violations of the NAAQS, and do not impede the ability of a State to attain or maintain the NAAQS or delay any interim milestones. EPA has issued two sets of regulations to implement the conformity requirements:

(1) The Transportation Conformity Rule[557] applies to transportation plans, programs, and projects that are developed, funded, or approved under title 23 or chapter 53 of title 49, U.S.C.

(2) The General Conformity Rule[558] applies to all other Federal actions not covered under transportation conformity. The General Conformity Rule establishes emissions thresholds, or de minimis levels, for use in evaluating the conformity of an action that results in emissions increases.[559] If the net increases of direct and indirect emissions exceed any of these thresholds, and the action is not otherwise exempt, then a conformity determination is required. The conformity determination can entail air quality modeling studies, consultation with EPA and State air quality agencies, and commitments to revise the SIP or to implement measures to mitigate air quality impacts.

The proposed CAFE standards and associated program activities are not developed, funded, or approved under title 23 or chapter 53 of title 49, U.S.C. Accordingly, this action and associated program activities are not subject to transportation conformity. Under the General Conformity Rule, a conformity determination is required where a Federal action would result in total direct and indirect emissions of a criteria pollutant or precursor originating in nonattainment or maintenance areas equaling or exceeding the rates specified in 40 CFR 93.153(b)(1) and (2). As explained

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[555] 42 U.S.C.7506(c)(1).

[556] 42 U.S.C. 7506(c)(2).

[557] 40 CFR part 51, subpart T, and part 93, subpart A.

[558] 40 CFR part 51, subpart W, and part 93, subpart B.

[559] 40 CFR 93.153(b).

below, NHTSA's proposed action results in neither direct nor indirect emissions as defined in 40 CFR 93.152.

The General Conformity Rule defines direct emissions as ''those emissions of a criteria pollutant or its precursors that are caused or initiated by the Federal action and originate in a nonattainment area and occur at the same time and place as the action and are reasonably foreseeable.'' [560] NHTSA's proposed action would set fuel economy standards for light-duty vehicles. It therefore would not cause or initiate direct emissions consistent with the meaning of the General Conformity Rule.[561] Indeed, the proposal in aggregate reduces emissions, and to the degree the model predicts small (and time-limited) increases, these increases are based on a theoretical response by individuals to fuel economy prices and savings, which are at best indirect.

Indirect emissions under the General Conformity Rule are those emissions of a criteria pollutant or its precursors: That are caused or initiated by the Federal action and originate in the same nonattainment or maintenance area but occur at a different time or place as the action; that are reasonably foreseeable; that the agency can practically control; and for which the agency has continuing program responsibility.[562] Each element of the definition must be met to qualify as indirect emissions. NHTSA has determined that, for purposes of general conformity, emissions (if any) that may result from the proposed fuel economy standards would not be caused by NHTSA's action, but rather would occur because of subsequent activities the agency cannot practically control. ''[E]ven if a Federal licensing, rulemaking, or other approving action is a required initial step for a subsequent activity that causes emissions, such initial steps do not mean that a Federal agency can practically control any resulting emissions.'' [563]

As the CAFE program uses performance-based standards, NHTSA cannot control the technologies vehicle manufacturers use to improve the fuel economy of passenger cars and light trucks. Furthermore, NHTSA cannot control consumer purchasing (which affects average achieved fleetwide fuel economy) and driving behavior (*i.e.,* operation of motor vehicles, as measured by VMT). It is the combination of fuel economy technologies, consumer purchasing, and driving behavior that results in criteria pollutant or precursor emissions. For purposes of analyzing the environmental impacts of the proposal and alternatives under NEPA, NHTSA has made assumptions and estimates regarding all of these factors. The agency's SEIS projects that increases in air toxics and criteria pollutants would occur in some nonattainment areas under certain alternatives in the near term, although over the longer term, all action alternatives see improvements. However, the proposed standards and alternatives do not mandate specific manufacturer decisions, consumer purchasing, or driver behavior, and NHTSA cannot practically control any of them.[564]

In addition, NHTSA does not have the statutory authority to control the actual VMT by drivers. As the extent of emissions depends directly on the operation of motor vehicles, changes in any emissions that could result from NHTSA's proposed standards are not changes the agency can practically control or for which the agency has continuing program responsibility. Therefore, the proposed standards and alternative standards considered by NHTSA would not cause indirect emissions under the General Conformity Rule, and a general conformity determination is not required.

3. National Historic Preservation Act (NHPA)

The NHPA (54 U.S.C. 300101 *et seq.*) sets forth Government policies and procedures regarding ''historic properties''—that is, districts, sites, buildings, structures, and objects included on or eligible for the National Register of Historic Places. Section 106 of the NHPA requires Federal agencies to ''take into account'' the effects of their actions on historic properties.[565] NHTSA concludes that the NHPA is not applicable to this proposal because the promulgation of CAFE standards for light-duty vehicles is not the type of activity that has the potential to cause effects on historic properties. However, NHTSA includes a brief, qualitative discussion of the impacts of the alternatives on historical and cultural resources in the SEIS.

4. Fish and Wildlife Conservation Act (FWCA)

The FWCA (16 U.S.C. 2901 *et seq.*) provides financial and technical assistance to States for the development, revision, and implementation of conservation plans and programs for nongame fish and wildlife. In addition, the Act encourages all Federal departments and agencies to utilize their statutory and administrative authorities to conserve and to promote conservation of nongame fish and wildlife and their habitats. NHTSA concludes that the FWCA does not apply to this proposal because it does not involve the conservation of nongame fish and wildlife and their habitats.

5. Coastal Zone Management Act (CZMA)

The Coastal Zone Management Act (16 U.S.C. 1451 *et seq.*) provides for the presentation, protection, development, and (where possible) restoration and enhancement of the Nation's coastal zone resources. Under the statute, States are provided with funds and technical assistance in developing coastal zone management programs. Each participating State must submit its program to the Secretary of Commerce for approval. Once the program has been approved, any activity of a Federal agency, either within or outside of the coastal zone, that affects any land or water use or natural resource of the coastal zone must be carried out in a manner that is consistent, to the maximum extent practicable, with the enforceable policies of the State's program.[566]

NHTSA concludes that the CZMA does not apply to this proposal because it does not involve an activity within, or outside of, the Nation's coastal zones that affects any land or water use or natural resource of the coastal zone. NHTSA has, however, conducted a qualitative review in its SEIS of the related direct, indirect, and cumulative impacts, positive or negative, of all the alternatives on potentially affected resources, including coastal zones.

6. Endangered Species Act (ESA)

Under Section 7(a)(2) of the ESA, Federal agencies must ensure that actions they authorize, fund, or carry out are ''not likely to jeopardize the continued existence'' of any federally listed threatened or endangered species or result in the destruction or adverse

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[560] 40 CFR 93.152.

[561] Dep't of Transp. v. Pub. Citizen, 541 U.S. at 772 (''[T]he emissions from the Mexican trucks are not 'direct' because they will not occur at the same time or at the same place as the promulgation of the regulations.'') NHTSA's action is to establish fuel economy standards for MYs 2024–2026 passenger cars and light trucks; an emissions increase, if any, would occur in a different place and well after promulgation of an eventual final rule.

[562] 40 CFR 93.152.

[563] *Id.*

[564] *See, e.g.,* Dep't of Transp. v. Pub. Citizen, 541 U.S. 752, 772–73 (2004); South Coast Air Quality Management District v. Federal Energy Regulatory Commission, 621 F.3d 1085, 1101 (9th Cir. 2010).

[565] Section 106 is codified at 54 U.S.C. 306108. Implementing regulations for the Section 106 process are located at 36 CFR part 800.

[566] 16 U.S.C. 1456(c)(1)(A).

modification of the designated critical habitat of these species.[567] If a Federal agency determines that an agency action may affect a listed species or designated critical habitat, it must initiate consultation with the appropriate Service—the U.S. Fish and Wildlife Service of the Department of the Interior and/or the National Oceanic and Atmospheric Administration's National Marine Fisheries Service of the Department of Commerce, depending on the species involved—in order to ensure that the action is not likely to jeopardize the species or destroy or adversely modify designated critical habitat.[568] Under this standard, the Federal agency taking action evaluates the possible effects of its action and determines whether to initiate consultation.[569]

Pursuant to Section 7(a)(2) of the ESA, NHTSA has considered the effects of the proposed standards and has reviewed applicable ESA regulations, case law, and guidance to determine what, if any, impact there might be to listed species or designated critical habitat. NHTSA has considered issues related to emissions of CO_2 and other GHGs, and issues related to non-GHG emissions. Based on this assessment, NHTSA determines that the action of setting CAFE standards does not require consultation under Section 7(a)(2) of the ESA. Accordingly, NHTSA has concluded its review of this action under Section 7 of the ESA.

7. Floodplain Management (Executive Order 11988 and DOT Order 5650.2)

These orders require Federal agencies to avoid the long- and short-term adverse impacts associated with the occupancy and modification of floodplains, and to restore and preserve the natural and beneficial values served by floodplains. Executive Order 11988 also directs agencies to minimize the impacts of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains through evaluating the potential effects of any actions the agency may take in a floodplain and ensuring that its program planning and budget requests reflect consideration of flood hazards and floodplain management. DOT Order 5650.2 sets forth DOT policies and procedures for implementing Executive Order 11988. The DOT order requires that the agency determine if a proposed action is within the limits of a base floodplain, meaning it is encroaching on the floodplain, and whether this encroachment is significant. If significant, the agency is required to conduct further analysis of the proposed action and any practicable alternatives. If a practicable alternative avoids floodplain encroachment, then the agency is required to implement it.

In this proposal, NHTSA is not occupying, modifying, and/or encroaching on floodplains. NHTSA therefore concludes that the orders do not apply to this proposal. NHTSA has, however, conducted a review of the alternatives on potentially affected resources, including floodplains, in its SEIS.

8. Preservation of the Nation's Wetlands (Executive Order 11990 and DOT Order 5660.1a)

These orders require Federal agencies to avoid, to the extent possible, undertaking or providing assistance for new construction located in wetlands unless the agency head finds that there is no practicable alternative to such construction and that the proposed action includes all practicable measures to minimize harms to wetlands that may result from such use. Executive Order 11990 also directs agencies to take action to minimize the destruction, loss, or degradation of wetlands in ''conducting Federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulating, and licensing activities.'' DOT Order 5660.1a sets forth DOT policy for interpreting Executive Order 11990 and requires that transportation projects ''located in or having an impact on wetlands'' should be conducted to assure protection of the Nation's wetlands. If a project does have a significant impact on wetlands, an EIS must be prepared.

NHTSA is not undertaking or providing assistance for new construction located in wetlands. NHTSA therefore concludes that these orders do not apply to this proposal. NHTSA has, however, conducted a review of the alternatives on potentially affected resources, including wetlands, in its SEIS.

9. Migratory Bird Treaty Act (MTBA), Bald and Golden Eagle Protection Act (BGEPA), Executive Order 13186

The MTBA (16 U.S.C. 703–712) provides for the protection of certain migratory birds by making it illegal for anyone to ''pursue, hunt, take, capture, kill, attempt to take, capture, or kill, possess, offer for sale, sell, offer for barter, barter, offer to purchase, purchase, deliver for shipment, ship, export, import, cause to be shipped, exported, or imported, deliver for transportation, carry or cause to be carried, or receive for shipment, transportation, carriage, or export'' any migratory bird covered under the statute.[570]

The BGEPA (16 U.S.C. 668–668d) makes it illegal to ''take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import'' any bald or golden eagles.[571] Executive Order 13186, ''Responsibilities of Federal Agencies to Protect Migratory Birds,'' helps to further the purposes of the MBTA by requiring a Federal agency to develop a Memorandum of Understanding (MOU) with the Fish and Wildlife Service when it is taking an action that has (or is likely to have) a measurable negative impact on migratory bird populations.

NHTSA concludes that the MBTA, BGEPA, and Executive Order 13186 do not apply to this proposal because there is no disturbance, take, measurable negative impact, or other covered activity involving migratory birds or bald or golden eagles involved in this rulemaking.

10. Department of Transportation Act (Section 4(f))

Section 4(f) of the Department of Transportation Act of 1966 (49 U.S.C. 303), as amended, is designed to preserve publicly owned park and recreation lands, waterfowl and wildlife refuges, and historic sites. Specifically, Section 4(f) provides that DOT agencies cannot approve a transportation program or project that requires the use of any publicly owned land from a public park, recreation area, or wildlife or waterfowl refuge of national, State, or local significance, unless a determination is made that:

(1) There is no feasible and prudent alternative to the use of land, and

(2) The program or project includes all possible planning to minimize harm to the property resulting from the use.

These requirements may be satisfied if the transportation use of a Section 4(f) property results in a de minimis impact on the area.

NHTSA concludes that Section 4(f) does not apply to this proposal because this rulemaking is not an approval of a transportation program nor project that requires the use of any publicly owned land.

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[567] 16 U.S.C. 1536(a)(2).

[568] *See* 50 CFR 402.14.

[569] *See* 51 FR 9926, 19949 (Jun. 3, 1986).

[570] 16 U.S.C. 703(a).

[571] 16 U.S.C. 668(a).

11. Executive Order 12898: ''Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations''

Executive Order 12898, ''Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations'' (Feb. 16, 1994), directs Federal agencies to ''promote nondiscrimination in federal programs substantially affecting human health and the environment, and provide minority and low-income communities access to public information on, and an opportunity for public participation in, matters relating to human health or the environment.'' E.O. 12898 also directs agencies to identify and consider any disproportionately high and adverse human health or environmental effects that their actions might have on minority and low-income communities and provide opportunities for community input in the NEPA process. CEQ has provided agencies with general guidance on how to meet the requirements of the E.O. as it relates to NEPA. A White House Environmental Justice Interagency Council established under E.O. 14008, ''Tackling the Climate Crisis at Home and Abroad,'' is expected to advise CEQ on ways to update E.O. 12898, including the expansion of environmental justice advice and recommendations. The White House Environmental Justice Interagency Council will advise on increasing environmental justice monitoring and enforcement.

Additionally, the 2021 DOT Order 5610.2(c), ''U.S. Department of Transportation Actions to Address Environmental Justice in Minority Populations and Low-Income Populations'' (May 14, 2021), describes the process for DOT agencies to incorporate environmental justice principles in programs, policies, and activities. The DOT's Environmental Justice Strategy specifies that environmental justice and fair treatment of all people means that no population be forced to bear a disproportionate burden due to transportation decisions, programs, and policies. It also defines the term *minority* and *low-income* in the context of DOT's environmental justice analyses. *Minority* is defined as a person who is Black, Hispanic or Latino, Asian American, American Indian or Alaskan Native, or Native Hawaiian or other Pacific Islander. *Low-income* is defined as a person whose household income is at or below the Department of Health and Human Services poverty guidelines. Low-income and minority populations may live in geographic proximity or be geographically dispersed/transient. In 2021, DOT reviewed and updated its environmental justice strategy to ensure that it continues to reflect its commitment to environmental justice principles and integrating those principles into DOT programs, policies, and activities.

Section VI and the SEIS discuss NHTSA's consideration of environmental justice issues associated with this proposal.

12. Executive Order 13045: ''Protection of Children From Environmental Health Risks and Safety Risks''

This action is subject to Executive Order 13045 (62 FR 19885, Apr. 23, 1997) because it is an economically significant regulatory action as defined by E.O. 12866, and NHTSA has reason to believe that the environmental health and safety risks related to this action, although small, may have a disproportionate effect on children. Specifically, children are more vulnerable to adverse health effects related to mobile source emissions, as well as to the potential long-term impacts of climate change. Pursuant to E.O. 13045, NHTSA must prepare an evaluation of the environmental health or safety effects of the planned regulation on children and an explanation of why the planned regulation is preferable to other potentially effect and reasonably feasible alternatives considered by NHTSA. Further, this analysis may be included as part of any other required analysis.

