Proposed Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation

United States
Environmental Protection
Agency

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EPA-420-R-16-020
November 2016

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Preface

The Environmental Protection Agency (EPA) is conducting a Midterm Evaluation of light-duty vehicle greenhouse gas (GHG) emissions standards for model years (MY) 2022-2025, as required under its regulations. EPA is seeking public comment on its proposed adjudicatory determination that the GHG standards currently in place for MY2022-2025 remain appropriate under the Clean Air Act and thus need not be amended to be either more or less stringent. This Proposed Determination follows a Draft Technical Assessment Report (TAR) issued jointly by EPA, the National Highway Traffic Safety Administration (NHTSA), and the California Air Resources Board (CARB) in July 2016. In the Draft TAR, the agencies examined a wide range of technical issues relevant to the appropriateness of the GHG emissions standards for MY2022-2025, based on significant research and consideration of information provided by manufacturers and other stakeholders. The Draft TAR was required by EPA regulations as the first step in the Midterm Evaluation process and we shared it with the public for their review and comments. For the next step, this Proposed Determination, EPA has considered public comments submitted on the Draft TAR as well as other information, and has updated its analyses where appropriate. EPA will again consider public comments received on the Proposed Determination as it proceeds with the final step in the Midterm Evaluation, a Final Determination regarding the appropriateness of the MY2022-2025 standards.

Comments must be received on or before December 30, 2016. Submit your comments, identified by Docket ID No. EPA-HQ-OAR-2015-0827 to the Federal eRulemaking Portal: http://www.regulations.gov. Follow the online instructions for submitting comments. Once submitted, comments cannot be edited or withdrawn. The EPA may publish any comment received to its public docket. Do not submit electronically any information you consider to be Confidential Business Information (CBI) or other information whose disclosure is restricted by statute. Multimedia submissions (audio, video, etc.) must be accompanied by a written comment. The written comment is considered the official comment and should include discussion of all points you wish to make. The EPA will not consider comments or comment contents located outside of the submission to the official dockets (i.e., located elsewhere on the web, cloud, or in another file sharing system). For additional submission methods, the full EPA public comment policy, information about CBI or multimedia submissions, and general guidance on making effective comments, please visit http://www2.epa.gov/dockets/commenting-epa-dockets.

Direct your comments to Docket ID No. EPA-HQ-OAR-2015-0827. EPA's policy is that all comments received will be included in the public docket without change and may be made available online at www.regulations.gov, including any personal information provided, unless the comment includes information claimed to be Confidential Business Information (CBI) or other information whose disclosure is restricted by statute.

The www.regulations.gov web site is an "anonymous access" system, which means EPA will not know your identity or contact information unless you provide it in the body of your comment. If you send an e-mail comment directly to EPA without going through www.regulations.gov, your e-mail address will be automatically captured and included as part of the comment that is placed in the public docket and made available on the Internet. If you submit an electronic comment, EPA recommends that you include your name and other contact information in the body of your comment and with any disk or CD–ROM, you submit. If EPA cannot read your comment due to technical difficulties and cannot contact you for clarification, EPA may not be able to consider your comment. Electronic files should avoid the use of special characters, any form of encryption, and be free of any defects or viruses. For additional information about EPA's public docket, visit the EPA Docket Center homepage at http://www.epa.gov/epahome/dockets.htm.

Do not submit CBI to EPA through http://www.regulations.gov or e-mail. Clearly mark the part or all of the information that you claim to be CBI. For CBI information in a disk or CD ROM that you mail to EPA, mark the outside of the disk or CD ROM as CBI and then identify electronically within the disk or CD ROM the specific information that is claimed as CBI. In addition to one complete version of the comment that includes information claimed as CBI, a copy of the comment that does not contain the information claimed as CBI must be submitted for inclusion in the public docket. Information so marked will not be disclosed except in accordance with procedures set forth in 40 CFR Part 2. 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.

Executive Summary

The rulemaking establishing the National Program for federal greenhouse gas (GHG) emissions and corporate average fuel economy (CAFE) standards for MY2017-2025 light-duty vehicles included a regulatory requirement for EPA to conduct a Midterm Evaluation (MTE) of the GHG standards established for MY2022-2025.[1] The Proposed Determination is the next step in EPA's MTE process, and in this document, the Administrator is making a Proposed Determination that, based on her evaluation of technical information available to her and significant input from the industry and other stakeholders, and in light of the factors listed in the 2012 final rule establishing the MY2017-2025 standards, those standards remain appropriate under section 202 (a) (1) of the Clean Air Act. EPA is seeking public comment on this proposed adjudicatory determination (hereafter "determination") that the GHG standards currently in place for MY2022-2025 remain appropriate under the Act and rulemaking to change them is not warranted. The Technical Support Document (TSD) provides additional detailed analyses supporting this Proposed Determination.

This Proposed Determination follows the July 2016 release of a Draft Technical Assessment Report (TAR), issued jointly by EPA, the National Highway Traffic Safety Administration (NHTSA), and the California Air Resources Board (CARB). In the Draft TAR, the agencies examined a wide range of issues relevant to GHG emissions standards for model years (MY) 2022-2025, and shared with the public its initial technical analyses of those issues. The Draft TAR was required by EPA's regulations as the first step in the Midterm Evaluation process. For the next step, this Proposed Determination, EPA has considered public comments on the Draft TAR and has updated its analyses where appropriate in response to comments and to reflect the latest available data, as discussed throughout this document and the TSD.

As the final step in the MTE, the Administrator must determine whether the MY2022-2025 GHG standards, established in 2012, are still appropriate under section 202 (a) (1) of the Clean Air Act (Act), in light of the record then before the Administrator, given the latest available data and information. Under the EPA regulations, this Final Determination must be made no later than April 1, 2018. However, the Administrator has discretion to make the Final Determination sooner than April 1, 2018, as EPA recognizes that long-term regulatory certainty and stability are important for the automotive industry and will contribute to the continued success of the national program, which in turn will reduce emissions, improve fuel economy, deliver important fuel savings to consumers, and benefit public health and welfare.

EPA received more than 200,000 public comments on the Draft TAR, with comments from about 90 organizations and the rest from individuals. EPA has considered those comments, as well as additional updated data and information, and where appropriate has made updates and improvements to our analyses. This record represents the most current information available, as informed by public comment, and provides the basis for the Administrator's Proposed Determination, as called for in the 2012 rule. Specific updates to our technology costs, technology effectiveness, modeling, consumer assessment, and other elements of our analysis are described in more detail throughout this document and its Appendix as well as in the accompanying TSD. Key updates and improvements include:

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[1] 40 CFR 86.1818-12(h).

- Updates to use the most recent fuel prices, vehicle sales volumes, and car/truck mix, from the Energy Information Administration's Annual Energy Outlook (AEO 2016)
- Updates to use the latest final model year of certified vehicle data (MY2015) in the baseline
- Updates to our vehicle simulation model to include the latest data on technology effectiveness, from the EPA vehicle benchmarking testing program and other sources, across vehicle types
- Updates to battery costs for electrified vehicles based on updated data from the literature
- Building in additional quality assurance checks of technology effectiveness estimates
- Updates to vehicle class definitions for effectiveness modeling and a greater resolution of vehicle types to provide more accuracy and precision in representing technology cost and effectiveness for the future vehicle fleet
- Better accounting for tire and aerodynamic improvements in the baseline vehicle fleet

Importantly, the analyses conducted for this Proposed Determination have corroborated the key conclusions reached in the Draft TAR, as we explain further below.

- A wider range of technologies exist for manufacturers to use to meet the MY2022-2025 standards, and at costs that are similar to or lower than, those projected in the 2012 rule.
- The auto industry can meet the standards primarily with advanced gasoline vehicle technologies and with very low levels of strong hybridization and full electrification (plug-in vehicles).
- The updated 2025 projections of fuel prices, car/truck mix, and the fleet-target illustrate that the footprint-based standards will continue to accommodate consumer choice and achieve significant GHG reductions and fuel savings across all vehicle types.

The EPA regulations state that in making the required determination, the Administrator shall consider the information available on the factors relevant to setting greenhouse gas emission standards under section 202(a) of the Clean Air Act for model years 2022 through 2025, including but not limited to:

- The availability and effectiveness of technology, and the appropriate lead time for introduction of technology;
- The cost on the producers or purchasers of new motor vehicles or new motor vehicle engines;
- The feasibility and practicability of the standards;
- The impact of the standards on reduction of emissions, oil conservation, energy security, and fuel savings by consumers;

- The impact of the standards on the automobile industry;
- The impacts of the standards on automobile safety;
- The impact of the greenhouse gas emission standards on the Corporate Average Fuel Economy standards and a national harmonized program; and
- The impact of the standards on other relevant factors.[2]

Consideration of the updated analyses in light of the above factors established in the 2012 rule form the basis for this Proposed Determination supporting the Administrator's proposal that the MY2022-2025 standards remain appropriate, as summarized below.

The Standards Are Feasible. In our technical assessment of the technologies available to meet the MY2022-2025 GHG standards, we present a range of feasible, cost-effective compliance pathways to meet the MY2022-2025 standards. EPA analyzed a "central case" low-cost pathway, as well as multiple sensitivity analyses, including various fuel price scenarios, indirect cost markups, and technology penetrations (e.g., different mixes of engine technologies, lower mass reductions, alternative transmission effectiveness estimates). This range of analyses demonstrates that compliance can be achieved through a number of different technology pathways, as is the intent of the performance-based GHG standards that provide each manufacturer with the flexibility to apply technologies in the way it views best to meet the needs of its customers. Given the rapid pace of automotive industry innovation, we believe there are, and will continue to be, emerging technologies that will be available in the MY2022-2025 time frame that could perform appreciably better at potentially lower cost than the technologies modeled in this Proposed Determination. Such technologies are exemplified by recent advances already seen in the marketplace that we did not anticipate when the standards were finalized four years ago (e.g., expanded use of continuously variable transmissions and higher compression ratio, naturally aspirated gasoline engines (Atkinson)). Updated information also shows that the technologies we did anticipate in 2012 are costing less, and are more effective, than we anticipated at that time.

EPA's Proposed Determination assessment provides projections for the MY2022-2025 standards for several key metrics, including a range of modeled "low-cost pathway" technology penetrations and per-vehicle average costs (Table ES-1); CO_2 target levels (Table ES-2); GHG and oil reductions (Table ES-3); industry-wide average costs, consumer fuel savings, and societal monetized benefits (Table ES-4); and consumer payback (Table ES-5). The Proposed Determination analysis results are similar to those of the Draft TAR, which are shown in the tables for comparison.

As in the Draft TAR, we project that the MY2022-2025 standards can be met largely through advances in gasoline vehicle technologies, such as improvements in engines, transmissions, light-weighting, aerodynamics, and accessories. Table ES-1 shows fleet-wide penetration rates for a subset of the technologies EPA projects could be utilized to comply with the MY2025 standards. The analyses further indicate that very low levels of strong hybrids and full electrification (plug-in hybrid electric vehicles (PHEV) or electric vehicles (EV)) technology will be needed to meet the standards. As noted above, we analyzed multiple sensitivity cases

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[2] 40 CFR 86.1818-12(h)(1).

which show that compliance can be achieved through a number of different technology pathways. These sensitivity cases, including various fuel price scenarios, cost markups, and technology penetrations (e.g., lower Atkinson penetration, lower mass reduction, alternative transmissions), are presented in Table ES-1 as a range of technology penetrations and per-vehicle costs.

Table ES-1 Selected Technology Penetrations (Absolute) and Per-Vehicle Average Costs (2015$) to Meet MY2025 GHG Standards (Incremental to the Costs to Meet the MY2021 Standards) [1]

	Draft TAR[2]	Proposed Determination[3]	
		Primary Analysis	Range of Sensitivities Analyzed
Turbocharged and downsized gasoline engines (%)	33%	34%	31 - 41%
Higher compression ratio, naturally aspirated gasoline engines (%)	44%	27%	5 - 41%
8 speed and other advanced transmissions[4] (%)	90%	93%	92 - 94%
Mass reduction (%)[5]	7%	9%	2 - 10%
Off-cycle technology[6]	not modeled	26%	13 - 51%
Stop-start (%)	20%	15%	12 - 39%
Mild Hybrid (%)	18%	18%	16 - 27%
Strong Hybrid (%)	<3%	2%	2 - 3%
Plug-in hybrid electric vehicle[7] (%)	<2%	2%	2%
Electric vehicle[7] (%)	<3%	3%	2 - 4%
Per vehicle cost (2015$)	$920	$875	$800 - $1,115

Notes:
[1] Percentages shown are absolute rather than incremental
[2] The Draft TAR values are based on AEO 2015 reference case; the Draft TAR reported average per vehicle costs of $894 in 2013$
[3] The Proposed Determination values are based on AEO 2016 reference case
[4] Including continuously variable transmissions (CVT)
[5] The 9% mass reduction for the Proposed Determination is relative to the 'null' package. Using the same approach, the Draft TAR 7% mass reduction relative to the MY2014 baseline becomes 9% relative to 'null'
[6] EPA did not model off-cycle technologies in the Draft TAR except for stop-start and active aerodynamics; for the Proposed Determination we are now also assessing additional off-cycle technologies as unique technologies that can be applied to a vehicle and that reduce CO_2 emissions by either 1.5 g/mi or 3 g/mi.
[7] Electric vehicle penetrations include the California Zero Emission Vehicles (ZEV) program

The Standards Will Achieve Significant CO_2 and Oil Reductions. Based on various assumptions including the AEO 2016 reference case projections of the car/truck mix out to 2025, the footprint-based GHG standards curves for MY2022-2025 are projected to achieve an industry-wide fleet average carbon dioxide (CO_2) target of 173 grams/mile (g/mi) in MY2025 (Table ES-2). The projected fleet average CO_2 target represents a GHG emissions level equivalent to 51.4 mpg (if all reductions were achieved exclusively through fuel economy improvements).[3] As shown in Table ES-2, these results are very similar to the Draft TAR

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[3] The projected MY2025 target of 173 g/mi represents an approximate 50% decrease in GHG emissions relative to the fuel economy standards that were in place in 2010. It is clear from current GHG manufacturer performance

projections (which were based on AEO 2015 fuel prices and fleet mix). As a sensitivity, we also include target projections based on two AEO 2016 scenarios in addition to the AEO 2016 reference case: a low fuel price case and a high fuel price case. As shown in Table ES-2, these fuel price cases translate into different projections for the car/truck fleet mix (e.g., with a higher truck share shown in the low fuel price case, and a lower truck share shown in the high fuel price case), which in turn leads to varying projections for the GHG CO_2 targets and MPG-e levels projected for MY2025. These estimated GHG target levels reflect changes in the latest projections about the MY2025 fleet mix compared to the projections in 2012 when the standards were first established. Under the footprint-based standards, the program is designed to ensure significant GHG reductions across the fleet, and each automaker's standard automatically adjusts based on the mix (size and volume) of vehicles it produces each model year.

In our analysis for this Proposed Determination, we are proposing to retain unaltered the existing MY2022-2025 standards established in the 2012 final rule, and as such are applying these same footprint-based standards to the updated fleet projections for MY2025. It is important to keep in mind that the updated MY2025 fleet wide projections reflected in this Proposed Determination are still just projections (as were the fleet projections in the 2012 rule and the Draft TAR) -- based on the latest available information, which will likely continue to change with future projections -- and that the actual GHG emissions/fuel economy level achieved in MY2025 will not be determined until the manufacturers have completed their MY2025 production.

Table ES-2 Projections for MY2025: Car/Truck Mix, CO_2 Target Levels, and MPG-equivalent[1]

	2012 Final Rule	Draft TAR	Proposed Determination		
	AEO 2011 Reference	AEO 2015 Reference	AEO 2016 Reference	AEO 2016 Low	AEO 2016 High
Car/truck mix	67/33%	52/48%	53/47%	44/56%	63/37%
CO_2 (g/mi)	163	175	173	178	167
MPG-e[2]	54.5	50.8	51.4	49.9	53.3

Notes:

[1] The CO_2 and MPG-e values shown here are 2-cycle compliance values. Projected real-world values are detailed in Chapter 3 of the TSD; for example, for the Proposed Determination AEO reference fuel price case, real-world CO_2 emissions performance would be 233 g/mi and real-world fuel economy would be about 36 mpg.

[2] Mile per gallon equivalent (MPG-e) is the corresponding fleet average fuel economy value if the entire fleet were to meet the CO_2 standard compliance level through tailpipe CO_2 improvements that also improve fuel economy. This is provided for illustrative purposes only, as we do not expect the GHG standards to be met only with fuel efficiency technology.

In Table ES-3, the reductions presented represent those that are expected to occur over the lifetime of MY2021-2025 vehicles.

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data that many automakers are earning air conditioner refrigerant GHG credits that reduce GHG emissions, but do not improve fuel economy. Accordingly, the projected MY2025 target of 173 g/mi represents slightly less than a doubling of fuel economy relative to the standards that were in place in 2010.

Table ES-3 Cumulative GHG and Oil Reductions for Meeting the MY2022-2025 Standards (Vehicle Lifetime Reductions)

	Draft TAR[1]	Proposed Determination[2]
GHG reduction (million metric tons, MMT CO_2e)	540	537
Oil reduction (billion barrels)	1.2	1.2

Notes:

[1] The Draft TAR values are based on AEO 2015 reference case

[2] The Proposed Determination values are based on AEO 2016 reference case

The Standards Will Provide Significant Benefits to Consumers and the Public. Tables ES-4 presents the societal monetized benefits associated with meeting the MY2025 standards. EPA also evaluated the benefit-costs of additional scenarios (AEO 2016 high and low fuel price scenarios) as discussed further in Section IV.A. In all cases, the net benefits far exceed the costs of the program. It is also notable that in all cases, the benefits and the fuel savings independently exceed the costs (i.e., the benefits exceed the costs without considering any fuel savings, and likewise fuel savings exceed the costs even without considering any other benefits).

Table ES-4 GHG Analysis of Lifetime Costs & Benefits to Meet the MY2022-2025 GHG Standards (for Vehicles Produced in MY2021-2025)[1] (Billions of $)

	Draft TAR[2]	Proposed Determination[3]	
	3 Percent Discount Rate	3 Percent Discount Rate	7 Percent Discount Rate
Vehicle Program	- $34	-$33	-$24
Maintenance	-$2	-$3	-$2
Fuel	$89	$92	$52
Benefits[1]	$41	$42	$32
Net Benefits	$94	$98	$59

Notes:

[1] All values are discounted back to 2016; see the Appendix Section C for details on discounting social cost of GHG and non-GHG benefits. The costs and benefits also reflect some early compliance with the MY2025 standard in MY2021, as discussed in Appendix C.1.

[2] The Draft TAR values are based on AEO 2015 reference case and 2013$

[3] The Proposed Determination values are based on AEO 2016 reference case and 2015$

When considering the payback of an average MY2025 vehicle compared to a vehicle meeting the MY2021 standards, we believe one of the most meaningful analyses is to look at the payback for consumers who finance their vehicle, as the vast majority of consumers (nearly 86 percent) purchase new vehicles through financing with average loan periods of over 67 months. Consumers who finance their vehicle with a 5-year loan would see payback within the first year. Consumers who pay cash for their vehicle would see payback in the 5th year of ownership. Consumers would save $1,650 over the lifetime of their new vehicle (i.e., net of increased lifetime costs and lifetime fuel savings). Even with the lowest fuel prices projected by AEO (shown in the Appendix Section C), the lifetime fuel savings outweigh increased lifetime costs.

Table ES-5 Payback Period and Net Lifetime Consumer Savings for an Average MY2025 Vehicle Compared to the MY2021 GHG Standards

	Draft TAR[1]	Proposed Determination[2]
Payback period – 5-year loan purchase[3] (years)	Not calculated	<1
Payback period – Cash purchase (years)	5	5
Net Lifetime Consumer Savings ($, discounted at 3%)	$1,620	$1,650

Notes:

[1] The Draft TAR values are based on AEO 2015 reference case and 2013$

[2] The Proposed Determination values are based on AEO 2016 reference case and 2015$

[3] Using an interest rate of 4.25 percent. The Appendix Section C also presents payback periods using 4-year and 6-year loan periods. We did not calculate the payback periods for loan purchases in the Draft TAR.

The Auto Industry is Thriving and Meeting the Standards More Quickly than Required. While the Proposed Determination analysis focuses on the MY2022-2025 standards, we note that the auto industry, on average, is over-complying with the first four years of the light-duty GHG standards (MY2012-2015). This has occurred concurrently with a period during which the automotive industry successfully rebounded after a period of economic distress. The recently-released 2016 Fuel Economy Trends Report and the GHG Manufacturer Performance Report for the 2015 Model Year show that the National Program is working even at low fuel prices and automakers are over-complying with the biggest annual increase in the standards yet.[4,5] The industry has now seen six consecutive years of fuel economy increases (with the biggest, most recent improvements from large SUVs and pickups) and strong vehicle sales through 2016, reflecting positive consumer response to vehicles complying with the standards.

While the Administrator is making a Proposed Determination in this document that the MY2022-2025 standards established in 2012 remain appropriate, she has also considered whether it would be appropriate to make the standards more stringent. In her view, the current record, including the current state of technology and the pace of technology development and implementation, could support a decision to adopt more stringent standards for 2022-2025. However, she also recognizes that supporting long-term planning and engineering by the automotive industry is an important consideration and will contribute to the continued success of the industry and the GHG standards program, which in turn will benefit consumers and reduce emissions. EPA also believes a decision to maintain the current standards provides support to a timely NHTSA rulemaking to adopt 2022-2025 standards, as well as to the California Air Resources Board to consider in its review of the California GHG vehicle standards for MY2022-2025 as part of its Advanced Clean Cars program,[6] and a harmonized national program. Thus, the Administrator has preliminarily concluded that it is appropriate to provide the full measure of

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[4] U.S. EPA, 2016. 2016 Fuel Economy Trends Report: www.epa.gov/fuel-economy/trends-report.

[5] U.S. EPA, 2016. GHG Manufacturer Performance Report for 2015 Model Year: https://www.epa.gov/regulations-emissions-vehicles-and-engines/ghg-emission-standards-light-duty-vehicles-manufacturer.

[6] California adopted its own GHG standards for MY2017-2025 in 2012 prior to EPA and NHTSA finalizing the National Program. Through direction from its Board in 2012, CARB both adopted a “deemed to comply” provision allowing compliance with EPA’s GHG standards in lieu of CARB’s standards, and committed to participate in the Midterm Evaluation (https://www.arb.ca.gov/msprog/consumer_info/advanced_clean_cars/consumer_acc_mtr.htm).

lead time for the 2022-2025 standards, rather than adopting new, more stringent standards with a shorter lead time.

Continued Reductions in CO_2 Emissions Are Essential to Help Address the Threat of Climate Change. In December 2015, the U.S. was one of over 190 signatories to the Paris Climate Agreement. In the Paris agreement, individual countries agreed to commit to putting nationally determined contributions (NDCs) for greenhouse gas emissions reductions to the United Nations Framework Convention on Climate Change. Further, the countries agreed to revise their NDCs every five years, with the expectation that they will strengthen over time. The Paris agreement reaffirms the goal of limiting global temperature increase to well below 2°Celsius, and for the first time urged efforts to limit the temperature increase to 1.5°Celsius. The U.S. submitted a non-binding intended NDC target of reducing economy-wide GHG emissions by 26-28 percent below its 2005 level in 2025 and to make best efforts to reduce emissions by 28 percent. The White House recently discussed the importance of near-term emission reductions, including to spur technology cost reductions that will facilitate sustained economy-wide emission reductions beyond 2025 in the United States Mid-Century Strategy, released in November 2016 at the same time that Canada and Mexico released their respective Mid-Century Strategies.[7]

EPA recognizes that climate change is a long-term global environmental challenge. Any meaningful plan to address the climate challenge must prioritize early GHG emissions reductions and make continual progress toward long-term goals. Transportation is projected to be an increasingly significant contributor to U.S. (and global) CO_2 emissions well into the future. Given that lead time issues are central to the automotive industry, beginning to identify appropriate GHG emissions targets for the light-duty vehicle sector beyond 2025 may facilitate more efficient investment planning strategies for both the pre-2025 and post-2025 time frames. While EPA is not yet prepared to begin a formal light-duty vehicle GHG emissions rulemaking process beyond MY2025, the agency believes that it is important to have a dialog with the industry and other key stakeholders, including the State of California and non-governmental organizations, about future light-duty vehicle GHG emissions reductions.

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[7] United States Mid-Century Strategy for Deep Carbonization, November 2016.

I. Overview of EPA's Proposed Determination on the Appropriateness of the Model Year 2022-2025 Light-duty Vehicle Greenhouse Gas Standards

A. Introduction

1. Overview of the Midterm Evaluation

The Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) have conducted two joint rulemakings to establish a coordinated National Program for federal greenhouse gas (GHG) emissions and corporate average fuel economy (CAFE) standards for light-duty vehicles. The agencies finalized the first set of National Program standards covering model years (MYs) 2012-2016 in May 2010[8] and the second set of standards, covering MYs 2017-2025, in October 2012.[9] The National Program established standards that increase in stringency year-over-year from MY2012 through MY2025, projected to reach a level by 2025 that nearly doubles fuel economy and cuts GHG emissions in half as compared to MY2010. Through the coordination of the National Program with the California Air Resources Board GHG standards, automakers can build one single fleet of vehicles across the U.S. that satisfies all GHG/CAFE requirements, and consumers can continue to have a full range of vehicle choices that meet their needs.[10] Most stakeholders strongly supported the National Program, including the auto industry, automotive suppliers, state and local governments, labor unions, NGOs, consumer groups, veterans groups, and others. In the agencies' 2012 final rules, the National Program was estimated to save 6 billion metric tons of carbon dioxide (CO_2) pollution and 12 billion barrels of oil over the lifetime of MY2012-2025 vehicles. The final standards are projected to provide significant savings for consumers due to reduced fuel use and consequent reduced fuel expenditures.

The 2012 final rule established standards through MY2025 to provide substantial lead time and regulatory certainty to the industry. Recognizing the rule's long time frame, EPA's rulemaking establishing GHG standards for model year MY2017-2025 light-duty vehicles included a regulatory commitment for the agency to conduct a Midterm Evaluation (MTE) of MYs 2022-2025 GHG standards.[11] Through the MTE, EPA must determine whether the GHG standards for model years 2022-2025, established in 2012, are still appropriate, within the meaning of section 202 (a) (1) of the Clean Air Act, in light of the record then before the Administrator, given the latest available data and information. See 40 CFR section 86.1818-12(h). This is an evaluation of the factual record in light of the specified factors in the regulation. Should the Administrator make the determination that the standards are not appropriate, based upon consideration of the decision factors in the regulation and the factual record available to the Administrator at the time of the determination, then EPA must initiate a rulemaking to amend the standards. See 40 CFR section 86.1818-12(h) (second sentence).

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[8] 75 FR 25324, May 7, 2010.

[9] 77 FR 62624, October 15, 2012.

[10] Subsequent to the adoption of California-specific GHG standards for MYs 2017-2025 and the adoption of the Federal standards for MY2017 and beyond, CARB adopted a "deemed to comply" provision in furtherance of a National Program whereby compliance with the Federal GHG standards would be deemed to be compliance with California's GHG program.

[11] See 40 CFR 86.1818-12(h).

The MTE is a data-driven and transparent process that is "a holistic assessment of all of the factors considered in standards setting," and "the expected impact of those factors on manufacturers' ability to comply, without placing decisive weight on any particular factor or projection." See 77 FR 62784 (Oct. 15, 2012). The MTE analysis is as robust and comprehensive as that in the original setting of the MY2017-2025 standards, *id.*, although the nature of the decision-making EPA is undertaking based on that analysis is very different. In the 2012 rule EPA was faced with establishing the MY2017-2025 standards, while in this Proposed Determination EPA must evaluate those standards in light of developments to date. *Id*.

In July 2016, EPA, NHTSA, and CARB jointly issued for public comment a Draft Technical Assessment Report (TAR) examining a wide range of issues relevant to the MY2022-2025 standards.[12] For EPA, the Draft TAR was the first formal step in the MTE process as required under EPA's regulations.[13] The Draft TAR was a technical report, not a decision document. It was an opportunity for all three agencies to share with the public their technical analyses relating to the appropriateness of the MY2022-2025 standards. The Draft TAR was the required first step in the process that will ultimately inform whether the MY2022-2025 GHG standards adopted by EPA in 2012 should remain in place or should change. As noted in the 2012 final rule preamble "EPA, NHTSA and CARB will jointly prepare a draft Technical Assessment Report (TAR) to inform EPA's determination on the appropriateness of the GHG standards and to inform NHTSA's rulemaking for the CAFE standards for MY2022–2025. The TAR will examine the same issues and underlying analyses and projections considered in the original rulemaking, including technical and other analyses and projections relevant to each agency's authority to set standards as well as any relevant new issues that may present themselves." See 77 FR 62784 (Oct. 15, 2012). A Final TAR was not contemplated in the 2012 final rule and is not required by EPA's regulations; nevertheless, the TSD accompanying this document serves this purpose for EPA's GHG determination of whether the MY2022-2025 remain appropriate.

This document is the next step in the MTE process – the Administrator's Proposed Determination. In this Proposed Determination, the Administrator is proposing to find that the MY2022-2025 standards remain appropriate under the Clean Air Act. Because the Administrator is proposing that there be no change to the MY2022-2025 standards currently in the regulations, in other words that there be no change in the standards' stringency (or any other aspect), this Proposed Determination does not include a Notice of Proposed Rulemaking.[14] See

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[12] 81 FR 49217, July 27, 2016.

[13] See 40 CFR 86.1818-12(h)(2)(i).