All of the action alternatives would reduce CO_2 emissions relative to the baseline and thus have positive effects on mitigating global climate change, and thus environmental and health effects associated with climate change. While environmental and health effects associated with criteria pollutant and toxic air pollutant emissions vary over time and across alternatives, negative effects, when estimated, are extremely small. This preamble and the SEIS discuss air quality, climate change, and their related environmental and health effects, noting where these would disproportionately affect children. In addition, Section VI of this preamble explains why NHTSA believes that the proposed standards are preferable to other alternatives considered.

E. Regulatory Flexibility Act

Pursuant to the Regulatory Flexibility Act (5 U.S.C. 601 *et seq.,* as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996), whenever an agency is required to publish a notice of proposed rulemaking or final rule, it must prepare and make available for public comment a regulatory flexibility analysis that describes the effect of the rule on small entities (*i.e.,* small businesses, small organizations, and small governmental jurisdictions). No regulatory flexibility analysis is required if the head of an agency certifies the rule will not have a significant economic impact on a substantial number of small entities. SBREFA amended the Regulatory Flexibility Act to require Federal agencies to provide a statement of the factual basis for certifying that a rule will not have a significant economic impact on a substantial number of small entities.

NHTSA has considered the impacts of this proposed rule under the Regulatory Flexibility Act and certifies that this proposed rule would not have a significant economic impact on a substantial number of small entities. The following is NHTSA's statement providing the factual basis for this certification pursuant to 5 U.S.C. 605(b).

Small businesses are defined based on the North American Industry Classification System (NAICS) code.[572] One of the criteria for determining size is the number of employees in the firm. For establishments primarily engaged in manufacturing or assembling automobiles, as well as light duty trucks, the firm must have less than 1,500 employees to be classified as a small business. This rule would affect motor vehicle manufacturers. As shown in Table IX–1, the agency have identified 13 small manufacturers of passenger cars, light trucks, and SUVs of electric, hybrid, and internal combustion engines. NHTSA acknowledges that some newer manufacturers may not be listed. However, those new manufacturers tend to have transportation products that are not part of the light-duty vehicle fleet and have yet to start production of light-duty vehicles. Moreover, NHTSA does not believe that there are a ''substantial number'' of these newer companies.[573]

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[572] Classified in NAICS under Subsector 336—Transportation Equipment Manufacturing for Automobile Manufacturing (336111), Light Truck (336112), and Heavy Duty Truck Manufacturing (336120). *https://www.sba.gov/document/support--table-size-standards.*

[573] 5 U.S.C. 605(b).

Table IX-1 – Small Domestic Vehicle Manufacturers

Manufacturers	Founded	Employees[574]	Estimated Annual Production[575]	Sale Price per Unit
Karma Automotive	2014	< 1,000	<100	$95,000 to $120,000
BXR Motors	2008	< 10	< 100	$155,000 to $185,000
Falcon Motorsports	2009	< 10	< 100	$300,000 to $400,000
Lucra Cars	2005	< 50	< 100	$70,000 to $220,000
Lyons Motor Car	2012	< 10	< 100	$1,400,000
Rezvani Motors	2014	< 10	< 100	$155,000 to $260,000
Rossion Automotive	2007	< 50	< 100	$90,000
Saleen	1984	< 200	< 100	$100,000
Shelby American	1962	< 200	< 100	$60,000 to $250,000
Panoz	1988	< 50	< 100	$155,000 to $175,000
Faraday Future	2014	< 1,000	0	$200,000 to $300,000
SF Motors	2016	< 500	0	N/A
Workhorse Group	2007	< 200	0	$52,000
Lordstown Motors	2019	<1,000	0	$52,500

NHTSA believes that the proposed rulemaking would not have a significant economic impact on the small vehicle manufacturers because under 49 CFR part 525, passenger car manufacturers building fewer than 10,000 vehicles per year can petition NHTSA to have alternative standards set for those manufacturers. Listed manufacturers producing ICE vehicles do not currently meet the standard and must already petition the agency for relief. If the standard is raised, it has no meaningful impact on these manufacturers—they still must go through the same process and petition for relief. Given there already is a mechanism for relieving burden on small businesses, which is the purpose of the Regulatory Flexibility Act, a regulatory flexibility analysis was not prepared.

Further, small manufacturers of electric vehicles would not face a significant economic impact. The method for earning credits applies equally across manufacturers and does not place small entities at a significant competitive disadvantage. In any event, even if the rule had a ‘‘significant economic impact’’ on these small EV manufacturers, the amount of these companies is not ‘‘a substantial number.’’ [576] For these reasons, their existence does not alter the agency's analysis of the applicability of the Regulatory Flexibility Act.

F. Executive Order 13132 (Federalism)

Executive Order 13132 requires Federal agencies to develop an accountable process to ensure ‘‘meaningful and timely input by State and local officials in the development of regulatory policies that have federalism implications. The order defines the term ‘‘[p]olicies that have federalism implications’’ to include regulations that have ‘‘substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government.’’ Under the order, agencies may not issue a regulation that has federalism implications, that imposes substantial direct compliance costs, unless the Federal Government provides the funds necessary to pay the direct compliance costs incurred by the State and local governments, or the agencies consult with State and local officials early in the process of developing the proposed regulation. NHTSA has complied with the order's requirements and consulted directly with the California Air Resources Board in developing a number of elements of this proposal. This proposal would not impose direct compliance costs on State or local governments, because the only entities directly subject to the proposal are vehicle manufacturers.

With regard to the federalism implications of the proposal, NHTSA has spoken to this issue separately at 86 FR 25980 (May 12, 2021), ‘‘Corporate Average Fuel Economy (CAFE) Preemption,’’ notice of proposed rulemaking. Comments on preemption of State and local laws related to fuel economy standards that are received to *this* NPRM will be deemed late comments to *that* NPRM (the comment period for which has closed) and will be considered as time permits.

G. Executive Order 12988 (Civil Justice Reform)

Pursuant to Executive Order 12988, ‘‘Civil Justice Reform’’ (61 FR 4729, Feb. 7, 1996), NHTSA has considered whether this rulemaking would have any retroactive effect. This proposal does not have any retroactive effect.

H. Executive Order 13175 (Consultation and Coordination With Indian Tribal Governments)

This proposal does not have tribal implications, as specified in Executive Order 13175 (65 FR 67249, Nov. 9, 2000). This proposal, if finalized, would be implemented at the Federal level and would impose compliance costs only on vehicle manufacturers. Thus, Executive Order 13175, which requires consultation with Tribal officials when agencies are developing policies that have ‘‘substantial direct effects’’ on Tribes and Tribal interests, should not apply to this proposal.

I. Unfunded Mandates Reform Act

Section 202 of the Unfunded Mandates Reform Act of 1995 (UMRA) requires Federal agencies to prepare a written assessment of the costs, benefits, and other effects of a proposed or final rule that includes a Federal mandate likely to result in the expenditure by State, local, or Tribal governments, in the aggregate, or by the private sector, of

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[574] Estimated number of employees as of June 2021, source: *Linkedin.com* and other websites reporting company profiles.

[575] Rough estimate of light duty vehicle production for model year 2020.

[576] 5 U.S.C. 605.

more than $100 million in any one year (adjusted for inflation with base year of 1995). Adjusting this amount by the implicit gross domestic product price deflator for 2018 results in $153 million (110.296/71.868 = 1.53).[577] Before promulgating a rule for which a written statement is needed, section 205 of UMRA generally requires NHTSA to identify and consider a reasonable number of regulatory alternatives and adopt the least costly, most cost-effective, or least burdensome alternative that achieves the objective of the rule. The provisions of section 205 do not apply when they are inconsistent with applicable law. Moreover, section 205 allows NHTSA to adopt an alternative other than the least costly, most cost-effective, or least burdensome alternative if the agency publishes with the rule an explanation of why that alternative was not adopted.

This proposal would not result in the expenditure by State, local, or Tribal governments, in the aggregate, of more than $153 million annually, but it will result in the expenditure of that magnitude by vehicle manufacturers and/or their suppliers. In developing this proposal, NHTSA considered alternative fuel economy standards both lower and higher than the preferred alternative. NHTSA tentatively concludes that the preferred alternative represents the least costly, most cost-effective, and least burdensome alternative that achieves the objectives of the proposal.

J. Regulation Identifier Number

The Department of Transportation assigns a regulation identifier number (RIN) to each regulatory action listed in the Unified Agenda of Federal Regulations. The Regulatory Information Service Center publishes the Unified Agenda in April and October of each year. The RIN contained in the heading at the beginning of this document may be used to find this action in the Unified Agenda.

K. National Technology Transfer and Advancement Act

Section 12(d) of the National Technology Transfer and Advancement Act (NTTAA) requires NHTSA and EPA to evaluate and use existing voluntary consensus standards in its regulatory activities unless doing so would be inconsistent with applicable law (*e.g.,* the statutory provisions regarding NHTSA's vehicle safety authority) or otherwise impractical.[578]

Voluntary consensus standards are technical standards developed or adopted by voluntary consensus standards bodies. Technical standards are defined by the NTTAA as ''performance-based or design-specific technical specification and related management systems practices.'' They pertain to ''products and processes, such as size, strength, or technical performance of a product, process or material.''

Examples of organizations generally regarded as voluntary consensus standards bodies include the American Society for Testing and Materials (ASTM), the Society of Automotive Engineers (SAE), and the American National Standards Institute (ANSI). If NHTSA does not use available and potentially applicable voluntary consensus standards, it is required by the Act to provide Congress, through OMB, an explanation of the reasons for not using such standards. There are currently no consensus standards that NHTSA administers relevant to this proposed CAFE standards.

L. Department of Energy Review

In accordance with 49 U.S.C. 32902(j)(1), NHTSA submitted this rule to the Department of Energy for review. The Department of Energy concluded that the standard would not adversely affect its conservation goals.

M. Paperwork Reduction Act

Under the procedures established by the Paperwork Reduction Act of 1995 (PRA) (44 U.S.C. 3501, *et seq.*), Federal agencies must obtain approval from the OMB for each collection of information they conduct, sponsor, or require through regulations. A person is not required to respond to a collection of information by a Federal agency unless the collection displays a valid OMB control number.

NHTSA is seeking OMB's approval for a revision to NHTSA's existing information collection for its reporting requirements under the Corporate Average Fuel Economy (CAFE) program (OMB control number 2127–0019). These reporting requirements are necessary to ensure compliance with its CAFE program. As described in this NPRM, NHTSA is proposing changes to the CAFE program's standardized reporting templates for manufacturers to submit information to NHTSA on their vehicle production and CAFE credits used to comply with the CAFE standards. These changes, if adopted, will result in additional burden to respondents.

The Information Collection Request (ICR) for a revision of an existing information collection described below has been forwarded to OMB for review and comment. In compliance with the requirements of the PRA, NHTSA asks for public comments on the following proposed collection of information for which the agency is seeking approval from OMB.

Title: Corporate Average Fuel Economy.

OMB Control Number: 2127–0019.

Form Numbers: NHTSA Form 1474 (CAFE Projections Reporting Template), NHTSA Form 1475 (CAFE Credit Template) and NHTSA Form 1621 (CAFE Credit Trade Template).

Type of Request: Revision of a currently approved collection.

Type of Review Requested: Regular.

Requested Expiration Date of Approval: Three years from date of approval.

Summary of the Collection of Information: As established by Congress under EPCA, and later amended by EISA, and implemented through NHTSA's regulations for automobile manufacturers complying with CAFE standards prescribed in 49 U.S.C. 32902, many types of reporting provisions exist as a part of the CAFE program. These reporting provisions are necessary for NHTSA to ensure manufacturers comply with CAFE standards and other CAFE requirements. Manufacturers are required to submit information on CAFE standards, exemptions, vehicles, technologies, and submit CAFE compliance test results. Manufacturers also provide information on any of the flexibilities and incentives they use during the model year to comply with CAFE standards.

More specifically, the current collection includes burden hours for small volume manufacturers to request exemptions allowing them to comply with lower alternative CAFE standards to accommodate mainly the sale of exotic sportscars. It also includes hours for manufacturers reporting information on corporate mergers and splits. Other required reporting includes manufacturers submitting information to NHTSA on CAFE credit transactions, plans and other documents associated with the costs of credit trades. In the April 30, 2020, final rule, to help manufacturers better organize credit information, NHTSA also issued a new standardized template for manufacturers to report credit transactions and to prepare credit trade documents. The template could generate the necessary documents that both parties would sign

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[577] Bureau of Economic Analysis, National Income and Product Accounts (NIPA), Table 1.1.9 Implicit Price Deflators for Gross Domestic Product. *https://bea.gov/iTable/index_nipa.cfm.*

[578] 15 U.S.C. 272.

to facilitate credit trades as well as simplified the organization of other types of credit transactions in addition to correctly performing the necessary mathematical calculations. Finally, the current collection also includes hours for manufacturers to provide pre-model year (PMY) and mid-model year (MMY) CAFE reports to NHTSA and a standardized reporting template adopted in the April 30, 2020, final rule to help manufacturer submit these reports. PMY and MMY reports contain early projections of manufacturers' vehicle and fleet level data demonstrating how they intend to comply with CAFE standards.

As part of this rulemaking, NHTSA is amending its previously approved collection for CAFE-related collections of information. NHTSA is proposing making changes to its reporting template for PMY and MMY reports and adding a new template for reporting the cost of credit trades and is proposing to add the burden hours for these changes to this collection.

Manufacturers identified several changes that were needed to the CAFE reporting template to accommodate different types of vehicles which NHTSA incorporated along with other functional changes.

Manufacturers have also expressed concern that disclosing trading terms may not be as simple as a spot purchase at a given price. As discussed in the April 30, 2020, final rule, manufacturers contend that a number of transactions for both CAFE and CO_2 credits involve a range of complexity due to numerous factors that are reflective of the marketplace, such as the volume of credits, compliance category, credit expiration date, a seller's compliance strategy, and even the CAFE penalty rate in effect at that time. In addition, manufacturers have a range of partnerships and cooperative agreements with their own competitors. Credit transactions can be an offshoot of these broader relationships, and difficult to price separately and independently. Thus, manufacturers argue that there may not be a reasonable, or even meaningful, presentation of market information in a transaction price. Therefore, NHTSA has developed a new template for capturing the price of credit trades that includes certain monetary and non-monetary terms of credit trading contracts. NHTSA proposes that manufacturers start using the new template starting September 1, 2022.

Description of the Need for the Information and the Proposed Use of the Information: Regulated entities are required to respond to inquiries covered by this collection. 49 U.S.C. 32907. 49 CFR parts 525, 534, 536, and 537.

Affected Public: Respondents are manufacturers of engines and vehicles within the North American Industry Classification System (NAICS) and use the coding structure as defined by NAICS including codes 33611, 336111, 336112, 33631, 33631, 33632, 336320, 33635, and 336350 for motor vehicle and parts manufacturing.

Frequency of response: Variable, based on compliance obligation. Please see PRA supporting documentation in the docket for more detailed information.

Average burden time per response: Variable, based on compliance obligation. Please see PRA supporting documentation in the docket for more detailed information.

Number of respondents: 23.

1. Estimated Total Annual Burden Hours and Costs

Table IX-2 – Estimated Burden for Reporting Requirements

Applies to:	Manufacturer		Government	
	Hours	Cost	Hours	Cost
Prior Collection	4020.4	$208,042.23	3,038.00	$141,246.78
Current Collection	4286.7	$224,964.52	3,038.00	$154,490.83
Difference	266.3	$16,921.98	0	$13.244.05

Public Comments Invited: You are asked to comment on any aspects of this information collection, including (a) whether the proposed collection of information is necessary for the proper performance of the functions of the Department, including whether the information will have practical utility; (b) the accuracy of the Department's estimate of the burden of the proposed information collection; (c) ways to enhance the quality, utility and clarity of the information to be collected; and (d) ways to minimize the burden of the collection of information on respondents, including the use of automated collection techniques or other forms of information technology.

Please submit any comments, identified by the docket number in the heading of this document, by the methods described in the ADDRESSES section of this document to NHTSA and OMB. Although comments may be submitted during the entire comment period, comments received within 30 days of publication are most useful.

N. Privacy Act

In accordance with 5 U.S.C. 553(c), NHTSA is soliciting comments from the public to inform the rulemaking process better. These comments will post, without edit, to *www.regulations.gov,* as described in DOT's systems of records notice, DOT/ALL–14 FDMS, accessible through *https://www.transportation.gov/individuals/privacy/privacy-act-system-records-notices.* In order to facilitate comment tracking and response, NHTSA encourages commenters to provide their names or the names of their organizations; however, submission of names is completely optional.

List of Subjects in 49 CFR Parts 531, 533, 536, and 537

Fuel economy, Reporting and recordkeeping requirements.

Regulatory Text

For the reasons discussed in the preamble, the National Highway Traffic Safety Administration proposes to amend 49 CFR chapter V as follows:

■ 1. Revise part 531 to read as follows:

PART 531—PASSENGER AUTOMOBILE AVERAGE FUEL ECONOMY STANDARDS

Appendix A to Part 531—Example of Calculating Compliance Under § 531.5(c)

Authority: 49 U.S.C. 32902; delegation of authority at 49 CFR 1.95.

§ 531.1 Scope.

This part establishes average fuel economy standards pursuant to section 502 (a) and (c) of the Motor Vehicle Information and Cost Savings Act, as amended, for passenger automobiles.

§ 531.2 Purpose.

The purpose of this part is to increase the fuel economy of passenger automobiles by establishing minimum levels of average fuel economy for those vehicles.

§ 531.3 Applicability.

This part applies to manufacturers of passenger automobiles.

§ 531.4 Definitions.

(a) *Statutory terms.* (1) The terms *average fuel economy, manufacture, manufacturer,* and *model year* are used as defined in section 501 of the Act.

(2) The terms *automobile* and *passenger automobile* are used as defined in section 501 of the Act and in accordance with the determination in part 523 of this chapter.

(b) *Other terms.* As used in this part, unless otherwise required by the context—

(1) *Act* means the Motor Vehicle Information and Cost Savings Act, as amended by Pub. L. 94–163.

(2) [Reserved]

§ 531.5 Fuel economy standards.

(a) Except as provided in paragraph (f) of this section, each manufacturer of passenger automobiles shall comply with the fleet average fuel economy standards in Table 1 to this paragraph (a), expressed in miles per gallon, in the model year specified as applicable:

Table 1 to Paragraph (a)

Model year	Average fuel economy standard (miles per gallon)
1978	18.0
1979	19.0
1980	20.0
1981	22.0
1982	24.0
1983	26.0
1984	27.0
1985	27.5
1986	26.0
1987	26.0
1988	26.0
1989	26.5
1990 - 2010	27.5

(b) For model year 2011, a manufacturer's passenger automobile fleet shall comply with the fleet average fuel economy level calculated for that model year according to Figure 1 to this paragraph (b) and the appropriate values in Table 2 to this paragraph (b).

Figure 1 to Paragraph (b)

$$Required\_Fuel\_Economy\_Level = \frac{N}{\sum_i \frac{N_i}{T_i}}$$

Where:

N is the total number (sum) of passenger automobiles produced by a manufacturer;

N_i is the number (sum) of the *ith* passenger automobile model produced by the manufacturer; and

T_i is the fuel economy target of the *ith* model passenger automobile, which is determined according to the following formula, rounded to the nearest hundredth:

$$\frac{1}{\frac{1}{a} + \left(\frac{1}{b} - \frac{1}{a}\right)\frac{e^{(x-c)d}}{1 + e^{(x-c)d}}}$$

Where:

Parameters *a, b, c,* and *d* are defined in Table 2 of this paragraph (b);

e = 2.718; and

x = footprint (in square feet, rounded to the nearest tenth) of the vehicle model.

Table 2 to Paragraph (b)-Parameters for the Passenger Automobile Fuel Economy Targets

Model year	Parameters			
	a (mpg)	*b* (mpg)	*c* (gal/mi/ft^2)	*d* (gal/mi)
2011	31.20	24.00	51.41	1.91

(c) For model years 2012–2026, a manufacturer's passenger automobile fleet shall comply with the fleet average fuel economy level calculated for that model year according to Figure 2 to this paragraph (c) and the appropriate values in Table 3 to this paragraph (c).

Figure 2 to Paragraph (c)

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

Where:

$CAFE_{required}$ is the fleet average fuel economy standard for a given fleet (domestic passenger automobiles or import passenger automobiles);

Subscript *i* is a designation of multiple groups of automobiles, where each group's designation, *i.e., i* = 1, 2, 3, etc., represents automobiles that share a unique model type and footprint within the applicable fleet, either domestic passenger automobiles or import passenger automobiles;

$Production_i$ is the number of passenger automobiles produced for sale in the United States within each *ith* designation, *i.e.,* which share the same model type and footprint; and

$TARGET_i$ is the fuel economy target in miles per gallon (mpg) applicable to the footprint of passenger automobiles within each *ith* designation, *i.e.,* which share the same model type and footprint, calculated according to Figure 3 to this paragraph (c) and rounded to the nearest hundredth of a mpg, *i.e.,* 35.455 = 35.46 mpg, and the summations in the numerator and denominator are both performed over all models in the fleet in question.

Figure 3 to Paragraph (c)

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

Where:

TARGET is the fuel economy target (in mpg) applicable to vehicles of a given footprint (*FOOTPRINT,* in square feet);

Parameters *a, b, c,* and *d* are defined in Table 3 to this paragraph (c); and

The *MIN* and *MAX* functions take the minimum and maximum, respectively, of the included values.

Table 3 to Paragraph (c)—Parameters for the Passenger Automobile Fuel Economy Targets, MYs 2012-2026

Model year	Parameters			
	a (mpg)	*b* (mpg)	*c* (gal/mi/ft^2)	*d* (gal/mi)
2012	35.95	27.95	0.0005308	0.006057
2013	36.80	28.46	0.0005308	0.005410
2014	37.75	29.03	0.0005308	0.004725
2015	39.24	29.90	0.0005308	0.003719
2016	41.09	30.96	0.0005308	0.002573
2017	43.61	32.65	0.0005131	0.001896
2018	45.21	33.84	0.0004954	0.001811
2019	46.87	35.07	0.0004783	0.001729
2020	48.74	36.47	0.0004603	0.001643
2021	49.48	37.02	0.000453	0.00162
2022	50.24	37.59	0.000447	0.00159
2023	51.00	38.16	0.000440	0.00157
2024	55.44	41.48	0.000405	0.00144
2025	60.26	45.08	0.000372	0.00133
2026	65.60	49.00	0.000343	0.00122

(d) In addition to the requirements of paragraphs (b) and (c) of this section, each manufacturer shall also meet the minimum fleet standard for domestically manufactured passenger automobiles expressed in Table 4 to this paragraph (d):

Table 4 to Paragraph (d)—Minimum Fuel Economy Standards for Domestically Manufactured Passenger Automobiles, MYs 2011-2026

Model year	Minimum standard
2011	27.8
2012	30.7
2013	31.4
2014	32.1
2015	33.3
2016	34.7
2017	36.7
2018	38.0
2019	39.4
2020	40.9
2021	39.9
2022	40.6
2023	41.1
2024	44.4
2025	48.2
2026	52.4

(e) The following manufacturers shall comply with the standards indicated in paragraphs (e)(1) through (15) of this section for the specified model years:

(1) *Avanti Motor Corporation.*

Table 5 to Paragraph (e)(1)--Average Fuel Economy Standard

Model year	Miles per gallon
1978	16.1
1979	14.5
1980	15.8
1981	18.2
1982	18.2
1983	16.9
1984	16.9
1985	16.9

(2) *Rolls-Royce Motors, Inc.*

Table 6 to Paragraph (e)(1)--Average Fuel Economy Standard

Model year	Miles per gallon
1978	10.7
1979	10.8
1980	11.1

1981	10.7
1982	10.6
1983	9.9
1984	10.0
1985	10.0
1986	11.0
1987	11.2
1988	11.2
1989	11.2
1990	12.7
1991	12.7
1992	13.8
1993	13.8
1994	13.8
1995	14.6
1996	14.6
1997	15.1
1998	16.3
1999	16.3

(3) *Checker Motors Corporation.*

Table 7 to Paragraph (e)(3)--Average Fuel Economy Standard

Model year	Miles per gallon
1978	17.6
1979	16.5
1980	18.5
1981	18.3
1982	18.4

(4) *Aston Martin Lagonda, Inc.*

Table 8 to Paragraph (e)(4)--Average Fuel Economy Standard

Model year	Miles per gallon
1979	11.5
1980	12.1
1981	12.2
1982	12.2
1983	11.3
1984	11.3
1985	11.4

(5) *Excalibur Automobile Corporation.*

Table 9 to Paragraph (e)(5)--Average Fuel Economy Standard

Model year	Miles per gallon
1978	11.5
1979	11.5
1980	16.2
1981	17.9
1982	17.9
1983	16.6
1984	16.6
1985	16.6

(6) *Lotus Cars Ltd.*

Table 10 to Paragraph (e)(6)--Average Fuel Economy Standard

Model year	Miles per gallon
1994	24.2
1995	23.3

(7) *Officine Alfieri Maserati, S.p.A.*

Table 11 to Paragraph (e)(7)--Average Fuel Economy Standard

Model year	Miles per gallon
1978	12.5
1979	12.5

(8) *Lamborghini of North America.*

Table 12 to Paragraph (e)(8)--Average Fuel Economy Standard

Model year	Miles per gallon
1983	13.7
1984	13.7

(9) *LondonCoach Co., Inc.*

Table 13 to Paragraph (e)(9)--Average Fuel Economy Standard

Model year	Miles per gallon
1985	21.0
1986	21.0
1987	21.0

(10) *Automobili Lamborghini S.p.A./ Vector Aeromotive Corporation.*

Table 14 to Paragraph (e)(10)--Average Fuel Economy Standard

Model year	Miles per gallon
1995	12.8
1996	12.6
1997	12.5

(11) *Dutcher Motors, Inc.*

Table 15 to Paragraph (e)(11)--Average Fuel Economy Standard

Model year	Miles per gallon
1986	16.0
1987	16.0
1988	16.0
1992	17.0
1993	17.0
1994	17.0
1995	17.0

(12) *MedNet, Inc.*

Table 16 to Paragraph (e)(12)--Average Fuel Economy Standard

Model year	Miles per gallon
1996	17.0
1997	17.0
1998	17.0

(13) *Vector Aeromotive Corporation.*

Table 17 to Paragraph (e)(13)--Average Fuel Economy Standard

Model year	Miles per gallon
1998	12.1

(14) *Qvale Automotive Group Srl.*

Table 18 to Paragraph (e)(14)--Average Fuel Economy Standard

Model year	Miles per gallon
2000	22.0
2001	22.0

(15) *Spyker Automobielen B.V.*

Table 19 to Paragraph (e)(15)--Average Fuel Economy Standard

Model year	Miles per gallon
2006	18.9
2007	18.9

§ 531.6 Measurement and calculation procedures.

(a) The fleet average fuel economy performance of all passenger automobiles that are manufactured by a manufacturer in a model year shall be determined in accordance with procedures established by the Administrator of the Environmental Protection Agency (EPA) under 49 U.S.C. 32904 and set forth in 40 CFR part 600.

(b) For model years 2017 and later, a manufacturer is eligible to increase the fuel economy performance of passenger cars in accordance with procedures established by the EPA set forth in 40 CFR part 600, subpart F, including any adjustments to fuel economy the EPA allows, such as for fuel consumption improvements related to air conditioning efficiency and off-cycle technologies. Manufacturers must provide reporting on these technologies as specified in 49 CFR 537.7 by the required deadlines.

(1) *Efficient air conditioning technologies.* A manufacturer that seeks to increase its fleet average fuel economy performance through the use of technologies that improve the efficiency of air conditioning systems must follow the requirements in 40 CFR 86.1868–12. Fuel consumption improvement values resulting from the use of those air conditioning systems must be determined in accordance with 40 CFR 600.510–12(c)(3)(i).

(2) *Off-cycle technologies on EPA's predefined list or using 5-cycle testing.* A manufacturer that seeks to increase its fleet average fuel economy performance through the use of off-cycle technologies must follow the requirements in 40 CFR 86.1869–12. A manufacturer is eligible to gain fuel consumption improvements for predefined off-cycle technologies in accordance with 40 CFR 86.1869–12(b) or for technologies tested using the EPA's 5-cycle methodology in accordance with 40 CFR 86.1869–12(c). The fuel consumption improvement is determined in accordance with 40 CFR 600.510–12(c)(3)(ii).

(3) *Off-cycle technologies using the alternative EPA-approved methodology.* A manufacturer is eligible to increase its fuel economy performance through use of an off-cycle technology requiring an application request made to the EPA in accordance with 40 CFR 86.1869–12(d).

(i) *Eligibility under the corporate average fuel economy (CAFE) program requires compliance with paragraphs (b)(3)(i)(A) through (C) of this section.* Paragraphs (b)(3)(i)(A), (B), and (D) of this section apply starting in model year 2024.

(A) A manufacturer seeking to increase its fuel economy performance using the alternative methodology for an off-cycle technology, if prior to the applicable model year, must submit to EPA a detailed analytical plan and be approved (*i.e.,* for its planned test procedure and model types for demonstration) in accordance with 40 CFR 86.1869–12(d).

(B) A manufacturer seeking to increase its fuel economy performance using the alternative methodology for an off-cycle technology must also submit an official credit application to EPA and obtain approval in accordance with 40 CFR 86.1869–12(e) prior to September of the given model year.

(C) Manufacturer's plans, applications, and requests approved by the EPA must be made in consultation with the National Highway Traffic Safety Administration (NHTSA). To expedite NHTSA's consultation with the EPA, a manufacturer must concurrently submit its application to NHTSA if the manufacturer is seeking off-cycle fuel economy improvement values under the CAFE program for those technologies. For off-cycle technologies that are covered under 40 CFR 86.1869–12(d), NHTSA will consult with the EPA regarding NHTSA's evaluation of the specific off-cycle technology to ensure its impact on fuel economy and the suitability of using the off-cycle technology to adjust the fuel economy performance.

(D) A manufacturer may request an extension from NHTSA for more time to obtain an EPA approval. Manufacturers should submit their requests 30 days before the deadlines in paragraphs (b)(3)(i)(A) through (C) of this section. Requests should be submitted to NHTSA's Director of the Office of Vehicle Safety Compliance at *cafe@dot.gov.*

(ii) *Review and approval process.* NHTSA will provide its views on the suitability of using the off-cycle technology to adjust the fuel economy performance to the EPA. NHTSA's evaluation and review will consider:

(A) Whether the technology has a direct impact upon improving fuel economy performance;

(B) Whether the technology is related to crash-avoidance technologies, safety critical systems or systems affecting safety-critical functions, or technologies designed for the purpose of reducing the frequency of vehicle crashes;

(C) Information from any assessments conducted by the EPA related to the application, the technology and/or related technologies; and

(D) Any other relevant factors.

(iii) *Safety.* (A) Technologies found to be defective, or identified as a part of NHTSA's safety defects program, and technologies that are not performing as intended, will have the values of approved off-cycle credits removed from the manufacturer's credit balance or adjusted if the manufacturers can remedy the defective technology. NHTSA will consult with the manufacturer to determine the amount of the adjustment.

(B) Approval granted for innovative and off-cycle technology credits under NHTSA's fuel efficiency program does not affect or relieve the obligation to comply with the Vehicle Safety Act (49 U.S.C. Chapter 301), including the ''make inoperative'' prohibition (49 U.S.C. 30122), and all applicable Federal motor vehicle safety standards issued thereunder (FMVSSs) (49 CFR part 571). In order to generate off-cycle or innovative technology credits manufacturers must state—

(*1*) That each vehicle equipped with the technology for which they are seeking credits will comply with all applicable FMVSS(s); and

(*2*) Whether or not the technology has a fail-safe provision. If no fail-safe provision exists, the manufacturer must explain why not and whether a failure of the innovative technology would affect the safety of the vehicle.