[14] An "adjudication" means "an agency process for the formulation of an order." 5 USC section 551 (7). An "order", in turn "means the whole or a part of a final disposition… of an agency in a manner other than rulemaking but including licensing." Id. section 551 (6). The Supreme Court has explained the "basic distinction between rulemaking and adjudication" as a difference between "proceedings for the purpose of promulgating policy-type rules or standards, on the one hand, and proceedings designed to adjudicate disputed facts in particular cases on the other." United States v. Fla. E. Coast Ry. Co., 410 U.S. 224, 244-45 (1973). Here, the Agency is not promulgating a policy-type rule or standard. Nor is the Agency changing a rule, creating a new rule, or changing any aspect of the existing rule. Rather, the Agency is considering and proposing to resolve the factual issues arising when considering the factors set out in section 86.1818 (h)(1) (e.g. practicability, feasibility, technology effectiveness, impacts on the automobile industry and on consumers, and safety). See Safari Club Int'l v. Jewell, 2016 U.S. LEXIS, 136235, *31-*36 (generally applicable enhancement findings made

section 86.1818-12(h). The net consequence of a final determination that the standards are appropriate would be preservation of the regulatory status quo, and so would be without legal effect on the regulated industry.[15]

The EPA regulations state that in making the required determination, the Administrator shall consider the information available on the factors relevant to setting greenhouse gas emission standards under section 202(a) of the Clean Air Act for model years 2022 through 2025, including but not limited to:

- The availability and effectiveness of technology, and the appropriate lead time for introduction of technology;
- The cost on the producers or purchasers of new motor vehicles or new motor vehicle engines;
- The feasibility and practicability of the standards;
- The impact of the standards on reduction of emissions, oil conservation, energy security, and fuel savings by consumers;
- The impact of the standards on the automobile industry;
- The impacts of the standards on automobile safety;
- The impact of the greenhouse gas emission standards on the Corporate Average Fuel Economy standards and a national harmonized program; and
- The impact of the standards on other relevant factors.[16]

The Preamble to the 2012 final rule further listed ten relevant factors that the agencies will consider at a minimum during the MTE, and all of these factors were in fact addressed in the Draft TAR.[17] These factors are:

- Development of powertrain improvements to gasoline and diesel powered vehicles
- Impacts on employment, including the auto sector;
- Availability and implementation of methods to reduce weight, including any impacts on safety;
- Actual and projected availability of public and private charging infrastructure for electric vehicles, and fueling infrastructure for alternative fueled vehicles;

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in the context of regulations governing import permits are adjudications). Moreover, Justice Scalia explained that the "central distinction between rulemaking and adjudication" is that "rules have legal consequences only for the future." Bowen v. Georgetown Univ. Hosp., 488 U.S. 204, 216-17 (Scalia, J., concurring). The present proposed order, if finalized, would not have future legal effect -- it would leave the current regulatory status quo unchanged and unaltered. Consequently, should EPA take final action, the action would be an order embodying the adjudicatory determination with respect to the appropriateness of the MY2022-2025 standards in light of the resolution of these factual issues. See also ICORE v. FCC, 985 F.2d 1075, 1082 (D.C. Cir. 1993) ("Not modifying a rule is not the same as 'formulating, amending, or repealing a rule', the APA definition of 'rule making'. 5 U.S.C. § 551(5)").

[15] A final order finding the standards to be appropriate would, however, be final agency action for purposes of judicial review. See 77 FR 62784.

[16] 40 CFR 86.1818-12(h).

[17] 77 FR 62784, October 15, 2012.

- Costs, availability, and consumer acceptance of technologies to ensure compliance with the standards, such as vehicle batteries and power electronics, mass reduction, and anticipated trends in these costs;
- Payback periods for any incremental vehicle costs associated with meeting the standards;
- Costs for gasoline, diesel fuel, and alternative fuels;
- Total light-duty vehicle sales and projected fleet mix;
- Market penetration across the fleet of fuel efficient technologies;
- Any other factors that may be deemed relevant to the review.

Among the other factors deemed relevant and addressed in the Draft TAR, EPA's analysis examined the potential impact of the California Zero Emission Vehicle (ZEV) program, which California has revised since the final rule. EPA also examined the availability and use of credits, including credits for emission reductions from air conditioning improvements and from off-cycle technologies. In gathering data and information for the Draft TAR, the agencies drew from a wide range of sources, including vehicle certifications data, research projects initiated by the agencies, input from stakeholders, and information from technical conferences, published literature, and studies published by various organizations. In the Draft TAR, EPA provided its initial technical assessment of the technologies available to meet the MY2022-2025 GHG standards and one feasible “low cost” compliance pathway. EPA also performed multiple sensitivity analyses which showed various other possible compliance pathways. In the Draft TAR, the agencies reached the following initial conclusions:

- A wider range of technologies exist for manufacturers to use to meet the MY2022-2025 standards, and at costs that are similar or lower, than those projected in the 2012 rule;

- The auto industry can meet the standards primarily with advanced gasoline vehicle technologies and with very low levels of strong hybridization and full electrification (plug-in vehicles);

- The updated 2025 projections of fuel prices, car/truck mix, and the fleet-target illustrate that the footprint-based standards will continue to accommodate consumer choice and achieve GHG reductions and fuel savings across all vehicle types.

Also as noted in the Draft TAR, since the 2012 final rule, vehicle sales have been strong, hitting an all-time high of 17.5 million vehicles in 2015, gas prices have dropped significantly, and truck share of the fleet has increased. At the same time, auto manufacturers have over-complied with the GHG program for each of the first four years of the program (MY2012-2015), and the industry as a whole has built a substantial bank of credits from the initial years of the program.[18] The technologies that reduce GHG emissions are entering the market at rapid rates, including more efficient engines and transmissions, aerodynamics, light-weighting, improved accessories, low rolling resistance tires, improved air conditioning systems, and others. Manufacturers are also using certain technologies that the agencies did not consider in their

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[18] “Greenhouse Gas Emission Standards for Light-duty Vehicles, Manufacturer Performance Report for the 2015 Model Year, November 2016, EPA-420-R-16-014.

evaluation in the 2012 rule, including higher compression ratio, naturally aspirated gasoline engines. Other technologies are being utilized at greater rates than the agencies postulated, an example being the greater-than-predicted penetration of continuously variable transmissions (CVTs). These emerging technologies have resulted in a projected compliance pathway which is slightly different than that of the 2012 final rulemaking (FRM) with respect to some of the specific technologies expected to be applied to meet the future standards. However, the conclusions of the 2012 FRM, the 2016 TAR, and this Proposed Determination are very similar: that advanced gasoline vehicles will be the predominant technologies required to meet the MY2025 standards. This assessment is similar to the conclusion of a 2015 study by the National Academy of Sciences which also found that the 2025 standards could be achieved primarily with advanced gasoline vehicle technologies.

The agencies received over 200,000 comments on the Draft TAR, with nearly 90 comments from organizations and the rest from individuals. EPA also has considered the few additional comments received after the close of the comment period on the Draft TAR.[19] The organization commenters included auto manufacturers and suppliers, environmental and other non-governmental organizations (NGOs), consumer groups, state and local governments and their associations, labor unions, fuels and energy providers, auto dealers, academics, national security experts, veteran’s groups, and others. These comments presented a range of views on whether the standards should be retained, or made more or less stringent, and, in some cases, provided additional factual information that has allowed EPA to improve its analyses in support of the Administrator’s Proposed Determination.

The Alliance of Automobile Manufacturers and Global Automakers commented that their members support the goals of the National Program. Honda supported keeping the existing MY2022-2025 standards but believed the costs would be significantly higher than EPA's analysis. Volkswagen also supported retaining the MY2022-2025 standards, based on its projected compliance strategy. Electric vehicle manufacturers Tesla and Faraday Future commented that the standards are too conservative and that projected growth in electric vehicles could allow the standards to be made more stringent. Other auto industry comments, however, generally expressed the view that the standards remain challenging and raised several concerns regarding the Draft TAR analysis. These automaker comments include (1) more advanced technology vehicles including strong hybrids and electric vehicles will be needed than projected by the agencies, (2) there is still significant uncertainty regarding consumer’s willingness to pay for advanced technology vehicles, (3) the regulations need to be further harmonized, and (4) further incentive and credit opportunities are needed.

Some automotive suppliers provided comments on the role that their products can play in meeting the standards. Suppliers of materials such as aluminum, steels, and plastics, commented on their product's important role in vehicle lightweighting. The Manufacturers of Emission Controls Association (MECA) praised the technical robustness of the Draft TAR and agreed with its conclusions that the 2025 standards are achievable with advanced gasoline vehicle technologies. CALSTART presented the results of a study on Tier 1 suppliers’ views of the MY2025 standards showing that: most suppliers believe that the standards should be maintained

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[19] After the close of the comment period, EPA received in the docket additional comments from Volkswagen, the Electric Drive Transportation Association, and the Alliance of Automobile Manufacturers (a non-technical comment), all of which EPA has considered.

or strengthened; suppliers want regulatory certainty having already made investments planning for the 2025 standards; and most suppliers would like the agencies to begin working now on standards beyond 2025. BorgWarner (a Tier 1 automotive supplier) commented that EPA has overestimated the ability of manufacturers to meet the standards using conventional technologies and the standards will require significantly more electrification than EPA has projected, similar to several auto manufacturer comments.

The National Automobile Dealers Association (NADA) encouraged the agencies to devote additional resources that they view as necessary to achieve a better understanding of customer behaviors and marketplace realities. NADA provided comments in several areas including harmonization, affordability, consumer demand for fuel economy, tradeoffs between fuel economy and other vehicle attributes, and consumer choice modeling.

Environmental organizations, consumer advocacy groups, state/local governments, and others expressed strong support for the standards and for EPA's Draft TAR analysis, and many suggested that the standards should be further strengthened. These groups pointed to even further technology developments expected before the 2025 time frame which have potential to improve effectiveness and reduce costs. They also expressed concern for the market shifts from cars to SUVs and trucks as reducing the CO_2 fleet average targets initially projected when the standards were set, and suggested that the standards should be strengthened to gain back these environmental benefits. Several of these commenters urged EPA to begin considering standards for beyond 2025 to ensure additional progress toward the deep reductions needed to address climate change.

Environmental NGOs supported EPA's Draft TAR analysis, commenting that the analysis demonstrates that the MY2022-2025 standards remain cost-effective and that the standards could be made more stringent either in the MY2022-2025 time frame or in MY2026 and later. The International Council on Clean Transportation (ICCT) commented that some of the assessments, for example in the areas of engine technology, lightweighting, and transmissions, are perhaps too conservative. UCS provided an analysis of SUVs disparity under the car/truck standard curves and argued for more stringent standards.

Consumer groups provided comments strongly supporting the standards, commenting that consumers continue to strongly support fuel efficiency improvements. Business for Innovative Climate and Energy Policy commented that a Ceres study found that the Detroit Three automakers will be profitable under the standards and that the standards provide insurance against future market losses in the event of a fuel price spike. The study also found that the regulatory certainty provided by long term standards are beneficial to auto suppliers investing in research, development, and production capacity for fuel-saving technologies.

State and local government organizations, and many non-environmental NGOs (including veterans' groups and energy security organizations) also provided comments supporting the current or even more stringent standards. The UAW commented that the standards have spurred investments in products that employ tens of thousands of its members and encouraged the continuation of the National Program with harmonized credits and flexibilities.

EPA has fully considered the public comments on the Draft TAR and has made a number of updates to its analyses as a result. Since the Draft TAR, EPA also has continued to gather and evaluate the most up-to-date information to inform our analyses for the Proposed Determination.

The public comments on the Draft TAR and other updated information, however, have not caused us to alter the fundamental Draft TAR findings noted above.

The Administrator, of course, has not reached any final conclusions. The Final Determination will be the Administrator's final determination on whether or not the MY2022-2025 standards are appropriate under section 202 (a)(1) of the Clean Air Act, in light of the record then before the Administrator. EPA's regulations specify that the determination shall be "based upon a record that includes the following:

- A draft Technical Assessment Report addressing issues relevant to the standard for the 2022 through 2025 model years;
- Public comment on the draft Technical Assessment Report;
- Public comment on whether the standards established for the 2022 through 2025 model years are appropriate under section 202(a) of the Clean Air Act; and
- Such other materials the Administrator deems appropriate."[20]

EPA is seeking public comment on this Proposed Determination that the GHG standards currently in place for MY2022-2025 remain appropriate under the Act. If those comments lead the Administrator to the determination that the standards are inappropriate, EPA would then initiate rulemaking seeking to amend those standards, as specified in the MTE regulation. If the Administrator determines that the standards remain appropriate, then no further action under the Midterm Evaluation would occur, the standards would remain unaltered in any manner, and the status quo would be maintained.

2. Background on the Light-duty Vehicle GHG Standards

Together, light-duty vehicles, which include passenger cars, sport utility vehicles, crossover utility vehicles, minivans, and pickup trucks, are presently responsible for approximately 60 percent of all U.S. transportation-related GHG emissions and fuel consumption.[21] The 2012 final rule projected that the National Program standards would result in MY2025 light-duty vehicles with nearly double the fuel economy and halve the GHG emissions compared to MY2010 vehicles. Collectively, these represented some of the most significant federal actions ever taken to reduce domestic GHG emissions and improve automotive fuel economy. In the 2012 final rule, based on future assumptions including car/truck share, EPA projected that its standards would lead to an average industry fleet wide emissions level of 163 grams/mile of carbon dioxide (CO_2) in model year 2025 (compared to 326 g/mile in MY2011), which is

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[20] 40 CFR 86.1818-12(h)(2).

[21] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014, EPA Publication number EPA 430-R-16-002, April 15, 2016.

equivalent to 54.5 mpg if this level were achieved solely through improvements in fuel economy.[22,23]

The light-duty GHG/fuel economy National Program is projected to achieve very large reductions in GHG emissions and oil consumption, as well as significant fuel savings for consumers. In the 2012 final rule analysis, EPA projected that the cumulative GHG emissions reductions over the lifetimes of the new light-duty vehicles sold in model years 2012 through 2025 would be 6 billion metric tons (these reductions would begin in calendar year 2012 and would end in the calendar year when the last model year 2025 vehicles would be retired from the fleet).[24] EPA projected the oil savings over the lifetime of these vehicles would be 12 billion barrels.

Because EPA GHG emissions standards will remain in effect unless and until they are changed, GHG emissions reductions will continue to accrue for vehicles sold after model year 2025, and these longer-term GHG emissions (CO_2e) reductions are not reflected in the 6 billion metric ton value above. In terms of on-the-ground reductions in specific calendar years, EPA projected, in the 2012 final rule analysis, that the National Program would yield GHG (CO_2e) emissions reductions of 180 million metric tons (MMT) in calendar year 2020, 380 MMT in 2025, 580 MMT in 2030, 860 MMT in 2040, and 1,100 MMT in calendar year 2050. The cumulative GHG emissions savings over calendar years 2012 through 2050 were projected to be 22 billion metric tons.[25]

In the 2012 final rule, the agencies projected that, in meeting the MY2025 standards, a wide range of vehicles would continue to be available, preserving consumer choice, and the Proposed Determination would leave consumer choice unconstrained. The agencies projected that the MY2025 standards would be met largely through advancements in conventional vehicle technologies, including advances in gasoline engines (such as downsized/turbocharged engines) and transmissions, vehicle weight reduction, improvements in vehicle aerodynamics, more efficient vehicle accessories, and lower rolling resistance tires. The agencies also projected that vehicle air conditioning systems would continue to improve by becoming more efficient and by increasing the use of alternative refrigerants and lower leakage systems. The agencies estimated that some increased electrification of the fleet would occur through the expanded use of stop/start

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[22] 163 g/mi would be equivalent to 54.5 mpg, if the entire fleet were to meet this CO_2 level through tailpipe CO_2 and fuel economy improvements. However, the agencies projected in the 2012 rulemaking analysis that a portion of these improvements will be made through improvements in air conditioning refrigerant leakage and the use of alternative refrigerants, which would contribute to reduced GHG emissions but would not contribute to fuel economy improvements. This is one reason why NHTSA's 48.7-49.7 mpg range differs from EPA's projected 54.5 mpg standard. See 77 FR 62627, October 15, 2012.

[23] The corresponding CO_2 "gap" is 1.24, i.e., multiplying 2-cycle tailpipe CO_2 by 1.24 yields projected real world CO_2 emissions. This 1.24 factor is actually less than the 1.25 factor used in the past because of the lower carbon content of ethanol.

[24] Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, Regulatory Impact Analysis, U.S. Environmental Protection Agency, EPA-420-R-12-016, August 2012, page 7-32.

[25] Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, Regulatory Impact Analysis, U.S. Environmental Protection Agency, EPA-420-R-12-016, August 2012, page 7-35.

and mild hybrid technologies, but projected that meeting the MY2025 standards would require only about five to nine percent of the fleet to be full hybrid electric vehicles (HEVs) and only about two to three percent of the fleet to be electric vehicles (EV) or plug-in hybrid electric vehicles (PHEVs).[26] All of these technologies were available at the time of the 2012 final rule, some on a limited number of vehicles while others were more widespread, and the agencies projected that manufacturers would be able to meet the standards through significant efficiency improvements in the technologies, as well as through increased usage of these and other technologies across the fleet.

The GHG emissions standards are attribute-based standards, using vehicle footprint as the attribute. Footprint is defined as a vehicle’s wheelbase multiplied by its average track width—in other words, the area enclosed by the points at which the wheels meet the ground. The standards are therefore generally based on a vehicle’s size: larger vehicles have numerically higher GHG emissions targets and smaller vehicles have numerically lower GHG emissions targets. Footprint-based standards help to distribute the burden of compliance across all vehicle footprints and across all manufacturers. Manufacturers are not compelled to build vehicles of any particular size or type, and each manufacturer has its own fleetwide standard for its car and truck fleets in each year that reflects the light-duty vehicles it chooses to produce. This approach also preserves consumer choice, as the standards do not constrain consumers’ opportunity to purchase the size of vehicle with the performance, utility and safety features that meet their needs. The Proposed Determination would leave consumer choice unconstrained.

Under the footprint-based standards, the footprint curve defines a GHG performance target for each separate car or truck footprint. Individual vehicles or models, however, are not required to meet the target on the curve. To determine its compliance obligation, a vehicle manufacturer would average the curve targets for a given year for each of its footprints of its vehicle models produced in that year, as weighted by the number of vehicles it produced of each model. Each manufacturer thus will have a GHG average standard that is unique to each of its car and truck fleets, depending on the footprints and production volumes of the vehicle models produced by that manufacturer in a given model year. A manufacturer will have separate footprint-based standards for passenger cars (like sedans, station wagons, and many 2WD sport-utility vehicles and crossovers) and for light trucks (like most 4WD and heavier 2WD sport-utility vehicles, minivans, and pickup trucks). The curves are mostly sloped, so that generally, vehicles with larger footprints will be subject to higher CO_2 grams/mile targets and lower CAFE mpg targets than vehicles with smaller footprints. This is because, other things being equal, smaller vehicles are more capable of achieving lower levels of CO_2 and higher levels of fuel economy than larger vehicles. 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 the EPA certification process), the final standards with which each 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. A manufacturer may have some models that exceed their target, and some that are below their target. Compliance with a fleet average standard is determined by comparing the

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[26] For comparison to vehicles for sale today, an example of a mild HEV is GM's eAssist (Buick Lacrosse), a strong HEV is the Toyota Prius, an EV is the Nissan Leaf, and a PHEV is the Chevrolet Volt.

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 for each model).

The footprint curves for the MY2012-2025 GHG standards are shown below in Figure I.1 and Figure I.2. Although the general model of the target curve equation is the same for each vehicle category and each year, the parameters of the curve equation differ for cars and trucks. Each parameter also changes on a model year basis, resulting in the yearly increases in stringency.[27]

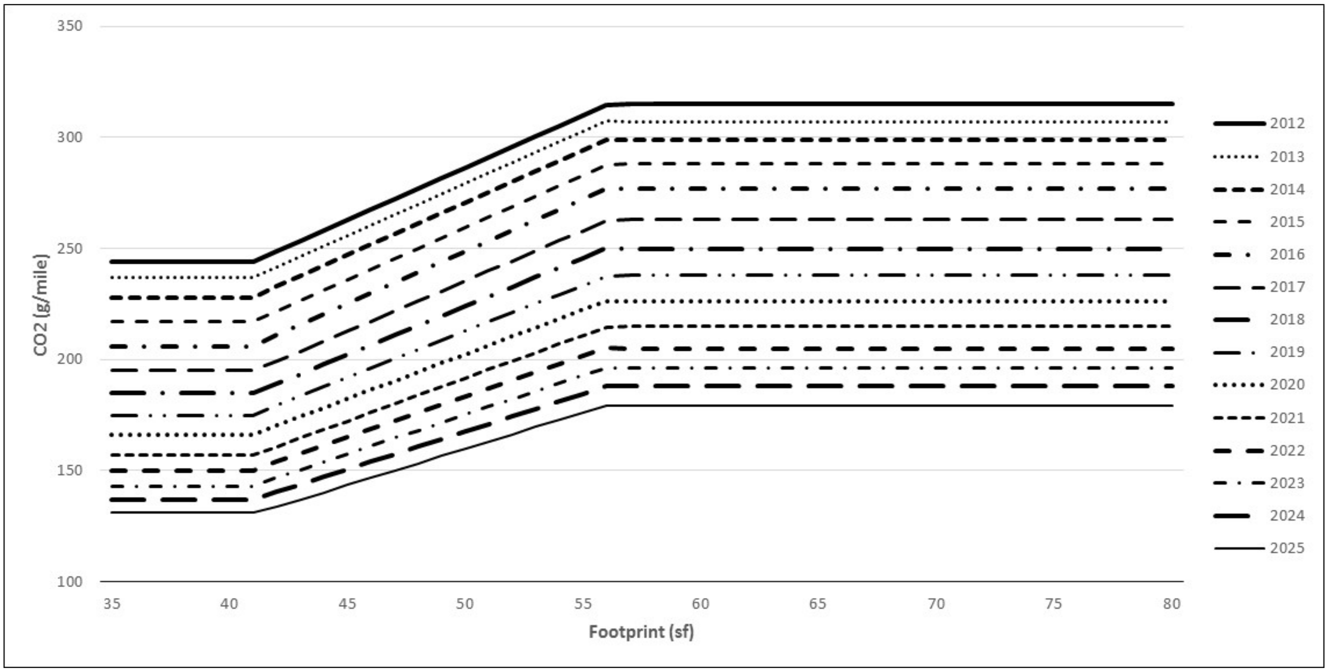

Figure I.1 CO_2 (g/mile) Passenger Car Standards Curves

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[27] See 40 CFR 86.1818-12(c).

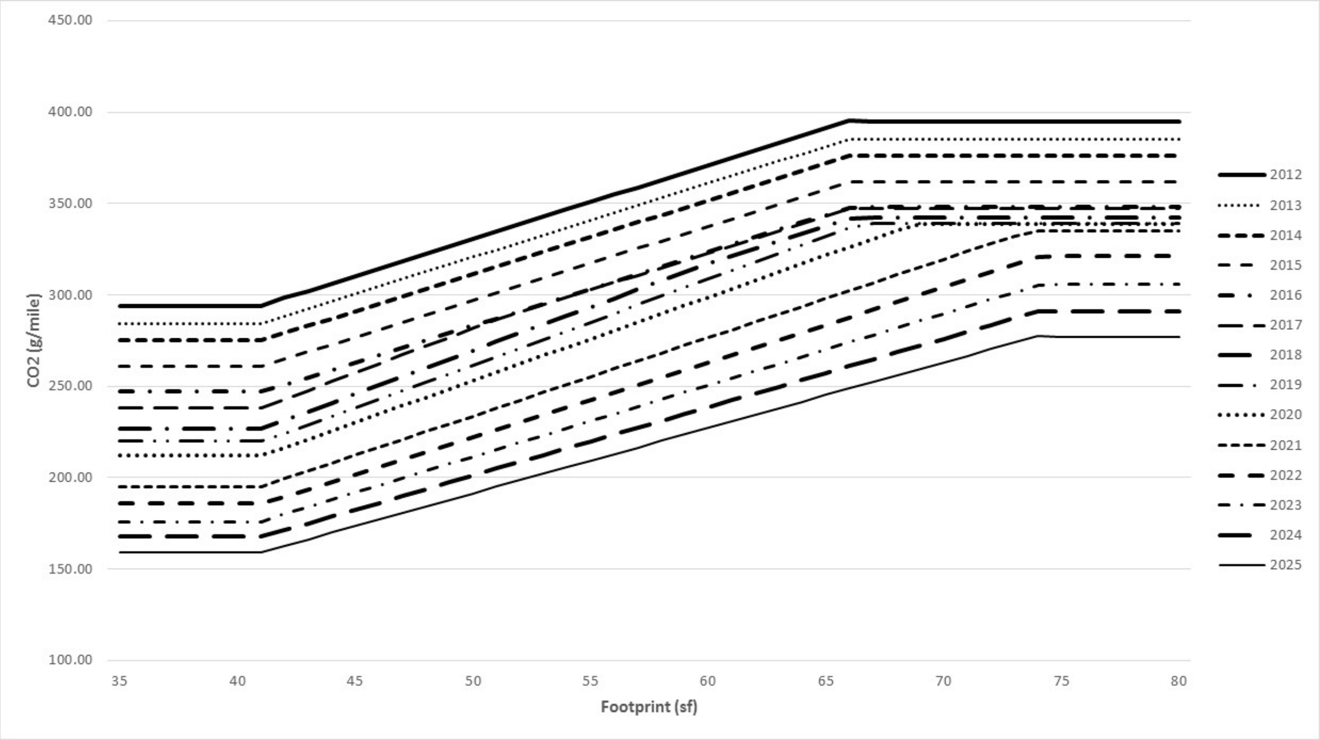

Figure I.2 CO₂ (g/mile) Light Truck Standards Curves

Chapter 3 of the Draft TAR summarized trends in the light-duty vehicle market in the four years since the 2012 final rule, including changes in fuel economy/GHG emissions, vehicle sales, gasoline prices, car/truck mix, technology penetrations, and vehicle power, weight and footprint. Since the 2012 final rule, vehicle sales have been strong, hitting an all-time high of 17.5 million vehicles in 2015, gas prices have dropped significantly, and truck share has grown. At the same time, fuel economy technologies are entering the market at rapid rates. The chapter also highlighted compliance to date with the GHG and CAFE standards. Since the Draft TAR, the MY2015 GHG Manufacturer Performance Report recently released by EPA shows that over-compliance continued for the first four years of the program, MY2012-2015.[28]

B. Climate Change as a Policy Driver

The primary policy driver for the greenhouse gas emission standards and their legal basis is the need to reduce the U.S. contribution to those emissions and global climate change. This section discusses EPA's current assessment of climate change science and its implications for EPA motor vehicle emissions policy.

1. Overview of Climate Change Science and Global Impacts

According to the National Research Council, "Emissions of CO_2 from the burning of fossil fuels have ushered in a new epoch where human activities will largely determine the evolution of

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[28] "Greenhouse Gas Emission Standards for Light-duty Vehicles, Manufacturer Performance Report for the 2015 Model Year," Environmental Protection Agency, November 2016, EPA-420-R-16-014.

Earth's climate. Because CO_2 in the atmosphere is long lived, it can effectively lock Earth and future generations into a range of impacts, some of which could become very severe. Therefore, emission reduction choices made today matter in determining impacts experienced not just over the next few decades, but in the coming centuries and millennia."[29]

In 2009, based on a large body of robust and compelling scientific evidence, the EPA Administrator issued the Endangerment Finding under CAA section 202(a)(1).[30] In the Endangerment Finding, the Administrator found that the current, elevated concentrations of GHGs in the atmosphere—already at levels unprecedented in human history—may reasonably be anticipated to endanger public health and welfare of current and future generations in the U.S. The D.C. Circuit later upheld the Endangerment Finding from all challenges. *Coalition for Responsible Regulation v. EPA, 684 F. 3d 102, 116-26 (D.C. Cir. 2012).*

Since the administrative record concerning the Endangerment Finding closed following the EPA's 2010 Reconsideration Denial, the climate has continued to change, with new records being set for a number of climate indicators such as global average surface temperatures, Arctic sea ice retreat, CO_2 concentrations, and sea level rise. Additionally, a number of major scientific assessments have been released that improve understanding of the climate system and further strengthen the case that GHGs endanger public health and welfare both for current and future generations. These assessments, from the Intergovernmental Panel on Climate Change (IPCC), the U.S. Global Change Research Program (USGCRP), and the National Research Council (NRC), include: IPCC's 2012 Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) and the 2013-2014 Fifth Assessment Report (AR5), the USGCRP's 2014 National Climate Assessment, Climate Change Impacts in the United States (NCA3), and the NRC's 2010 Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean (Ocean Acidification), 2011 Report on Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia (Climate Stabilization Targets), 2011 National Security Implications for U.S. Naval Forces (National Security Implications), 2011 Understanding Earth's Deep Past: Lessons for Our Climate Future (Understanding Earth's Deep Past), 2012 Sea Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future, 2012 Climate and Social Stress: Implications for Security Analysis (Climate and Social Stress), and 2013 Abrupt Impacts of Climate Change (Abrupt Impacts) assessments.

The findings of the recent scientific assessments confirm and further expand the science that supported the 2009 Endangerment Finding. The NCA3 indicates that climate change "threatens human health and well-being in many ways, including impacts from increased extreme weather events, wildfire, decreased air quality, threats to mental health, and illnesses transmitted by food, water, and disease-carriers such as mosquitoes and ticks."[31] Most recently, the USGCRP released a new assessment, "The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment" (also known as the USGCRP Climate and Health Assessment). This assessment finds that "climate change impacts endanger our health" and that in the United States we have "observed climate-related increases in our exposure to elevated temperatures;

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[29] National Research Council (NRC), Climate Stabilization Targets, p.3.

[30] "Endangerment and Cause or Contribute Findings for Greenhouse Gases under section 202(a) of the Clean Air Act," 74 FR 66496 (Dec. 15, 2009) ("Endangerment Finding").

[31] USGCRP, Third National Climate Assessment, p. 221.

more frequent, severe, or longer lasting extreme events; diseases transmitted through food, water, or disease vectors such as ticks and mosquitoes; and stresses to mental health and well-being." The assessment determines that "[e]very American is vulnerable to the health impacts associated with climate change." Climate warming will also likely "make it harder for any given regulatory approach to reduce ground-level ozone pollution," and, unless offset by reductions of ozone precursors, it is likely that "climate-driven increases in ozone will cause premature deaths, hospital visits, lost school days, and acute respiratory symptoms."[32]

Assessments find that certain populations are particularly vulnerable to climate change. The USGCRP Climate and Health Assessment identifies several disproportionately vulnerable populations, including those with low income, some communities of color, immigrant groups, indigenous peoples, pregnant women, vulnerable occupational groups, persons with disabilities, and persons with preexisting or chronic medical conditions. The Climate and Health Assessment also concludes that children’s unique physiology and developing bodies contribute to making them particularly vulnerable to climate change. Children also have unique behaviors and exposure pathways that could increase their exposure to environmental stressors, like contaminants in dust or extreme heat events. Impacts from climate change on children are likely expected from heat waves, air pollution, infectious and waterborne illnesses, disruptions in food safety and security, and mental health effects resulting from extreme weather events. For example, climate change can disrupt food safety and security by significantly reducing food quality, availability and access. Children are more susceptible to this disruption because nutrition is important during critical windows of development and growth. Older people with pre-existing chronic heart or lung disease are at higher risk of mortality and morbidity both as a result of climate warming and during extreme heat events. Pre-existing chronic disease also increases susceptibility to adverse cardiac and respiratory impacts of air pollution and to more severe consequences from infectious and waterborne diseases. Limited mobility among older adults can also increase health risks associated with extreme weather and floods.

The new assessments also confirm and further expand the science that supported the 2009 Endangerment Finding. The NRC assessment Understanding Earth’s Deep Past stated that "[b]y the end of this century, without a reduction in emissions, atmospheric CO_2 is projected to increase to levels that Earth has not experienced for more than 30 million years." In fact, that assessment stated that “the magnitude and rate of the present GHG increase place the climate system in what could be one of the most severe increases in radiative forcing of the global climate system in Earth history.”[33] Because of these unprecedented changes in atmospheric concentrations, several assessments state that we may be approaching critical, poorly understood thresholds. The NRC Abrupt Impacts report analyzed the potential for abrupt climate change in the physical climate system and abrupt impacts of ongoing changes that, when thresholds are crossed, could cause abrupt impacts for society and ecosystems. The report categorized a decrease in ocean oxygen content (with attendant threats to aerobic marine life); increase in intensity, frequency, and duration of heat waves; and increase in frequency and intensity of extreme precipitation events (droughts, floods, hurricanes, and major storms) as climate impacts with moderate risk of an abrupt change within this century. The NRC Abrupt Impacts report also analyzed the threat of rapid state changes in ecosystems and species extinctions as examples

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[32] USGCRP, The Impacts of Climate Change on Human Health in the United States, 2016.

[33] National Research Council, Understanding Earth’s Deep Past, p. 138.

of an irreversible impact that is expected to be exacerbated by climate change. Species at most risk include those whose migration potential is limited, whether because they live on mountaintops or fragmented habitats with barriers to movement, or because climatic conditions are changing more rapidly than the species can move or adapt. While some of these abrupt impacts may be of low or moderate probability in this century, the probability for a significant change in many of these processes after 2100 was judged to be higher, with severe impacts likely should the abrupt change occur. Future temperature changes will be influenced by what emissions path the world follows. In its high emission scenario, the IPCC AR5 projects that global temperatures by the end of the century will likely be 2.6°C to 4.8°C (4.7 to 8.6°F) warmer than today. There is very high confidence that temperatures on land and in the Arctic will warm even faster than the global average. However, according to the NCA3, significant reductions in emissions would lead to noticeably less future warming beyond mid-century, and therefore less impact to public health and welfare. According to the NCA3, regions closer to the poles are projected to receive more precipitation, while the dry subtropics expand (colloquially, this has been summarized as wet areas getting wet and dry regions getting drier), while "[t]he widespread trend of increasing heavy downpours is expected to continue, with precipitation becoming less frequent but more intense." Meanwhile, the NRC Climate Stabilization Targets assessment found that the area burned by wildfire in parts of western North America is expected to grow by 2 to 4 times for 1°C (1.8°F) of warming. The NCA also found that "[e]xtrapolation of the present observed trend suggests an essentially ice-free Arctic in summer before mid-century." Retreating snow and ice, and emissions of carbon dioxide and methane released from thawing permafrost, are very likely to amplify future warming.

Since the 2009 Endangerment Finding, the IPCC AR5, the USGCRP NCA3, and three of the new NRC assessments provide estimates of projected global average sea level rise. These estimates, while not always directly comparable as they assume different emissions scenarios and baselines, are at least 40 percent larger than, and in some cases more than twice as large as, the projected rise estimated in the IPCC AR4 assessment, which was referred to in the 2009 Endangerment Finding. The NRC Sea Level Rise assessment projects a global average sea level rise of 0.5 to 1.4 meters by 2100. The NRC National Security Implications assessment indicates that “the Department of the Navy should expect roughly 0.4 to 2 meters global average sea-level rise by 2100.” The NRC Climate Stabilization Targets assessment states that a global average temperature increase of 3°C will lead to a global average sea level rise of 0.5 to 1 meter by 2100. These NRC and IPCC assessments continue to recognize and characterize the uncertainty inherent in accounting for melting ice sheets in sea level rise projections. For example, the NRC Abrupt Impacts report considered destabilization of the West Antarctic Ice Sheet (which could cause 3-4 m of potential sea level rise) “within this century to be plausible, with an unknown although probably low probability.”

Carbon dioxide in particular has unique impacts on ocean ecosystems. The NRC Climate Stabilization Targets assessment found that coral bleaching will likely increase due both to warming and ocean acidification. Ocean surface waters have already become 30 percent more acidic over the past 250 years due to absorption of CO_2 from the atmosphere. According to the NCA3, this "ocean acidification makes water more corrosive, reducing the capacity of marine organisms with shells or skeletons made of calcium carbonate (such as corals, krill, oysters, clams, and crabs) to survive, grow, and reproduce, which in turn will affect the marine food chain." The NRC Understanding Earth’s Deep Past assessment notes four of the five major coral reef crises of the past 500 million years appear to have been driven by acidification and warming that followed GHG increases of similar magnitude to the emissions increases expected over the next hundred years. The NRC Abrupt Impacts assessment specifically highlighted similarities between the projections for future acidification and warming and the extinction at the end of the Permian which resulted in the loss of an estimated 90 percent of known species.

In addition to future impacts, the NCA3 emphasizes that climate change driven by human emissions of GHGs is already happening now and it is happening in the U.S. According to the IPCC AR5 and the NCA3, there are a number of climate-related changes that have been observed recently, and these changes are projected to accelerate in the future:

- The planet warmed about 0.85°C (1.5°F) from 1880 to 2012. It is extremely likely (>95 percent probability) that human influence was the dominant cause of the observed warming since the mid-20th century, and likely (>66 percent probability) that human influence has more than doubled the probability of occurrence of heat waves in some locations. In the Northern Hemisphere, the last 30 years were likely the warmest 30-year period of the last 1400 years.
- Global sea levels rose 0.19 m (7.5 inches) from 1901 to 2010. Contributing to this rise was the warming of the oceans and melting of land ice. It is likely that 275 gigatons per year of ice melted from land glaciers (not including ice sheets) since 1993, and that the rate of loss of ice from the Greenland and Antarctic ice sheets increased substantially in recent years, to 215 gigatons per year and 147 gigatons per year respectively since 2002. For context, 360 gigatons of ice melt is sufficient to cause global sea levels to rise 1 mm.
- Annual mean Arctic sea ice has been declining at 3.5 to 4.1 percent per decade, and Northern Hemisphere snow cover extent has decreased at about 1.6 percent per decade for March and 11.7 percent per decade for June.
- Permafrost temperatures have increased in most regions since the 1980s, by up to 3°C (5.4°F) in parts of Northern Alaska.
- Winter storm frequency and intensity have both increased in the Northern Hemisphere. The NCA3 states that the increases in the severity or frequency of some types of extreme weather and climate events in recent decades can affect energy production and delivery, causing supply disruptions, and compromise other essential infrastructure such as water and transportation systems.

In addition to the changes documented in the assessment literature, there have been other climate milestones of note. In 2009, the year of the Endangerment Finding, the average concentration of CO_2 as measured on top of Mauna Loa was 387 parts per million, far above preindustrial concentrations of about 280 parts per million.[34] The average concentration in 2015 was 401 parts per million, the first time an annual average concentration has exceeded 400 parts per million since record keeping began at Mauna Loa in 1958, and likely for at least the past

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[34] ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_annmean_mlo.txt.

800,000 years.[35] Arctic sea ice has continued to decline, with September of 2012 marking the record low in terms of Arctic sea ice extent, 40 percent below the 1979-2000 median. Sea level has continued to rise at a rate of 3.3 mm per year (1.3 inches/decade) since satellite observations started in 1993, more than twice the average rate of rise in the 20th century prior to 1993.[36] In addition, 2015 was the warmest year globally in the modern global surface temperature record, going back to 1880, breaking the record previously held by 2014; this now means that the last 15 years have been 15 of the 16 warmest years on record.[37]

These assessments and observed changes raise concerns that reducing emissions of GHGs across the globe is necessary in order to avoid the worst impacts of climate change, and underscore the urgency of reducing emissions now. The NRC Committee on America's Climate Choices listed a number of reasons "why it is imprudent to delay actions that at least begin the process of substantially reducing emissions."[38] For example:

- "The faster emissions are reduced, the lower the risks posed by climate change. Delays in reducing emissions could commit the planet to a wide range of adverse impacts, especially if the sensitivity of the climate to GHGs is on the higher end of the estimated range.
- Waiting for unacceptable impacts to occur before taking action is imprudent because the effects of GHG emissions do not fully manifest themselves for decades and, once manifested, many of these changes will persist for hundreds or even thousands of years.
- In the committee's judgment, the risks associated with doing business as usual are a much greater concern than the risks associated with engaging in strong response efforts."

Several commenters submitted statements discussing the urgency of reducing greenhouse gas emissions. The comments cited recent record global temperatures and atmospheric concentrations of carbon dioxide, estimates from the National Climatic Data Center of damages from extreme weather events, the recent USGCRP Climate and Health Assessment, the NCA3, and estimates of how much emission reductions are necessary in order to stay below 2 degrees Celsius above preindustrial temperatures. EPA has considered these comments, which are consistent with the scientific information discussed in this section and reinforce our conclusion that rising concentrations of greenhouse gases endanger human health and welfare. EPA continues to rely on the best technical and scientific information, primarily the recent, major assessments by the USGCRP, the IPCC, and the National Academies, and these assessments continue to demonstrate the urgent need to address emissions of greenhouse gases.

2. Overview of Climate Change Impacts in the United States

The NCA3 assessed the climate impacts in eight regions of the U.S., noting that changes in physical climate parameters such as temperatures, precipitation, and sea ice retreat were already

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[35] http://www.esrl.noaa.gov/gmd/ccgg/trends/.

[36] Blunden, J., and D. S. Arndt, Eds., 2016: State of the Climate in 2015. Bull. Amer. Meteor. Soc., 97 (8), S1-S275.

[37] http://www.ncdc.noaa.gov/sotc/global/201513.

[38] NRC, 2011: America's Climate Choices, The National Academies Press, p. 2.

having impacts on forests, water supplies, ecosystems, flooding, heat waves, and air quality. The U.S. average temperatures have similarly increased by 1.3 to 1.9°F since 1895, with most of that increase occurring since 1970, and the most recent decade was the U.S.'s hottest as well as the world's hottest. Moreover, the NCA3 found that future warming is projected to be much larger than recent observed variations in temperature, with 2 to 4°F warming expected in most areas of the U.S. over the next few decades, and up to 10°F possible by the end of the century assuming continued increases in emissions. Extreme heat events will continue to become more common, and extreme cold less common. Additionally, precipitation is considered likely to increase in the northern states, decrease in the southern states, and with the heaviest precipitation events projected to increase everywhere.

In the Northeast, temperatures increased almost 2°F from 1895 to 2011, precipitation increased by about 5 inches (10 percent), and sea level rise of about a foot has led to an increase in coastal flooding. In the future, if emissions continue to increase, the Northeast is projected to experience 4.5 to 10°F of warming by the 2080s. This is expected to lead to more heat waves, coastal and river flooding, and intense precipitation events. Sea levels in the Northeast are expected to increase faster than the global average because of subsidence, and changing ocean currents may further increase the rate of sea level rise.

In the Southeast, average annual temperature during the last century cycled between warm and cool periods. A warm peak occurred during the 1930s and 1940s followed by a cool period and temperatures then increased again from 1970 to the present by an average of 2°F. Louisiana has already lost 1,880 square miles of land in the last 80 years due to sea level rise and other contributing factors. The Southeast is exceptionally vulnerable to sea level rise, extreme heat events, hurricanes, and decreased water availability. Major risks of further warming include significant increases in the number of hot days (95°F or above) and decreases in freezing events, as well as exacerbated ground level ozone in urban areas. Projections suggest that there may be fewer hurricanes in the Atlantic in the future, but they will be more intense, with more Category 4 and 5 storms. The NCA identified New Orleans, Miami, Tampa, Charleston, and Virginia Beach as cities at particular risk of flooding.

In the Northwest, temperatures increased by about 1.3°F between 1895 and 2011. Snowpack in the Northwest is an important freshwater source for the region. More precipitation falling as rain instead of snow has reduced the snowpack, and warmer springs have corresponded to earlier snowpack melting and reduced stream flows during summer months. Drier conditions have increased the extent of wildfires in the region. Average annual temperatures are projected to increase by 3.3°F to 9.7°F by the end of the century (depending on future global GHG emissions), with the greatest warming is expected during the summer. Continued increases in global GHG emissions are projected to result in up to a 30 percent decrease in summer precipitation. Warmer waters are expected to increase disease and mortality in important fish species, including Chinook and sockeye salmon. Ocean acidification also threatens species such as oysters, with the Northwest coastal waters already being some of the most acidified worldwide due to coastal upwelling and other local factors.

In Alaska, temperatures have changed faster than anywhere else in the U.S. Annual temperatures increased by about 3°F in the past 60 years. Warming in the winter has been even greater, rising by an average of 6°F. Glaciers in Alaska are melting at some of the fastest rates on Earth. Permafrost soils are also warming and beginning to thaw. Drier conditions had already contributed to larger wildfires in the 10 years prior to the NCA3 than in any previous decade since the 1940s, when recordkeeping began, and subsequent years have seen even more wildfires. By the end of this century, continued increases in GHG emissions are expected to increase temperatures by 10 to 12°F in the northernmost parts of Alaska, by 8 to 10°F in the interior, and by 6 to 8°F across the rest of the state. These increases will exacerbate ongoing arctic sea ice loss, glacial melt, permafrost thaw and increased wildfire, and threaten humans, ecosystems, and infrastructure.

In the Southwest, temperatures are now about 2°F higher than the past century, and are already the warmest that region has experienced in at least 600 years. The NCA notes that there is evidence that climate-change induced warming on top of recent drought has influenced tree mortality, wildfire frequency and area, and forest insect outbreaks. At the time of publication of the NCA, even before the last 2 years of extreme drought in California, tree ring data was already indicating that the region might be experiencing its driest period in 800 years. The Southwest is projected to warm an additional 5.5 to 9.5°F over the next century if emissions continue to increase. Winter snowpack in the Southwest is projected to decline (consistent with recent record lows), reducing the reliability of surface water supplies for cities, agriculture, cooling for power plants, and ecosystems. Sea level rise along the California coast is projected to worsen coastal erosion, increase flooding risk for coastal highways, bridges, and low-lying airports, and pose a threat to groundwater supplies in coastal cities. In addition, “The combination of a longer frost-free season, less frequent cold air outbreaks, and more frequent heat waves accelerates crop ripening and maturity, reduces yields of corn, tree fruit, and wine grapes, stresses livestock, and increases agricultural water consumption.” Increased drought, higher temperatures, and bark beetle outbreaks are likely to contribute to continued increases in wildfires.

The rate of warming in the Midwest has markedly accelerated over the past few decades. Temperatures rose by more than 1.5°F from 1900 to 2010, but between 1980 and 2010 the rate of warming was three times faster than from 1900 through 2010. Precipitation generally increased over the last century, with much of the increase driven by intensification of the heaviest rainfalls. Several types of extreme weather events in the Midwest (e.g., heat waves and flooding) have already increased in frequency and/or intensity due to climate change. In the future, if emissions continue increasing, the Midwest is expected to experience 5.6 to 8.5°F of warming by the 2080s, leading to more heat waves. Specific vulnerabilities highlighted by the NCA include long-term decreases in agricultural productivity, changes in the composition of the region’s forests, increased public health threats from heat waves and degraded air and water quality, negative impacts on transportation and other infrastructure associated with extreme rainfall events and flooding, and risks to the Great Lakes including shifts in invasive species, increases in harmful algal blooms, and declining beach health.

High temperatures (more than 100°F in the Southern Plains and more than 95°F in the Northern Plains) are projected to occur much more frequently by mid-century. Increases in extreme heat will increase heat stress for residents, energy demand for air conditioning, and water losses. In Hawaii, other Pacific islands, and the Caribbean, rising air and ocean temperatures, shifting rainfall patterns, changing frequencies and intensities of storms and drought, decreasing base flow in streams, rising sea levels, and changing ocean chemistry will affect ecosystems on land and in the oceans, as well as local communities, livelihoods, and cultures. Low islands are particularly at risk.

Low-lying islands are particularly at risk. Moreover, “warmer oceans are leading to increased coral bleaching events and disease outbreaks in coral reefs, as well as changed distribution patterns of tuna fisheries. Ocean acidification will reduce coral growth and health. Warming and acidification, combined with existing stresses, will strongly affect coral reef fish communities.” For Hawaii and the Pacific islands, future sea surface temperatures are projected to increase 2.3°F by 2055 and 4.7°F by 2090 under a scenario that assumes continued increases in emissions.

3. Importance of the Transportation Sector in Greenhouse Gas Emissions Inventories

The most recent U.S. GHG emission inventory[39] includes seven greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). Mobile sources, which include cars, light trucks and medium-duty passenger vehicles (the largest sport utility vehicles and full-size passenger vans), heavy-duty trucks and buses, airplanes, railroads, marine vessels, and a variety of smaller sources, are significant contributors of four of the seven GHGs listed above. CO_2, CH_4, and N_2O emissions are present in vehicle tailpipe emissions, and HFCs are used in automotive air conditioning systems. In recent years, the annual GHG emissions inventory due to light-duty vehicles has been slightly more than 1 billion metric tons per year.

In October of 2016, nearly 200 countries reached an agreement to phase down HFCs. At the 28th Meeting of the Parties to the Montreal Protocol in Kigali, Rwanda, these countries committed to cut the production and consumption of HFCs by more than 80 percent over the next 30 years. EPA is assessing the degree to which this new agreement will moderate the growth rate of HFC emissions in the U.S.[40]

In 2014, mobile sources emitted 29 percent of all U.S. GHG emissions, the second largest contribution after power plants in that year. Transportation sources, which are largely synonymous with mobile sources but which exclude certain off-highway sources such as farm and construction equipment, account for 26 percent of U.S. GHG emissions. Motor vehicles alone, which include cars, light trucks and medium-duty passenger vehicles, heavy-duty trucks and buses, and motorcycles, are responsible for 22 percent of U.S. GHG emissions. CO_2 emissions represent 96 percent of total mobile source GHG emissions.[41] The motor vehicles covered by the light-duty GHG standards (cars, light trucks, and medium-duty passenger vehicles) account for 16 percent of all U.S. GHG emissions.

EPA recognizes that climate change is a long-term global environmental challenge. Any meaningful plan to address the climate challenge must prioritize early GHG emissions reductions and make continual progress toward long-term goals. And transportation is projected to be an

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[39] Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2014, U.S. Environmental Protection Agency, 2016, available at https://www.epa.gov/ghgreporting/greenhouse-gas-reporting-program-and-us-inventory-greenhouse-gas-emissions-and-sinks.

[40] See https://www.whitehouse.gov/the-press-office/2016/10/15/fact-sheet-nearly-200-countries-reach-global-deal-phase-down-potent.

[41] Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2014, U.S. Environmental Protection Agency, 2016, available at https://www.epa.gov/ghgreporting/greenhouse-gas-reporting-program-and-us-inventory-greenhouse-gas-emissions-and-sinks.

increasingly significant contributor to U.S. (and global) CO_2 emissions well into the future. In its nationally determined contribution to the Paris Agreement, the U.S. committed to a 26-28 percent GHG emissions reduction below 2005 levels by 2025. The White House recently reiterated the commitment to these reductions in the United States Mid-Century Strategy, released in November 2016, which also discussed the need for further emission reductions beyond 2025. At the end of this document, EPA discusses the need and opportunities for substantial GHG emissions reductions from light-duty vehicles beyond 2025.

II. Assessment of Technology Costs, Effectiveness, and Lead Time

A. Introduction

Technology assessment was a critical element of the development of the 2017-2025 GHG standards in the 2012 final rulemaking (FRM). The standards were ultimately guided by a detailed assessment of GHG-reducing technologies that were available as of the 2012 calendar year time frame. This assessment included technologies that were currently in production at the time, or pending near term release, as well as consideration of further developments in technologies where there was reliable evidence that those technologies could be feasibly deployed by 2025.

The MTE is making a determination as to whether the information analyzed since the standards were established calls into question the appropriateness of the MY2022-2025 standards, initially established in the 2012 rule. With respect to technology, a primary aspect of the MTE is to examine the technology assumptions that guided development of the MY2022-2025 standards, and update the assumptions accordingly based on developments in the industry that have occurred since 2012, as well as expected future developments by the 2025 time frame. As the first step in the MTE process, the 2016 Draft TAR summarized the current state of technology through the mid-2016-time frame, technology developments since the FRM, and the likely future developments through MY2025. The Draft TAR found that the fleet penetration of many of the GHG-reducing technologies identified in the FRM has proceeded steadily, accompanied by new technologies not anticipated at the time. Technology assumptions for cost, effectiveness, and availability were then revised and incorporated into the Draft TAR GHG Assessment, a substantial and comprehensive update to the assessment performed for the 2012 FRM.

As the next step in the MTE process, for this Proposed Determination, a Technical Support Document (TSD) builds on the Draft TAR by detailing the updates and refinements EPA has made to the technology assessment since the completion of the Draft TAR, based on updated information and public comments received on the Draft TAR. It also provides a full explanation of all of the underlying technical work that supports this Proposed Determination. This includes a detailed accounting of the technology assumptions and inputs used in the Proposed Determination technology assessment. Beyond the technologies assessed for this Proposed Determination, there are other technologies, such as electric turbo-charging, variable compression ratio, dynamic cylinder deactivation, and P2-configuration mild-hybridization, that are under active development and have the potential to provide further cost-effective GHG reductions by the 2025 time frame.

B. Rationale for How this Technology Assessment Supports the Proposed Determination

Since the 2012 FRM, EPA has continuously evaluated the state of GHG-reducing technologies based on many sources including new vehicle certifications, technology benchmarking, full vehicle simulation modeling, technical literature reviews and technical conference information, vehicle manufacturer and supplier meetings, and the 2015 National

Academy of Sciences (NAS) report.[42] This effort produced a technology assessment for the Draft TAR that built upon what was considered for the 2012 Final Rule. Subsequently, updated information and public comments have informed this technology assessment which supports the Proposed Determination that the MY2022-2025 standards remain appropriate.

Some auto industry commenters raised concerns regarding the Draft TAR analyses, commenting that the EPA models are overly optimistic. Other public comments supported EPA's conclusions in the Draft TAR and made recommendations that would result in higher effectiveness than EPA estimated in the Draft TAR. Upon considering all the public comments, EPA has made updates for this Proposed Determination where appropriate. These key comments and updates are summarized below and in Appendix Section A, and detailed in Chapter 2 of the TSD.

In some cases, the commenters either did not provide any supporting evidence or provided evidence that was incomplete or not applicable or relevant to an assessment of the cost, effectiveness, and implementation feasibility in MYs 2022-2025. In particular, the conclusion drawn by the Alliance of Automobile Manufacturers that "MY2021 and MY2025 targets cannot be met with the suite of technologies at the deployment rates projected by the Agencies in the 2012 FRM" is based on the premise that the only possible technology available in MY2025 will be represented by technology already contained in the Draft TAR's MY2014 baseline fleet and that technology will not improve in efficiency. EPA disagrees. It is not plausible that the best gasoline powertrain efficiencies of today represent the limit of achievable efficiencies in the future. Even setting aside the assumption that the best available technologies today will undergo no improvement in future years (a premise the auto industry has disproved time and again), the methodology used in the Alliance-contracted study (which was not peer reviewed) does not even allow for the recombination of existing technologies, and thus severely and unduly limits potential effectiveness increases obtainable by MY2025. EPA disagrees with this assumption that the only technology combinations available in MY2025 are those that are present in the MY2014 fleet. Indeed, events have already disproven this assumption. To provide one specific example, Ford has introduced a 10-speed automatic transmission on the MY2017 F150, paired with a turbocharged downsized engine, which is a technology combination that was not previously available and was therefore not considered in the Alliance-contracted study. In contrast, EPA's projections of effectiveness through MY2025 include technology packages that are achievable and cost-effective, but do not exist in the fleet in MY2014; for example, a 24 bar turbocharged downsized engine with cooled EGR, or a high compression ratio Atkinson cycle engine with cylinder deactivation and cooled EGR paired with an efficient high speed, high efficiency, high ratio spread transmission. EPA's approach for evaluating technology effectiveness is based on detailed data for individual technologies and physics-based vehicle modeling of combinations of technologies. We believe that these particular comments by the Alliance with respect to future technology effectiveness are drawn from an approach that is overly simplistic, lacks rigor, and therefore does not call into question EPA's determination that this technology assessment supports the Proposed Determination that the MY2022-2025

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[42] "Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles," National Research Council of the National Academies, June 2015.

standards remain appropriate. A more detailed response to the Alliance-contracted study is provided in the TSD (Chapter 2.3.3 and Appendix A).

Several commenters, including many NGOs, state and local government organizations, and consumer groups, supported EPA's assessment in the Draft TAR as a robust assessment of technology availability showing multiple cost-effective paths to comply with the 2025 standards. Some groups even believed our assessment to be conservative; for example, the International Council on Clean Transportation (ICCT) expressed the view that there are some key areas where the Draft TAR analysis "is still somewhat behind what is already happening in the market." ICCT and ACEEE cite examples of technologies that EPA did not model, like e-boost, variable compression ratio, and dynamic cylinder deactivation,

EPA's modeling methodology includes use of a "lumped parameter model" (LPM), which models incremental effectiveness differences between vehicle technology packages. In comments addressing EPA's modeling methodology, Global Automakers contended that the LPM tended to "over-predict the GHG reductions and fuel savings that various fuel economy technologies could provide." EPA disagrees that the LPM, when utilized as intended, makes inaccurate predictions.[43] The LPM is calibrated to the results of the full vehicle physics-based ALPHA model, and enables the efficient estimation of effectiveness values for hundreds of thousands of technology packages that would be neither feasible nor necessary from a computational resources standpoint to model individually in ALPHA. The LPM's effectiveness estimates are reliable due both to their basis in fully simulated vehicle packages, as well as to the physical principles applied to interpolate between simulated packages. Specifically, the use of energy loss categories within the LPM ensures that the combined benefits of multiple technologies in a package are not double counted when two technologies are competing to reduce the same loss. When used as intended within the bounds of the calibration, the LPM is an appropriate tool for assessing the effectiveness of advanced technology packages. EPA's assessment is also supported by both the 2010 and the 2015 studies published by the National Academy of Sciences – for example, in the 2015 report the NAS stated, “The committee notes that the use of full vehicle simulation modeling in combination with lumped parameter modeling and teardown studies contributed substantially to the value of the Agencies’ estimates of fuel consumption and costs, and it therefore recommends they continue to increase the use of these methods to improve their analysis."[44] Note that both the 2010 and the 2015 NAS Committees specifically evaluated earlier versions of the EPA-developed LPM that informed the Committee’s findings and recommendations.

For this Proposed Determination, EPA has adopted one of the quality assurance tests recommended in the Alliance-contracted report. As described in Chapter 2.3.3.5 and Appendix B of the TSD, EPA has determined the powertrain efficiency value for each of the non-electrified

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[43] The Alliance used the LPM to make absolute predictions of absolute improvements, acknowledging candidly that this usage "differs from LPM's intended function." See TSD Chapter 2.3.3.5.4.

[44] See Findings 8.7 and 10.12 and Recommendation 8.3 of “Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles published by the Committee on the Assessment of Technologies for Improving Fuel Economy of Light-duty Vehicles”; Phase 2; Board on Energy and Environmental Systems; Division on Engineering and Physical Sciences; National Research Council, ISBN 978-0-309-37388-3, 2015. See also Chapter 8 (page 118) of “Assessment of Fuel Economy Technologies for Light-Duty Vehicles;” Committee on the Assessment of Technologies for Improving Light-Duty Vehicle Fuel Economy; National Research Council; ISBN 978-0-309-15607-3, 2010.

technology packages applied by the OMEGA model, and confirmed that the emissions reductions estimated by the LPM are consistent with those produced by the physics-based ALPHA model across a broad range of vehicles and technologies.

The belief that estimates of technology effectiveness in the Draft TAR were overly optimistic led the Alliance, Global Automakers, and several individual automakers to conclude that more strong hybrids and electric vehicles will be needed to achieve the standards (MY2025 in particular) than projected by the agencies. Other criticisms were aimed at the differences in the Draft TAR projected penetrations of some individual technologies from those projected in the 2012 FRM. For example, the Global Automakers and its members commented that "the agencies should investigate and document why their previous predictions (from the FRM) were inaccurate." In fact, this "inaccuracy" is the failure to anticipate the extent of innovation and increased efficiencies in the intervening years between the FRM and Draft TAR, the very sorts of improvements that the Alliance contractor report assumes will not occur between now and 2025. EPA does not agree that some variation in modeled technology penetrations from the FRM to the Draft TAR to this Proposed Determination is an indication that the basic analysis and analytic approach were unsound. On the contrary, EPA expects that incorporating new technologies and unforeseen applications that have emerged since the 2012 FRM would have an impact on the penetrations of technologies in the cost-effective pathway modeled by OMEGA. For example, the application of direct injection Atkinson cycle engines in non-hybrids, greater penetration of continuously variable transmissions (CVT), and 48-volt mild hybridization would all tend to influence projected technology penetrations. In addition, the development of several technologies has proceeded differently than was assumed in the FRM, including development of downsized turbo-charged engines, cylinder deactivation, and electrification. What is more notable than the variations in projections of conventional technologies is the consistently low level of strong electrification that has been projected by EPA in the 2010 TAR, the 2011 NPRM, the 2012 FRM, the 2016 TAR and this Proposed Determination, and further confirmed by the 2015 National Academy of Sciences (NAS) study.[45] The 2015 NAS study on fuel economy technologies also found that the 2025 standards would be achieved largely through improvements to a range of technologies that can be applied to a gasoline vehicle without the use of strong hybrids, PHEV, or EV technology. Despite the many updates and improved precision of EPA's technology assessment and compliance analysis over the past six years, the modeled compliance costs and penetrations of strong electrification have remained highly consistent, thus further supporting EPA's determination that this technology assessment supports the Proposed Determination that the MY2022-2025 standards remain appropriate.