Appendix A to Part 531—Example of Calculating Compliance Under § 531.5(c)

Assume a hypothetical manufacturer (Manufacturer X) produces a fleet of domestic passenger automobiles in MY 2012 as follows:

TABLE I TO APPENDIX A

Model type						
Group	**Carline name**	**Basic engine (L)**	**Transmission class**	**Description**	**Actual measured fuel economy (mpg)**	**Volume**
1	PC A FWD	1.8	A5	2-door sedan	34.0	1,500
2	PC A FWD	1.8	M6	2-door sedan	34.6	2,000
3	PC A FWD	2.5	A6	4-door wagon	33.8	2,000
4	PC A AWD	1.8	A6	4-door wagon	34.4	1,000
5	PC A AWD	2.5	M6	2-door hatchback	32.9	3,000
6	PC B RWD	2.5	A6	4-door wagon	32.2	8,000
7	PC B RWD	2.5	A7	4-door sedan	33.1	2,000
8	PC C AWD	3.2	A7	4-door sedan	30.6	5,000
9	PC C FWD	3.2	M6	2-door coupe	28.5	3,000
Total						27,500

Note to this Table I: Manufacturer X's required fleet average fuel economy standard level would first be calculated by determining the fuel economy targets applicable to each unique model type and footprint combination for model type groups 1-9 as illustrated in Table II to this appendix:

Manufacturer X calculates a fuel economy target standard for each unique model type and footprint combination.

TABLE II TO APPENDIX A

Model type				Description	Base tire size	Wheelbase (inches)	Track width F&R average (inches)	Footprint (ft^2)	Volume	Fuel economy target standard (mpg)
Group	Carline name	Basic engine (L)	Transmission class							
1	PC A FWD	1.8	A5	2-door sedan	205/75 R14	99.8	61.2	42.4	1,500	35.01
2	PC A FWD	1.8	M6	2-door sedan	215/70 R15	99.8	60.9	42.2	2,000	35.14
3	PC A FWD	2.5	A6	4-door wagon	215/70 R15	100.0	60.9	42.3	2,000	35.08
4	PC A AWD	1.8	A6	4-door wagon	235/60 R15	100.0	61.2	42.5	1,000	35.95
5	PC A AWD	2.5	M6	2-door hatchback	225/65 R16	99.6	59.5	41.2	3,000	35.81
6	PC B RWD	2.5	A6	4-door wagon	265/55 R18	109.2	66.8	50.7	8,000	30.33
7	PC B RWD	2.5	A7	4-door sedan	235/65 R17	109.2	67.8	51.4	2,000	29.99
8	PC C AWD	3.2	A7	4-door sedan	265/55 R18	111.3	67.8	52.4	5,000	29.52

9	PC C FWD	3.2	M6	2-door coupe	225/65 R16	111.3	67.2	51.9	3,000	29.76
Total									27,500	

Note to this Table II: With the appropriate fuel economy targets determined for each unique model type and footprint combination, Manufacturer X's required fleet average fuel economy standard would be calculated as illustrated in Figure 1 to this appendix:

Figure 1 to Appendix A—Calculation of Manufacturer X's Fleet Average Fuel Economy Standard using Table II to Appendix A

$$Fleet\ Average\ Fuel\ Economy\ Standard = \frac{(Manufacturer's\ Domestic\ Passenger\ Automobile\ Production\ for\ Applicable\ Model\ Year)}{\sum_i \left(\frac{Group_1\ Production}{Group_1 Target\ Standard} + \frac{Group_2\ Production}{Group_{12a} Target\ Standard} + \cdots \frac{Group_9\ Production}{Group_9 Target\ Standard}\right)}$$

$$Fleet\ Average\ Fuel\ Economy\ Standard = \frac{(27{,}500)}{\left(\frac{1500}{35.01} + + \frac{2000}{35.14} + \frac{2000}{35.08} + \frac{1000}{35.95} + \frac{3000}{35.81} + + \frac{8000}{30.33} + \frac{2000}{29.99} + \frac{5000}{29.52} + \frac{3000}{29.79}\right)} = 31.6\text{mpg}$$

Figure 2 to Appendix A—Calculation of Manufacturer X's Actual Fleet Average Fuel Economy Performance Level using Table I to Appendix A

$$Fleet\ Average\ Fuel\ Economy\ Performance = \frac{(Manufacturer's\ Domestic\ Passenger\ Automobile\ Production\ for\ Applicable\ Model\ Year)}{\sum_i \left(\frac{Group_1\ Production}{Group_1 Performance} + \frac{Group_2\ Production}{Group_2 Performance} + \cdots \frac{Group_9\ Production}{Group_9 Performance}\right)}$$

$$Fleet\ Average\ Fuel\ Economy\ Performance = \frac{(27{,}500)}{\left(\frac{1500}{34.0} + \frac{2000}{34.6} + \frac{2000}{33.8} + \frac{1000}{34.4} + \frac{3000}{32.9} + \frac{8000}{32.2} + \frac{2000}{33.1} + \frac{5000}{30.6} + \frac{3000}{28.5}\right)} = 32.0\text{ mpg}$$

Note to Figure 2 to this appendix: Since the actual fleet average fuel economy performance of Manufacturer X's fleet is 32.0 mpg, as compared to its required fleet fuel economy standard of 31.6 mpg, Manufacturer X complied with the CAFE standard for MY 2012 as set forth in §531.5(c).

2. Revise part 533 to read as follows:

PART 533—LIGHT TRUCK FUEL ECONOMY STANDARDS

Authority: 49 U.S.C. 32902; delegation of authority at 49 CFR 1.95.

§ 533.1 Scope.

This part establishes average fuel economy standards pursuant to section 502(b) of the Motor Vehicle Information and Cost Savings Act, as amended, for light trucks.

§ 533.2 Purpose.

The purpose of this part is to increase the fuel economy of light trucks by establishing minimum levels of average fuel economy for those vehicles.

§ 533.3 Applicability.

This part applies to manufacturers of light trucks.

§ 533.4 Definitions.

(a) *Statutory terms.* (1) The terms *average fuel economy, average fuel economy standard, fuel economy, import, manufacture, manufacturer,* and *model year* are used as defined in section 501 of the Act.

(2) The term *automobile* is used as defined in section 501 of the Act and in accordance with the determinations in part 523 of this chapter.

(3) The term *domestically manufactured* is used as defined in section 503(b)(2)(E) of the Act.

(b) *Other terms.* As used in this part, unless otherwise required by the context—

(1) *Act* means the Motor Vehicle Information Cost Savings Act, as amended by Public Law 94–163.

(2) *Light truck* is used in accordance with the determinations in part 523 of this chapter.

(3) *Captive import* means with respect to a light truck, one which is not domestically manufactured but which is imported in the 1980 model year or thereafter by a manufacturer whose principal place of business is in the United States.

(4) *4-wheel drive, general utility vehicle* means a 4-wheel drive, general purpose automobile capable of off-highway operation that has a wheelbase of not more than 280 centimeters, and that has a body shape similar to 1977 Jeep CJ–5 or CJ–7, or the 1977 Toyota Land Cruiser.

(5) *Basic engine* means a unique combination of manufacturer, engine displacement, number of cylinders, fuel system (as distinguished by number of carburetor barrels or use of fuel injection), and catalyst usage.

(6) *Limited product line light truck* means a light truck manufactured by a manufacturer whose light truck fleet is powered exclusively by basic engines which are not also used in passenger automobiles.

§ 533.5 Requirements.

(a) Each manufacturer of light trucks shall comply with the following fleet average fuel economy standards, expressed in miles per gallon, in the model year specified as applicable:

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Table 1 to Paragraph (a)

Model year	2-wheel drive light trucks		4-wheel drive light trucks		Limited product line light trucks
	Captive imports	Other	Captive imports	Other	
1979	17.2	15.8			
1980	16.0	16.0	14.0	14.0	14.0
1981	16.7	16.7	15.0	15.0	14.5

Table 2 to Paragraph (a)

Model year	Combined standard		2-wheel drive light trucks		4-wheel drive light trucks	
	Captive imports	Others	Captive imports	Others	Captive imports	Others
1982	17.5	17.5	18.0	18.0	16.0	16.0
1983	19.0	19.0	19.5	19.5	17.5	17.5
1984	20.0	20.0	20.3	20.3	18.5	18.5
1985	19.5	19.5	19.7	19.7	18.9	18.9
1986	20.0	20.0	20.5	20.5	19.5	19.5
1987	20.5	20.5	21.0	21.0	19.5	19.5
1988	20.5	20.5	21.0	21.0	19.5	19.5
1989	20.5	20.5	21.5	21.5	19.0	19.0
1990	20.0	20.0	20.5	20.5	19.0	19.0
1991	20.2	20.2	20.7	20.7	19.1	19.1

Table 3 to Paragraph (a)

Model year	Combined standard	
	Captive imports	Other
1992	20.2	20.2
1993	20.4	20.4
1994	20.5	20.5
1995	20.6	20.6

Table 4 to Paragraph (a)

Model year	Standard
2001	20.7
2002	20.7
2003	20.7
2004	20.7
2005	21.0
2006	21.6
2007	22.2
2008	22.5
2009	23.1
2010	23.5

Figure 1 to Paragraph (a)

$$Required\_Fuel\_Economy\_Level = \frac{N}{\sum_i \frac{N_i}{T_i}}$$

Where:

N is the total number (sum) of light trucks produced by a manufacturer;

N_i is the number (sum) of the *ith* light truck model type produced by a manufacturer; and

T_i is the fuel economy target of the *ith* light truck model type, which is determined according to the following formula, rounded to the nearest hundredth:

$$T = \frac{1}{\frac{1}{a} + \left(\frac{1}{b} - \frac{1}{a}\right)\frac{e^{(x-c)d}}{1 + e^{(x-c)d}}}$$

Where:

Parameters *a, b, c,* and *d* are defined in Table 5 to this paragraph (a);

e = 2.718; and

x = footprint (in square feet, rounded to the nearest tenth) of the model type.

Table 5 to Paragraph (a)—Parameters for the Light Truck Fuel Economy Targets for MYs 2008-2011

Model year	**Parameters**			
	***a* (mpg)**	***b* (mpg)**	***c* (gal/mi/ft^2)**	***d* (gal/mi)**
2008	28.56	19.99	49.30	5.58
2009	30.07	20.87	48.00	5.81
2010	29.96	21.20	48.49	5.50
2011	27.10	21.10	56.41	4.28

Figure 2 to Paragraph (a)

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

Where:

$CAFE_{required}$ is the fleet average fuel economy standard for a given light truck fleet;

Subscript i is a designation of multiple groups of light trucks, where each group's designation, *i.e., i* = 1, 2, 3, etc., represents light trucks that share a unique model type and footprint within the applicable fleet;

$Production_i$ is the number of light trucks produced for sale in the United States within each $_{ith}$ designation, *i.e.,* which share the same model type and footprint; and

$TARGET_i$ is the fuel economy target in miles per gallon (mpg) applicable to the footprint of light trucks within each *ith* designation, *i.e.,* which share the same model type and footprint, calculated according to either Figure 3 or Figure 4 to this paragraph (a), as appropriate, and rounded to the nearest hundredth of a mpg, *i.e.,* 35.455 = 35.46 mpg, and the summations in the numerator and denominator are both performed over all models in the fleet in question.

Figure 3 to Paragraph (a)

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

Where:

TARGET is the fuel economy target (in mpg) applicable to vehicles of a given footprint (*FOOTPRINT,* in square feet);

Parameters *a, b, c,* and *d* are defined in Table 6 to this paragraph (a); and

The *MIN* and *MAX* functions take the minimum and maximum, respectively, of the included values.

Table 6 to Paragraph (a)—Parameters for the Light Truck Fuel Economy Targets for MYs 2012-2016

Model year	Parameters			
	a (mpg)	*b* (mpg)	*c* (gal/mi/ft^2)	*d* (gal/mi)
2012	29.82	22.27	0.0004546	0.014900
2013	30.67	22.74	0.0004546	0.013968
2014	31.38	23.13	0.0004546	0.013225
2015	32.72	23.85	0.0004546	0.011920
2016	34.42	24.74	0.0004546	0.010413

Figure 4 to Paragraph (a)

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

Where:

TARGET is the fuel economy target (in mpg) applicable to vehicles of a given footprint (*FOOTPRINT*, in square feet);

Parameters *a, b, c, d, e, f, g,* and *h* are defined in Table 7 to this paragraph (a); and

The *MIN* and *MAX* functions take the minimum and maximum, respectively, of the included values.

Table 7 to Paragraph (a)—Parameters for the Light Truck Fuel Economy Targets for MYs 2017-2026

	Parameters							
Model year	***a*** **(mpg)**	***b*** **(mpg)**	***c*** **(gal/mi/ft^2)**	***d*** **(gal/mi)**	***e*** **(mpg)**	***f*** **(mpg)**	***g*** **(gal/mi/ft^2)**	***h*** **(gal/mi)**
2017	36.26	25.09	0.0005484	0.005097	35.10	25.09	0.0004546	0.009851
2018	37.36	25.20	0.0005358	0.004797	35.31	25.20	0.0004546	0.009682
2019	38.16	25.25	0.0005265	0.004623	35.41	25.25	0.0004546	0.009603
2020	39.11	25.25	0.0005140	0.004494	35.41	25.25	0.0004546	0.009603
2021	39.71	25.63	0.000506	0.00443	NA	NA	NA	NA
2022	40.31	26.02	0.000499	0.00436	NA	NA	NA	NA
2023	40.93	26.42	0.000491	0.00429	NA	NA	NA	NA
2024	44.48	26.74	0.000452	0.00395	NA	NA	NA	NA
2025	48.35	29.07	0.000416	0.00364	NA	NA	NA	NA
2026	52.56	31.60	0.000382	0.00334	NA	NA	NA	NA

(b)(1) For model year 1979, each manufacturer may:

(i) Combine its 2- and 4-wheel drive light trucks and comply with the average fuel economy standard in paragraph (a) of this section for 2-wheel drive light trucks; or

(ii) Comply separately with the two standards specified in paragraph (a) of this section.

(2) For model year 1979, the standard specified in paragraph (a) of this section for 4-wheel drive light trucks applies only to 4-wheel drive general utility vehicles. All other 4-wheel drive light trucks in that model year shall be included in the 2-wheel drive category for compliance purposes.

(c) For model years 1980 and 1981, manufacturers of limited product line light trucks may:

(1) Comply with the separate standard for limited product line light trucks; or

(2) Comply with the other standards specified in paragraph (a) of this section, as applicable.

(d) For model years 1982–91, each manufacture may:

(1) Combine its 2- and 4-wheel drive light trucks (segregating captive import and other light trucks) and comply with the combined average fuel economy standard specified in paragraph (a) of this section; or

(2) Comply separately with the 2-wheel drive standards and the 4-wheel drive standards (segregating captive import and other light trucks) specified in paragraph (a) of this section.

(e) For model year 1992, each manufacturer shall comply with the average fuel economy standard specified in paragraph (a) of this section (segregating captive import and other light trucks).

(f) For each model year 1996 and thereafter, each manufacturer shall combine its captive imports with its other light trucks and comply with the fleet average fuel economy standard in paragraph (a) of this section.

(g) For model years 2008–2010, at a manufacturer's option, a manufacturer's light truck fleet may comply with the fuel economy standard calculated for each model year according to Figure 1 to paragraph (a) of this section and the appropriate values in Table 5 to paragraph (a) of this section, with said option being irrevocably chosen for that model year and reported as specified in § 537.8 of this chapter.

(h) For model year 2011, a manufacturer's light truck fleet shall comply with the fleet average fuel economy standard calculated for that model year according to Figure 1 to paragraph (a) of this section and the appropriate values in Table 5 to paragraph (a) of this section.

(i) For model years 2012–2016, a manufacturer's light truck fleet shall comply with the fleet average fuel economy standard calculated for that model year according to Figures 2 and 3 to paragraph (a) of this section and the appropriate values in Table 6 to paragraph (a) of this section.

(j) For model years 2017–2025, a manufacturer's light truck fleet shall comply with the fleet average fuel economy standard calculated for that model year according to Figures 2 and 4 to paragraph (a) of this section and the appropriate values in Table 7 to paragraph (a) of this section.