It should also be noted that the technology penetrations EPA projects in all of these analyses each represent only one potential pathway for compliance with future standards, and are based on the premise that technologies are applied in a way that minimizes the cost of compliance with MY2025 standards. In practice, vehicle manufacturers are free to choose to apply technology based on many factors including not only cost, but also other factors such as familiarity and experience with technology, vehicle functional and marketing objectives, supplier capacity and experience, manufacturing capacity, global technology availability and technology innovations. Therefore, a manufacturer's actual MY2025 compliance pathway may be different from the

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[45] “Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles,” National Research Council of the National Academies, June 2015.

pathways presented in this Proposed Determination. Put another way, because the standards are performance-based, they can be met in any way a manufacturer chooses. Although EPA models one potential compliance path (or, with sensitivity analyses, several paths), this modeling is not meant to (and does not purport to) chart the only such path, or to otherwise dictate or constrain manufacturer choice. The burst of innovation and concurrent advancements in competing engine and transmission technologies, spurred at least in part by the advent of the MY2012 and later standards, is an indication that the standards do not constrain compliance options. In addition, as discussed throughout this Proposed Determination, EPA believes that the main prediction in the 2012 rulemaking and the Draft TAR (as well as corroborated by the 2015 NAS Report) -- that the standards are achievable largely through improvements to gasoline vehicle technologies at reasonable cost -- appears to remain valid with respect to available technology.

The Appendix Section B of this document and Chapter 2 of the TSD contain details of our technology assessment, including summaries of public comments received on EPA's technology assessment, how EPA has updated its analysis in response to the comments and other information, and the key technology developments and assumptions that distinguish EPA’s assessment for this Proposed Determination from that of the Draft TAR.

III. Assessment of Consumer Impacts, Employment and Other Factors

A. Consumer Issues

As part of the midterm evaluation, EPA must consider "the cost on the … purchasers of new motor vehicles" and "the practicability of the standards," as well as "the impact of the standards on … fuel savings by consumers."[46] Consistent with this requirement, EPA committed that it would examine "Costs, availability, and consumer acceptance of technologies to ensure compliance with the standards, such as vehicle batteries and power electronics, mass reduction, and anticipated trends in these costs."[47] This section reviews issues affecting consumer acceptance of the technologies that can be used to meet the standards. With the program in effect since MY2012, the evidence focuses on experience to date on broader consumer impacts of vehicles subject to the standards. Appendix Section B.1 and TSD Chapter 4 provide the details underlying this assessment.

Since the National Program standards went into effect in MY2012, vehicle sales have increased every year, achieving record levels. At the same time that GHG emissions have fallen to record low levels, vehicle footprint has dropped since its peak in 2014, horsepower has increased or stayed constant, and weight has been roughly constant. The standards are likely to have had some effect on vehicle sales. On the one hand, the vehicles designed to meet the standards will become more expensive, which would, by itself, discourage sales. On the other hand, the vehicles will have improved fuel economy and thus lower operating costs due to significant fuel savings, which could encourage sales. Which of these effects dominates for potential vehicle buyers when they are considering a purchase will determine the effect on sales. We have not identified a scientifically sound way to provide a quantitative estimate of the effect that the existing standards have had on sales. But it is clear from empirical evidence that the standards have not prevented the automobile market from recovering to pre-recession sales levels--indeed, to record sales levels.

Some comments have raised concern that the standards will have adverse effects on other vehicle characteristics, such as performance or handling. As discussed in Appendix Sections B.1.4, and B.1.5 and TSD Chapters 4.1 and 4.2, EPA has not found evidence to date of these effects. An analysis of evaluations of fuel-saving technologies in professional auto reviews found more positive assessments of each technology than negative assessments in MY2014 and MY2015 vehicles. Though some automakers may receive negative evaluations for a specific technology, other automakers receive positive evaluations for that technology. This finding suggests that the quality of implementation of the technologies may vary, but some manufacturers are already able to deliver improved customer experience using these technologies today, and quality of implementation will likely improve over time for all manufacturers. Moreover, some of these technologies appear to have ancillary benefits to consumers in terms of performance and handling. For instance, mass reduction both reduces fuel consumption and increases handling and performance.

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[46] 40 CFR section 86.1818 (h) (1) (ii), (iii), and (iv).

[47] 77 Federal Register 62784.

As discussed in Section II, despite some auto manufacturers' comments that high penetration rates of both full hybrids and electric vehicles will be needed to meet the MY2025 standards, EPA continues to find that the standards can be met predominantly with advanced conventional gasoline vehicle. If so, then consumer acceptance issues hinge primarily on the acceptability of the technologies for advanced conventional gasoline vehicles; as noted above, the data to date confirm that consumers generally do not have concerns with these technologies. In the Draft TAR and this Proposed Determination, we nevertheless assess consumer response to plug-in electric vehicles (PEVs), which are one option for compliance with the standards. Concerns over range and cost are often cited as primary obstacles to PEV adoption; as discussed in Appendix Section A.3.7, technological advances are reducing those barriers. Research suggests that lack of awareness and understanding of PEVs, perhaps including misunderstanding, itself creates another barrier to adoption. Some studies suggest that experience with the technology increases acceptance. Thus, consumer acceptance of PEVs may depend, not only on technological advances, but also on the feedback loop associated with other consumers purchasing PEVs. California and the nine other states that have adopted the ZEV program have underway significant efforts to increase consumer awareness about PEVs as well as available charging infrastructure. With the very low proportion of PEVs projected to be needed for compliance, EPA expects that compliance will mostly depend on advanced conventional vehicles. We believe the evidence to date indicates that we would not expect to see significant issues with consumer acceptance of the 2022-2025 standards.

We also examine the effects of the standards on vehicle affordability. Because low-income households are much more likely to buy used vehicles than new ones, the effects of the standards on low-income households will come via the used vehicle market. There, current evidence indicates fairly flat prices in recent years, suggesting that used vehicle buyers are benefiting from reduced fuel costs without having to pay any notable up-front cost premium for more efficient vehicles. We have not found evidence that consumers have had problems getting loans for new vehicles. In addition, as discussed in Proposed Determination Appendix Section C.2.4, the fuel savings exceed the increased loan payments and other costs in the first year of loans with duration of 5 or more years. We also examined the availability of low-priced new vehicles, an entry point for the new vehicle market, and find that low-priced vehicles continue to be offered, and appear to be gaining additional features. In the MY2022-2025 time frame, the primary effects on affordability of vehicle sales are still likely to be due to broader macroeconomic factors, such as economic activity and overall employment; any impacts of the standards are likely to be secondary to those broader economic factors. More detail on affordability is provided in Appendix B.1.6 and TSD Chapter 4.3.

Overall, therefore, EPA's assessments indicate that consumers have clearly benefited from reduced fuel costs from the standards and, to date, there is little, if any, evidence that consumers have experienced adverse effects from any other implications of the standards. Information provided by commenters either supports this conclusion or does not rely on current information or reasonable predictions of future impacts. Vehicle sales continue to be strong. Most likely these sales levels are not due to the standards, but rather to economic recovery from the 2008-2009 recession. Nevertheless, there is no evidence to suggest that the standards have impeded sales, and some evidence that the technologies being used to meet the standards provide ancillary benefits that may enhance consumers’ acceptance of the vehicles. We have not found any evidence that the technologies used to meet the standards have imposed unavoidable "hidden costs" in the form of adverse effects on other vehicle attributes. Similarly, we have not identified significant effects on vehicle affordability to date. Given the lead times provided to automakers to achieve the MY2022-25 standards, and the evidence to date of consumer acceptance of technologies being used to meet the standards, EPA expects that any effects of the standards on the vehicle market will be small relative to market responses to broader macroeconomic conditions.

B. Employment Impacts

The Presidential Memorandum that requested development of the National Program sought a program that would “strengthen the [auto] industry and enhance job creation in the United States.”[48] Executive Order 13563, “Improving Regulation and Regulatory Review” (January 18, 2011), states, “Our regulatory system must protect public health, welfare, safety, and our environment while promoting economic growth, innovation, competitiveness, and job creation.”[49] In addition, the 2017-25 final rule lists "Impacts on employment, including the auto sector" as one of the factors to be considered in the Midterm Evaluation, and the regulations cite "the impact of the standards on the automobile industry" as one of the factors the Administrator must consider in making her determination on the appropriateness of the standards.[50] EPA is accordingly providing this discussion of the potential employment effects of the standards. Section B.2. of the Appendix to this document contains additional assessment of employment impacts, including an overview of employment in the auto industry in recent years, and an analysis estimating the employment effects of the standards. EPA’s assessment finds that, while the 2022-2025 standards may have some effect on employment in the auto sector, this effect is likely to be small enough that it cannot be distinguished from macroeconomic and other factors affecting auto sector employment.

The primary employment effects of these standards are expected to be found in several key sectors: auto manufacturers, auto parts manufacturing, auto dealers, fuel production and supply, and consumers (via the employment effects of their fuel savings). In an economy with full employment, the primary employment effect of standards is likely to be to shift employment from one sector to another, rather than to increase or decrease employment. For that reason, we focus our partial quantitative analysis on employment in the regulated sector, to examine the impacts on that sector directly. We discuss the likely direction of other impacts in the regulated sector as well as in other directly related sectors, but we do not quantify those impacts, because they are more difficult to quantify with reasonable accuracy, particularly so far into the future.

For the regulated industry, the partial employment impact due to the increased employment needs associated with increased vehicle costs is expected to be positive. The total effect of the standards on motor vehicle employment depends in addition on the effect of the standards on changes in vehicle sales, which are not quantified; thus, we do not estimate the total effects of the standards in the regulated industry.

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[48] President Barack Obama. “Presidential Memorandum Regarding Fuel Efficiency Standards. The White House, Office of the Press Secretary, May 21, 2010. http://www.whitehouse.gov/the-press-office/presidential-memorandum-regarding-fuel-efficiency-standards.

[49] President Barack Obama. "Executive Order 13563 of January 18, 2011: Improving Regulation and Regulatory Review." Federal Register 76(14) (January 21, 2011): 3821-3823.

[50] 77 Federal Register 62784.

Effects in other sectors that are affected by vehicle sales are also ambiguous. Reduced petroleum fuel production implies less employment in the petroleum sectors, although there could be increases in employment related to providing infrastructure for alternative fuels if manufacturers choose to comply with the standard through increased production of vehicles that use those fuels. Finally, consumer spending is expected to affect employment through changes in expenditures in general retail sectors; net fuel savings by consumers are expected to increase demand (and therefore employment) in other sectors. Thus, while the standards are likely to have some effect on employment, this effect is likely to be small enough that it cannot be distinguished from other factors affecting employment, especially macroeconomic conditions. As has been noted, under conditions of full employment, any changes in employment levels in the regulated sector due to this program are mostly expected to be offset by changes in employment in other sectors.

C. Other Relevant Factors

1. Vehicle Safety Effects

In setting emissions standards for mobile source air pollutants, EPA considers factors relevant to public health and welfare, including safety. See, e.g. 74 FR at 49464/3 (Sept. 28, 2009). As part of this Proposed Determination, EPA has assessed the potential of the MY2022-2025 standards to affect vehicle safety. (EPA, of course, also considered the issue of safety in initially promulgating the standards. See 77 FR 62740-768).

In the Draft TAR (Chapter 8), EPA, NHTSA and CARB reviewed the relationships between mass, size, and fatality risk based on the statistical analysis of historical crash data, which included an updated analysis led by NHTSA using the most recent available crash data. Upon review of the limited public comments on this issue as discussed in Appendix Section B.3.1, EPA continues to believe that the Draft TAR analysis represents the most up-to-date safety analysis. For this Proposed Determination, EPA used the results from this updated analysis to calculate the estimated safety impacts of the modeled mass reductions over the lifetimes of new vehicles in response to MY2022-2025 standards. As described further in Appendix Section B.3.1, on net, the EPA analysis shows small net fatality decreases over the lifetimes of MY2021 through 2025 vehicles.

2. Alternative Fuel Infrastructure

Although the Draft TAR projected that only a very small fraction of the fleet will need to be PEVs to meet the MY2025 standards, alternative fuel vehicles such as battery electric vehicles (BEVs)**,** plug-in hybrid electric vehicles (PHEVs) (collectively called plug-in electric vehicles, or PEVs), and fuel cell electric vehicles (FCEVs) are an essential part of any future vehicle fleet intended to meet long term climate and air quality goals, as discussed in Section V. In addition, other alternative fuels such as ethanol (E85) and compressed natural gas (CNG) have the potential to contribute to GHG emission reductions. Chapter 9 of the Draft TAR provided an overview of alternative fuel vehicle infrastructure, including the status, costs, and trends in PEV charging infrastructure and hydrogen infrastructure, and examined the challenges being addressed to scale up the infrastructure as advanced vehicle sales grow in response to market demand and for compliance with the federal standards. Chapter 9 of the Draft TAR concluded that infrastructure does not present a barrier for alternative fuel vehicles to be used in meeting the 2022-2025 national program GHG and fuel economy standards. As we discuss in Appendix

Section B.3.2, overall, we continue to conclude that infrastructure will not present a barrier for the small numbers of alternative fuel vehicles that we expect manufacturers to choose to produce as a part of their compliance with the MY2022-2025 GHG standards.

In public comments on the Draft TAR, several stakeholders discussed the conclusions of the Draft TAR about the sufficiency of existing and expected infrastructure development. A number of these comments, generally from the automotive manufacturing industry, focused on the commenters' belief that a greater degree of infrastructure development would be needed because they expect that more of these vehicles will be needed to meet the standards. However, as we discuss in Section IV below and in Appendix Section C.1, we continue to conclude that only a few percent of PEVs will be needed to meet the standards based on evaluation of potential least cost compliance pathways. Other comments from the Alliance of Automobile Manufacturers raised issues that we believe were adequately addressed in Chapter 9 of the Draft TAR, as discussed further in Appendix Section B.3.2. Therefore, we also continue to conclude that current and expected expansion of electric charging and hydrogen fueling infrastructure, as discussed in Chapter 9 of the Draft TAR, will be sufficient to supply that segment of the automotive fleet.

3. Standards Design Elements

In the design of the MY2012 – 2025 GHG standards, EPA carefully considered the impact the standards can have on vehicle utility and consumer choice such that the automotive companies have the ability to maintain vehicle utility and consumer choice while complying with the standards. EPA decided to use vehicle “footprint” as the attribute to determine the GHG standards for a given automotive manufacturer’s fleet (the standard being the production-weighted average of the footprint-based targets for each vehicle produced). The light-duty vehicle GHG standards are curves based on the footprint attribute (Section I shows a graphical depiction of the footprint curves). There are separate passenger car footprint-based standards and light-truck footprint-based standards. Under this approach, the larger the vehicle footprint the less numerically stringent (i.e., higher) the corresponding CO_2 target level. The curves become more stringent year-over-year as the standards are phased-in through MY2025. These footprint based standards were designed to promote GHG emissions improvements in vehicles of all sizes, and are not expected to create incentives for manufacturers to change the size of their vehicles in order to comply with the standards. (The large increase in the number of large SUVs in the fleet from MY2012 to 2015, as shown in the recent Trends report,[51] illustrates this point, since more of these larger-footprint vehicles were produced as the standards increased in stringency, yet this segment also showed the most improvement in GHG reductions over the same time period). Moreover, since the standards are based on the unique, sales-weighted fleet average for each manufacturer, no specific vehicle must meet a given footprint target.

EPA received a variety of comments regarding the footprint approach, discussed below and in more detail in Appendix Section B.3.3. Several commenters stressed the importance of the footprint-based standards in ensuring consumer choice and encouraging emissions reductions across vehicles of all sizes. Several commenters expressed concern regarding the footprint standards, asserting that vehicle footprints are increasing over time. Related to the comments

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[51] Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2016,” EPA Office of Transportation and Air Quality, November 2016.

regarding footprint, EPA received comments supporting a backstop standard. EPA also received comment on the current light truck definition.

These commenters suggest various changes to the form of the standards, the footprint curves, or vehicle definitions to address concerns regarding the projected overall less stringent projected 2025 fleetwide CO_2 target level of the program compared to the projections made in the 2012 final rule. The commenters' recommendations would suggest changing the program to address the issue that the standards are now projected to reach a slightly lower fleetwide CO_2 target level by 2025, due primarily to shifts in consumer preferences toward larger footprint vehicles. In many cases, these suggested changes would have the effect of making the standards more stringent. This Proposed Determination that the MY2022-2025 standards remain appropriate is based on the footprint curves and vehicle definitions currently in the regulations. EPA believes that the program is operating as it was designed and as discussed in Section IV below, EPA is proposing that the existing MY2022-2025 standards remain appropriate. EPA recognized in the MY2012-2016 rule that footprints could be larger (or smaller) in the future based in part on consumer demands that are external to the rule.[52] While average footprint has remained relatively flat since the standards were first established,[53] the market shift toward higher truck share in recent years has the same effect of increasing the fleetwide GHG emissions level necessary to meet the GHG standards. This is because, for the same footprint level, the truck curve has a higher GHG emissions target than does the car curve. EPA is not aware of any evidence that the standards structure itself is motivating the shift from cars to trucks, beyond the market forces such as lower gasoline prices. EPA also notes that the program has only been implemented for a relatively short period (we have final data for four model years, MY2012-2015) and the shifts in consumer preferences may not indicate a long-term trend (truck share, including those vehicles that must meet the truck GHG standards, was 43 percent in MY2015 and has ranged from 33 percent to 48 percent since MY2004).

4. Credits, Incentives, and Flexibilities

The National Program was designed with a wide range of optional flexibilities to allow manufacturers to maintain consumer choice, spur technology development, and reduce compliance costs, while achieving significant GHG reductions. Chapter 11 of the Draft TAR provided an overview of these provisions which include averaging, banking, and trading of credits, air conditioning system credits, off-cycle technology credits, and advanced technology vehicle incentives including incentives for large pickups using advanced technologies.

EPA received several comments on various aspects of the credit program, which we discuss further in Appendix Section B.3.4. For example, some auto industry commenters encouraged the agency to broaden the off-cycle credits program and to consider credits for connected/autonomous vehicle technology. Other commenters, including NGOs, cautioned against expanding the off-cycle credits program without further data to support that credit levels reflect actual real-world emissions reductions. Auto manufacturers and their trade associations also generally commented in support of extending or expanding incentives for advanced technology vehicles, including the vehicle "multipliers" for EVs, PHEV, and fuel cell vehicles

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[52] 75 FR 25355, May 7, 2010.

[53] Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2016," EPA Office of Transportation and Air Quality, November 2016.

(which currently end after MY2021), and the provision to not count upstream electricity emissions in a manufacturer's compliance calculations (which currently begins to phase-out after MY2021).

EPA believes that the MY2022-2025 standards remain appropriate with the credit and incentive provisions currently in place and EPA is not proposing any changes to these provisions as part of this Proposed Determination. Nevertheless, several of these provisions were developed in the 2012 rulemaking to incentivize very advanced technologies that will likely be needed for long-term GHG reductions beyond the 2025 time frame, such as plug-in hybrid electric vehicles, all electric vehicles, and fuel cell vehicles (see Section V of this document for additional detail). EPA requests comment below, in addition to the request for comment on this Proposed Determination, regarding the need for continued incentives for these technologies, including for the 2022-2025 model years.

5. Program Harmonization

EPA received several comments regarding harmonization of the EPA and NHTSA programs. The Alliance commented that the National Program has not resulted in harmonization across the EPA, NHTSA, and CARB programs. Global Automakers commented that they believe areas that need greater harmonization include regulatory process, modeling methodology, standards and credits programs, and federal and state programs. These comments and others are further described in Section B.3.5 of the Appendix.

The Alliance and Global Automakers have characterized many of the above items as significant harmonization issues. While some of their suggestions may provide opportunity for future regulatory streamlining, the current program delivers on the original intent of harmonization as envisioned by the National Program. In the 2009 Notice of Intent (NOI) preceding the MY2012-2016 rulemaking, EPA and NHTSA provided a clear view of the National Program, stating "Both agencies seek to propose a coordinated program that can achieve important reductions in GHG emissions and improvements in fuel economy…based on technology that will be commercially available and that can be incorporated at a reasonable cost."[54] The 2009 NOI states that the National Program "will reflect a carefully coordinated and harmonized approach to implementing these two statutes and will be in accordance with all substantive and procedural requirements imposed by law" and "Key elements of a harmonized and coordinated National Program the agencies intend to propose are the level and form of the standard, the available compliance mechanisms, and general implementation elements." At the outset, the National Program was predicated on "two separate sets of standards" and that "most companies would also apply some air conditioning improvements to reduce GHG emissions" and that those "would not translate into fuel economy improvements." It was clear that there would be differences, as the 2009 NOI states "Given differences in their respective statutory authorities, however, the agencies anticipate there will be some important differences in the development of their proposals." The NOI anticipated that the CAFE standards would be somewhat lower than the mile per gallon equivalent of the corresponding GHG standards due to some of these items but that the agencies would generally attempt to harmonize its standards "in a way that allows them to achieve their respective statutory and regulatory goals." The NOI further states that the goal of the National Program is to provide "regulatory compatibility that allows manufacturers to

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[54] 74 FR 24008, May 22, 2009.

build a single national light-duty fleet that would comply with both the GHG and CAFE standards."

EPA believes that the National Program has been implemented consistent with the vision the agencies have communicated from the earliest stages of the program. The National Program was possible because of the close relationship between reducing CO_2 tailpipe emissions and improving fuel economy. The more fuel efficient a vehicle is, the less fuel it burns to travel a given distance; the less fuel it burns, the less CO_2 is emitted in traveling that distance. Therefore, the same sets of technologies that improve fuel efficiency also at the same time reduce CO_2 emissions (note there are some technologies that reduce GHG emissions but do not improve fuel efficiency, for example, reduction of air conditioning refrigerant emissions). In this way, the National Program allows auto manufacturers to use a common set of technologies to simultaneously address both issues of reducing CO_2 emissions and improving fuel efficiency. (See 75 FR 25327, May 7, 2010).

Going back to the first time the agencies established standards for the 2012-2016 model years, EPA and NHTSA were clear that there were some important differences in the statutory authorities (see 75 FR 25330, May 7, 2010; see also 77 FR 62674), and that the stringency of the respective standards was in fact established to account for differences in air conditioning improvements. The agencies have worked to establish a National Program subject to the differences in statutory authorities. The differences in certain aspects of the GHG and CAFE programs existed when the MY2022-2025 were first established and do not lead EPA to find that the GHG standards for MYs 2022-2025 are no longer appropriate.

In the MY2017-2025 rulemaking, the agencies took steps to maintain equivalent stringency and ensure that a single fleet of vehicles may be produced by a manufacturer that meets both the CAFE and GHG standards. Statutory differences between the CAA and EPCA/EISA result in restrictions for credit transfers and trading and domestic and import car fleets under CAFE that don't exist for the GHG standards. Also, under CAFE, manufacturers are not able to generate and use credits based on air conditioning refrigerant leakage reductions. These factors were appropriately considered in establishing MY2022-2025 GHG standards and in EPA's Draft TAR evaluation of those standards.

EPA and NHTSA have also pledged and taken many steps to enhance one-stop compliance procedures and testing provisions with the program. Thus, compliance is based on a single test procedure. Little to no additional data is required to demonstrate compliance with either the CAA GHG standards or the CAFE fuel economy standards. Certification, testing, reporting, and associated compliance activities are essentially identical under both programs. EPA accommodated the EPCA-EISA provisions whereby manufacturers can pay fines in lieu of compliance by adopting the Temporary Lead Time Allowance Alternative Standards, which allows OEMs which had paid fines under CAFE additional lead time to come into compliance with the full complement of the GHG standards. The agencies have adopted the same credit and incentive provisions to the extent authorized by law.

In their comments on the Draft TAR, the Alliance and Global Automakers refer to issues raised in their June 2016 petition that they believe are relevant for the MTE. Several of the issues involve changes sought for the CAFE program rather than EPA's GHG program and therefore are not relevant to whether the GHG standards themselves remain appropriate and are not within EPA's statutory authority to address. There were three issues raised in the June 20, 2016 petition that are relevant to the GHG program. These were not direct harmonization issues. This petition is a separate action, and EPA would need to address it separately, on its own merits. Nevertheless, none of the issues raised in the petition would change EPA's assessment of the appropriateness of the MY2022-2025 standards. EPA is making a proposed determination that the MY2022-2025 standards are still appropriate, based on the existing regulations, including the credit provisions raised in the auto petition. EPA intends to work with the Petitioners and other stakeholders in the future as we carefully consider the requests made in the June 2016 petition.

IV. EPA's Proposed Assessment of the Appropriateness of the MY2022-2025 GHG Standards

In our technical assessment of the technologies available to meet the MY2022-2025 GHG standards, we present a range of feasible, cost-effective compliance pathways to meet the MY2022-2025 standards. EPA analyzed a “central case” low-cost pathway, as well as multiple sensitivity analyses, including various fuel price scenarios, indirect cost markups, and technology penetrations (e.g., lower Atkinson engine penetration, lower mass reductions, alternative transmission effectiveness estimates). This range of analyses demonstrates that compliance can be achieved through a number of different technology pathways, as is the intent of the performance-based GHG standards that provide each manufacturer with the flexibility to apply technologies in the way it views best to meet the needs of its customers.

Since the Draft TAR, EPA has updated its modeling assessment and methodology based on consideration of public comments and other information. Details of these updates and the resulting analyses are provided in Section C of the Appendix and in the accompanying Technical Support Document.

In this Section IV, we present summaries of the results of the analyses we have conducted as part of this Midterm Evaluation on the various factors and considerations laid out in the 2012 rule (Section IV.A) and discussion of our assessment of each of those factors, in light of those analyses (Section IV.B). Section IV.C contains the Administrator’s Proposed Determination.

A. Summary of the Results of EPA’s Proposed Determination Analysis

As in the analysis of the MYs 2017-2025 rulemaking (the 2012 FRM) and the Draft TAR, our evaluation includes identifying potentially available technologies and assessing their effectiveness, cost, and impacts. The wide number of technologies that are available, and likely to be used in combination, requires a method to account for their combined cost and effectiveness, as well as estimates of their availability to be applied to vehicles. The basic methodologies and modeling tools used in this Proposed Determination (and for the Draft TAR) are similar in many ways to those EPA has used since first setting light-duty GHG standards for the MY2012-2016 standards in 2010, and again for the MY2017-2025 standards in 2012. However, EPA has continued to refine these modeling tools and to update the inputs based on the best available data as well as in response to public comments.

As was done in establishing the GHG standards for MY2012-2016 and 2017-2025, EPA is using a computerized program called the Optimization Model for reducing Emissions of Greenhouse gases from Automobiles (OMEGA). The OMEGA model optimizes to achieve the greatest level of GHG emissions reduction at the lowest cost technology options while considering technology and safety-related penetration caps. The result is a description of which technologies could be added to each vehicle and vehicle platform to meet a certain CO_2 target, along with the resulting costs and achieved CO_2 levels.

EPA’s Proposed Determination assessment provides projections for the MY2022-2025 standards for several key metrics, including a range of modeled “low-cost pathway” technology penetrations and per-vehicle average costs; GHG and oil reductions; consumer payback; and industry-wide average costs, consumer fuel savings, and societal monetized benefits. Our analysis results are summarized below with additional details and results presented in Appendix Section C.

1. CO_2 Target and Achieved Levels

The footprint-based GHG standards (i.e., the standard curves as shown in Section I, Figures I-1 and I-2) apply to individual vehicles. Depending on the footprint and model year of that individual vehicle, its target value can be determined by selecting the appropriate point on the standard curve. A fleet of vehicles—whether a car or truck fleet, a given manufacturer's fleet, or the entire fleet—complying with its individual targets (determined by the standard curves) while giving consideration to the sales, or sales weighting, of each would result in a target value for that given fleet.

As shown in Table IV.1, the overall fleet performance in MY2025 is predicted to achieve 173 g/mi using AEO2016 reference projections. This increase in CO_2 emissions relative to the 2012 FRM can be largely attributed to the increased market share of trucks relative to the fleet projected in the 2012 FRM. Relative to the Draft TAR, the slight decrease in the 2025 CO2 target (from 175 g/mi to 173 g/mi) can be attributed to a small increase in car share relative to the AEO 2015 projections used in the Draft TAR. Table IV.1 shows the car/truck shares in the 2012 FRM, the Draft TAR, and this analysis to help illustrate how the car/truck mix impacts the target values. The different AEO 2016 fuel price cases (see Chapter 3 of the TSD for more details on these fuel prices) result in unique fleet projections since higher fuel prices are projected to result in fewer truck and more car sales, while lower fuel prices are projected to result in fewer car sales and more truck sales. As a result of these fleet mix differences, the manufacturer-specific footprint based standards would result in different fleet-wide CO_2 target values for each AEO 2016 fuel price case and projected fleet. While we have conducted additional sensitivity runs beyond varying the fuel price projections, only these two fuel price sensitivities (high and low) result in unique CO_2 target values. Additional details are discussed in the Appendix Section C.1.

Table IV.1 Projections for MY2025: Car/Truck Mix, CO_2 Target Levels, and MPG-equivalent[1]

	2012 Final Rule	Draft TAR	**Proposed Determination**		
	AEO 2011 Reference	AEO 2015 Reference	**AEO 2016 Reference**	AEO 2016 Low	AEO 2016 High
Car/truck mix	67/33%	52/48%	**53/47%**	44/56%	63/37%
CO_2 (g/mi)	163	175	**173**	178	167
MPG-e[2]	54.5	50.8	**51.4**	49.9	53.3

Notes:

[1] The CO_2 and MPG-e values shown here are 2-cycle compliance values. Projected real-world values are detailed in Chapter 3 of the TSD; for example, for the Proposed Determination AEO reference fuel price case, real-world CO_2 emissions performance would be 233 g/mi and real-world fuel economy would be about 36 mpg.

[2] Mile per gallon equivalent (MPG-e) is the corresponding fleet average fuel economy value if the entire fleet were to meet the CO2 standard compliance level through tailpipe CO2 improvements that also improve fuel economy. This is provided for illustrative purposes only, as we do not expect the GHG standards to be met only with fuel efficiency technology.

We present the projected CO_2 targets and CO_2 achieved levels in MY2025 in Table IV.2 and Table IV.3. The CO_2 targets represent the footprint-based standards that each manufacturer is projected to meet in MY2025, based on its projected fleet mix. The CO_2 achieved levels represent EPA's estimate of the actual CO_2 levels each manufacturer will attain. As shown, the target and achieved levels for the fleet as a whole are the same except for Tesla, which is the only manufacturer of solely electric vehicles, so its projected achieved CO_2 emissions (which account for upstream CO_2 emissions as discussed in Appendix C.1) are far less than its target levels. However, because EPA's model allows for full transfers of credits across the car and truck fleets, the CO_2 achieved for cars vs. trucks may be quite different from those of the footprint targets, which is a function of the model optimizing the least-cost pathway to achieving the targets. The central analysis results, which uses the AEO 2016 reference fuel price case, represent the fleet meeting the MY2022 through MY2025 standards in their respective model years, and the fleet meeting the MY2025 standards indefinitely thereafter.

Table IV.2 CO_2 Targets in MY2025 – Central Case (gCO_2/mi)

	Car	Truck	Combined
BMW	148	194	159
FCA	153	202	187
FORD	150	220	191
GM	149	222	185
HONDA	143	189	165
HYUNDAI/KIA	148	185	154
JLR	157	190	183
MAZDA	145	182	159
MERCEDES	151	193	168
MITSUBISHI	134	170	148
NISSAN	144	198	165
SUBARU	142	173	166
TESLA	172		172
TOYOTA	145	202	170
VOLKSWAGEN	144	189	158
VOLVO	152	184	168
Fleet	147	202	**173**

Table IV.3 CO_2 Achieved in MY2025 -- Control Case (gCO_2/mi)

	Car	**Truck**	**Combined**
BMW	155	175	159
FCA	172	194	187
FORD	162	213	191
GM	163	209	185
HONDA	152	181	165
HYUNDAI/KIA	152	164	154
JLR	187	184	183
MAZDA	149	175	159
MERCEDES	161	181	168
MITSUBISHI	146	154	148
NISSAN	149	189	165
SUBARU	179	164	166
TESLA	111		111
TOYOTA	146	200	170

VOLKSWAGEN	148	181	158
VOLVO	166	172	168
Fleet	155	193	**173**

2. Cost Per Vehicle

As shown in Table IV.4, EPA's current, updated analysis shows that the average per vehicle cost to meet the MY2025 standards in MY2025 (compared to meeting the MY2021 standards in MY2025) is $875. This is the estimated cost of meeting the MY2025 standards incremental to the cost to meet the MY2021 standards (reference case). These costs are less than those estimated in the 2012 FRM (about $1,100) and in the Draft TAR. In the Draft TAR, EPA estimated average per-vehicle costs of $894 in 2013$ ($920 in 2015$). Additional details are presented in the Appendix Section C.1.

Table IV.4 Incremental Per-Vehicle Average Costs to Comply with the MY2025 Standards in the Central Analysis (2015$)

	Car	Truck	Fleet
Manufacturer	2025	2025	2025
BMW	$1,189	$1,651	$1,296
FCA	$1,068	$1,379	$1,284
Ford	$729	$795	$768
GM	$774	$898	$835
Honda	$647	$746	$695
Hyundai/Kia	$674	$829	$699
JLR	$739	$1,573	$1,401
Mazda	$314	$914	$539
Mercedes	$1,403	$1,321	$1,369
Mitsubishi	$918	$885	$905
Nissan	$775	$1,016	$867
Subaru	$526	$671	$640
Tesla	$0	$0	$0
Toyota	$499	$949	$698
Volkswagen	$1,074	$2,218	$1,425
Volvo	$467	$1,345	$910
Fleet	**$749**	**$1,018**	**$875**

3. Technology Penetration

Table IV.5 shows fleet-wide penetration rates for a subset of the technologies EPA projects could be utilized to comply with the MY2025 standards. As with the 2012 FRM, the 2015 NAS report, and the Draft TAR, EPA projects that the MY2022-2025 standards can be met largely through advancements in gasoline vehicle technologies, such as improvements in engines, transmissions, light-weighting, aerodynamics, and accessories, including moderate levels of mild hybridization (i.e., 48 volt systems which improve the efficiency of gasoline vehicles at much less cost than strong hybrids). While we project that some manufacturers will utilize some level of strong electrification as a compliance path, EPA projects that across the fleet only very low levels of strong hybrids and full electrification (plug-in hybrid electric vehicles (PHEV) or electric vehicles (EV)) technology will be needed to meet the standards.

Regarding the technology penetration for higher compression ratio, naturally aspirated gasoline engines (Atkinson 2), in their comments on the Draft TAR, AAM stated that they did not believe that the market penetration of Atkinson 2 technology, projected in the Draft TAR of over 40 percent, is likely or feasible. For this Proposed Determination, the penetration of Atkinson 2 is expected be 27 percent in 2025 MY, as shown below. This reduction in Atkinson penetration is not in direct response to this AAM comment, but rather the result of refinements in EPA's effectiveness modeling that more appropriately reflect the relative improvements allocated to advanced engines and transmissions in powertrain packages.

EPA also analyzed multiple sensitivity cases which show that compliance can be achieved through a number of different technology pathways. These sensitivity cases, including various fuel price scenarios, cost markups, and technology penetrations are presented in Table IV.5 as a range of technology penetrations and per-vehicle costs. For example, in order to acknowledge that manufacturers may choose to focus on turbo-downsized engines over Atkinson technology (notwithstanding EPA's assessment that there is ample lead time to adopt the Atkinson technology should manufacturers choose to do so, see the TSD Chapter 2.3.4.1.8), EPA conducted a sensitivity restricting Atkinson application. Other sensitivities included different fuel price cases, varying indirect costs, restricting application of mass reduction, alternative transmission paths, and various assumptions about the use of credit mechanisms. Details of the technology penetration cases are shown in the Appendix Section C.1.

Table IV.5 Selected Technology Penetrations (Absolute) and Per-Vehicle Average Costs to Meet MY2025 GHG Standards (Incremental to the Costs to Meet the MY2021 Standards, 2015$) [1]

	Draft TAR[2]	Proposed Determination[3]	
		Primary Analysis	Range of Sensitivities Analyzed
Turbocharged and downsized gasoline engines (%)	33%	34%	31-41%
Higher compression ratio, naturally aspirated gasoline engines (%)	44%	27%	5-41%
8 speed and other advanced transmissions[4] (%)	90%	93%	92-94%
Mass reduction (%)[5]	7%	9%	2-10%
Off-cycle technology[6]	not modeled	26%	13 - 51%
Stop-start (%)	20%	15%	12-39%
Mild Hybrid (%)	18%	18%	16-27%
Strong Hybrid (%)	<3%	2%	2-3%
Plug-in hybrid electric vehicle[7] (%)	<2%	2%	2%
Electric vehicle[7] (%)	<3%	3%	2-4%
Per vehicle cost ($)	$920	**$875**	**$800 - $1,115**

Notes:

[1] Percentages shown are absolute rather than incremental

[2] The Draft TAR values are based on AEO 2015 reference case; the Draft TAR reported average per vehicle costs of $894 in 2013$

[3] The Proposed Determination values are based on AEO 2016 reference case

[4] Including continuously variable transmissions (CVT)

[5] The 9% mass reduction for the Proposed Determination is relative to the 'null' package. Using the same approach, the Draft TAR 7% mass reduction relative to the MY2014 baseline becomes 9% relative to 'null'

6 EPA did not model off-cycle technologies in the Draft TAR except for stop-start and active aerodynamics; for the Proposed Determination we are now also assessing additional off-cycle technologies as unique technologies that can be applied to a vehicle and that reduce CO2 emissions either 1.5 g/mi and 3 g/mi.

[7] Electric vehicle penetrations include the California Zero Emission Vehicles (ZEV) program

4. Reductions in GHG Emissions and Fuel Consumption

As in the 2012 final rule establishing MY2017-2025 standards and the Draft TAR, EPA used its OMEGA Inventory Costs and Benefits Tool (ICBT) to project the emissions and fuel consumption impacts of the MY2022-2025 standards. EPA has analyzed the emissions inventory impacts, fuel, and electricity consumption results in several ways: for a given set of calendar years (not cumulative), by a given model year cohort of vehicles, and by cumulative sums of impacts due to vehicle model years included in the MY2022-2025 standards (over the vehicle lifetimes, as discussed in the TSD Chapter 3). Details of these analysis are shown in the Appendix Section C.2.

EPA estimates that GHG emission decreases will total nearly 540 million metric tons (MMT) over the lifetimes of MY2022-2025 vehicles (Table IV.6). On a calendar year basis, we estimate GHG reductions of more than 40 MMT in 2025, growing to more than 230 MMT by 2050 (Table IV.7).

Table IV.6 MY Lifetime Emission Reductions of the MY2022-2025 Standards on GHGs (MMT CO2e)

Model Year	Downstream (including A/C)	Fuel Production & Distribution	Electricity	**Total**
2021	26.6	8.5	-1.2	**34**
2022	55.2	17.6	-1.8	**71**
2023	84.0	26.7	-2.5	**108**
2024	112	35.5	-3.2	**144**
2025	139	44.3	-3.9	**180**
Sum	**417**	**133**	**-12.6**	**537**

Note: These values are expressed as emission reductions, such that positive values imply an emissions decrease, and negative values imply an emissions increase.

Table IV.7 Annual Emissions Reductions of the MY2022-2025 Standards on GHGs in Select Calendar Years (MMT CO2e)

Calendar Year	**2025**	**2030**	**2040**	**2050**
Net GHG	40.6	102	185	**234**
Net CO2	39.7	99.5	181	228
Net other GHG	0.89	2.23	4.07	5.12
Downstream GHG	32.4	81.3	148	186
Fuel Production and Distribution GHG	9.08	22.8	41.5	52.2
Electricity Upstream GHG	-0.95	-2.28	-4.10	-5.14

Note: These values are expressed as emission reductions, such that positive values imply an emissions decrease, and negative values imply an emissions increase.

EPA estimates significant reductions in fuel consumption of more than 50 billion gallons (or 1.2 billion barrels) of retail gasoline over the lifetime of MY2022-2025 vehicles, as presented in Table IV.8. On an annual impacts basis, we estimate the MY2022-2025 standards will reduce fuel consumption by 21 billion gallons (or 0.5 billion barrels) by 2050, as presented in Table IV.9.

Table IV.8 MY Lifetime Impacts of the MY2022-2025 Standards on Retail Gasoline

Model Year	Retail Gasoline (billion gallons)	Retail Gasoline (billion barrels)
2021	-3.22	-0.08
2022	-6.69	-0.16
2023	-10.2	-0.24
2024	-13.5	-0.32
2025	-16.9	-0.40
Sum	**-50.5**	**-1.20**

Note: These values are expressed as absolute inventory changes, such that negative values imply a decrease in consumption, and positive values imply an increase in consumption.

Table IV.9 Annual Impacts of the MY2022-2025 Standards on Petroleum Fuel Consumption

Calendar Year	Petroleum Gasoline (billion gallons)	Petroleum Gasoline (billion barrels)
2025	-3.65	-0.09
2030	-9.15	-0.22
2040	-16.7	-0.40
2050	**-21.0**	**-0.50**

Note: These values are expressed as absolute inventory changes, such that negative values imply a decrease in consumption, and positive values imply an increase in consumption.

5. Consumer Benefits: Payback Period and Lifetime Fuel Savings

EPA has assessed two metrics important to consumers who purchase a MY2025 vehicle with lower GHG emissions and improved fuel efficiency – the fuel savings expected over the life of that vehicle, and the “payback period” or the point at which consumer savings from reduced gasoline expenditures exceed the upfront costs of the vehicle. For example, relative to the MY2021 standards, a new MY2025 vehicle is estimated to cost on average about $875 more due to the addition of new GHG reducing/fuel economy improving technology (see Table IV.5). This new technology will result in lower fuel consumption and, therefore, savings in fuel expenditures. An important question is how many months or years would pass before the fuel savings exceed the cumulative costs.

Table IV.10 and Table IV.11 present EPA’s estimates of net costs associated with owning a new MY2025 vehicle (using AEO 2016 reference fuel prices; 3 percent discount rate). For purposes of this analysis, we are using a “sales weighted average vehicle” which means the combined car/truck fleet, weighted by sales on the cost side and usage on the fuel savings side, to arrive at a single weighted vehicle analysis. To estimate the cumulative vehicle costs, we have included the sales tax on the new car purchase and the increased insurance premiums that would result from the more valuable vehicle (see Chapter 3 of the TSD). Additional payback period scenarios, including using a 7 percent discount rate and AEO high and low fuel prices, are presented in the Appendix Section C.2.4. As shown in Table IV.10, payback when the vehicle is purchased with cash occurs in the 5th year of ownership.

Table IV.10 Payback Period for the Sales Weighted Average MY2025 Vehicle Relative to the Reference Case Standards, AEO 2016 Reference Fuel Price Case, Cash Purchase (3% discounting, 2015$)

Year of Ownership	Delta Cost per Vehicle	Delta Taxes per Vehicle	Delta Insurance[1] per Vehicle	Delta Purchase Costs per Vehicle	Delta Maintenance Costs per Vehicle	Delta Fuel Costs per Vehicle	Cumulative Delta Operating Costs per Vehicle
1st	$863[2]	$47	$16	$926	$6	-$238	$693
2nd	$0	$0	$15	$15	$6	-$232	$483
3rd	$0	$0	$14	$14	$5	-$223	$279
4th	$0	$0	$13	$13	$5	-$213	$85
5th	$0	$0	$12	$12	$5	-$202	**-$100**
6th	$0	$0	$11	$11	$5	-$189	-$274
7th	$0	$0	$10	$10	$4	-$178	-$437
8th	$0	$0	$9	$9	$4	-$166	-$589

Note:

[1] Insurance costs include depreciation effects and all cost metrics shown include vehicle survival rate factors.

[2] The $863 delta cost per vehicle was calculated from the average per-vehicle cost of $875 discounted at 3 percent to the mid-year point of the first year of ownership.

Since the Draft TAR, based on comments from the auto industry, we have expanded our assessment of payback period to calculate the payback periods for loan purchases. Fiat Chrysler Automobiles (FCA) pointed out that most (nearly 86 percent) new vehicles are purchased via financing instead of cash.[55] FCA and the Alliance of Automobile Manufacturers commented that the average new car loan is over 67 months, and more than 60 percent of loans are for 61 or more months. Further, 29 percent of loans are for 73-84 months.[56] Therefore, we believe it is important to illustrate the payback associated with loan terms of 5-6 years. Table IV.11 shows the payback using a 5-year (60-month) loan, using a loan rate of 4.25 percent (as further discussed in Chapter 3 of the TSD). Consumers who buy a MY2025 vehicle with a 5-year loan would see a payback during their first year of ownership. We also evaluate the payback period for 4-year and 6-year loan periods in the Appendix Section C.2.4.

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[55] Experian, 2015: "Majority of Consumers Rely on Financing as Loan Amounts for New Vehicles Skyrocket to Reach Another All-Time High." https://www.experianplc.com/media/news/2015/q4-2014-safm-part-2/.

[56] Zabritski, Melinda (2015). "State of the Automotive Finance Market Second Quarter 2015." Experian Automotive, http://www.experian.com/assets/automotive/white-papers/experian-auto-2015-q2.pdf?WT.srch=Auto_Q22015FinanceTrends_PDF , accessed 9/25/2015; Gardner, Greg (2015). "New-car loans keep getting longer." USA Today June 1, 2015, http://www.usatoday.com/story/money/cars/2015/06/01/new-car-loans-term-length/28303991/ , downloaded 9/25/2015.

Table IV.11 Payback Period for the Sales Weighted Average MY2025 Vehicle Relative to the Reference Case Standards, AEO 2016 Reference Fuel Price Case, 5-year (60 Month) Loan Purchase (3% discounting, 2015$)

Year of Ownership	Delta Cost per Vehicle	Delta Taxes per Vehicle	Delta Insurance[2] per Vehicle	Delta Purchase Costs per Vehicle	Delta Maintenance Costs per Vehicle	Delta Fuel Costs per Vehicle	Cumulative Delta Operating Costs per Vehicle
1st	$863[1]	$47	$16	$217	$6	-$238	**-$16**
2nd	$0	$0	$15	$209	$6	-$232	-$32
3rd	$0	$0	$14	$201	$5	-$223	-$49
4th	$0	$0	$13	$193	$5	-$213	-$64
5th	$0	$0	$12	$184	$5	-$202	-$78
6th	$0	$0	$11	$11	$5	-$189	-$251
7th	$0	$0	$10	$10	$4	-$178	-$414
8th	$0	$0	$9	$9	$4	-$166	-$567

Note:

[1] Insurance costs include depreciation effects and all cost metrics shown include vehicle survival rate factors.

[2] The $863 delta cost per vehicle was calculated from the average per-vehicle cost of $875 discounted at 3 percent to the mid-year point of the first year of ownership.

Table IV.12 shows the lifetime fuel savings and the lifetime net savings (fuel savings less increased vehicle costs) associated with the MY2025 standards (using AEO reference/high/low fuel prices at both the 3 percent and 7 percent discount rates). These analyses compare the lifetime savings associated with a vehicle meeting the MY2025 standards to a vehicle meeting the MY2021 standards in MY2025 (the reference case). These values include added costs associated with maintenance, insurance, and taxes, and the fuel savings resulting from less fuel usage.

Table IV.12 Lifetime Fuel Savings and Net Savings for the Sales-Weighted Average MY2025 Vehicle Purchased with Cash under Each of the AEO 2016 Fuel Price Cases (2015$)

Case	3 Percent Discount Rate		7 Percent Discount Rate	
	Lifetime Fuel Savings	Lifetime Net Savings	Lifetime Fuel Savings	Lifetime Net Savings
AEO High Fuel Prices	$4,209	$3,054	$3,223	$2,145
AEO Reference Fuel Prices	**$2,804**	**$1,648**	$2,128	$1,051
AEO Low Fuel Prices	$1,899	$723	$1,439	$345

6. Benefits and Costs of the MY2022-2025 Standards

In this section, EPA presents results of its model year analysis, which looks at the lifetimes of MY2021-2025 vehicles. In our model year analysis, we look at the impacts over the lifetimes of MY2021-2025 vehicles. We present the results of its calendar year analysis, which looks at annual impacts through the year 2050, in Appendix Section C.3. The inventory inputs and monetary inputs used to generate the tables presented here are discussed in Appendix C and Chapter 3 of the TSD, where we present $/ton, $/gallon and $/mile premiums, as applicable, that are applied to the inventory inputs to generate the benefit cost analysis results.

Table IV.13 summarizes EPA's model year lifetime BCA results. In the central analysis presented in the table, we use AEO 2016 reference fuel prices and fleet projections, and, as noted, we include our estimate of EV and PHEV sales required by the ZEV program in the reference and control case fleets. The values in this table are discounted at 3 percent and 7 percent back with the exception of the social costs of greenhouse gases which are discounted at the discount rate used in their generation. All values are discounted to CY 2016. Importantly, Table IV.13 shows that our central analysis technology and maintenance costs are estimated at roughly $36 billion ($32.6 billion vehicle program + $2.9 billion maintenance) and benefits excluding fuel savings are estimated at roughly $42 billion (using the 3 percent average SC-GHG value). In other words, even without fuel savings, benefits outweigh costs.

We present the detailed central case results and sensitivity case results using AEO high and low cases in Appendix Section C.3. The differences in all categories when comparing across fuel price cases are the result of the different fleet makeups across fuel prices, different ZEV program sales projections across fuel prices cases, and the different fuel prices themselves and their impact on fuel savings. Importantly, Table IV.13 shows that, in all cases, the net benefits and the fuel savings independently exceed the costs (i.e., the net benefits exceed the costs without considering any fuel savings, and likewise fuel savings exceed the costs even without considering any other benefits).

Table IV.13 MY Lifetime Costs & Benefits in Each AEO Fuel Price Case (Billions of 2015$)

	3 Percent Discount Rate			7 Percent Discount Rate		
	AEO Low	AEO Ref	AEO High	AEO Low	AEO Ref	AEO High
Vehicle Program	-$34.7	-$32.6	-$31.6	-$25.4	-$23.9	-$23.1
Maintenance	-$3.1	-$2.9	-$2.4	-$1.8	-$1.7	-$1.4
Fuel	$61.3	$91.6	$138.7	$34.9	$52.2	$80.0
Benefits	$42.9	$41.9	$42.2	$33.2	$31.9	$31.3
Net Benefits	$66.4	**$98.0**	$147.0	$40.9	$58.5	$86.7

Note: Benefits and Net Benefits values presented here use the mid-point value of the non-GHG range for the applicable discount rate and the central SC-GHG values (average SC-CO2, average SC-CH4, and average SC-N2O, each at 3 percent) discounted at 3 percent in all cases.

B. Summary of EPA's Assessment of the Appropriateness of the MY2022-2025 Standards

As discussed in Section I, through the Midterm Evaluation, the Administrator must determine whether the GHG standards for model years 2022-2025, established in 2012, are still appropriate, within the meaning of section 202 (a) (1) of the Clean Air Act, , given the latest available data and information in the record then before the Administrator.[57] In this Proposed Determination, the Administrator is proposing to determine that the GHG standards currently in place for MYs 2022-2025 remain appropriate under the Clean Air Act. The consequence of this determination, if made final, would be unchanged standards, no other alteration in the rules, and thus a continuation of the current regulatory status quo. EPA has fully considered public comments submitted on the Draft TAR, as well as other updated information. EPA has updated its analyses where appropriate in response to comments and to reflect the latest available data, as discussed throughout this Proposed Determination and the TSD.

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[57] See 40 CFR section 86.1818-12(h).

The EPA regulations state that in making the required determination, the Administrator shall consider the information available on the factors relevant to setting greenhouse gas emission standards under section 202(a) of the Clean Air Act for model years 2022 through 2025, including but not limited to:

- The availability and effectiveness of technology, and the appropriate lead time for introduction of technology;
- The cost on the producers or purchasers of new motor vehicles or new motor vehicle engines;
- The feasibility and practicability of the standards;
- The impact of the standards on reduction of emissions, oil conservation, energy security, and fuel savings by consumers;
- The impact of the standards on the automobile industry;
- The impacts of the standards on automobile safety;
- The impact of the greenhouse gas emission standards on the Corporate Average Fuel Economy standards and a national harmonized program; and
- The impact of the standards on other relevant factors.[58]

In the following paragraphs, we present a discussion of each of these factors in light of the analyses conducted in the Draft TAR, the updated information in the TSD, and this document.

The first several factors address technology availability and effectiveness, lead time for implementing technologies, and the costs, feasibility and practicability of the standards. As discussed in Section II, auto industry commenters raised concerns that the effectiveness of gasoline technologies was not sufficient to reach the 2025 standards, and believed that higher penetrations of electrified vehicles would be needed and at higher costs. Underlying these concerns, the auto industry commenters pointed to what they viewed as overly optimistic assumptions in the EPA modeling – that is, they believed EPA's estimated technology effectiveness was too high, and costs were too low. Specifically, these commenters asserted that some of the gasoline engine technologies, mainly the Atkinson cycle engine technology, considered in EPA's analysis would not be available to many manufacturers in the MY2022-2025 time frame.

In contrast, comments from environmental NGOs, non-environmental NGOs, state/local governments, and consumer groups expressed strong support for the MY2022-2025 standards and believed they should be made more stringent. These groups viewed EPA's technical analysis in the Draft TAR as providing a robust and transparent technical foundation that supports the finding that the standards can be met with cost-effective technologies. Several organizations, such as ICCT, pointed to additional technologies they believe have the potential to enter the market by the 2025 time frame, affording automakers with even more technology options and at potentially lower costs.

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[58] 40 CFR 86.1818-12(h)(1).

As discussed in Section II and further in Section B of the Appendix to this Proposed Determination, upon full evaluation of the public comments, EPA has updated our analysis in response to the technically relevant auto industry comments as explained throughout this document and the TSD (e.g., quality checks on effectiveness modeling, analysis of powertrain efficiency metrics, updating baseline to use the now-available 2015 final certification data). On the basis of this analysis, which is fully laid out in the Draft TAR, and the TSD and Appendices to this Proposed Determination, EPA does not agree with the auto industry comments that advanced gasoline technologies are insufficient to meet the 2025 standards cost-effectively. First, the industry commenters provided little actual data to substantiate their comments that effectiveness of specific technologies should be lower. For the data we did receive, we fully evaluated it and provide responses. For example, Ford submitted data on transmission effectiveness, which we assessed and concluded these data in fact corroborate EPA’s estimates (see TSD Chapter 2.3.4.10). Second, the auto industry associations’ claim that advanced gasoline technologies cannot reach the MY2025 standards is based on a study that has significant flaws and makes some extremely conservative and unrealistic assumptions, including that over the next nine years until 2025, the efficiency of today’s technologies will not improve and technologies will not advance beyond those in the fleet today. EPA's review of the literature, including but not limited to the 2015 NAS study, makes it clear that advanced gasoline vehicle technologies will improve over the next nine years. In addition, the significant technology advances that have already occurred in just the four years between 2012-2016 are a strong indication that technology will continue to advance beyond that existing at any given moment in time, with clear potential for substantial gains over the next nine years to 2025. EPA fully responds further to this study in Section B of the Appendix to this Proposed Determination document and in Appendix A of the TSD. Third, in regard to concerns about the feasibility and lead time of Atkinson engine technology, we show in Chapter 2 of the TSD (including in comment responses in Section 2.3.4.10), and discuss further below, that the Atkinson technology is presently feasible and can be incorporated further into the light duty fleet with ample lead time before the 2022 MY (for example, most of the base technology is already in place, and the technology does not involve a major powertrain shift). Moreover, as shown in the sensitivity case where use of Atkinson cycle engines was constrained to 10 percent, other cost effective engine technologies were available to meet the MY2022-2025 without needing substantial penetrations of strong hybrids, PHEVs and EVs. Thus, it is our initial conclusion that the use of Atkinson cycle engines is just one technology among the many potential advanced engine technology options for compliance, as we discuss further below.

As shown in the discussion of EPA’s technology penetrations (Table IV.5 above and the Appendix Section C), EPA has projected a range of potential compliance pathways for each manufacturer and the industry as a whole to meet the MY2022-2025 standards. In those tables, we show a “central case” and eight sensitivity cases, three of which show different technology approaches that could be taken (compliance without additional mass reduction, without use of advanced high gear spread transmissions and without use of high compression ratio naturally aspirated engines beyond what is already in the market. The other sensitivity cases show potential paths should fuel prices be lower or higher than the fuel prices used in the central case, should trading of credits across manufacturers occur more broadly than they already are and should technology indirect costs (and total costs) be higher than we have estimated. All of these sensitivity analyses, as well as the central case, indicate that the standards can be met largely through utilization of a suite of advanced gasoline vehicle technologies, with modest penetration of stop-start and mild hybrids and relatively low penetrations of strong hybrids, PHEVs and EVs. This does not mean that other potential pathways are not possible or desirable; in fact, the standards are performance-based and thus allow each auto manufacturer to choose its own future path to compliance, depending on what technologies it views best to meet the needs of its customers, while still complying with the standards. For example, while our analysis (both the central case and the multiple sensitivity analyses) indicates that very few strong hybrids, plug-in electric vehicles, or electric vehicles will be needed to meet the 2025 GHG standards (in other words, EPA projects that the use of advanced gasoline technologies is sufficient to meet the 2025 standards, and is potentially a lowest cost compliance path), several firms have announced plans to pursue EV and PHEV technologies. Thus, the actual penetration of those technologies may turn out to be higher than the EPA's projected pathways, driven by goals and interests beyond compliance with the MY2022-2025 GHG standards.

EPA is projecting average per vehicle costs of about $875 across the fleet (in our central case) and from about $800 to $1,115 across our eight sensitivity cases, as shown in Table IV.5. These costs are similar to, in fact lower than (in all but one sensitivity case), those projected in the 2012 rule, which EPA estimated at about $1,100 (see Table 12.44 of the Draft TAR). This decrease is not surprising—technology to achieve environmental improvements has often proved to be less costly than EPA's initial estimates.[59] Captured in these costs, we see significant increases in advanced engine technologies, comprising more than 60 percent of the fleet across a range of engines including turbo-downsized 18 bar and 24 bar, naturally-aspirated Atkinson cycle, and Miller cycle engines. We also see significant increases of advanced transmission technology projected to be implemented on more than 90 percent of the fleet, which includes continuously variable transmissions (CVTs) and eight-speed automatic transmissions. Stop-start technology and mild hybrid electrification are projected to be used on nearly 15 percent and 18 percent, respectively, of the fleet. EPA is projecting very low levels of strong or full hybrids (2 percent) and EV/PHEVs (5 percent) as absolute levels in the fleet, though note that a portion of the EV/PHEV penetration is attributed to the ZEV program; the incremental penetration of EV/PHEVs needed to meet the EPA GHG standards is projected to be less than one percent.

These technology pathway initial findings are similar to the types of technologies that EPA projected in establishing the standards in the 2012 rule, although the specific technologies within the advanced engine, advanced transmission, and mild hybrid categories have been updated from the 2012 rule to reflect the current state of technological development (hence the lower estimated per vehicle cost than in the 2012 rule). For example, additional engine technologies, such as the naturally aspirated Atkinson cycle and Miller cycle, were not even considered in the 2012 rule. Similarly, transmission technology has developed such that CVTs are now emerging as a more popular choice for manufacturers than the dual-clutch transmissions we had mainly considered in 2012.[60] Mild hybrid technology has developed with more sophisticated 48-volt systems now offering a more cost-effective option than the 110-volt systems we had considered in the 2012 rule. The fact that these technologies have developed and improved so rapidly in the past four years since the MY2022-2025 standards were established provides a strong indication that the

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[59] U.S. EPA, National Center for Environmental Economics (2014). "Retrospective Study of the Costs of EPA Regulations: A Report of Four Case Studies." EPA 240-F-14-001, https://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0575.pdf/$file/EE-0575.pdf including its literature review, Chapter 1.1.

[60] 77 FR 62852-62883; October 15, 2012.

pace of innovation is likely to continue (contrary to the central premise of the technical analysis supporting the auto industry comments). We expect that this trend will continue, likely affording manufacturers even more technology options, and at potentially lower cost, than the Administrator was able to consider at this time for the Proposed Determination.