§ 533.6 Measurement and calculation procedures.

(a) Any reference to a class of light trucks manufactured by a manufacturer shall be deemed—

(1) To include all light trucks in that class manufactured by persons who control, are controlled by, or are under common control with, such manufacturer; and

(2) To include only light trucks which qualify as non-passenger vehicles in accordance with 49 CFR 523.5 based upon the production measurements of the vehicles as sold to dealerships; and

(3) To exclude all light trucks in that class manufactured (within the meaning of paragraph (a)(1) of this section) during a model year by such manufacturer which are exported prior to the expiration of 30 days following the end of such model year.

(b) The fleet average fuel economy performance of all light trucks that are manufactured by a manufacturer in a model year shall be determined in accordance with procedures established by the Administrator of the Environmental Protection Agency (EPA) under 49 U.S.C. 32904 and set forth in 40 CFR part 600.

(c) For model years 2017 and later, a manufacturer is eligible to increase the fuel economy performance of light trucks in accordance with procedures established by the EPA set forth in 40 CFR part 600, subpart F, including any adjustments to fuel economy the EPA allows, such as for fuel consumption improvements related to air conditioning efficiency, off-cycle technologies, and hybridization and other performance-based technologies for full-size pickup trucks that meet the requirements specified in 40 CFR 86.1803. Manufacturers must provide reporting on these technologies as specified in 49 CFR 537.7 by the required deadlines.

(1) *Efficient air conditioning technologies.* A manufacturer that seeks to increase its fleet average fuel economy performance through the use of technologies that improve the efficiency of air conditioning systems must follow the requirements in 40 CFR 86.1868–12. Fuel consumption improvement values resulting from the use of those air conditioning systems must be determined in accordance with 40 CFR 600.510–12(c)(3)(i).

(2) *Incentives for advanced full-size light-duty pickup trucks.* The eligibility of a manufacturer to increase its fuel economy using hybridized and other performance-based technologies for full-size pickup trucks must follow 40 CFR 86.1870–12 and the fuel consumption improvement of these full-size pickup truck technologies must be determined in accordance with 40 CFR 600.510–12(c)(3)(iii). Manufacturers may also combine incentives for full size pickups and dedicated alternative fueled vehicles when calculating fuel economy performance values in 40 CFR 600.510–12.

(3) *Off-cycle technologies on EPA's predefined list or using 5-cycle testing.* A manufacturer that seeks to increase its fleet average fuel economy performance through the use of off-cycle technologies must follow the requirements in 40 CFR 86.1869–12. A manufacturer is eligible to gain fuel consumption improvements for predefined off-cycle technologies in accordance with 40 CFR 86.1869–12(b) or for technologies tested using the EPA's 5-cycle methodology in accordance with 40 CFR 86.1869–12(c). The fuel consumption improvement is determined in accordance with 40 CFR 600.510–12(c)(3)(ii).

(4) *Off-cycle technologies using the alternative EPA-approved methodology.* A manufacturer is eligible to increase its fuel economy performance through use of an off-cycle technology requiring an application request made to the EPA in accordance with 40 CFR 86.1869–12(d).

(i) *Eligibility under the corporate average fuel economy (CAFE) program requires compliance with paragraphs (c)(4)(i)(A) through (C) of this section.* Paragraphs (c)(4)(i)(A) through (C) of this section apply starting in model year 2024.

(A) A manufacturer seeking to increase its fuel economy performance using the alternative methodology for an off-cycle technology, if prior to the applicable model year, must submit to EPA a detailed analytical plan and be approved (*i.e.,* for its planned test procedure and model types for demonstration) in accordance with 40 CFR 86.1869–12(d).

(B) A manufacturer seeking to increase its fuel economy performance using the alternative methodology for an off-cycle technology must also submit an official credit application to EPA and obtain approval in accordance with 40 CFR 86.1869–12(e) prior to September of the given model year.

(C) Manufacturer's plans, applications and requests approved by the EPA must be made in consultation with the National Highway Traffic Safety Administration (NHTSA). To expedite NHTSA's consultation with the EPA, a manufacturer must concurrently submit its application to NHTSA if the manufacturer is seeking off-cycle fuel economy improvement values under the CAFE program for those technologies. For off-cycle technologies that are covered under 40 CFR 86.1869–12(d), NHTSA will consult with the EPA regarding NHTSA's evaluation of the specific off-cycle technology to ensure its impact on fuel economy and the suitability of using the off-cycle technology to adjust the fuel economy performance.

(ii) *Review and approval process.* NHTSA will provide its views on the suitability of using the off-cycle technology to adjust the fuel economy performance to the EPA. NHTSA's evaluation and review will consider:

(A) Whether the technology has a direct impact upon improving fuel economy performance;

(B) Whether the technology is related to crash-avoidance technologies, safety critical systems or systems affecting safety-critical functions, or technologies designed for the purpose of reducing the frequency of vehicle crashes;

(C) Information from any assessments conducted by the EPA related to the application, the technology and/or related technologies; and

(D) Any other relevant factors.

(E) NHTSA will collaborate to host annual meetings with EPA at least once by July 30th before the model year begins to provide general guidance to the industry on past off-cycle approvals.

(iii) *Safety.* (A) Technologies found to be defective, or identified as a part of NHTSA's safety defects program, and technologies that are not performing as intended, will have the values of approved off-cycle credits removed from the manufacturer's credit balance or adjusted if the manufacturers can remedy the defective technology. NHTSA will consult with the manufacturer to determine the amount of the adjustment.

(B) Approval granted for innovative and off-cycle technology credits under NHTSA's fuel efficiency program does not affect or relieve the obligation to comply with the Vehicle Safety Act (49 U.S.C. Chapter 301), including the ''make inoperative'' prohibition (49 U.S.C. 30122), and all applicable Federal motor vehicle safety standards issued thereunder (FMVSSs) (49 CFR part 571). In order to generate off-cycle or innovative technology credits manufacturers must state—

(*1*) That each vehicle equipped with the technology for which they are seeking credits will comply with all applicable FMVSS(s); and

(*2*) Whether or not the technology has a fail-safe provision. If no fail-safe provision exists, the manufacturer must explain why not and whether a failure of the innovative technology would affect the safety of the vehicle.

Appendix A to Part 533—Example of Calculating Compliance Under § 533.5(i)

Assume a hypothetical manufacturer (Manufacturer X) produces a fleet of light trucks in MY 2012 as follows:

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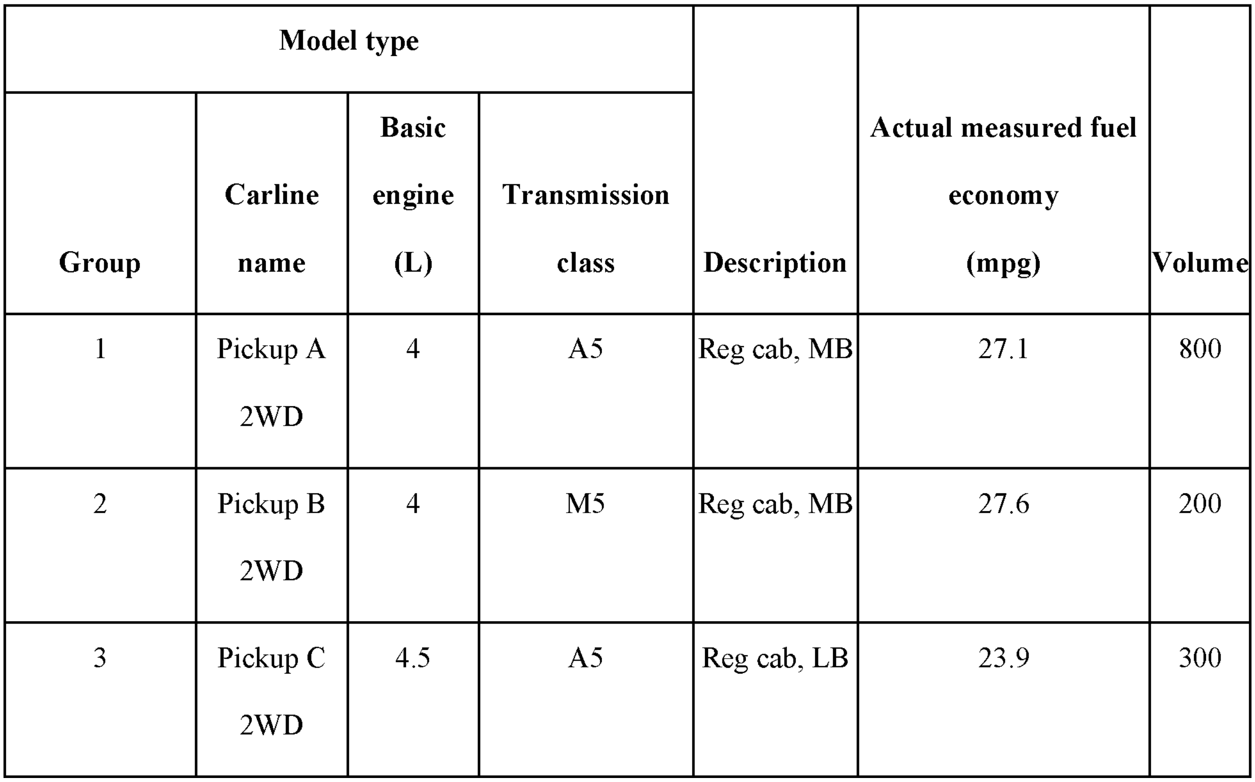
TABLE I TO APPENDIX A



Model type				Description	Actual measured fuel economy (mpg)	Volume
Group	Carline name	Basic engine (L)	Transmission class			
1	Pickup A 2WD	4	A5	Reg cab, MB	27.1	800
2	Pickup B 2WD	4	M5	Reg cab, MB	27.6	200
3	Pickup C 2WD	4.5	A5	Reg cab, LB	23.9	300

4	Pickup C 2WD	4	M5	Ext cab, MB	23.7	400
5	Pickup C 4WD	4.5	A5	Crew cab, SB	23.5	400
6	Pickup D 2WD	4.5	A6	Crew cab, SB	23.6	400
7	Pickup E 2WD	5	A6	Ext cab, LB	22.7	500
8	Pickup E 2WD	5	A6	Crew cab, MB	22.5	500
9	Pickup F 2WD	4.5	A5	Reg cab, LB	22.5	1,600
10	Pickup F 4WD	4.5	A5	Ext cab, MB	22.3	800
11	Pickup F 4WD	4.5	A5	Crew cab, SB	22.2	800
Total	6,700					

Note to this Table I: Manufacturer X's required fleet average fuel economy standard level would first be calculated by determining the fuel economy targets applicable to each unique model type and footprint combination for model type groups 1-11 as illustrated in Table II to this appendix.

Manufacturer X calculates a fuel economy target standard for each unique model type and footprint combination.

TABLE II TO APPENDIX A

Model type										
Group	**Carline name**	**Basic engine (L)**	**Transmission class**	**Description**	**Base tire size**	**Wheelbase (inches)**	**Track width F&R average (inches)**	**Footprint (ft^2)**	**Volume**	**Fuel economy target standard (mpg)**
1	Pickup A 2WD	4	A5	Reg cab, MB	235/75R15	100.0	68.8	47.8	800	27.30
2	Pickup B 2WD	4	M5	Reg cab, MB	235/75R15	100.0	68.2	47.4	200	27.44
3	Pickup C 2WD	4.5	A5	Reg cab, LB	255/70R17	125.0	68.8	59.7	300	23.79
4	Pickup C 2WD	4	M5	Ext cab, MB	255/70R17	125.0	68.8	59.7	400	23.79
5	Pickup C 4WD	4.5	A5	Crew cab, SB	275/70R17	150.0	69.0	71.9	400	22.27
6	Pickup D 2WD	4.5	A6	Crew cab, SB	255/70R17	125.0	68.8	59.7	400	23.79
7	Pickup E 2WD	5	A6	Ext cab, LB	255/70R17	125.0	68.8	59.7	500	23.79
8	Pickup E 2WD	5	A6	Crew cab, MB	285/70R17	125.0	69.2	60.1	500	23.68
9	Pickup F 2WD	4.5	A5	Reg cab, LB	255/70R17	125.0	68.9	59.8	1,600	23.76

10	Pickup F 4WD	4.5	A5	Ext cab, MB	275/70R17	150.0	69.0	71.9	800	22.27
11	Pickup F 4WD	4.5	A5	Crew cab, SB	285/70R17	150.0	69.2	72.1	800	22.27
Total									6,700	

Note to this Table II: With the appropriate fuel economy targets determined for each unique model type and footprint combination, Manufacturer X's required fleet average fuel economy standard would be calculated as illustrated in Figure 1 to this appendix:

Figure 1 to Appendix A--Calculation of Manufacturer X's Fleet Average Fuel Economy Standard using Table II of Appendix A

$$Fleet\ Average\ Fuel\ Economy\ Standard = \frac{(Manufacturer's\ light\ truck\ Production\ for\ Applicable\ Model\ Year)}{\sum_i\left(\frac{Group_1\ Production}{Group_1 Target\ Standard} + \frac{Group_{2a}\ Production}{Group_2 Target\ Standard} + \cdots \frac{Group_{11}\ Production}{Group_{11} Target\ Standard}\right)}$$

$$Fleet\ Average\ Fuel\ Economy\ Standard = \frac{(6{,}700)}{\left(\frac{800}{27.30} + \frac{200}{27.44} + + \frac{300}{23.79} + \frac{400}{23.79} + \frac{400}{22.27} + \frac{400}{23.79} + + \frac{500}{23.79} + \frac{500}{23.68} + \frac{1600}{23.76} + \frac{800}{22.27} + \frac{800}{22.27}\right)}$$

$$= 23.7\text{ mpg}$$

FIGURE 2 TO APPENDIX A—CALCULATION OF MANUFACTURER X'S ACTUAL FLEET AVERAGE FUEL ECONOMY PERFORMANCE LEVEL USING TABLE I OF APPENDIX A

$$Fleet\ Average\ Fuel\ Economy\ Performance = \frac{(Manufacturer's\ Light\ TruckProduction\ for\ Applicable\ Model\ Year)}{\sum_i\left(\frac{Group_1\ Production}{Group_1 Performance} + \frac{Group_2\ Production}{Group_2 Performance} + \cdots \frac{Group_{11}\ Production}{Group_{11} Performance}\right)}$$

$$Fleet\ Average\ Fuel\ Economy\ Performance = \frac{(6{,}700)}{\left(\frac{800}{27.1} + \frac{200}{27.6} + \frac{300}{23.9} + \frac{400}{23.7} + \frac{400}{23.5} + \frac{400}{23.6} + \frac{500}{22.7} + \frac{500}{22.5} + \frac{1600}{22.5} + \frac{800}{22.3} + \frac{800}{22.2}\right)} = 23.3\text{ mpg}$$

NOTE TO FIGURE 2 TO THIS APPENDIX: Since the actual fleet average fuel economy performance of Manufacturer X's fleet is 23.3 mpg, as compared to its required fleet fuel economy standard of 23.7 mpg, Manufacturer X did not comply with the CAFE standard for MY 2012 as set forth in §533.5(i).

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■ 3. Revise part 536 to read as follows:

PART 536—TRANSFER AND TRADING OF FUEL ECONOMY CREDITS

Authority: 49 U.S.C. 32903; delegation of authority at 49 CFR 1.95.

§ 536.1 Scope.

This part establishes regulations governing the use and application of corporate average fuel economy (CAFE) credits up to three model years before and five model years after the model year in which the credit was earned. It also specifies requirements for manufacturers wishing to transfer fuel economy credits between their fleets and for manufacturers and other persons wishing to trade fuel economy credits to achieve compliance with prescribed fuel economy standards.

§ 536.2 Application.

This part applies to all credits earned (and transferable and tradable) for exceeding applicable average fuel economy standards in a given model year for domestically manufactured passenger cars, imported passenger cars, and light trucks.

§ 536.3 Definitions.

(a) *Statutory terms.* All terms defined in 49 U.S.C. 32901(a) are used pursuant to their statutory meaning.