Lead time is a significant component of technical feasibility, and in their comments on the Draft TAR, several organizations expressed differing views on lead time. Global Automakers asserted that the Draft TAR "does not give sufficient consideration to the lead time necessary to integrate the required technologies over the many models in a manufacturer's product line." Global Automakers' concern was with adoption of entirely new powertrains, and pointed to the specific example of EPA's estimated projection of naturally aspirated, Atkinson cycle engines. The Alliance of Auto Manufacturers submitted similar comments. If additional manufacturers choose to utilize Atkinson cycle engines, EPA believes that there would be ample lead time to do so. As discussed in the TSD[61], the steps required to implement an Atkinson cycle engine are relatively modest compared to implementing other engine technologies. The technology requires changing the intake valve cam phaser to one with a higher range of control authority; increasing the geometric compression ratio, generally through revisions to the piston crown and cylinder head combustion chamber surfaces; and minor revisions to the intake port geometry in order to improve turbulence generation (see the TSD, Chapter 2, which describes the technology, provides examples of current implementations, and discusses the lead times needed to implement this technology). The requisite cam phaser hardware is readily available to any manufacturer, and the technology is not restricted by patent protections. No major alterations of the powertrain are necessary. EPA's assessment is that it is feasible for this technology to be incorporated by any manufacturer and that there is sufficient lead time between now and MY2022-2025 that this technology could represent a high penetration rate of a company's products. It also is not plausible that manufacturers would ignore a higher-efficiency lower cost technology that a number of their competitors are already adopting or announced plans to adopt. In fact, several manufacturers, including Hyundai, Mazda, FCA, and Toyota, are implementing forms of Atkinson cycle engine technology today,[62] and other automakers have told EPA confidentially that they are planning to follow this path for some of their engines by the MY2022-2025 time frame.

It is also important to underscore that EPA's projected technology penetrations are meant to illustrate one of many possible technology pathways to achieve compliance with the MY2022-2025 GHG standards. The rules do not mandate the use of any particular form of technology; the standards are performance-based and thus manufacturers are free to select among the suite of technologies they best believe is right for their vehicles to achieve compliance. As we have seen in recent years with the rapid advances in a wide range of GHG-reduction technologies, we

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[61] See Chapter 2.3.4.1.8 of the TSD.

[62] As an example of product implementation time line, Mazda introduced a line of Atkinson-cycle engines over a 5-year period, concurrent with the introduction of the engines across Mazda's U.S. line-up of passenger cars and cross-overs, as well as other Mazda vehicles sold outside the U.S. Specifically, Mazda introduced a 2.0 liter (L) in 2012, a 2.5 L in 2013, a 1.5 L in 2014, and a 2.5 L turbocharged version with cooled EGR in 2016. In the U.S., Mazda integrated the Atkinson-cycle engines into their vehicle line up as follows: MY2012 Mazda3, MY2013 Mazda6 and CX-5, MY2015 CX-3, MY2016 CX-9 and MX-5. This time line demonstrates that provided sufficient lead time, OEMs can develop next-generation gasoline engines and introduce them across many vehicle models in a 5-year time period.

expect that ongoing innovation will result in further improvements to existing technologies and the emergence of others. As discussed in Section IV.A.3 above and further in Appendix Section C.1, the use of Atkinson cycle engines is just one technology among the many potential technology pathways to compliance. In this Proposed Determination, as in the Draft TAR, EPA analyzed multiple additional potential technology pathways by which the industry could comply with the MY2022-2025 standards, including a pathway that limited the application of Atkinson engines to a maximum of 10 percent (see Appendix Section C.1.2, the "Non-ATK2 Path" sensitivity case) and Chapter 12.1.2 of the Draft TAR) and concluded that there are other cost-effective pathways to meet the MY2022-2025 standards not requiring substantial penetration of strong hybrid, PHEV, or EVs, and that there is ample lead time to do so.

Toyota commented that it believes lead time was not properly accounted for in the Draft TAR for the levels of hybridization and electrification it asserts will be needed to meet the MY2022-2025 standards. In this Proposed Determination, as in the Draft TAR, EPA’s projections to date indicate that only very low levels of strong hybrids (2 percent) and plug-in vehicles (5 percent) will be needed by 2025, and we believe that there will be adequate lead time for manufacturers to achieve these low levels over the next nine years. We also recognize that manufacturers have other considerations beyond the U.S. GHG vehicle standards for contemplating more vehicle electrification options for their customers. For example, in October 2015, Toyota announced a global environmental sustainability goal of reducing new vehicle CO_2 emissions by 90 percent by 2050 (from 2010 levels), which included specific targets for achieving significant sales of hybrids and fuel cell vehicles.[63] EPA applauds corporate goals for achieving even greater GHG reductions to address climate change, because, as discussed in Section V, much deeper GHG reductions will be needed beyond the 2025 standards to meet the U.S. commitments to address climate change.

Several NGOs recognized the value and adequacy of the lead time already provided by the standards. The International Council on Clean Transportation (ICCT) highlighted “a key advantage of setting regulatory standards with such a long lead time – that there is time for widespread diffusion of emerging technologies across companies.” ICCT recommended that EPA not assume restrictive constraints on automaker technology paths based on past and near-term automaker technology decisions, since they believe in the 2022-2025 time frame innovative technologies are emerging that can be deployed more widely than the agencies estimate.

In considering whether lead time for the 2022-2025 standards is adequate, EPA recognizes that the standards for MY2022-2025 were first established in October 2012, providing the auto manufacturers with up to 13 years of lead time for product planning to meet these standards. In the 2012 rule, EPA concluded that, “EPA agrees that the long lead time in this rulemaking should provide additional certainty to manufacturers in their product planning. EPA believes that there are several factors that have quickened the pace with which new technologies are being brought to market, and this will also facilitate regulatory compliance.”[64] As noted, in setting the standards in 2012, EPA was beginning to see that technologies were being brought to market at a quickened pace, and this trend has clearly continued over the past four years, as EPA discusses in depth in Section II of this Proposed Determination. EPA’s 2016 CO_2 and Fuel Economy Trends

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[63] “Toyota Unveils Bold New Environmental Targets,” http://newsroom.toyota.co.jp/en/detail/9889509 (last accessed on November 2, 2016).

[64] 77 FR 62880; October 15, 2012.

report provides even further evidence of the rapid pace at which manufacturers are bringing advanced technologies into the fleet. For example, GM, Honda and Hyundai have implemented advanced transmissions on 80-90 percent of their fleets within the past five years. Over that same time period, GM and Ford have implemented turbocharged engines on 29 percent and 46 percent, respectively. Given that EPA projects that the fleet as a whole could reach the 2025 standards with penetrations of 27 percent turbo-downsized 18 bar engines, and 7 percent turbo-downsized 24 bar engines, these penetration rates are achievable given the pace with which some manufacturers have already implemented similar technologies.[65] Gasoline direct injection (GDI) engines were used in less than 3 percent of the fleet in 2008, and are now projected to be on almost 50 percent of vehicles in MY2016, with Mazda and other manufacturers employing GDI across almost their entire fleets. Technology adoption rates and the pace of innovation have accelerated even beyond what EPA expected when initially setting these standards, which will further aid in addressing any potential for lead time concerns. By the time manufacturers must meet the MY2025 standards, since the standards were set in 2012, they will have had up to 13 years of lead time for product planning and at least 2-3 product redesign cycles, and at present manufacturers still have 6 to 9 years of lead time until the MY2022-2025 standards, with at least 1-2 redesign cycles.[66]

EPA has also evaluated the progress of the existing fleet in meeting standards in future model years. See the TSD Appendix C. This assessment shows that more than 100 individual MY2016 vehicle versions, or about 17 percent of the fleet, already meet future footprint-based CO_2 targets for MY2020 with current powertrains and air conditioning improvements. When we include an estimate of 5 g/mi of off-cycle credits,[67] then 21 percent of the MY2016 fleet can already meet the MY2020 footprint-based CO_2 targets -- four years ahead of schedule. Notably, the majority of these vehicles are gasoline powertrains, and the vehicles include nearly every vehicle type, including midsize cars, SUVs, and pickup trucks, and span nearly every major manufacturer. It is important to note that not all vehicles are required to be below their individual targets, and in fact EPA expects that manufacturers will be able to comply with the standards with roughly 50 percent of their production meeting or falling below the footprint based targets. This analysis is another positive indication that the fleet is on track to meet future standards, especially given the 6 to 9 years of lead time remaining to MY2022-2025.

Consequently, evaluating the factors EPA is required to consider under factors (i), (ii), and (iii) of the mid-term evaluation rules, based on the current record before the Administrator (and subject to further consideration of public comment), there is available technology to meet the 2022-2025 standards, it is available at reasonable cost, there is adequate lead time to meet those standards, and the standards are thus feasible and practicable.

EPA also has considered the impact of the standards on reduction of emissions, oil conservation, energy security, and fuel savings by consumers, again as required by the Midterm Evaluation rules. As shown in Table IV.6 and Table IV.7 above, EPA projects that the MY2022-

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[65] EPA 2016 CO2 and Fuel Economy Trends Report, Figures 6.2, 6.3 and 6.5.

[66] Redesign cycles are summarized in the Appendix Section A and are discussed in greater detail in the 2012 FRM final Joint Technical Support Document, EPA-420-R-12-901, at Section 3.5.1

[67] This is a conservative assumption given that manufacturers on average are already reporting in MY2015 the use of 3 g/mi of off-cycle credits across the fleet, with some manufacturers reporting more than 4 g/mi off-cycle credits.

2025 standards will reduce GHG emissions annually by more than 230 million metric tons (MMT) by 2050, and nearly 540 MMT over the lifetime of MY2022-2025 vehicles (see Table IV.6). These standards are projected to reduce oil consumption by 50 billion gallons (Table IV.8), and to save U.S. consumers nearly $92 billion over the lifetime of MY2022-2025 vehicles (Table IV.13). On average for a MY2025 vehicle (compared to a vehicle meeting the MY2021 standards), consumers will save more than $2,800 in total fuel costs over that vehicles' lifetime, with a net savings of $1,650 after taking into consideration the upfront increased vehicle costs (see Table IV.12, at 3 percent discount rate). EPA considers a range of societal benefits of the standards, including the social costs of carbon and other GHGs, health benefits, energy security, the value of time saved for refueling, and others. Benefits are expected to far outweigh the costs, with net benefits totaling $98 billion over the lifetime of MY2022-2025 vehicles (3 percent discount rate), as shown in Table IV.13. This analysis would also support a conclusion that the current standards remain appropriate from the standpoint of impacts of the standards on emissions, oil conservation, energy security, and fuel savings

EPA has assessed the impacts of the standards on the automobile industry per section 86.1818-12(h)(v). We have estimated the costs required to meet the MY2022-2025 standards at about $33 billion (Table IV.13), with an average per-vehicle cost of about $875 (Table IV.4 and Table IV.5). These costs are less than those originally projected when EPA first established these standards in the 2012 rule; at that time, we had projected an average per vehicle cost of approximately $1,100 (see Table 12.44 of the Draft TAR). We found those (higher) projected costs to be reasonable in the 2012 FRM, and the lower projected costs projected here thus continue to support the appropriateness of the standards.

In addition to costs, EPA has assessed impacts on the auto industry in terms of potential impacts on vehicle sales and employment, as discussed in Section III above and further described in Appendix Section B and the TSD Chapter 4. As part of these assessments, EPA has also evaluated a range of issues affecting consumers, addressing the factor, "the cost on the producers or purchasers of new motor vehicles or new motor vehicle engines," section 86.1818-12 (h) (ii), also discussed at length in Appendix Section B and the TSD Chapter 4. As discussed in those sections, auto industry and automobile dealer commenters expressed concerns that EPA had failed to adequately assess consumer impacts as part of the Draft TAR, and expressed concerns about impacts on consumers from higher vehicle prices, and the potential for losses in vehicle sales and resulting job losses, if consumers either could not afford, or were not willing to pay the increased vehicle prices. Consumer groups and NGOs, on the other hand, indicated that consumer interest in fuel economy is strong, that fuel economy is the number one attribute consumers want to see improved, that consumer satisfaction is strongly tied to improved fuel economy, and that consumers highly value the fuel savings that comes from strong GHG vehicle standards. EPA's responses to these comments are fully discussed in Appendix Sections B.1 and B.2, and Chapter 4 of the TSD.

EPA's assessments indicate that, to date, there is little, if any, evidence that consumers have experienced adverse effects from the standards. Vehicle sales continue to be strong, likely due not to the standards, but rather to economic recovery from the 2008-2009 recession. Nevertheless, the standards do not appear to have impeded sales. We also have not found any evidence that the technologies used to meet the standards have imposed "hidden costs" in the form of adverse effects on other vehicle attributes. Similarly, we have not identified significant effects on vehicle affordability to date. We recognize that the standards will have some impact on the price of new vehicles, but we do not believe that the standards have significantly reduced the availability of model choices for consumers at any particular price point, including the lowest price vehicle segment. Given the lead time provided since the 2012 rule for automakers to achieve the MY2022-25 standards, and the evidence to date of consumer acceptance of technologies being used to meet the standards, EPA expects that any effects of the standards on the vehicle market will be small relative to market responses to broader macroeconomic conditions. See Appendix Section B.1 and Chapter 4 of the TSD for a full discussion of consumer issues.

In assessing potential impacts on auto industry employment, see section 86.1818-12 (h)(v), EPA's assessment is that there is a positive effect of the partial employment impact of increased expenditures on vehicle technology. That is, we project job growth in the automotive manufacturing sector and automotive parts manufacturing sector, due to the need to increase expenditures for vehicle technologies needed to meet the standards. We do not attempt to quantitatively estimate the total effects of the standards on the automobile industry, due to the significant uncertainties underlying any estimate of the impacts on vehicle sales. Nor do we quantitatively estimate the total effects on employment at the national level, because such effects depend heavily on the state of overall employment in the economy (see Appendix Section B.2). Nevertheless, EPA's assessment is that, while the standards are likely to have some effect on employment, this effect (whether positive or negative) is likely to be small enough that it cannot be distinguished from other factors affecting employment, especially macroeconomic conditions and their effect on vehicle sales. We further note that, under conditions of full employment, any changes in employment levels in the regulated sector due to these standards are mostly expected to be offset by changes in employment in other sectors. See Appendix Section B.2.

EPA has assessed the potential impacts of the standards on automobile safety, as discussed in Section III.C.1 above and further described in Appendix Section B.3.1. Consistent with the Draft TAR's safety assessment, EPA has again assessed the potential of the MY2022-2025 standards to affect vehicle safety. In the Draft TAR (Chapter 8), the agencies reviewed the relationships between mass, size, and fatality risk based on the statistical analysis of historical crash data, which included a new analysis performed by using the most recent available crash data. EPA used this updated analysis[68] to calculate the estimated safety impacts of the modeled mass reductions over the lifetimes of new vehicles in response to MY2022-2025 standards. As in initially promulgating these standards and in our Draft TAR assessment, EPA's assessment for this Proposed Determination is that the fleet can achieve modest levels of mass reduction as one technology among many to meet the MY2022-2025 standards without any net increase in fatalities.

Finally, EPA has assessed the impacts of the standards on the CAFE standards and a national harmonized program. See section 86.1818-12 (h)(vii). EPA notes that NHTSA has established augural standards for MY2022-2025 and must by statute undertake a *de novo* notice and

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[68] 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. Washington, DC: National Highway Traffic Safety Administration.

comment rulemaking to establish final standards for these model years. Under the Energy Policy and Conservation Act (EPCA) statute, as amended by the Energy Independence and Security Act (EISA), NHTSA must establish final standards at least 18 months before the beginning of each model year.[69] The statute requires the Secretary of Transportation to consult with the EPA Administrator in establishing fuel economy standards.[70] The EPCA/EISA statute includes a number of factors that NHTSA must consider in deciding maximum feasible average fuel economy, including “the effect of other motor vehicle standards of the Government on fuel economy.”[71] Thus, in determining the CAFE standards for MY2022-2025, NHTSA can take into consideration the light-duty GHG standards, and indeed did so in initially establishing the MY2017-2021 CAFE standards and the augural MY2022-2025 standards. See 77 FR 62669, 62720, 62803-804. EPA believes that by providing information on our evaluation of the current record and our proposal to retain the current GHG standards for MY2022-2025, we are enabling, to the greatest degree possible, NHTSA to take this analysis and the GHG standards into account in considering the appropriate CAFE standards for MY2022-2025.

In comments on the Draft TAR, as well as in a separate petition, auto industry commenters raised concerns about lack of harmonization across the EPA, NHTSA, and California programs. However, as we discuss in detail in Section III.C.5 and further in Appendix Section B.3.5, EPA and NHTSA have harmonized many elements of the National Program, including test procedures, testing and data collection, reporting, and other compliance activities. In developing the National Program, EPA’s national GHG standards also addressed the concern about unique state-level GHG standards, in that California allows manufacturers to demonstrate compliance with the California standards by showing compliance with the EPA GHG standards (referred to as the “deemed to comply” provision).

Going back to the first time the agencies established standards for the 2012-2016 model years, EPA and NHTSA were clear that there were some important differences in the statutory authorities,[72] and that the stringency of the respective standards was in fact established to account for differences in air conditioning improvements, which reduce GHG emissions but do not affect fuel economy. The MY2022-2025 GHG standards were established in recognition of the differences in certain aspects of the GHG and CAFE programs,[73] such as certain aspects of the credit programs which are limited by statute under the CAFE program. Thus, the fact that such differences continue to exist, as fully recognized in setting the standards initially, does not lead EPA to find that the GHG standards for MYs 2022-2025 are no longer appropriate. Other aspects of the auto manufacturers' harmonization comments, as detailed in Section III.C.5 and Appendix Section B.3.5, raise issues that are not unique to the 2022-2025 model years and are not material to our assessment of the appropriateness of the standards for those years (e.g., suggestions for streamlining the off-cycle credit approval process), and thus are outside the scope of EPA’s decision on the appropriateness of the MY2022-2025 standards. EPA is making a proposed determination that the MY2022-2025 standards are still appropriate, based on the

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[69] 42 U.S.C. 32902(a).

[70] 42 U.S.C. 32902(b)(1).

[71] 42 U.S.C. 32902(f).

[72] See 75 FR 25330, May 7, 2010; see also 77 FR 62674.

[73] 77 FR 62674, October 15, 2012.

existing regulations, including the credit provisions raised in the auto industry comments on harmonization.

C. Proposed Determination

Having considered available information on each of the above factors required by the regulations, under 40 CFR 86.1818-12(h), the Administrator is proposing to determine that the GHG standards currently in place for MYs 2022-2025 remain appropriate under section 202(a)(1) and (2) of the Clean Air Act. EPA has fully considered public comments submitted on the Draft TAR, as well as other updated information. EPA has updated its analyses where appropriate in response to comments and to reflect the latest available data. The consequence of this determination, if finalized, would be a continuation of the current status quo. The regulations themselves would be unaltered as a result of the determination.

In the Administrator's view, the record clearly establishes that, in light of technologies available today and improvements we project will occur between now and MY2022-2025, it will be practical and feasible for automakers to meet the 2022-2025 standards with cost-effective strategies that will achieve the significant GHG emissions reduction goals of the program, while delivering significant reductions in oil consumption and fuel savings for consumers, and without having material adverse impact on the industry, safety, or consumers. The 2015 National Academy of Sciences study on fuel economy technologies also found that the 2025 standards would be achieved largely through improvements to a range of technologies that can be applied to a gasoline vehicle without the use of strong hybrids, PHEV, or EV technology. The study further found that the footprint-based standards are likely to have little effect on vehicle and overall highway safety. EPA has considered the feasibility of the standards under several different scenarios of future fuel prices and fleet mix (see Section IV.A and Appendix Section C), which showed only very small variations in average per-vehicle cost or technology penetration mix, and thus, our conclusion that the 2022-2025 standards can be met with cost-effective technologies holds across all these scenarios. EPA recognizes that not all of these technologies have been implemented in a widespread manner, but it also recognizes that the purpose of the Midterm Evaluation is to assess whether the standards remain appropriate in light of the pace of compliance and technological development in the industry. As discussed above, the technological development of advanced gasoline vehicle technologies has surpassed EPA’s expectations when we initially adopted the standards. Although we anticipated in 2012 that the standards could be met primarily using advanced gasoline engine and transmission technologies, the range of technology development has been more extensive and effective than anticipated. EPA concludes that the 2022-2025 standards could be largely met simply by implementation of these technologies, but we recognize that we are at the mid-point of these standards and it would be unreasonable, in light of past developments, ongoing investment by the industry, and EPA's extensive review of the literature on future technologies and improvements to existing technologies, to expect that no further technology development would occur that could be implemented for model year 2022-2025 vehicles. Even the Draft TAR was not able to consider or model all of the technologies being developed because of the rapid pace of development. As discussed in Section II and Appendix Section B, EPA did not consider for this Proposed Determination several technologies that we know are under active development and may potentially provide additional cost-effective technology pathway options for meeting the 2025 standards; examples of such technologies include electric boosting, dynamic cylinder deactivation, and variable compression ratio. Thus, in light of the pace of progress in reducing GHG emissions since the 2022-2025 standards were adopted, the success of automakers in achieving the standards to date while vehicle sales are strong, the projected costs of the standards, the impact of the standards on reducing emissions and fuel costs for consumers, and the other factors identified in 40 CFR 86.1818-12(h) and discussed above, the Administrator concludes that it would be inappropriate to revise the 2022-2025 standards to make them less stringent.

The Administrator has also considered whether, in light of these factors and the record (including public comments urging more stringent standards), it would be appropriate to make the standards more stringent. She recognizes that the current record, including the current state of technology and the pace of technology development and implementation, could support a decision to adopt more stringent standards for 2022-2025 (or, put more precisely, could support a decision to initiate rulemaking proposing to amend the standards to increase their stringency). However, given the overall need to significantly reduce greenhouse gases in the transportation sector, especially given expected growth in vehicle travel, the Administrator also recognizes that regulatory certainty is an important consideration. Regulatory certainty gives the automakers the time they need to conduct long-term planning and engineering that could lead to major advancements in technology while contributing to the continued success of the industry and the GHG standards program, which in turn will benefit consumers and reduce emissions. She also believes a decision to maintain the current standards provides support to a timely NHTSA rulemaking to adopt 2022-2025 standards and a harmonized national program. Thus, the Administrator has preliminarily concluded that it is appropriate to provide the full measure of lead time for the 2022-2025 standards, rather than initiating rulemaking to adopt new, more stringent standards with a shorter lead time.

Accordingly, the Administrator is proposing to conclude that in light of all the prescribed factors, and considering the entire record, the current 2022-2025 standards are appropriate and should be retained. EPA is seeking public comment on this proposed determination that the GHG standards currently in place for MY2022-2025 remain appropriate under the Clean Air Act.

V. The Need and Opportunity for Substantial GHG Emissions Reductions from Light-Duty Vehicles Beyond 2025

A. Introduction

The previous sections of this document present the Administrator's Proposed Determination under the Midterm Evaluation of the MY2022-2025 light-duty vehicle greenhouse gas (GHG) emissions standards, as required by regulations. Her preliminary conclusion, as set out above, is that the standards remain appropriate under the Clean Air Act and EPA's regulatory criteria. She also notes that the present record could potentially support making those standards more stringent. One of the "other factors" EPA may consider under the MTE regulations is potential future developments in succeeding model years and how the MY2022-2025 standards might relate to those developments. This final section considers those issues. Specifically, this section discusses the MY2026 and later time frame.

The long-term trajectory of the automobile industry has been one of improved fuel economy and reduced emissions of air pollution, with very positive results for consumers, the auto industry, labor, energy independence, and public health and the environment. These innovations have also been positive for American technology developers and manufacturers, providing opportunities to market American technology around the world. There is every reason to expect these trends to continue. Given the particular threat that climate change poses to the United States and countries around the world, the agency believes it is important to share with the public an initial EPA estimate of the GHG emissions reductions that will likely be necessary from the light-duty vehicle sector if it is to continue to make meaningful contributions to reducing long-term GHG emissions. In addition, EPA wants to begin the process of engaging a wide range of stakeholders on how ongoing automotive technology innovation can help achieve light-duty vehicle sector GHG emissions reductions. Finally, the agency received several comments on the Draft Technical Assessment Report (TAR) urging EPA to consider long-term climate issues.[74]

Climate change is a long-term global environmental challenge. GHG emissions accumulate in the atmosphere over time, atmospheric concentrations have been growing for decades, and the average atmospheric CO_2 concentration of 401 ppm in 2015 is likely the highest level for at least the last 800,000 years.[75] As discussed in more detail in Section I, the Earth has warmed by more than 0.8 C (1.5 F) over the past century, with U.S. impacts that have already been documented. The last 15 years have been 15 of the 16 warmest years on record.[76] Left unaddressed, global average temperatures could rise as much as 4.8 C (8.6 F) by the end of this century, relative to today, with a projected range of sea level rise of 1-4 feet by 2100. Extreme temperatures and other events in the U.S. could lead to thousands of deaths and trillions of dollars in economic

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[74] EPA received relevant comments from Consumers Union, The International Council on Clean Transportation, University of Illinois Applied Environmental Law Program et al, Northeast States for Coordinated Air Use Management, National Association of Clean Air Agencies, American Lung Association et al, and Fuel Freedom Foundation, among others.

[75] IPCC, 2013. Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

[76] http://www.ncdc.noaa.gov/sotc/global/201513.

damages.[77] While some excess carbon dioxide (the primary greenhouse gas) in the atmosphere is absorbed (for example, by the ocean), other excess carbon dioxide remains in the atmosphere for thousands of years, due in part to the very slow process by which carbon is transferred to ocean sediments. It would take a very long time for atmospheric GHG levels to reach an equilibrium, let alone begin to decrease, even if annual GHG emissions loadings were reduced significantly. Accordingly, any meaningful plan to address the climate challenge must prioritize early GHG emissions reductions and make continual progress over the long-term.

Lead time issues are central to the automotive industry. Conventional vehicle design cycles are typically about 5 years, while transformational technologies can take much longer to develop, commercialize, and achieve mainstream consumer acceptance. Technological innovation is opening major new opportunities for transformational changes, some driven by climate concerns and some independent of climate. Beginning a dialog on potential GHG emissions reductions for the automotive sector for the post-2025 time frame may facilitate more efficient investment planning strategies for both the pre-2025 and post-2025 time frames.

Individual states are also beginning to address the long-term nature of the climate challenge. For example, while the State of California's light-duty vehicle GHG emissions standards currently mirror the National Program through MY2025, the state has already laid the foundation for longer term actions. In 2015, the Governor issued an Executive Order that established new 2030 GHG emissions targets with the goal of reducing statewide GHG emissions by 40 percent below 1990 levels in 2030, and in 2016 the legislature passed a law codifying the 2030 GHG targets.

EPA is not prepared to begin a formal light-duty vehicle GHG emissions rulemaking process beyond MY2025. Nevertheless, the agency believes that it is important to have a dialog with the industry and other key stakeholders about future light-duty vehicle GHG emissions reductions, as well as possible regulatory incentives and flexibilities. This section is a first step in that process, and EPA looks forward to working with a wide range of stakeholders on this important topic in the future.

B. The Need to Go Beyond MY2025 Standards

The U.S. National Program light-duty vehicle GHG emissions standards through MY2025, currently in place and initially determined to be maintained under the Proposed Determination, are considered to be one of the most important steps taken by any country to address long-term GHG emissions. The projected fleetwide MY2025 GHG standard of 173 grams/mile, as discussed in Section IV, represents an approximate 50 percent reduction from the baseline GHG emissions level in MY2011 prior to the beginning of the National Program.[78] EPA projects that

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[77] Melillo, Richmond, and Yohe, 2014. Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 841 pp. doi: 10.7930/J0Z31WJ2.

[78] For more details on the values discussed in this paragraph, as well as the derivation of the curves in Figure V.1, see Memorandum to the Docket, Analysis Supporting Statements in Proposed Determination Section V.B, November 23, 2016.

the cumulative GHG emissions savings for the lifetimes of the vehicles sold in MY2012-2025 to be on the order of 6 billion metric tons.[79] [80]

But, the substantial GHG savings from the National Program are only a critical step toward achieving the continuing, and larger, GHG reductions that will be necessary for the light-duty vehicle sector in the longer term.

Figure V.1 illustrates this important point with three curves that address light-duty vehicle plus upstream fuel GHG emissions (including vehicle GHG emissions from the tailpipe and air conditioner operation, and upstream GHG emissions from transportation fuel production and distribution) over the 2005-2050 time frame.

The three curves are the same for 2005 through 2025 and show that light-duty sector GHG emissions are currently declining and will decrease at a faster rate beginning around 2020 as vehicles meeting increasingly stringent standards continue to propagate throughout the fleet.

The three curves in Figure V.1 begin to diverge beginning in 2026 based on different assumptions about the post-2025 time frame.[81]

The upper "Business-As-Usual" curve assumes that there are no major regulatory or other changes in the light-duty sector after 2025 (that is, that the MY2025 GHG standards remain in place indefinitely thereafter). This curve leads to overall GHG emissions reductions through about 2035, and then the curve flattens and GHG emissions begin to grow again around 2040 and would continue to grow in the post-2050 time frame.

The middle "4.5 percent per year reduction" curve assumes that the average annual stringency increase reflected in the National Program GHG standards for MY2012-2025 is reflected in new standards for MY2026-2050 as well. This curve shows that maintaining the annual stringency rate trajectory of the current National Program out to 2050 would yield significant light-duty vehicle GHG emissions reductions.

The bottom curve reflects a trajectory fitted to achieve a 72 percent reduction in light-duty vehicle GHG emissions from 2010 levels in 2050. This is the upper bound projection of a range for global GHG emissions reductions in 2050 provided by the Intergovernmental Panel on Climate Change (IPCC) to stabilize atmospheric GHG concentrations around 450 ppm and as "likely" to limit global temperature rise to below 2 C.[82] The 450 ppm atmospheric GHG concentration goal has also been adopted by some automotive companies as well.[83]

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[79] Regulatory Impact Analysis: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, EPA-420-R-12-016, August 2012, Table 7.4-2, page 7-32.

[80] Memorandum to the Docket, Analysis Supporting Statements in Proposed Determination Section V.B, November 23, 2016.

[81] Ibid.

[82] Climate Change 2014, Synthesis Report, Summary for Policymakers, Intergovernmental Panel on Climate Change Fifth Assessment Report.

[83] Ford Motor Company Sustainability Report 2015/2016 at http://corporate.ford.com/microsites/sustainability-report-2015-16/doc/sr15-sustainability.pdf.

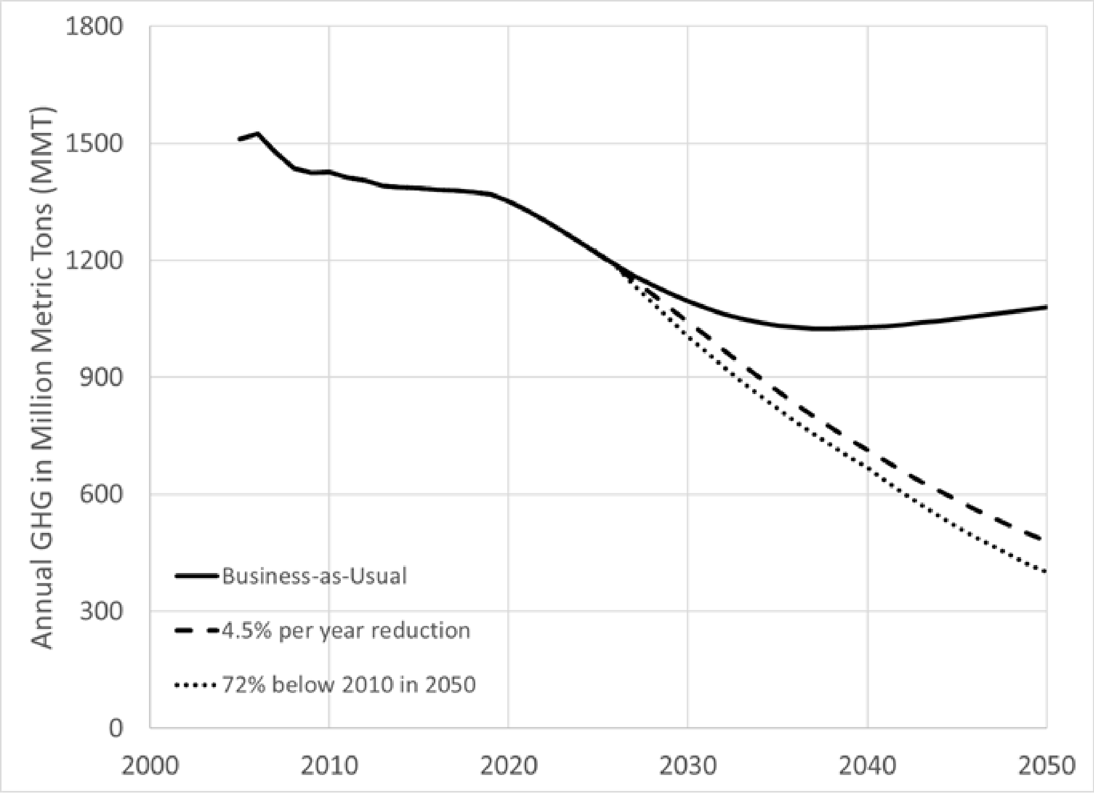

Figure V.1 Light-Duty Vehicle Plus Upstream Fuel GHG Emissions to 2050

Figure V.1 shows that the business-as-usual scenario will not provide long-term GHG emissions reductions. On the other hand, maintaining the 4.5 percent annual stringency rate of improvement reflected in the current National Program will yield long-term GHG emissions reductions close to the upper bound IPCC projection of what is necessary to maintain the global temperature rise to 2 C.

C. The Potential for Transformational Change in the Light-Duty Sector to Reduce Long-Term GHG Emissions

Transformational change in personal transportation seems imminent, driven by a convergence of demographic, technology, and economic factors. The CEO of one major domestic automaker recently stated, “The automotive industry will see more changes in the next five years than in the previous 50 years.”[84] A second automaker CEO said "[t]he next 20 years will see a radical transformation of our industry."[85] While it is impossible to predict the relative impacts of these

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[84] Mary Barra, CEO, General Motors, http://media.gm.com/media/intl/en/opel/news.detail.html/content/Pages/news/intl/en/2016/opel/02-08-mary-barra-16-car-symposium-bochum.html.

[85] Bill Ford, CEO, Ford Motor Company, http://www.wsj.com/articles/bill-ford-on-the-future-of-transportation-we-cant-simply-sell-more-cars-1404763769.

various factors, it seems highly likely that we are indeed on the cusp of transformational change in the light-duty vehicle sector.

There are numerous demographic factors which have the potential to contribute to transformational changes in personal transportation including:

- A possible shift in the paradigm of personal vehicle ownership that has been a given for previous generations;[86] for example, in dense urban regions, issues such as congestion and availability of convenient parking can decrease the attractiveness of vehicle ownership compared to other transportation options.
- A greater emphasis on accessibility and connectivity as opposed to individual mobility.[87]
- Increasing interest in urban lifestyles designed around the needs of people relative to suburban lifestyles designed in part around cars.[88]

For a century, U.S. light-duty vehicles have been powered by internal combustion engines almost exclusively fueled with gasoline. The current rate of automotive technological innovation is unprecedented. There are now a number of alternative technologies that could lead to major technological changes in the marketplace:

- There are now about 25 plug-in electric vehicles (dedicated battery-powered electric vehicles and plug-in hybrid electric vehicles) in the U.S. market, with market share recently reaching 1 percent of total light-duty sales.[89] The California Air Resources Board's Zero Emission Vehicle program has been a key driver in promoting the commercialization of electric vehicles. Of the 13 largest manufacturers representing over 99 percent of the market, 9 companies currently market a plug-in electric vehicle, and more new models have been announced by individual automakers. Vehicle cost and range have been the primary barriers to greater consumer acceptance, but battery costs have been declining and electric vehicle range has been increasing. Most notably, at least two manufacturers are commercializing mainstream electric vehicles with ranges in excess of 200 miles, a significant increase over the sub-100 miles' ranges that had been the norm for mainstream offerings in the last few years. Electric vehicles are increasing market share in other countries as well, most notably in China.
- The electric grid has become cleaner over the last several years due to market forces associated with lower prices of natural gas, wind, and solar and declining market share of coal. EPA's Clean Power Plan, currently under judicial review, would

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[86] Ibid.

[87] Ibid.

[88] Ford Motor Company Sustainability Report 2015/2016 at http://corporate.ford.com/microsites/sustainability-report-2015-16/doc/sr15-sustainability.pdf.

[89] Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2016, U.S. EPA Office of Transportation and Air Quality, EPA-420-R-16-010, November 2016, www.epa.gov/fuel-economy/trends-report.

continue to reduce GHG emissions from the electric grid. The combination of high-efficiency electric propulsion and a low-GHG electric grid makes plug-in electric vehicles a leading potential game changer for personal transportation.

- Fuel cell electric vehicle technology continues to advance. A limited number of fuel cell vehicles are now available for lease and sale in select regions of the country, most notably in California which is supporting the development of a network of hydrogen fueling stations. Fuel cells may be particularly attractive for larger high-range vehicle applications. A fuel cell vehicle fueled with hydrogen produced from renewable processes is another potential light-duty sector game changer. The biggest barrier to fuel cell vehicle commercialization is generally considered to be hydrogen availability and cost. Japan has adopted various measures to promote fuel cell vehicles and hydrogen fuel availability.
- Biofuels can play an important role by replacing fossil-fuel consumption in the transportation sector, in particular for end-uses that are difficult to electrify. Furthermore, biofuels have the potential to reduce GHG emissions across the existing fleet, which will be especially important as plug-in electric and fuel cell vehicles market penetration increases. Greatly expanding the supply of biofuels will require further technological advances to increase feedstock yields and reduce production costs, particularly for "drop-in" cellulosic and non-food based fuels that have the greatest potential to reduce GHG emissions. Furthermore, safeguards will be needed to ensure that as bioenergy expands it does not diminish the land carbon sink or cause other adverse environmental impacts.
- Connected and automated (or autonomous) vehicles (CAVs) are considered to be the technology with the greatest potential to transform multiple facets of personal transportation. The literature suggests that CAVs could decrease or increase overall light-duty sector GHG emission.[90] CAVs could significantly improve on-road efficiency and GHG emissions if they were optimized for moderate speeds, accelerations, and decelerations; minimal braking and idle; platooning; and better matching vehicle movement with maximum vehicle powertrain efficiency. CAVs could also improve efficiency and GHG emissions by optimizing route planning, i.e., minimizing vehicle miles traveled and congestion. Even more compelling, if combined with new mobility approaches such as shared vehicle ownership and shared vehicle occupancy, CAVs could facilitate large GHG emissions reductions by "right sizing" where vehicle design is better matched to the utility needed for individual trips, higher occupancy, achieving higher vehicle miles traveled per vehicle which facilitates faster fleet turnover, etc. CAVs are an emerging technology and there are risks of higher GHG emissions as well. For example, CAVs could lead to higher vehicle miles traveled due to new user groups or due to the reduced monetary and/or time cost associated with travel. CAVs could also be programmed to operate at very high highway cruising speeds to save time, but which could increase GHG emissions. GHG emissions impacts need to be taken into consideration early on in CAV

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[90] "Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles," Zia Wadud, Don MacKenzie, and Paul Leiby, Transportation Research Part A 86 (2016) 1-18.

commercialization in order to ensure that CAVs are part of a long-term climate solution.

Finally, there are economic factors that could promote transformational changes as well:

- Given that 99 percent of vehicles used for personal transport are privately owned, that such vehicles sit idle for 96 percent of the time, that 60 percent of trips are single occupancy, and that most seats are empty for most trips, provides a business case for alternatives to the private vehicle ownership model. For example, total annual ownership costs of a relatively new light-duty vehicle are about $8,500 for a midsize sedan and over $10,000 for an SUV, representing the second highest expense for most households, yet the vehicle sits unused most of the time.[91]
- In densely populated urban areas, expenses associated with parking and insurance can be much higher than in suburban or rural areas, which changes the basic economics associated with personal vehicle ownership. Accordingly, relatively new business concepts such as transportation network companies (ride sourcing) and car sharing now exist in nearly all large U.S. cities, complementing traditional transit programs.
- The evolution of the world automotive market means that, in order to succeed and prosper in the long run, it appears that automakers must compete not only in one or two regional markets, but in all of the major global automotive markets.
- Economic opportunities for a much wider universe of private sector actors related to personal transportation services, evidenced by the large number of business start-ups, automakers buying stakes in emerging companies, and interest by non-automotive companies in the automotive market.

With respect to long-term GHG emissions reductions, Table V.1 shows that while many of the potential transformational forces could provide positive “tailwinds” to help move towards lower light-duty sector GHG emissions, some of the same transformational forces could provide negative “headwinds” with respect to GHG emissions as well.

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[91] http://newsroom.aaa.com/auto/your-driving-costs/.

Table V.1 Qualitative Impacts of Possible Transformational Forces on Light-Duty GHG Emissions

Transformational Technology/Strategy	Likely Impact on GHG Emissions
Electric vehicles w/low-GHG electricity	Lower
Fuel cell vehicles w/low-GHG hydrogen	Lower
Biofuels w/low-GHG emissions	Lower
Vehicle automation/connectivity	
• Eco driving/platooning	Lower
• Route planning	Lower
• Greater highway cruising speeds	Higher
• More travel due to reduced dollars/time	Higher
• More travel from new user groups	Higher
New mobility approaches	
• Higher occupancy	Lower
• Right sizing of vehicle	Lower
• System optimization	Lower
• Faster fleet turnover	Lower
Smart growth, urban planning, transit	Lower

D. Stakeholder Dialogue

Framed by the discussion above, EPA believes that it is important to have a dialogue with a wide range of stakeholders, such as automakers, the State of California and other States, non-governmental organizations and others, on the wide range of potential mechanisms and issues associated with achieving light-duty vehicle GHG emissions reductions in the post-2025 time frame.

Appendix
to the
Proposed Determination

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Appendix A Updates to Assessment of Technology Costs, Effectiveness, and Lead Time

A.1 Introduction

The Proposed Determination document outlined how the technology assessment EPA has conducted for this Proposed Determination has corroborated the key conclusions reached in the Draft Technical Assessment Report (TAR), and described the rationale for how this assessment supports the Administrator's proposed determination that the MY2022-2025 standards remain appropriate.

This Appendix A to the Proposed Determination document serves to provide further detail on the technology assessment conducted for the Proposed Determination. It describes how EPA has updated the assessment based on the latest available data, and reviews the key public comments and updated information that led to these updates. It also provides as background a brief overview of the key methodologies and approaches used in conducting the assessment, and key updates applicable to them. While this Appendix A provides a high level overview of these topics, more complete discussion of each topic, and discussion of additional public comments received, can be found in the corresponding chapters of the Technical Support Document (TSD).

A.2 Key Updates to Technology Assessment

Like the technology assessment conducted for the Draft TAR, the Proposed Determination technology assessment includes a wide array of fundamental assumptions, modeling constructs, and general methodologies, as well as assumptions for cost and effectiveness of specific fuel-saving and GHG-reducing technologies. Key updates found in this Proposed Determination assessment, and detailed in the following subsections, include:

- Updated baseline fleet, based on MY2015 GHG compliance data, the latest complete data set available
- Updated projections of future fuel prices and vehicle sales to AEO 2016, the latest available
- Updated all monetized values to 2015 dollars
- Better accounting for tire and aerodynamic improvements in the baseline fleet
- Updated accounting for light duty truck mass reduction in the baseline fleet
- Updated ZEV program sales using data from the California Air Resources Board
- Updated vehicle class definitions for modeling effectiveness to improve representativeness of power-to-weight and road load characteristics
- Expanded vehicle classification structure from 19 to 29 vehicle types to improve the resolution of cost-effectiveness estimates as applied in the OMEGA model
- Updated characterization and modeling of certain advanced engine technologies, including Atkinson cycle
- Updated effectiveness estimates for certain advanced transmission technologies
- Updated battery costs for plug-in vehicles, resulting from several battery modeling improvements such as an improved battery sizing method, updated data from electrified vehicles released or certified since the Draft TAR, and an improved

accounting for energy consumption and the potential for road load technology improvements

- Added accounting in the compliance modeling for upstream emissions of plug-in vehicles phasing in from MYs 2022 to 2025
- Incorporating additional off-cycle technology options into OMEGA to better account for manufacturers' expected use of off-cycle credit opportunities.
- Conducting additional sensitivity analyses to show the cost and technology penetration impacts of alternative technology pathways
- Updated vehicle simulation model, ALPHA, to include the latest data on technology effectiveness from the EPA vehicle benchmarking testing program and other sources, across vehicle types
- Added quality assurance checks of technology effectiveness estimates into ALPHA and LPM

The following sections provide additional detail on many of these updates. Complete descriptions of these updates, as well as further discussion of additional public comments received on the Draft TAR and updated information considered for the Proposed Determination assessment, can be found in the corresponding chapters of the TSD. For specific technology cost and effectiveness values used in the Proposed Determination assessment, please refer to Chapter 2 of the TSD.

A.2.1 Baseline Fleet

As a starting point in the assessment, EPA creates a baseline fleet, or "baseline," which is a representation of the existing vehicle fleet prior to the addition of fuel economy-improving and GHG-reducing technologies that manufacturers might introduce for compliance with the standards. Together with a "reference" fleet, the baseline allows for tracking the volumes and types of technologies present in the fleet and how they may change under various scenarios. The baseline fleet is described in more detail in Chapter 1 of the TSD.

In comments on the Draft TAR, EPA received a number of comments regarding the creation of the baseline fleet. The commenters almost universally agreed that the baseline is vitally important, although opinions varied on the information sources that should go into its creation.

The Alliance of Automobile Manufacturers (AAM) made several comments pointing to what it characterized as "significant errors" in the development of the baseline fleet used in the development of the Draft TAR. Many of their comments focused on the accuracy of the technologies identified and the assessment of the amount of mass reduction, lower rolling resistance tires and aerodynamic technologies that have already been implemented in the current fleet. The Union of Concerned Scientists (UCS) and Natural Resources Defense Council (NRDC) also recommended using an updated MY2014 fleet, as some technology has been used to improve vehicle performance in lieu of improving efficiency. There were also several comments, both for and against, EPA's inclusion of the California ZEV program vehicles in the baseline fleet. Chapters 1 and 2 of the TSD provide additional detail on these and other comments.

EPA has reviewed and considered these comments and in response has made several updates to its development and assessment of the baseline fleet. EPA has updated the baseline using

MY2015 GHG compliance data, which is the latest complete set of data available. EPA has also made adjustments to better represent the degree to which low rolling resistance tires, aerodynamic technologies, and mass reduction have been implemented in the fleet. These updates are outlined in the sections below, and more detail can be found in Chapters 1 and 2 of the TSD.

EPA continues to include the California ZEV program vehicles in the construction of the baseline and reference fleets. More discussion of comments received on this topic is found in Chapter 1.2.1.1 (The ZEV Regulation in OMEGA) of the TSD. EPA has included an updated ZEV forecast provided by the California Air Resources Board (CARB). Complete details regarding the updated ZEV forecast and how the ZEV mandate is reflected in EPA's fleet forecast can be found in Chapter 1.2 of the TSD.

A.2.1.1 MY2015 Basis

The MY2015 GHG compliance data is the most recent complete set currently available of U.S. vehicle data that includes actual manufacturer vehicle volumes and CO_2 values. The MY2015 volumes and CO_2 values come from the EPA Verify Database. The data contained in the Verify system are quite robust since they undergo a significant number of quality checks by the manufacturer, the Verify database software, and EPA's certification staff. The finalized 2015 GHG certification data are thus the most accurate representation of vehicle and technology mix for the 2015 model year.[1] EPA supplemented this data with valve train information from WardsAuto, and curb weights and power steering information from NHTSA's 2015 Volpe Baseline Fleet file created for the Draft TAR.

A.2.1.2 Representation of Tire Rolling Resistance and Aerodynamic Drag Reduction Technologies

Some public comments pointed out that, in the Draft TAR, EPA had acknowledged that "low rolling resistance tires are increasingly specified by OEMs in new vehicles," yet had not apparently accounted for this existing penetration of this technology in the baseline fleet. Similarly, some OEM commenters pointed out that aerodynamic improvements have been implemented in new vehicle designs over the past four years, and felt that these improvements were not adequately reflected in the Draft TAR aerodynamic technology baseline. These commenters expressed concern that EPA's Draft TAR technology assessment may have overestimated the rolling resistance and aerodynamic drag reductions that could be achieved at the estimated cost levels.

In response, for this Proposed Determination assessment, EPA has updated its assessment of tire rolling resistance and aerodynamic drag reduction technologies by accounting for their estimated presence in the baseline fleet and modifying the permissible application of these technologies accordingly. To account for aerodynamic drag reduction technology, EPA used coast down coefficients from 2015 certification test data to estimate the aerodynamic performance of each vehicle in relation to the other vehicles in the same market class. The vehicles were then binned into one of three aerodynamic technology levels according to the

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[1] We note that this 2015 MY baseline fleet is not identical to that established by NHTSA in the Draft TAR, since that fleet reflected mid-year manufacturer reports rather than the final certified data used here. See Draft TAR Chapter 13.1.1.

potential for future improvement. A similar approach was applied to tire rolling resistance technology. Complete detail on these updates is provided in Chapters 1 and 2 of the TSD. Even after this updated accounting for technology present in the fleet, our analysis indicates that low rolling resistance and aerodynamic drag reducing technologies continue to play an important role in the fleet compliance analysis.

A.2.1.3 Mass Reduction for Light-Duty Trucks

In the Draft TAR, EPA's analysis assigned levels of mass reduction specific to each vehicle in the baseline fleet in order to account for variation between current vehicles in the cost and feasibility of achieving additional mass reduction. This was achieved by comparing the 2008 and 2014 versions of each model according to the sales weighted average curb weights of the various trim levels after adjusting for changes in size, additional safety requirements, and drive type. This same methodology was again used for this Proposed Determination assessment, applied to the updated MY2015 baseline fleet. Although EPA did not receive specific comments on the characterization of mass reduction for pickup trucks in the baseline fleet, EPA has refined the tracking of the pickup truck lineages over time for this Proposed Determination assessment in order to better characterize the cost and feasibility of additional mass reduction for these vehicles.

Unlike passenger cars, light-duty pickup trucks are produced with a variety of cabin and bed configurations, and the mix of the configurations produced often varies from year to year. The model-level approach used in the Draft TAR did not distinguish the change in mass that occurred due to shifts in the production shares of the various pickup truck configurations from the changes in mass that occurred within a given configuration. For example, using the Draft TAR approach, a greater proportion of crew cab configurations in MY2015 would be reflected as an increase in curb weight from MY2008, even if the MY2015 vehicle was lighter than the corresponding configuration in MY2008. For this Proposed Determination assessment, EPA has estimated the amount of mass reduction for pickup trucks in the baseline fleet by comparing curb weights (with adjustments for size, safety equipment, and drive type) for corresponding cab configurations in MYs 2008 and 2015, thereby minimizing the influence of shifts in production shares of the various configurations over that period.

A.2.2 Vehicle Classification in LPM and ALPHA

The determination of appropriate values for technology effectiveness and cost depends on the characteristics of the particular vehicle to which the technology is applied. For the purposes of the EPA technology assessment, grouping of vehicles into distinct classes is an important factor in representing the baseline and modeled fleets in various components of the analysis, such as the LPM and the ALPHA model.

In the FRM and Draft TAR, six vehicle classes were defined for the purpose of characterizing technology effectiveness. These classes were derived from the vehicle size classifications used for fuel economy labeling defined in 40 CFR §600.315-08 and were based on vehicle interior volume and gross vehicle weight rating attributes. The classes were similar to commonly recognized market segments. The classification of vehicles for estimation of technology costs in the FRM and Draft TAR accounted for the various engine and valvetrain configurations most prevalent in the baseline fleet, and together with the six effectiveness classes produced a total of

19 vehicle types. At the time, EPA considered the basis and number of these vehicle groupings to provide adequate resolution for an assessment of cost and effectiveness across the entire fleet.

A public comment received from FCA stated that "vehicle classes in the LPM require greater resolution," citing as an example, "...the Fiat 500 Turbo and the V6 Chrysler 300 AWD are assigned the same benefits for every technology. This is inappropriate given the vehicle size, engine size, and drivetrain difference between them." (p. 35, FCA comments).

In response to the FCA comment and similar comments from other stakeholders, for this Proposed Determination, EPA has refined the vehicle classification approach in several ways.

First, for the purpose of assigning the most representative estimates for technology effectiveness, EPA has classified vehicles according to the attributes of vehicle road load power and the ratio of engine power to vehicle weight. Unlike the Draft TAR's size-based effectiveness classifications, the ALPHA model effectiveness estimates are now developed according to low, medium, and high vehicle power-to-weight levels, abbreviated as 'LPW', 'MPW', and 'HPW', respectively. The first two of these are divided further into low and high vehicle road load categories, abbreviated as 'LRL' and 'HRL'. An additional class dedicated to trucks with heavy towing and hauling capability results in a total of six ALPHA classes for technology effectiveness, as shown in Table A.1.

Table A.1 ALPHA Classes for Characterizing Technology Effectiveness

ALPHA Class	Power-to-Weight Ratio	Vehicle Road Load
LPW_LRL	Low	Low
LPW_HRL	Low	High
MPW_LRL	Medium	Low
MPW_RHL	Medium	High
HPW	High	-
Truck	-	-

Second, as described in more detail in TSD Chapter 2.3.1.4 (Vehicle Classification), EPA has incorporated curb weight values directly into the vehicle classification criteria for assigning technology costs, while still considering engine configuration as in the FRM and Draft TAR. For this updated analysis, technology costs are applied to vehicles within a narrower range of curb weights, thus improving the representativeness of the costs applied. This is particularly relevant for electrification and mass reduction; two technologies for which the costs are directly related to vehicle curb weight.

Third, for this Proposed Determination EPA has expanded the number of vehicle types to 29 from the 19 vehicle types used in the FRM and Draft TAR analyses. Increasing the number of vehicle types was done in part to accommodate the additional curb weight criteria described above, and also to add additional resolution within a vehicle type to better reflect the vehicle attributes which impact estimates for technology effectiveness and cost and also responds to the Draft TAR’s stakeholder comments. The vehicle type definitions are derived from the combination of cost and effectiveness classifications, and are shown in Table A.2 along with examples of some of the higher volume vehicle models in the MY2015 fleet.

Compared to the Draft TAR, these 29 vehicle types each contain a narrower range of values of the vehicle characteristics that have the greatest influence on technology effectiveness and cost; specifically power-to-weight ratio, road load power, curb weight, and original engine configuration. The overall result of the updated vehicle classification approach used in this Proposed Determination is a set of ALPHA classes and vehicle types that provide greater resolution than the 19 vehicle types used in the Draft TAR, and advance the goal of applying the most representative cost and effectiveness estimates for technologies applied to the MY2015 fleet. A result is that the median power-to-weight ratio within each class has increased, reflecting the change in the 2015 fleet relative to the lower-powered 2007-2010 exemplar vehicles used in the FRM and Draft TAR. See also Chapter 2.3.3.2.3 of the TSD, "Comparison to Draft TAR Classification Approach and Exemplar Vehicles."

Table A.2 Expanded Classification of Vehicle Types

Veh Type	ALPHA Class	Curb Wgt Class	Engine Config	Example	Veh Type	ALPHA Class	Curb Wgt Class	Engine Config	Example
1	LPW_LRL	1	I4 DOHC	Sentra, Corolla	16	MPW_LRL	3	V6 DOHC	IS250
2	MPW_LRL	1	I4 DOHC	Dart, Focus	17	LPW_HRL	3	V6 DOHC	Transit
3	MPW_LRL	2	I4 DOHC	Altima, Camry	18	HPW	4	V6 DOHC	Charger
4	LPW_HRL	2	I4 DOHC	Rogue, Patriot	19	MPW_HRL	4	V6 DOHC	Pathfinder, Journey
5	MPW_LRL	3	I4 DOHC	Malibu, 200	20	HPW	5	V6 DOHC	Camaro
6	LPW_HRL	3	I4 DOHC	Forester, Cherokee	21	MPW_HRL	5	V6 DOHC	Grand Cherokee
7	LPW_HRL	4	I4 DOHC	Outback, Equinox	22	Truck	6	V6 DOHC	Tacoma, Frontier
8	Truck	6	I4 DOHC	Colorado, Tacoma	23	HPW	5	V8 OHV	Charger
9	Truck	6	V6 OHV	Silverado, Sierra	24	MPW_HRL	5	V8 OHV	Taho, Suburban
10	HPW	3	V6 SOHC	RDX, TLX	25	Truck	6	V8 OHV	Silverado, Sierra
11	MPW_HRL	4	V6 SOHC	Odyssey	26	HPW	4	V8 DOHC	Mustang, SL550
12	LPW_LRL	1	V6 DOHC	Cruze,Focus turbos	27	HPW	5	V8 DOHC	QX80, GL550
13	MPW_LRL	2	V6 DOHC	Fiesta turbo	28	MPW_HRL	5	V8 DOHC	GX460, Sequoia
14	LPW_LRL	2	V6 DOHC	Passat	29	Truck	6	V8 DOHC	Tundra, F150
15	HPW	3	V6 DOHC	ES350, Impala, Q50					

A.2.3 Engine Technologies

A.2.3.1 Atkinson Cycle

EPA considered two primary types of Atkinson-cycle engine technologies in the Draft TAR. The first Atkinson technology is referred to as "ATK1." This technology designation reflects the application of Atkinson cycle operation on engines that are primarily equipped in hybrid electric vehicles such as the Toyota Prius and the Ford Fusion. The second Atkinson technology is referred to as "ATK2." This technology designation reflects the application of Atkinson cycle engine operation in a conventional powertrain architecture, where the sole source of power to the vehicle is provided by an internal combustion engine, such as in the Mazda SKYACTIV-G architecture and the Toyota Tacoma pickup truck. EPA's assessment of Atkinson technology effectiveness is based on high fidelity engine maps obtained through engine benchmarking of the Mazda SKYACTIV-G engines performed at EPA's National Vehicle and Fuel Emissions

Laboratory. The methodology for benchmarking the engines and the results are detailed in several peer reviewed papers.

In addition to the commercially available ATK2 architecture, EPA has also researched and developed further enhancements that improve the effectiveness ATK2 technology. These enhancements to ATK2 include the application of Cooled Exhaust Gas Recirculation (cEGR), higher geometric compression ratio (CR), and cylinder deactivation (DEAC). The ATK2 technology has been available currently with cEGR and higher CR in Japan and Europe, respectively, and the application of DEAC on future applications of the SKYACTIV-G engine has been publicly announced by Mazda.

In public comments on the Draft TAR, the Alliance of Automobile Manufacturers (AAM) and some of its members commented on the application of Atkinson-cycle engine technologies in the future fleet. The comments stated that EPA had been "overly optimistic" in its assessment of the technology, and that: "The advanced Atkinson technology package with cEGR and cylinder deactivation should not be utilized in the MTE analysis until the technology can be demonstrated to operate across all modeled operating points." EPA does not agree with these comments. The Atkinson engine technology is already demonstrated in the light-duty fleet in non-hybrid applications.

In addition, AAM maintained that the penetration rate projected by EPA for Atkinson engine technologies in 2025 MY are not feasible and may not reflect individual vehicle manufacturers' selected "technology pathway" for future compliance, suggesting that there would be insufficient lead time to implement this technology. However, for all manufacturers, EPA believes that there is sufficient lead-time to adopt the ATK2 technology. Many of the building blocks required to operate an engine in an Atkinson-mode, similar to the Mazda SKYACTIV-G engine are already available in the 2016 MY fleet. These include gasoline direct injection and a high level of control authority over the valve train. More discussion of this topic is found in Chapter 2.3.4.1.8 of the TSD.

The commenter also stated that EPA's analysis had not adequately accounted for limitations reflecting effects such as knock, cooled EGR rejection, and effective compression ratio. AAM also commented on EPA's use of Tier 2 fuel to establish engine effectiveness and suggested that the use of lower octane, 91 RON fuel would be more appropriate for determining the effectiveness of engine technologies.

It should be noted that use of a higher geometric CR does not necessarily result in operation at a higher effective CR. Atkinson Cycle and Miller Cycle engines derive efficiency improvements from the increased expansion ratio available at higher geometric CR but also have the capability to vary effective CR continuously during engine operation by changing valve event timing (e.g., either late or early intake valve opening) by varying camshaft phaser positioning. Thus the actual effective CR of Atkinson Cycle and Miller Cycle is often comparable, or even in some cases reduced, relative to the CR of other GDI engines due to knock limitations.