(b) *Other terms.* As used in the part:

Above standard fuel economy means, with respect to a compliance category, that the automobiles manufactured by a manufacturer in that compliance category in a particular model year have greater average fuel economy (calculated in a manner that reflects the incentives for alternative fuel automobiles per 49 U.S.C. 32905) than that manufacturer's fuel economy standard for that compliance category and model year.

Adjustment factor means a factor used to adjust the value of a traded or transferred credit for compliance purposes to ensure that the compliance value of the credit when used reflects the total volume of oil saved when the credit was earned.

Below standard fuel economy means, with respect to a compliance category, that the automobiles manufactured by a manufacturer in that compliance category in a particular model year have lower average fuel economy (calculated in a manner that reflects the incentives for alternative fuel automobiles per 49 U.S.C. 32905) than that manufacturer's fuel economy standard for that compliance category and model year.

Compliance means a manufacturer achieves compliance in a particular compliance category when:

(1)(i) The average fuel economy of the vehicles in that category exceed or meet the fuel economy standard for that category; or

(ii) The average fuel economy of the vehicles in that category do not meet the fuel economy standard for that category, but the manufacturer proffers a sufficient number of valid credits, adjusted for total oil savings, to cover the gap between the average fuel economy of the vehicles in that category and the required average fuel economy.

(2) A manufacturer achieves compliance for its fleet if the conditions in paragraph (1)(i) or (ii) of this definition are simultaneously met for all compliance categories.

Compliance category means any of three categories of automobiles subject to Federal fuel economy regulations. The three compliance categories recognized by 49 U.S.C. 32903(g)(6) are domestically manufactured passenger automobiles, imported passenger automobiles, and non-passenger automobiles (''light trucks'').

Credit holder (or holder) means a legal person that has valid possession of credits, either because they are a manufacturer who has earned credits by exceeding an applicable fuel economy standard, or because they are a designated recipient who has received credits from another holder. Credit holders need not be manufacturers, although all manufacturers may be credit holders.

Credits (or fuel economy credits) means an earned or purchased allowance recognizing that the average fuel economy of a particular manufacturer's vehicles within a particular compliance category and model year exceeds that manufacturer's fuel economy standard for that compliance category and model year. One credit is equal to $\frac{1}{10}$ of a mile per gallon above the fuel economy standard per one vehicle within a compliance category. Credits are denominated according to model year in which they are earned (vintage), originating manufacturer, and compliance category.

Expiry date means the model year after which fuel economy credits may no longer be used to achieve compliance with fuel economy regulations. Expiry dates are calculated in terms of model years: For example, if a manufacturer earns credits for model year 2011, these credits may be used for compliance in model years 2008–2016.

Fleet means all automobiles that are manufactured by a manufacturer in a particular model year and are subject to fuel economy standards under 49 CFR parts 531 and 533. For the purposes of this part, a manufacturer's fleet means all domestically manufactured and imported passenger automobiles and non-passenger automobiles (''light trucks''). ''Work trucks'' and medium and heavy trucks are not included in this definition for purposes of this part.

Light truck means the same as ''non-passenger automobile,'' as that term is defined in 49 U.S.C. 32901(a)(17), and as ''light truck,'' as that term is defined at 49 CFR 523.5.

Originating manufacturer means the manufacturer that originally earned a particular credit. Each credit earned will be identified with the name of the originating manufacturer.

Trade means the receipt by the National Highway Traffic Safety Administration (NHTSA) of an instruction from a credit holder to place one of its credits in the account of another credit holder. A credit that has been traded can be identified because the originating manufacturer will be a different party than the current credit holder. Traded credits are moved from one credit holder to the recipient credit holder within the same compliance category for which the credits were originally earned. If a credit has been traded to another credit holder and is subsequently traded back to the originating manufacturer, it will be deemed not to have been traded for compliance purposes.

Transfer means the application by a manufacturer of credits earned by that manufacturer in one compliance category or credits acquired be trade (and originally earned by another manufacturer in that category) to achieve compliance with fuel economy standards with respect to a different compliance category. For example, a manufacturer may purchase light truck credits from another manufacturer, and transfer them to achieve compliance in the manufacturer's domestically manufactured passenger car fleet. Subject to the credit transfer limitations of 49 U.S.C. 32903(g)(3), credits can also be transferred across compliance categories and banked or saved in that category to be carried forward or backwards later to address a credit shortfall.

Vintage means, with respect to a credit, the model year in which the credit was earned.

§ 536.4 Credits.

(a) *Type and vintage.* All credits are identified and distinguished in the accounts by originating manufacturer, compliance category, and model year of origin (vintage).

(b) *Application of credits.* All credits earned and applied are calculated, per 49 U.S.C. 32903(c), in tenths of a mile per gallon by which the average fuel economy of vehicles in a particular compliance category manufactured by a manufacturer in the model year in which the credits are earned exceeds the applicable average fuel economy standard, multiplied by the number of vehicles sold in that compliance category. However, credits that have been traded between credit holders or transferred between compliance categories are valued for compliance purposes using the adjustment factor specified in paragraph (c) of this section, pursuant to the ''total oil savings'' requirement of 49 U.S.C. 32903(f)(1).

(c) *Adjustment factor.* When traded or transferred and used, fuel economy credits are adjusted to ensure fuel oil savings is preserved. For traded credits, the user (or buyer) must multiply the calculated adjustment factor by the number of shortfall credits it plans to offset in order to determine the number of equivalent credits to acquire from the earner (or seller). For transferred credits, the user of credits must multiply the calculated adjustment factor by the number of shortfall credits it plans to offset in order to determine the number of equivalent credits to transfer from the compliance category holding the available credits. The adjustment factor is calculated according to the following formula:

$$A = \left(\frac{VMTu * MPGae * MPGse}{VMTe * MPGau * MPGsu} \right)$$

Where:

A = Adjustment factor applied to traded and transferred credits. The quotient shall be rounded to 4 decimal places.

VMTe = Lifetime vehicle miles traveled as provided in the following table for the model year and compliance category in which the credit was earned.

VMTu = Lifetime vehicle miles traveled as provided in the following table for the model year and compliance category in which the credit is used for compliance.

Table 1 to Paragraph (c)

Model year	Lifetime Vehicle Miles Traveled (VMT)					
	2012	2013	2014	2015	2016	2017-2025
Passenger Cars	177,238	177,366	178,652	180,497	182,134	195,264
Light Trucks	208,471	208,537	209,974	212,040	213,954	225,865

MPGse = Required fuel economy standard for the originating (earning) manufacturer, compliance category, and model year in which the credit was earned.

MPGae = Actual fuel economy for the originating manufacturer, compliance category, and model year in which the credit was earned.

MPGsu = Required fuel economy standard for the user (buying) manufacturer, compliance category, and model year in which the credit is used for compliance.

MPGau = Actual fuel economy for the user manufacturer, compliance category, and model year in which the credit is used for compliance.

§ 536.5 Trading infrastructure.

(a) *Accounts.* NHTSA maintains ''accounts'' for each credit holder. The account consists of a balance of credits in each compliance category and vintage held by the holder.

(b) *Who may hold credits.* Every manufacturer subject to fuel economy standards under 49 CFR part 531 or 533 is automatically an account holder. If the manufacturer earns credits pursuant to this part, or receives credits from another party, so that the manufacturer's account has a non-zero balance, then the manufacturer is also a credit holder. Any party designated as a recipient of credits by a current credit holder will receive an account from NHTSA and become a credit holder, subject to the following conditions:

(1) A designated recipient must provide name, address, contacting information, and a valid taxpayer identification number or Social Security number;

(2) NHTSA does not grant a request to open a new account by any party other than a party designated as a recipient of credits by a credit holder; and

(3) NHTSA maintains accounts with zero balances for a period of time, but reserves the right to close accounts that have had zero balances for more than one year.

(c) *Automatic debits and credits of accounts.* (1) To carry credits forward, backward, transfer credits, or trade credits into other credit accounts, a manufacturer or credit holder must submit a credit instruction to NHTSA. A credit instruction must detail and include:

(i) The credit holder(s) involved in the transaction.

(ii) The originating credits described by the amount of the credits, compliance category and the vintage of the credits.

(iii) The recipient credit account(s) for banking or applying the originating credits described by the compliance category(ies), model year(s), and if applicable the adjusted credit amount(s) and adjustment factor(s).

(iv) For trades, a contract authorizing the trade signed by the manufacturers or credit holders or by managers legally authorized to obligate the sale and purchase of the traded credits.

(2) Upon receipt of a credit instruction from an existing credit holder, NHTSA verifies the presence of sufficient credits in the account(s) of the credit holder(s) involved as applicable and notifies the credit holder(s) that the credits will be debited from and/or

credited to the accounts involved, as specified in the credit instruction. NHTSA determines if the credits can be debited or credited based upon the amount of available credits, accurate application of any adjustment factors and the credit requirements prescribed by this part that are applicable at the time the transaction is requested.

(3) After notifying the credit holder(s), all accounts involved are either credited or debited, as appropriate, in line with the credit instruction. Traded credits identified by a specific compliance category are deposited into the recipient's account in that same compliance category and model year. If a recipient of credits as identified in a credit instruction is not a current account holder, NHTSA establishes the credit recipient's account, subject to the conditions described in paragraph (b) of this section, and adds the credits to the newly-opened account.

(4) NHTSA will automatically delete unused credits from holders' accounts when those credits reach their expiry date.

(5) Starting January 1, 2022, manufacturers or credit holders issuing credit instructions or providing credit allocation plans as specified in paragraph (d) of this section, must use and submit the NHTSA Credit Template fillable form (Office of Management and Budget (OMB) Control No. 2127–0019, NHTSA Form 1475). The NHTSA Credit Template is available for download on NHTSA's website. If a credit instruction includes a trade, the NHTSA Credit Template must be signed by managers legally authorized to obligate the sale and/or purchase of the traded credits from both parties to the trade. The NHTSA Credit Template signed by both parties to the trade serves as an acknowledgement that the parties have agreed to trade credits, and does not dictate terms, conditions, or other business obligations of the parties. Manufacturers must submit the template along with other requested information through the CAFE email, *cafe@dot.gov.* NHTSA reserves the right to request additional information from the parties regarding the terms of the trade.

(6) Starting September 1, 2022, manufacturers or credit holders trading credits must use and submit the NHTSA Credit Value Reporting Template fillable form (OMB Control No. 2127–0019, NHTSA Form 1621). The NHTSA Credit Template is available for download on NHTSA's website. The template will provide NHTSA with the price paid for the credits including a description of any other monetary or non-monetary terms affecting the price of the traded credits, such as any technology exchanged or shared for the credits, any other non-monetary payment for the credits, or any other agreements related to the trade. Manufacturers must submit the template along with other requested information through the CAFE email, *cafe@dot.gov.* NHTSA reserves the right to request additional information from the parties regarding the terms of the trade.

(7) NHTSA will consider claims that information submitted to the agency under this section is entitled to confidential treatment under 5 U.S.C. 552(b) and under the provisions of part 512 of this chapter if the information is submitted in accordance with the procedures of part 512.

(d) *Compliance.* (1) NHTSA assesses compliance with fuel economy standards each year, utilizing the certified and reported CAFE data provided by the Environmental Protection Agency (EPA) for enforcement of the CAFE program pursuant to 49 U.S.C. 32904(e). Credit values are calculated based on the CAFE data from the EPA. If a particular compliance category within a manufacturer's fleet has above standard fuel economy, NHTSA adds credits to the manufacturer's account for that compliance category and vintage in the appropriate amount by which the manufacturer has exceeded the applicable standard.

(2) If a manufacturer's vehicles in a particular compliance category have below standard fuel economy, NHTSA will provide written notification to the manufacturer that it has failed to meet a particular fleet target standard. The manufacturer will be required to confirm the shortfall and must either: Submit a plan indicating how it will allocate existing credits or earn, transfer and/or acquire credits; or pay the appropriate civil penalty. The manufacturer must submit a plan or payment within 60 days of receiving agency notification.

(3) Credits used to offset shortfalls are subject to the three- and five-year limitations as described in § 536.6.

(4) Transferred credits are subject to the limitations specified by 49 U.S.C. 32903(g)(3) and this part.

(5) The value, when used for compliance, of any credits received via trade or transfer is adjusted, using the adjustment factor described in § 536.4(c), pursuant to 49 U.S.C. 32903(f)(1).

(6) Credit allocation plans received from a manufacturer will be reviewed and approved by NHTSA. Starting in model year 2022, use the NHTSA Credit Template and the Credit Trade Cost Template (OMB Control No. 2127–0019, NHTSA Forms 1475 and 1621) to record the credit transactions and the costs for any credit trades requested in the credit allocation plan. The template is a fillable form that has an option for recording and calculating credit transactions for credit allocation plans. The template calculates the required adjustments to the credits. The credit allocation plan and the completed transaction templates must be submitted to NHTSA. NHTSA will approve the credit allocation plan unless it finds that the proposed credits are unavailable or that it is unlikely that the plan will result in the manufacturer earning sufficient credits to offset the subject credit shortfall. If the plan is approved, NHTSA will revise the respective manufacturer's credit account accordingly. If the plan is rejected, NHTSA will notify the respective manufacturer and request a revised plan or payment of the appropriate fine.

(e) *Reporting.* (1) NHTSA periodically publishes the names and credit holdings of all credit holders. NHTSA does not publish individual transactions, nor respond to individual requests for updated balances from any party other than the account holder.

(2) NHTSA issues an annual credit status letter to each party that is a credit holder at that time. The letter to a credit holder includes a credit accounting record that identifies the credit status of the credit holder including any activity (earned, expired, transferred, traded, carry-forward and carry-back credit transactions/allocations) that took place during the identified activity period.

§ 536.6 Treatment of credits earned prior to model year 2011.

(a) Credits earned in a compliance category before model year 2008 may be applied by the manufacturer that earned them to carryback plans for that compliance category approved up to three model years prior to the year in which the credits were earned, or may be applied to compliance in that compliance category for up to three model years after the year in which the credits were earned.

(b) Credits earned in a compliance category during and after model year 2008 may be applied by the manufacturer that earned them to carryback plans for that compliance category approved up to three years prior to the year in which the credits were earned, or may be held or applied for up to five model years after the year in which the credits were earned.

(c) Credits earned in a compliance category prior to model year 2011 may not be transferred or traded.

§ 536.7 Treatment of carryback credits.

(a) Carryback credits earned in a compliance category in any model year may be used in carryback plans approved by NHTSA, pursuant to 49 U.S.C. 32903(b), for up to three model years prior to the year in which the credit was earned.

(b) For purposes of this part, NHTSA will treat the use of future credits for compliance, as through a carryback plan, as a deferral of penalties for non-compliance with an applicable fuel economy standard.

(c) If NHTSA receives and approves a manufacturer's carryback plan to earn future credits within the following three model years in order to comply with current regulatory obligations, NHTSA will defer levying fines for non-compliance until the date(s) when the manufacturer's approved plan indicates that credits will be earned or acquired to achieve compliance, and upon receiving confirmed CAFE data from EPA. If the manufacturer fails to acquire or earn sufficient credits by the plan dates, NHTSA will initiate compliance proceedings.

(d) In the event that NHTSA fails to receive or approve a plan for a non-compliant manufacturer, NHTSA will levy fines pursuant to statute. If within three years, the non-compliant manufacturer earns or acquires additional credits to reduce or eliminate the non-compliance, NHTSA will reduce any fines owed, or repay fines to the extent that credits received reduce the non-compliance.

(e) No credits from any source (earned, transferred and/or traded) will be accepted in lieu of compliance if those credits are not identified as originating within one of the three model years after the model year of the confirmed shortfall.

§ 536.8 Conditions for trading of credits.

(a) *Trading of credits.* If a credit holder wishes to trade credits to another party, the current credit holder and the receiving party must jointly issue an instruction to NHTSA, identifying the quantity, vintage, compliance category, and originator of the credits to be traded. If the recipient is not a current account holder, the recipient must provide sufficient information for NHTSA to establish an account for the recipient. Once an account has been established or identified for the recipient, NHTSA completes the trade by debiting the transferor's account and crediting the recipient's account. NHTSA will track the quantity, vintage, compliance category, and originator of all credits held or traded by all account-holders.

(b) *Trading between and within compliance categories.* For credits earned in model year 2011 or thereafter, and used to satisfy compliance obligations for model year 2011 or thereafter:

(1) Manufacturers may use credits originally earned by another manufacturer in a particular compliance category to satisfy compliance obligations within the same compliance category.

(2) Once a manufacturer acquires by trade credits originally earned by another manufacturer in a particular compliance category, the manufacturer may transfer the credits to satisfy its compliance obligations in a different compliance category, but only to the extent that the CAFE increase attributable to the transferred credits does not exceed the limits in 49 U.S.C. 32903(g)(3). For any compliance category, the sum of a manufacturer's transferred credits earned by that manufacturer and transferred credits obtained by that manufacturer through trade must not exceed that limit.

(c) *Changes in corporate ownership and control.* Manufacturers must inform NHTSA of corporate relationship changes to ensure that credit accounts are identified correctly and credits are assigned and allocated properly.

(1) In general, if two manufacturers merge in any way, they must inform NHTSA how they plan to merge their credit accounts. NHTSA will subsequently assess corporate fuel economy and compliance status of the merged fleet instead of the original separate fleets.

(2) If a manufacturer divides or divests itself of a portion of its automobile manufacturing business, it must inform NHTSA how it plans to divide the manufacturer's credit holdings into two or more accounts. NHTSA will subsequently distribute holdings as directed by the manufacturer, subject to provision for reasonably anticipated compliance obligations.

(3) If a manufacturer is a successor to another manufacturer's business, it must inform NHTSA how it plans to allocate credits and resolve liabilities per 49 CFR part 534.

(d) *No short or forward sales.* NHTSA will not honor any instructions to trade or transfer more credits than are currently held in any account. NHTSA will not honor instructions to trade or transfer credits from any future vintage (*i.e.,* credits not yet earned). NHTSA will not participate in or facilitate contingent trades.

(e) *Cancellation of credits.* A credit holder may instruct NHTSA to cancel its currently held credits, specifying the originating manufacturer, vintage, and compliance category of the credits to be cancelled. These credits will be permanently null and void; NHTSA will remove the specific credits from the credit holder's account, and will not reissue them to any other party.

(f) *Errors or fraud in earning credits.* If NHTSA determines that a manufacturer has been credited, through error or fraud, with earning credits, NHTSA will cancel those credits if possible. If the manufacturer credited with having earned those credits has already traded them when the error or fraud is discovered, NHTSA will hold the receiving manufacturer responsible for returning the same or equivalent credits to NHTSA for cancellation.

(g) *Error or fraud in trading.* In general, all trades are final and irrevocable once executed, and may only be reversed by a new, mutually-agreed transaction. If NHTSA executes an erroneous instruction to trade credits from one holder to another through error or fraud, NHTSA will reverse the transaction if possible. If those credits have been traded away, the recipient holder is responsible for obtaining the same or equivalent credits for return to the previous holder.

§ 536.9 Use of credits with regard to the domestically manufactured passenger automobile minimum standard.

(a) Each manufacturer is responsible for compliance with both the minimum standard and the attribute-based standard.

(b) In any particular model year, the domestically manufactured passenger automobile compliance category credit excess or shortfall is determined by comparing the actual CAFE value against either the required standard value or the minimum standard value, whichever is larger.

(c) Transferred or traded credits may not be used, pursuant to 49 U.S.C. 32903(g)(4) and (f)(2), to meet the domestically manufactured passenger automobile minimum standard specified in 49 U.S.C. 32902(b)(4) and in 49 CFR 531.5(d).

(d) If a manufacturer's average fuel economy level for domestically manufactured passenger automobiles is lower than the attribute-based standard, but higher than the minimum standard, then the manufacturer may achieve compliance with the attribute-based standard by applying credits.

(e) If a manufacturer's average fuel economy level for domestically manufactured passenger automobiles is lower than the minimum standard, then the difference between the minimum standard and the manufacturer's actual fuel economy level may only be relieved by the use of credits earned by that manufacturer within the domestic passenger car compliance category which have not been transferred or traded. If the manufacturer does not have available earned credits to offset a credit shortage below the minimum standard then the manufacturer can submit a carry-back plan that indicates sufficient future credits will be earned in its domestic passenger car compliance category or will be subject to penalties.

§ 536.10 Treatment of dual-fuel and alternative fuel vehicles—consistency with 49 CFR part 538.

(a) Statutory alternative fuel and dual-fuel vehicle fuel economy calculations are treated as a change in the underlying fuel economy of the vehicle for purposes of this part, not as a credit that may be transferred or traded. Improvements in alternative fuel or dual fuel vehicle fuel economy as calculated pursuant to 49 U.S.C. 32905 and limited by 49 U.S.C. 32906 are therefore attributable only to the particular compliance category and model year to which the alternative or dual-fuel vehicle belongs.

(b) If a manufacturer's calculated fuel economy for a particular compliance category, including any statutorily-required calculations for alternative fuel and dual fuel vehicles, is higher or lower than the applicable fuel economy standard, manufacturers will earn credits or must apply credits or pay civil penalties equal to the difference between the calculated fuel economy level in that compliance category and the applicable standard. Credits earned are the same as any other credits, and may be held, transferred, or traded by the manufacturer subject to the limitations of the statute and this part.

(c) For model years (MYs) up to and including MY 2019, if a manufacturer builds enough dual fuel vehicles (except plug-in hybrid electric vehicles) to improve the calculated fuel economy in a particular compliance category by more than the limits set forth in 49 U.S.C. 32906(a), the improvement in fuel economy for compliance purposes is restricted to the statutory limit. Manufacturers may not earn credits nor reduce the application of credits or fines for calculated improvements in fuel economy based on dual fuel vehicles beyond the statutory limit.

(d) For model years 2020 and beyond, a manufacturer must calculate the fuel economy of dual fueled vehicles in accordance with 40 CFR 600.510–12(c).

■ 4. Revise part 537 to read as follows:

PART 537—AUTOMOTIVE FUEL ECONOMY REPORTS

Authority: 49 U.S.C. 32907, delegation of authority at 49 CFR 1.95.

§ 537.1 Scope.

This part establishes requirements for automobile manufacturers to submit reports to the National Highway Traffic Safety Administration (NHTSA) regarding their efforts to improve automotive fuel economy.

§ 537.2 Purpose.

The purpose of this part is to obtain information to aid the National Highway Traffic Safety Administration in valuating automobile manufacturers' plans for complying with average fuel economy standards and in preparing an annual review of the average fuel economy standards.

§ 537.3 Applicability.

This part applies to automobile manufacturers, except for manufacturers subject to an alternate fuel economy standard under section 502(c) of the Act.

§ 537.4 Definitions.

(a) *Statutory terms.* (1) The terms *average fuel economy standard, fuel, manufacture,* and *model year* are used as defined in section 501 of the Act.

(2) The term *manufacturer* is used as defined in section 501 of the Act and in accordance with part 529 of this chapter.

(3) The terms *average fuel economy, fuel economy,* and *model type* are used as defined in subpart A of 40 CFR part 600.

(4) The terms *automobile, automobile capable of off-highway operation,* and *passenger automobile* are used as defined in section 501 of the Act and in accordance with the determinations in part 523 of this chapter.

(b) *Other terms.* (1) The term *loaded vehicle weight* is used as defined in subpart A of 40 CFR part 86.

(2) The terms *axle ratio, base level, body style, car line, combined fuel economy, engine code, equivalent test weight, gross vehicle weight, inertia weight, transmission class,* and *vehicle configuration* are used as defined in subpart A of 40 CFR part 600.

(3) The term *light truck* is used as defined in part 523 of this chapter and in accordance with determinations in part 523.

(4) The terms *approach angle, axle clearance, brakeover angle, cargo carrying volume, departure angle, passenger carrying volume, running clearance,* and *temporary living quarters* are used as defined in part 523 of this chapter.

(5) The term *incomplete automobile manufacturer* is used as defined in part 529 of this chapter.

(6) As used in this part, unless otherwise required by the context:

(i) *Act* means the Motor Vehicle Information and Cost Savings Act (Pub. L. 92–513), as amended by the Energy Policy and Conservation Act (Pub. L. 94–163).

(ii) *Administrator* means the Administrator of the National Highway Traffic Safety Administration or the Administrator's delegate.

(iii) *Current model year* means:

(A) In the case of a pre-model year report, the full model year immediately following the period during which that report is required by § 537.5(b) to be submitted.

(B) In the case of a mid-model year report, the model year during which that report is required by § 537.5(b) to be submitted.

(iv) *Average* means a production-weighted harmonic average.

(v) *Total drive ratio* means the ratio of an automobile's engine rotational speed (in revolutions per minute) to the automobile's forward speed (in miles per hour).

§ 537.5 General requirements for reports.

(a) For each current model year, each manufacturer shall submit a pre-model year report, a mid-model year report, and, as required by § 537.8, supplementary reports.

(b)(1) The pre-model year report required by this part for each current model year must be submitted during the month of December (*e.g.,* the pre-model year report for the 1983 model year must be submitted during December, 1982).

(2) The mid-model year report required by this part for each current model year must be submitted during the month of July (*e.g.,* the mid-model year report for the 1983 model year must be submitted during July 1983).

(3) Each supplementary report must be submitted in accordance with § 537.8(c).

(c) Each report required by this part must:

(1) Identify the report as a pre-model year report, mid-model year report, or supplementary report as appropriate;

(2) Identify the manufacturer submitting the report;

(3) State the full name, title, and address of the official responsible for preparing the report;

(4) Be submitted on CD–ROM for confidential reports provided in accordance with § 537.12 and by email for non-confidential (*i.e.,* redacted) versions of reports. The content of reports must be provided in a PDF or MS Word format except for the information required in § 537.7 which must be provided in a MS Excel format. Submit 2 copies of the CD–ROM to: Administrator, National Highway Traffic Administration, 1200 New Jersey Avenue SW, Washington, DC 20590, and submit reports electronically to the following secure email address: *cafe@dot.gov;*

(5) Identify the current model year;

(6) Be written in the English language; and

(7)(i) Specify any part of the information or data in the report that the manufacturer believes should be withheld from public disclosure as trade secret or other confidential business information.

(ii) With respect to each item of information or data requested by the manufacturer to be withheld under 5 U.S.C. 552(b)(4) and 15 U.S.C. 2005(d)(1), the manufacturer shall:

(A) Show that the item is within the scope of sections 552(b)(4) and 2005(d)(1);

(B) Show that disclosure of the item would result in significant competitive damage;

(C) Specify the period during which the item must be withheld to avoid that damage; and

(D) Show that earlier disclosure would result in that damage.

(d) Beginning with model year 2023, each manufacturer shall generate reports required by this part using the NHTSA CAFE Projections Reporting Template (Office of Management and Budget (OMB) Control No. 2127–0019, NHTSA Form 1474). The template is a fillable form.

(1) *Report type selection.* Select the option to identify the report as a pre-model year report, mid-model year report, or supplementary report as appropriate.

(2) *Required information.* Complete all required information for the manufacturer and for all vehicles produced for the current model year required to comply with corporate average fuel economy (CAFE) standards. Identify the manufacturer submitting the report, including the full name, title, and address of the official responsible for preparing the report and a point of contact to answer questions concerning the report.

(3) *Report generation.* Use the template to generate confidential and non-confidential reports for all the domestic and import passenger cars and light truck fleet produced by the manufacturer for the current model year. Manufacturers must submit a request for confidentiality in accordance with part 512 of this chapter to withhold projected production sales volume estimates from public disclosure. If the request is granted, NHTSA will withhold the projected production sales volume estimates from public disclose until all the vehicles produced by the manufacturer have been made available for sale (usually one year after the current model year).

(4) *Report submission.* Submit confidential reports and requests for confidentiality to NHTSA on CD–ROM in accordance with § 537.12. Email copies of non-confidential (*i.e.,* redacted) reports to NHTSA's secure email address: *cafe@dot.gov.* Requests for confidentiality must be submitted in a PDF or MS Word format. Submit 2 copies of the CD–ROM to: Administrator, National Highway Traffic Administration, 1200 New Jersey Avenue SE, Washington, DC 20590, and submit emailed reports electronically to the following secure email address: *cafe@dot.gov.*

(5) *Confidentiality requests.* Manufacturers can withhold information on projected production sales volumes under 5 U.S.C. 552(b)(4) and 15 U.S.C. 2005(d)(1). In accordance, the manufacturer must:

(i) Show that the item is within the scope of sections 552(b)(4) and 2005(d)(1);

(ii) Show that disclosure of the item would result in significant competitive damage;

(iii) Specify the period during which the item must be withheld to avoid that damage; and

(iv) Show that earlier disclosure would result in that damage.

(e) Each report required by this part must be based upon all information and data available to the manufacturer 30 days before the report is submitted to the Administrator.

§ 537.6 General content of reports.

(a) *Pre-model year and mid-model year reports.* Except as provided in paragraph (c) of this section, each pre-model year report and the mid-model year report for each model year must contain the information required by § 537.7(a).

(b) *Supplementary report.* Except as provided in paragraph (c) of this section, each supplementary report for each model year must contain the information required by § 537.7(a)(1) and (2), as appropriate for the vehicle fleets produced by the manufacturer, in accordance with § 537.8(b)(1), (2), (3), and (4) as appropriate.

(c) *Exceptions.* The pre-model year report, mid-model year report, and supplementary report(s) submitted by an incomplete automobile manufacturer for any model year are not required to contain the information specified in § 537.7(c)(4)(xv) through (xviii) and (c)(5). The information provided by the incomplete automobile manufacturer under § 537.7(c) shall be according to base level instead of model type or carline.

§ 537.7 Pre-model year and mid-model year reports.

(a) *Report content.* (1) Provide a report with the information required by paragraphs (b) and (c) of this section for each domestic and import passenger automobile fleet, as specified in part 531 of this chapter, for the current model year.

(2) Provide a report with the information required by paragraphs (b) and (c) of this section for each light truck fleet, as specified in part 533 of this chapter, for the current model year.

(3) For model year 2023 and later, for passenger cars specified in part 531 of this chapter and light trucks specified in part 533 of this chapter, provide the information for pre-model and mid-model year reports in accordance with the NHTSA CAFE Projections Reporting Template (OMB Control No. 2127–0019, NHTSA Form 1474). The required reporting template can be downloaded from NHTSA's website.

(b) *Projected average and required fuel economy.* (1) State the projected average fuel economy for the manufacturer's automobiles determined in accordance with § 537.9 and based upon the fuel economy values and projected sales figures provided under paragraph (c)(2) of this section.

(2) State the projected final average fuel economy that the manufacturer anticipates having if changes implemented during the model year will cause that average to be different from the average fuel economy projected under paragraph (b)(1) of this section.

(3) State the projected required fuel economy for the manufacturer's passenger automobiles and light trucks determined in accordance with

§§ 531.5(c) and 533.5 of this chapter and based upon the projected sales figures provided under paragraph (c)(2) of this section. For each unique model type and footprint combination of the manufacturer's automobiles, provide the information specified in paragraphs (b)(3)(i) and (ii) of this section in tabular form. List the model types in order of increasing average inertia weight from top to bottom down the left side of the table and list the information categories in the order specified in paragraphs (b)(3)(i) and (ii) of this section from left to right across the top of the table. Other formats, such as those accepted by the EPA, which contain all the information in a readily identifiable format are also acceptable. For model year 2023 and later, for each unique model type and footprint combination of the manufacturer's automobiles, provide the information specified in paragraphs (b)(3)(i) and (ii) of this section in accordance with the CAFE Projections Reporting Template (OMB Control No. 2127–0019, NHTSA Form 1474).

(i) In the case of passenger automobiles:

(A) Beginning model year 2013, base tire as defined in § 523.2 of this chapter;

(B) Beginning model year 2013, front axle, rear axle, and average track width as defined in § 523.2 of this chapter;

(C) Beginning model year 2013, wheelbase as defined in § 523.2 of this chapter; and

(D) Beginning model year 2013, footprint as defined in § 523.2 of this chapter.

(E) The fuel economy target value for each unique model type and footprint entry listed in accordance with the equation provided in part 531 of this chapter.

(ii) In the case of light trucks:

(A) Beginning model year 2013, base tire as defined in § 523.2 of this chapter;

(B) Beginning model year 2013, front axle, rear axle, and average track width as defined in § 523.2 of this chapter;

(C) Beginning model year 2013, wheelbase as defined in § 523.2 of this chapter; and

(D) Beginning model year 2013, footprint as defined in § 523.2 of this chapter.

(E) The fuel economy target value for each unique model type and footprint entry listed in accordance with the equation provided in part 533 of this chapter.

(4) State the projected final required fuel economy that the manufacturer anticipates having if changes implemented during the model year will cause the targets to be different from the target fuel economy projected under paragraph (b)(3) of this section.

(5) State whether the manufacturer believes that the projections it provides under paragraphs (b)(2) and (4) of this section, or if it does not provide an average or target under paragraphs (b)(2) and (4), the projections it provides under paragraphs (b)(1) and (3) of this section, sufficiently represent the manufacturer's average and target fuel economy for the current model year for purposes of the Act. In the case of a manufacturer that believes that the projections are not sufficiently representative for the purposes of the preceding sentence, state the specific nature of any reason for the insufficiency and the specific additional testing or derivation of fuel economy values by analytical methods believed by the manufacturer necessary to eliminate the insufficiency and any plans of the manufacturer to undertake that testing or derivation voluntarily and submit the resulting data to the Environmental Protection Agency under 40 CFR 600.509.

(c) *Model type and configuration fuel economy and technical information.* (1) For each model type of the manufacturer's automobiles, provide the information specified in paragraph (c)(2) of this section in tabular form. List the model types in order of increasing average inertia weight from top to bottom down the left side of the table and list the information categories in the order specified in paragraph (c)(2) of this section from left to right across the top of the table. For model year 2023 and later, CAFE reports required by this part, shall for each model type of the manufacturer's automobiles, provide the information in specified in paragraph (c)(2) of this section in accordance with the NHTSA CAFE Projections Reporting Template (OMB Control No. 2127–0019, NHTSA Form 1474) and list the model types in order of increasing average inertia weight from top to bottom.

(2)(i) Combined fuel economy; and

(ii) Projected sales for the current model year and total sales of all model types.

(3) For pre-model year reports only through model year 2022, for each vehicle configuration whose fuel economy was used to calculate the fuel economy values for a model type under paragraph (c)(2) of this section, provide the information specified in paragraph (c)(4) of this section in accordance with the NHTSA CAFE Projections Reporting Template (OMB Control No. 2127–0019, NHTSA Form 1474).

(4)(i) Loaded vehicle weight;

(ii) Equivalent test weight;

(iii) Engine displacement, liters;

(iv) SAE net rated power, kilowatts;

(v) SAE net horsepower;

(vi) Engine code;

(vii) Fuel system (number of carburetor barrels or, if fuel injection is used, so indicate);

(viii) Emission control system;

(ix) Transmission class;

(x) Number of forward speeds;

(xi) Existence of overdrive (indicate yes or no);

(xii) Total drive ratio (N/V);

(xiii) Axle ratio;

(xiv) Combined fuel economy;

(xv) Projected sales for the current model year;

(xvi)(A) In the case of passenger automobiles:

(*1*) Interior volume index, determined in accordance with subpart D of 40 CFR part 600; and

(*2*) Body style;

(B) In the case of light trucks:

(*1*) Passenger-carrying volume; and

(*2*) Cargo-carrying volume;

(xvii) Frontal area;

(xviii) Road load power at 50 miles per hour, if determined by the manufacturer for purposes other than compliance with this part to differ from the road load setting prescribed in 40 CFR 86.177–11(d); and

(xix) Optional equipment that the manufacturer is required under 40 CFR parts 86 and 600 to have actually installed on the vehicle configuration, or the weight of which must be included in the curb weight computation for the vehicle configuration, for fuel economy testing purposes.

(5) For each model type of automobile which is classified as a non-passenger vehicle (light truck) under part 523 of this chapter, provide the following data:

(i) For an automobile designed to perform at least one of the following functions in accordance with § 523.5(a) of this chapter indicate (by ''yes'' or ''no'' for each function) whether the vehicle can:

(A) Transport more than 10 persons (if yes, provide actual designated seating positions);

(B) Provide temporary living quarters (if yes, provide applicable conveniences as defined in § 523.2 of this chapter);

(C) Transport property on an open bed (if yes, provide bed size width and length);

(D) Provide, as sold to the first retail purchaser, greater cargo-carrying than passenger-carrying volume, such as in a cargo van and quantify the value which should be the difference between the values provided in paragraphs (c)(4)(xvi)(B)(*1*) and (*2*) of this section; if a vehicle is sold with a second-row seat, its cargo-carrying volume is determined with that seat installed, regardless of whether the manufacturer has described that seat as optional; or

(E) Permit expanded use of the automobile for cargo-carrying purposes or other non-passenger-carrying purposes through:

(*1*) For non-passenger automobiles manufactured prior to model year 2012, the removal of seats to permit expanded use of the automobile for cargo-carrying purposes or other non-passenger-carrying purposes through means provided by the automobile's manufacturer or with simple tools, such as screwdrivers and wrenches, so as to create a flat, floor level, surface extending from the forward-most point of installation of those seats to the rear of the automobile's interior; or

(*2*) For non-passenger automobiles manufactured in model year 2008 and beyond, for vehicles equipped with at least 3 rows of designated seating positions as standard equipment, permit expanded use of the automobile for cargo-carrying purposes or other nonpassenger-carrying purposes through the removal or stowing of foldable or pivoting seats so as to create a flat, leveled cargo surface extending from the forward-most point of installation of those seats to the rear of the automobile's interior.

(ii) For an automobile capable of off-highway operation, identify which of the features below qualify the vehicle as off-road in accordance with § 523.5(b) of this chapter and quantify the values of each feature:

(A) 4-wheel drive; or

(B) A rating of more than 6,000 pounds gross vehicle weight; and

(C) Has at least four of the following characteristics calculated when the automobile is at curb weight, on a level surface, with the front wheels parallel to the automobile's longitudinal centerline, and the tires inflated to the manufacturer's recommended pressure. The exact value of each feature should be quantified:

(*1*) Approach angle of not less than 28 degrees.

(*2*) Breakover angle of not less than 14 degrees.

(*3*) Departure angle of not less than 20 degrees.

(*4*) Running clearance of not less than 20 centimeters.

(*5*) Front and rear axle clearances of not less than 18 centimeters each.

(6) The fuel economy values provided under paragraphs (c)(2) and (4) of this section shall be determined in accordance with § 537.9.

(7) Identify any air-conditioning (AC), off-cycle, and full-size pick-up truck technologies used each model year to calculate the average fuel economy specified in 40 CFR 600.510–12.

(i) Provide a list of each air conditioning efficiency improvement technology utilized in your fleet(s) of vehicles for each model year. For each technology identify vehicles by make and model types that have the technology, which compliance category those vehicles belong to and the number of vehicles for each model equipped with the technology. For each compliance category (domestic passenger car, import passenger car, and light truck), report the air conditioning fuel consumption improvement value in gallons/mile in accordance with the equation specified in 40 CFR 600.510–12(c)(3)(i).

(ii) Provide a list of off-cycle efficiency improvement technologies utilized in your fleet(s) of vehicles for each model year that is pending or approved by the EPA. For each technology identify vehicles by make and model types that have the technology, which compliance category those vehicles belong to, the number of vehicles for each model equipped with the technology, and the associated off-cycle credits (grams/mile) available for each technology. For each compliance category (domestic passenger car, import passenger car, and light truck), calculate the fleet off-cycle fuel consumption improvement value in gallons/mile in accordance with the equation specified in 40 CFR 600.510–12(c)(3)(ii).

(iii) Provide a list of full-size pickup trucks in your fleet that meet the mild and strong hybrid vehicle definitions as specified in 40 CFR 86.1803–01. For each mild and strong hybrid type, identify vehicles by make and model types that have the technology, the number of vehicles produced for each model equipped with the technology, the total number of full-size pickup trucks produced with and without the technology, the calculated percentage of hybrid vehicles relative to the total number of vehicles produced, and the associated full-size pickup truck credits (grams/mile) available for each technology. For the light truck compliance category, calculate the fleet pickup truck fuel consumption improvement value in gallons/mile in accordance with the equation specified in 40 CFR 600.510–12(c)(3)(iii).

§ 537.8 Supplementary reports.

(a)(1) Except as provided in paragraph (d) of this section, each manufacturer whose most recently submitted semiannual report contained an average fuel economy projection under § 537.7(b)(2) or, if no average fuel economy was projected under that section, under § 537.7(b)(1), that was not less than the applicable average fuel economy standard and who now projects an average fuel economy which is less than the applicable standard shall file a supplementary report containing the information specified in paragraph (b)(1) of this section.

(2) Except as provided in paragraph (d) of this section, each manufacturer that determines that its average fuel economy for the current model year as projected under § 537.7(b)(2) or, if no average fuel economy was projected under § 537.7(b)(2), as projected under § 537.7(b)(1), is less representative than the manufacturer previously reported it to be under § 537.7(b)(3), this section, or both, shall file a supplementary report containing the information specified in paragraph (b)(2) of this section.

(3) For model years through 2022, each manufacturer whose pre-model or mid-model year report omits any of the information specified in § 537.7(b) or (c) shall file a supplementary report containing the information specified in paragraph (b)(3) of this section.

(4) Starting model year 2023, each manufacturer whose pre-model or mid-model year report omits any of the information shall resubmit the information with other information required in accordance with the NHTSA CAFE Projections Reporting Template (OMB Control No. 2127–0019, NHTSA Form 1474).

(b)(1) The supplementary report required by paragraph (a)(1) of this section must contain:

(i) Such revisions of and additions to the information previously submitted by the manufacturer under this part regarding the automobiles whose projected average fuel economy has decreased as specified in paragraph (a)(1) of this section as are necessary—

(A) To reflect the decrease and its cause; and

(B) To indicate a new projected average fuel economy based upon these additional measures.

(ii) An explanation of the cause of the decrease in average fuel economy that led to the manufacturer's having to submit the supplementary report required by paragraph (a)(1) of this section.

(2) The supplementary report required by paragraph (a)(2) of this section must contain:

(i) A statement of the specific nature of and reason for the insufficiency in the representativeness of the projected average fuel economy;

(ii) A statement of specific additional testing or derivation of fuel economy values by analytical methods believed by the manufacturer necessary to eliminate the insufficiency; and

(iii) A description of any plans of the manufacturer to undertake that testing or derivation voluntarily and submit the resulting data to the Environmental Protection Agency under 40 CFR 600.509.

(3) The supplementary report required by paragraph (a)(3) of this section must contain:

(i) All of the information omitted from the pre-model year report under § 537.6(c)(2); and

(ii) Such revisions of and additions to the information submitted by the manufacturer in its pre-model year report regarding the automobiles produced during the current model year as are necessary to reflect the information provided under paragraph (b)(3)(i) of this section.

(4) The supplementary report required by paragraph (a)(4) of this section must contain:

(i) All information omitted from the pre-model or mid-model year reports under § 537.6(c)(2); and

(ii) Such revisions of and additions to the information submitted by the manufacturer in its pre-model or mid-model year reports regarding the automobiles produced during the current model year as are necessary to reflect the information provided under paragraph (b)(4)(i) of this section.

(c)(1) Each report required by paragraph (a)(1), (2), (3), or (4) of this section must be submitted in accordance with § 537.5(c) not more than 45 days after the date on which the manufacturer determined, or could have determined with reasonable diligence, that the report was required.

(2) [Reserved]

(d) A supplementary report is not required to be submitted by the manufacturer under paragraph (a)(1) or (2) of this section:

(1) With respect to information submitted under this part before the most recent semiannual report submitted by the manufacturer under this part; or

(2) When the date specified in paragraph (c) of this section occurs:

(i) During the 60-day period immediately preceding the day by which the mid-model year report for the current model year must be submitted by the manufacturer under this part; or

(ii) After the day by which the pre-model year report for the model year immediately following the current model year must be submitted by the manufacturer under this part.

(e) For model years 2008, 2009, and 2010, each manufacturer of light trucks, as that term is defined in 49 CFR 523.5, shall submit a report, not later than 45 days following the end of the model year, indicating whether the manufacturer is opting to comply with 49 CFR 533.5(f) or (g).

§ 537.9 Determination of fuel economy values and average fuel economy.

(a) *Vehicle subconfiguration fuel economy values.* (1) For each vehicle subconfiguration for which a fuel economy value is required under paragraph (c) of this section and has been determined and approved under 40 CFR part 600, the manufacturer shall submit that fuel economy value.

(2) For each vehicle subconfiguration specified in paragraph (a)(1) of this section for which a fuel economy value approved under 40 CFR part 600, does not exist, but for which a fuel economy value determined under 40 CFR part 600 exists, the manufacturer shall submit that fuel economy value.

(3) For each vehicle subconfiguration specified in paragraph (a)(1) of this section for which a fuel economy value has been neither determined nor approved under 40 CFR part 600, the manufacturer shall submit a fuel economy value based on tests or analyses comparable to those prescribed or permitted under 40 CFR part 600 and a description of the test procedures or analytical methods used.

(4) For each vehicle configuration for which a fuel economy value is required under paragraph (c) of this section and has been determined and approved under 40 CFR part 600, the manufacturer shall submit that fuel economy value.

(b) *Base level and model type fuel economy values.* For each base level and model type, the manufacturer shall submit a fuel economy value based on the values submitted under paragraph (a) of this section and calculated in the same manner as base level and model type fuel economy values are calculated for use under subpart F of 40 CFR part 600.

(c) *Average fuel economy.* Average fuel economy must be based upon fuel economy values calculated under paragraph (b) of this section for each model type and must be calculated in accordance with subpart F of 40 CFR part 600, except that fuel economy values for running changes and for new base levels are required only for those changes made or base levels added before the average fuel economy is required to be submitted under this part.

§ 537.10 Incorporating documents into reports.

(a) A manufacturer may incorporate by reference in a report required by this part any document other than a report, petition, or application, or portion thereof submitted to any Federal department or agency more than two model years before the current model year.

(b) A manufacturer that incorporates by references a document not previously submitted to the National Highway Traffic Safety Administration shall append that document to the report.

(c) A manufacturer that incorporates by reference a document shall clearly identify the document and, in the case of a document previously submitted to the National Highway Traffic Safety Administration, indicate the date on which and the person by whom the document was submitted to this agency.

§ 537.11 Public inspection of information.

Except as provided in § 537.12, any person may inspect the information and data submitted by a manufacturer under this part in the docket section of the National Highway Traffic Safety Administration. Any person may obtain copies of the information available for inspection under this section in accordance with the regulations of the Secretary of Transportation in part 7 of this title.

§ 537.12 Confidential information.

(a) *Granting confidential treatment.* Information made available under § 537.11 for public inspection does not include information for which confidentiality is requested under § 537.5(c)(7), is granted in accordance with section 505 of the Act and section 552(b) of Title 5 of the United States Code and is not subsequently released under paragraph (c) of this section in accordance with section 505 of the Act.

(b) *Denial of confidential treatment.* When the Administrator denies a manufacturer's request under § 537.5(c)(7) for confidential treatment of information, the Administrator gives the manufacturer written notice of the denial and reasons for it. Public disclosure of the information is not made until after the ten-day period immediately following the giving of the notice.

(c) *Release of confidential information.* After giving written notice to a manufacturer and allowing ten days, when feasible, for the manufacturer to respond, the Administrator may make available for public inspection any information submitted under this part that is relevant to a proceeding under the Act, including information that was granted confidential treatment by the Administrator pursuant to a request by the manufacturer under § 537.5(c)(7).

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Steven S. Cliff,

Acting Administrator.

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