EPA continues to believe that ATK2 engine technologies offer an additional cost effective alternative in a broad assortment of advanced gasoline engine technologies expected to be applied by vehicle manufacturers to meet future GHG standards. This palette builds upon some of the foundational technology that already has wide application across the entire light-duty fleet including gasoline direct-injection (GDI), increased valve phasing authority, and higher geometric CR. These foundational technologies allow vehicle manufacturers to operate engines in some vehicles in both conventional and Atkinson cycle modes as demonstrated by the Chrysler Pacifica plug-in hybrid in which the 3.6L Pentastar engine is operated in Atkinson mode, and the Toyota Tacoma pick-up truck. Hyundai has introduced a 2.0L Atkinson Cycle engine as the base engine for the 2017 Elantra. In addition, these foundational technologies allow vehicle manufacturers the ability to operate turbocharged engines in Miller-cycle modes, which is Atkinson-cycle applied to boosted engines.

We also received comments that the relatively low cost of ATK2 has the impact of lowering the OMEGA-estimated cost per vehicle. In response, it is important to note that EPA's projection of ATK2 penetration in the light-duty fleet is only one of several cost-effective engine technology alternatives available to manufacturers to meet the 2025 MY GHG standards. In both the Draft TAR and this Proposed Determination, we have run sensitivities showing the impacts on costs per vehicle under a scenario where very little ATK2 technology is used for compliance. In these sensitivities, we have capped the ATK2 technology at a 10 percent level (note that Mazda uses this technology extensively today, as well as other manufacturers, and roughly 7 percent of today's fleet already uses the technology). The results show minor increases in costs per vehicle, but clearly show that pathways to compliance exist at reasonable costs and without extensive utilization of strong hybrid and electrified vehicles (see Draft TAR Table 12.48 and Section C.1.2 of this Appendix).

AAM comments also suggested that a discrepancy existed between the torque curves used in the ALPHA model and an EPA-authored SAE paper on this topic, and that this error carried over into ALPHA and the LPM. EPA disagrees with this conclusion. A detailed analysis of this claim and the use of torque curves in modeling of Atkinson engines is found in Chapter 2.3.4.1.8 of the Draft TSD. In considering this and other comments on ATK2, for this Proposed Determination analysis, EPA revisited its modeling of ATK2 and chose to implement further improvements to the torque curve used for ATK2 modeling, as discussed in that chapter.

For more discussion of comments received on EPA's analysis and modeling of Atkinson cycle engines in the Draft TAR, see Chapter 2.3.4.1.8 of the TSD (Atkinson Cycle Engines in Non-HEV Applications).

A.2.3.2 Turbocharged, Downsized Engines

Turbocharged, downsized engines continue to be a prominent technology applied by vehicle manufacturers to improve vehicle powertrain efficiency. The 2016 Trends Report shows the penetration rate of turbo-downsized engines into the light-duty fleet has increased from 3 percent in 2008 to approximately 22 percent in MY2016.[2] Turbocharged, downsized engines are adopting head-integrated exhaust manifolds or separate, water-cooled exhaust manifolds. These systems also use separate coolant loops for the head/manifold and for the engine block. The changes allow faster warmup, improved temperature control of critical engine components, further engine downspeeding, and reduce the necessity for commanded enrichment for component protection. The net result is improved efficiency over the regulatory cycles and

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[2] Light-duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends Report, EPA-420-R-16-010, November 2016.

during real world driving. Engine downspeeding also has synergies with recently developed, high-gear-ratio spread transmissions that may result in further drive cycle efficiency improvements.

In public comments on the Draft TAR, the Alliance of Auto Manufacturers (AAM) made several observations regarding turbocharged downsized engines. Among them, AAM requested that "EPA outline its rationale for using an experimental single cylinder engine map as the basis of their analysis of turbocharged downsizing technology rather than using actual production engines that were benchmarked by EPA (Ford 1.6 L Ecoboost and Ford 2.7 L Ecoboost)."

EPA notes that technology has advanced past these two Ford engines, making these engines inappropriate for evaluating potential technologies for meeting the 2025 standards. Thus, the engine EPA analyzed was a multi-cylinder engine at an advanced stage of development, as described in the papers cited within the Draft TAR and as described within Draft TAR Table 5.63. A number of technologies were used in Ricardo's development of this engine that go significantly beyond the technology of the Ford 1.6L Ecoboost (introduced in 2010) or the Ford 2.7L Ecoboost (introduced in 2015). The technologies used by Ricardo during the Ethanol Boost Direct Injection (EBDI) development program better reflect the state of technology that EPA expects to see in 2025, which is 10-15 years after the initial introduction of the engines referenced by AAM. More discussion is found in Chapter 2.3.4.1.9 of the TSD.

Additional detail in response to this and other public comments on turbocharged downsized engines is provided in TSD Chapter 2.3.4.1 (Engines: Data and Assumptions) and other parts of the TSD that relate to engine technology modeling.

A.2.4 Transmission Technologies

Several different transmission architectures are available for use in light duty vehicles. Conventional automatic transmissions (ATs) are the most popular type, and still dominate the light-duty fleet. Manual transmissions (MTs), although less popular than in the past, are also still part of the fleet. Both ATs and MTs have, among other improvements, seen an increase in the number of gears employed. These older technologies are increasingly being displaced by two advanced technologies: dual-clutch transmissions (DCTs), which have significantly lower parasitic losses than ATs, and continuously variable transmissions (CVTs), which can vary their ratio to target any place within their overall spread.

As EPA stated in the Draft TAR, in the analysis conducted for the 2012 rule, EPA estimated that DCT transmissions would be very effective in reducing fuel consumption and CO_2 emissions, less expensive than current automatic transmissions, and thus a highly likely pathway used by manufacturers to comply with the standards. This expectation was supported by comments from many OEMs at the time of the 2012 rule indicating that DCTs were part of their future compliance strategies. EPA also discussed in the Draft TAR that the 2017-2025MY FRM analysis also predicted a low effectiveness associated with CVTs (due to the high internal losses and small ratio spans of CVTs in the fleet at that time), and thus CVTs were not included in the FRM fleet modeling. However, internal losses in current CVTs have been much reduced and ratio spans have increased from their predecessors, leading to increased effectiveness and further adoption rates in the fleet, particularly in the smaller car segments. The new CVTs also tend to give the best effectiveness for their cost.

In public comments on the Draft TAR, the Alliance of Automobile Manufacturers (AAM) raised a number of concerns on transmission effectiveness. One of the comments was related to EPA's estimated effectiveness differences between current six- and eight-speed transmissions. The Alliance provided an attachment entitled, "EPA ALPHA Samples Transmission Walk," authored by Ford, in support. The transmission walk attachment suggests that a 6-speed to 8-speed high efficiency gearbox 1 (HEG1) transmission upgrade would result in a 4.4 percent - 5.0 percent effectiveness increase, rather than the 8.6 percent to 9.0 percent calculated by Ford using ALPHA simulation runs.

However, the Ford document acknowledges a number of differences between their simulation methodology and EPA's simulation methodology:

- The Ford simulation engine used a 2.0L EcoBoost engine, compared to EPA's naturally aspirated GDI engines
- The Ford simulation assumed the same lockup strategy between transmissions; EPA's did not
- The Ford simulation used transmission efficiency maps from a Ford 8F24/8F35; EPA used benchmarked 845RE (ZF 8HP45) transmission as detailed in the Draft TAR
- The Ford simulation assumed no engine displacement reduction when the transmission is upgraded; EPA applied a "performance neutral" engine downsizing strategy.

As described in the Draft TAR (Table 5.77), EPA expects that effectiveness percentages reported for transmissions paired with unimproved engines would be reduced when the same transmission is paired with a more advanced engine. Thus, Ford's technology walk using an EcoBoost engine would be expected to deliver a lower effectiveness than a comparable tech walk using the naturally aspirated engines modeled in ALPHA.

EPA also believes that, generally, eight-speed transmissions within the fleet are of a later vintage than six-speed transmissions within the fleet, and it is appropriate, when assigning effectiveness, to account for the entire package of transmission technology changes between a typical six- and eight- speed transmission. Thus, EPA uses representative transmissions, such as the six-speed 6T40 and the eight-speed 8HP45, in modeling, with the understanding that transmission efficiency, torque converter (TC) efficiency, and TC lockup strategy are different between the two. This assumption is reflected by the fact that the additional incremental effectiveness incorporated into HEG2 is reduced when applied to eight-speed transmissions, which are already assumed to contain some efficiency improvements in addition to the added gear ratios and spread.

In the EPA analysis, engine displacement was appropriately reduced to maintain a consistent acceleration performance across different technology packages. The Ford transmission walk explicitly maintained engine size, with no allowance for maintaining performance, arguing that engine displacement reduction results in "significant gradeability degradation." EPA disagrees with this assessment. Both Ford and the Alliance define a "gradeability" metric of maintaining top gear at 75 mph while climbing a given grade. While this may have been an appropriate gradeability metric for vehicles containing vintage four-speed transmissions, EPA does not believe this metric is appropriate for advanced eight-speed transmissions, where downshifts are less noticeable to the driver.

When applying the effect of these differences to the Ford simulation, the results are consistent with the EPA effectiveness measurements taken from ALPHA sample runs and cited by Ford in their transmission walk. EPA thus views the information in Ford's transmission walk appendix as corroborative.

The Alliance also commented that "manufacturers expect that moving from TRX11 to TRX22 will deliver effectiveness improvements in that range of 1 percent-2 percent." Although the Alliance provided no data to support this comment, they did provide the Ford transmission walk referenced above, which provided an industry estimate that moving from TRX11 to TRX21 would deliver an effectiveness improvement of 4.4 percent to 5.0 percent. This is inconsistent with the Alliance's statement that advancing farther to TRX22 will provide a total benefit of at most 2 percent (and, as just explained, the transmission walk calculation is inappropriately constrained as well).

The Alliance also commented on what they consider to be marginal improvements due to HEG2, offering in support of their comment that FCA realized a CO_2 benefit of approximately 0.8 percent unadjusted combined FE when implementing friction reduction and hydraulic system upgrades to their eight-speed transmission.

EPA estimates of HEG2 effectiveness in eight-speed transmissions are based on modeling studies conducted by EPA and published in a 2016 paper referenced in the Draft TAR.[3] This paper outlines potential steps to improve transmission effectiveness, including increasing gear spread, reducing drag torque, reducing oil pump losses, reducing creep torque, implementing earlier torque converter lockup, and reducing engine size to maintain performance neutrality.

These specific advanced transmission technologies were assessed and reported on by transmission supplier ZF, who applied some of the technologies to their new 8-speed transmission (the 8HP50) and modeled the effect of others.[4] Results from the EPA simulations of these technologies (reported in the 2016 paper referenced above) were close to, but somewhat lower than, the ZF estimates. The actual effectiveness values used in the Lumped Parameter Model (LPM), quoted by the Alliance in their comments, are more conservative yet, so that the effectiveness numbers used by EPA for HEG2 in the Draft TAR analysis represent a conservative analysis compared to what transmission manufacturer ZF estimates can be achieved.

The Alliance acknowledges that the modifications completed by FCA constituted only a portion of the HEG2 benefits expected by EPA given that certain additional improvements (notably a change in gear ratios) was not undertaken. In fact, HEG2 does include a basket of technologies that can be implemented individually or in combination by manufacturers. EPA does not expect all HEG2 technologies to be implemented simultaneously. FCA chose to

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[3] Moskalik, A., Hula, A., Barba, D., and Kargul, J., "Investigating the Effect of Advanced Automatic Transmissions on Fuel Consumption Using Vehicle Testing and Modeling," SAE Int. J. Engines 9(3):1916-1928, 2016, doi:10.4271/2016-01-1142.

[4] Greiner, J., Grumbach, M., Dick, A., and Sasse, C., "Advancement in NVH- and Fuel-Saving Transmission and Driveline Technologies," SAE Technical Paper 2015-01-1087, 2015, doi:10.4271/2015-01-1087.

implement a portion of the HEG2 technologies, and the benefit of approximately 0.8 percent is a representative proportion of the 2.7 percent effectiveness projected by EPA when moving from transmission level TRX21 to TRX22. The 0.8 percent effectiveness realized by FCA for the technologies implemented is slightly lower than the values estimated by transmission supplier ZF in their published work, but are consistent with EPA's implementation of HEG2 in the LPM.

In the Draft TAR and in this Proposed Determination, EPA used a system of "bins" to classify transmissions, rather than evaluating each individual technology. See Draft TAR Chapter 5.3.4.2.1 and TSD Chapter 2.3. These bins are TRX11 (Baseline 6-speed), TRX12 (Improved 6-speed), TRX 21 (Baseline 8-speed and baseline CVT), and TRX22 (Improved 8-speed and improved CVT). The Alliance commented on the "binning" of different types of transmissions (i.e., conventional ATs, CVTs, and DCTs) into the TRX designations. EPA believes that the potential effectiveness gains between TRX levels, while arising from different technology packages within each transmission type, will be very similar among transmission types as noted in both the Draft TAR and TSD. Furthermore, using the general TRX designation maintains a transmission type within a specific vehicle throughout the analysis maintaining an appropriate mix of transmission types. Thus, EPA believes maintaining a TRX transmission designation is the best methodology for assessing technology cost and effectiveness while maintaining manufacturer transmission type selections.

The Alliance also disagreed with EPA's estimates for efficiency increases in CVTs. Toyota also commented, "Toyota believes that the transmission effectiveness becomes less due to the practical challenges." However, the Union of Concerned Scientists commented in support of EPA's assumptions for CVTs, pointing to the clear benefits to CVTs as an enabling technology.

EPA has updated its estimate of CVT effectiveness within the TRX transmission structure for this Proposed Determination, and believes that it is conservative given the current and future efficiency and gear spread of CVTs. More detail on these is found in updates Chapter 2.3.4.2 of the TSD.

A.2.5 Battery Costs

Battery electric vehicles (BEVs) are vehicles with all-electric drive powered by batteries charged from an outside source of electricity (usually the electric grid). The Draft TAR analysis modeled three BEV configurations, designated BEV75, BEV100 and BEV200 (having 75, 100, and 200 miles range, respectively).

A number of comments received on the Draft TAR related to EPA's projection of battery costs for BEVs, most of them suggesting that projected battery costs and battery sizes were conservative compared to recent trends and industry forecasts.

For example, two BEV manufacturers, Tesla Motors and Faraday Future, specifically critiqued the battery costs and sizing in the Draft TAR. Tesla Motors commented, "Improvements in battery cell design and scale manufacturing at the Gigafactory will enable Tesla to achieve cell-level and pack-level costs by 2020 that are far below the 2025 Draft TAR assumptions." Faraday Future cited a 2016 report by the International Energy Agency (IEA) that described current battery costs as under $250 per kWh, pointing out that this estimate was "in the lower range of costs" in the Draft TAR, and that the same report suggested $125 per kWh was a realistic target for 2022. While the IEA estimate is reasonably consistent with the Draft TAR battery cost projection for longer-range BEVs in this time frames, it serves as an additional example of a growing trend of independent estimates that support and, in some cases, suggest lower costs than the projections in the Draft TAR.

In developing the battery cost estimates for the Draft TAR, EPA recognized the uncertainty inherent to projecting battery costs several years into the future, and accordingly sought to develop reasonably conservative estimates for both battery cost per kWh and battery capacity for a given range. For the Draft TAR, EPA compared the 2012 FRM projected cost per kWh for BEV200 to other references, such as the Nykvist & Nilsson survey[5] and the General Motors announcement of battery cell costs for the Chevy Bolt.[6] Somewhat unexpectedly, the 2012 FRM cost projections appeared very conservative with respect to the GM costs (converted to an estimated pack-level basis).[7] The Draft TAR cost projections were found to be in better agreement, while remaining conservative. The Draft TAR capacity projections, although improved as well, also remained conservative as compared to the battery capacities of some existing vehicles. At the time, EPA felt that this was acceptable given the uncertainties associated with technology forecasting, and uncertainties regarding industry best practices for battery design and specification, given the relatively early stage of the industry.

Through continued monitoring of the industry after completion of the Draft TAR, EPA has become increasingly aware of examples of formal and informal industry battery cost projections that parallel or even undercut the projected cost per kWh for BEV batteries projected in the Draft TAR for the 2020 time frame and beyond. In light of this trend, EPA became concerned that the Draft TAR pack cost estimates, which are the primary component of BEV costing, may be at risk of becoming overly conservative, since they are the product of an already conservative battery sizing and a cost per kWh that was possibly more conservative than intended.

This information also reinforced the conclusion that battery costs are continuing to change rapidly, and that EPA should therefore update its battery cost projections for the Proposed Determination analysis. Based on these and similar comments as well as updated information that became available or verified since the Draft TAR, EPA has updated the battery analysis by which electrified vehicle battery costs are projected for the 2022 to 2025 time frame. Complete detail is provided in Chapter 2.3.4.3.7 of the TSD (Cost of Batteries for xEVs). Some key updates include:

- Improvements to the method by which PEV energy consumption is estimated
- Re-optimization of pack topologies to better assign cell and module sizes
- Increased maximum cell size for some BEV and PHEV packs based on recent industry examples
- Adjustments to improvements in mass reduction, aerodynamic drag, and rolling resistance to account for technology already present in the fleet
- Inclusion of updated information on several BEV and PHEV models that were released or certified after completion of the Draft TAR analysis

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[5] Nykvist, B. and Nilsson, M.; "Rapidly Falling Costs of Battery Packs for Electric Vehicles," Nature Climate Change, March 2015; doi: 10.1038/NCLIMATE2564.

[6] General Motors, "General Motors 2015 Global Business Conference," Presentation, October 1, 2015, slide 52 in 2015_GBC_Combined_PDF_v3.pdf.

[7] GM pack-level costs were estimated from cell-level costs. See Draft TAR p. 5-123.

- Inclusion of information regarding PHEV full useful life certification that influences how PHEV battery capacity is specified
- Revision of the derating factor (a factor in calculating the EPA label range) for BEV200 based on recent certification examples
- Changes in curb weights and power targets resulting from increased resolution of LPM vehicle classes

Combined, the updates have two primary effects on the battery cost projections for the Proposed Determination analysis:

- Projected battery capacities now more closely parallel the capacities seen in recent production PEVs of similar curb weight and range
- Projected pack costs for some modeled PEVs are reduced as a result of the changes to projected pack capacities and, in some cases, slight reduction in projected cost per kWh.

A.2.6 Upstream Emissions Accounting in Compliance Modeling

The 2012 FRM established a temporary incentive for plug-in vehicles (PEVs) by setting the tailpipe compliance value for the electricity usage of PEVs to 0 g/mi for certain years of the rule. For MYs 2017-2021, all PEVs are eligible for 0 g/mi tailpipe emissions accounting. For MYs 2022-2025, 0 g/mi is allowed up to a per-company cumulative sales cap: 1) 600,000 vehicles for companies that sell 300,000 BEV/PHEV/FCVs in MYs 2019-2021; 2) 200,000 vehicles for all other manufacturers. For sales above these thresholds, manufacturers will be required to account for the net upstream GHG emissions for the electric portion of operation in their compliance calculation, using accounting methodologies set out in the FRM.[8]

Our Draft TAR analyses did not consider upstream emissions of PEVs in compliance modeling. Given the growing rate of PEV sales, it now appears that some manufacturers are likely to exceed the sales levels beyond which net upstream emissions would have to be considered in their compliance determination, while other manufacturers likely will not. For this Proposed Determination analysis, we now include upstream emissions for BEV operation and the electricity portion of PHEV operation in the compliance determinations for all manufacturers by MY2025. Because we wish to be conservative in our estimates, we have chosen to model all MY2025 PEVs as including upstream emissions in their compliance determinations even though it is not expected that all manufacturers will exceed the sale thresholds by then.

A.2.7 Off-Cycle in OMEGA

In past analyses, EPA has included technology costs and additional off-cycle credits for active aerodynamics (Aero2) and stop-start. While the off-cycle credits of these technologies were never considered when determining the feasibility of the standards, as air conditioning credits were, they have been considered to be relatively cost effective and expected to be widely used to

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[8] See 40 CFR 86.1866-12(a)(3)

meet the standards. As a result, past analyses have shown considerable penetration of these technologies in our control case OMEGA runs.

Beyond off-cycle credits provided for active aero and stop-start, there are other technologies for which EPA provides off-cycle credits. Those technologies are included in what EPA calls the "off-cycle menu" and were codified in the 2012 FRM which specifies the level of credit available to those technologies.[9] Manufacturers also have additional opportunities to seek off-cycle technology credits.[10]

Until now, we have not included the use of these menu off-cycle technologies in our OMEGA modeling since we did not have estimates of their costs. In comments on the Draft TAR, several auto industry commenters suggested that they plan to expand their use of off-cycle credits, including the menu technologies, in the coming years, and some went on to suggest that EPA remove the current 10 gram/mile cap on use of menu technologies. Although EPA is not proposing to remove the cap (as explained in Section B.3.4 of this Proposed Determination Appendix), these comments strongly suggest that manufacturers appear to be planning to maximize their use of these technologies throughout their fleets. In EPA's latest GHG Manufacturer Performance Report for MY2015, auto manufacturers used a fleetwide average 3.0 gCO_2/mi of off-cycle menu credits. This makes clear that these credits are important to manufacturers and are, evidently, cost effective approaches to controlling GHGs.

For this Proposed Determination analysis, we are incorporating as technology options into OMEGA the use of off-cycle credit opportunities in addition to A/C, Aero2 and stop-start. The approach being used in this Proposed Determination is not to focus on particular off-cycle technologies or their costs and credits, but rather to estimate the additional costs and credits based on the costs estimated by OMEGA. Specifically, we used the "single OEM" or "Perfect Trading" OMEGA run presented in the Draft TAR as a sensitivity (see Draft TAR Chapter 12.1.2). That run estimated impacts of perfect trading amongst OEMs since the fleet was run as a single OEM. This is a "best case" or least-cost scenario. Using the results of that run, for the control case in 2025, the costs associated with achieving the reference case targets of roughly 237 gCO_2/mi were $442, and the costs of the control case targets of roughly 199 gCO_2/mi were $1,307. Note that both of these costs and the CO_2 values noted are OMEGA-core values and, as such, do not consider A/C credits, which is what we want for this analysis. Using the results of this "perfect trading" run further, we were able to generate the cost per gCO_2/mi from which we used the $34 value and applied a 30 percent premium resulting in a $45 (2013$) cost for each gram of CO_2 reduced. This cost was applied to an "off-cycle technology level 1" credit of 1.5 gCO_2/mi. For an off-cycle level 2 credit of 3 g/mi, we applied a 60 percent premium to the $34 value to arrive at a $55/$gCO_2$/mi value (2013$). Table A.3 shows the credit values and costs now added to the OMEGA model's technology packages.

Table A.3 Cost and Credit Values for Off-cycle (OC1 and OC2) Technologies

Off-cycle "Technology"	Valued at (in 2013$)	Credit Value	DMC (in 2015$)
OC1	$45/$gCO_2$/mi	1.5 gCO_2/mi	$69
OC2	$55/$gCO_2$/mi	3.0 gCO_2/mi	$170

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[9] See 40 CFR 86.1869-12(b).

[10] See 40 CFR 86.1869-12.

A.2.8 Additional OMEGA Sensitivities

The OMEGA model evaluates the relative cost and effectiveness of available technologies and applies them to a defined vehicle fleet in order to meet a specified GHG emission target. Once the regulatory target (whether the target adopted in the rule, or an alternative target) has been met, OMEGA reports out the cost and societal benefits of doing so, as well as the projected penetrations of technologies within the fleet. OMEGA is designed to apply technology in a manner similar to the way that a vehicle manufacturer might make such decisions. In general, the model considers three factors which EPA believes are important to the manufacturer: 1) the cost of the technology, 2) the value which the consumer is likely to place on improved fuel economy and 3) the degree to which the technology moves the manufacturer towards achieving its fleet wide CO_2 emission target.

The technology penetrations and potential compliance paths that OMEGA projects are sensitive to many input variables. OMEGA thus provides an opportunity to conduct sensitivity analyses to determine the effect of various alternative scenarios, such as the availability or unavailability of certain technologies, the presence or elimination of incentives or credits, different baseline assumptions, and many other hypotheticals.

For this Proposed Determination assessment, EPA ran an extensive suite of sensitivity cases examining the impact of a number of variables, including:

- Using RPEs instead of ICMs to estimate indirect costs
- Using AEO 2016 high and low fuel price cases, which varies both fuel prices and projected fleet characteristics
- “Perfect” credit trading across all manufacturers, which should represent the most cost effective case
- No Car/Truck transfers across a single manufacturer's fleet, which forces cars to meet the car curve standards and trucks to meet the truck curve standards (a more restrictive scenario)
- No additional mass reduction beyond that included in the projected baseline fleet
- A non-Atkinson engine technology path which sets a penetration cap on Atkinson-2 technology at 10 percent in both the reference and control cases
- A pathway which doesn't allow for transmission efficiency improvements beyond today's levels

Many of these sensitivity cases were added to the Proposed Determination assessment in response to concerns expressed by industry commenters, for example, with regard to Atkinson cycle engines, potential for mass reduction, and transmission efficiency improvements. EPA notes some key observations on each of these sensitivity analyses:

- Fuel prices have little impact on the cost per vehicle outcomes or the technology penetration outcomes
- Higher fuel prices do not result in substantially different fleet electrification
- Using RPEs instead of ICMs increases cost per vehicle on the order of $163
- The incremental cost per vehicle result is not heavily dependent on mass reduction and, therefore, the mass reduction cost curves

- Limiting estimated penetration of the Atkinson-2 engine technology would increase estimated cost per vehicle by roughly $45
- The case where car/truck transfers are not allowed has little impact on overall cost per vehicle, but affects cars and trucks differently
- The overall cost per vehicle impact the perfect trading sensitivity is not large

These sensitivity analyses and the implications they suggest are described in greater detail in Section C.1.2 of this Appendix.

A.3 Cost and Effectiveness Methodologies

A.3.1 Cost Methodology

The following section reviews the primary sources and approaches to estimating direct and indirect manufacturing costs, and public comments relating to them. For more detailed information on the comments as well as the overall cost methodology that EPA uses, please refer to the Technical Support Document (TSD).

A.3.1.1 Approach to Estimating Direct Manufacturing Costs

EPA's methodology for estimating both direct manufacturing (DMC) costs and indirect costs has continued to develop from both of the light-duty GHG FRMs and from the Draft TAR. Estimates of DMC come from many sources: detailed paper studies and analyses, published reports, supplier- and OEM-provided data (which would generally be considered confidential business information (CBI)), and teardown studies.

The 2015 NAS Report agreed with EPA's assessment that teardown studies are the most reliable source of DMC estimates. NAS encouraged the agencies to continue to make use of tear-down studies (NAS Recommendation 8.3), and this advice was reflected in EPA's continued use of teardown studies to develop many of the technology cost assumptions in the Draft TAR. Public comments on the Draft TAR received from the American Council for an Energy-Efficient Economy (ACEEE) and the Union of Concerned Scientists (UCS) additionally were supportive of EPA's use of teardown studies. Accordingly, EPA has continued to rely on teardown studies for cost information for this Proposed Determination.

A “tear-down” involves breaking down a technology into its fundamental parts and manufacturing processes by completely disassembling actual vehicles and vehicle subsystems and precisely determining what is required for its production. The result of the tear-down is a “bill of materials” for each and every part of the vehicle or vehicle subsystem. This tear-down method of costing technologies is often used by manufacturers to benchmark their products against competitive products. Historically, vehicle and component tear-down has not been done on a large scale by researchers and regulators due to the expense required for such studies. Many technology cost studies in the literature are instead based on information collected from OEMs, suppliers, or "experts" in the industry and are thus non-reproducible and non-transparent.

EPA therefore sponsored a number of teardown studies that are completely transparent and include a tremendous amount of data and analyses to improve accuracy. While tear-down studies are highly accurate at costing technologies for the year in which the study is intended, their accuracy, like that of all cost projections, may diminish over time as costs are extrapolated further into the future because of uncertainties in predicting commodity (and raw material) prices, labor rates, and manufacturing practices. The projected costs may be higher or lower than predicted.

Since the early development of the MY2012-2016 rule, EPA has contracted with FEV, Inc. to conduct tear-down cost studies. For use in an EPA cost analysis, the teardown costs thus derived from a subject vehicle are scaled to smaller and larger vehicles, and also to different technology configurations. FEV's methodology was documented in a report published as part of the MY2012-2016 rulemaking process.[11] Over the course of the contract between EPA and FEV, FEV performed teardown-based studies on many technologies. A complete list may be found in TSD Chapter 2.3.2.1.1 (Costs from Tear-down Studies).

As in the 2012 FRM and Draft TAR, there are a number of technologies in this analysis for which costs were determined using the rigorous tear-down method described in this section. Where applicable, these costs have been carried over to the Proposed Determination analysis after adjustment for dollar years.

Several cost studies were completed and used in support of the 2017-2025 FRM. These include vehicle tear downs of a Ford Fusion power-split hybrid and a conventional Ford Fusion (the latter served as a baseline vehicle for comparison). In addition to providing power-split HEV costs, the results for individual components in these vehicles were subsequently used to develop costs for the P2 hybrid used in the following MY2017-2025 FRM.[12] An additional cost study in support of the Draft TAR included an I4 mild hybrid system (2013 Malibu with eAssist, a 130V system) replacing a conventional I4 engine.

EPA has relied on the findings of FEV for estimating the cost of the technologies covered by the tear-down studies. However, it should be noted that FEV based their costs on the assumption that these technologies would be mature when produced in large volumes (450,000 units or more for each component or subsystem). If manufacturers are not able to employ the technology at the volumes assumed in the FEV analysis with fully learned costs, then the costs for each of these technologies would be expected to be higher. There is also the potential for stranded capital if technologies are introduced too rapidly for some indirect costs to be fully recovered. While EPA considers the FEV tear-down analysis results to be generally valid for the 2022-2025 timeframe for fully mature, high sales volumes, FEV performed supplemental analysis for the 2012 FRM to consider potential stranded capital costs, and we have included these in our primary analyses of program costs.

This Proposed Determination analysis, like the Draft TAR, uses technology costs from teardown studies conducted since the FRM. For this Proposed Determination assessment, EPA has retained the new technologies added for the Draft TAR, specifically a 48-Volt mild hybrid (costs for mild hybrids are based in large part on the 130V mild hybrid teardown), a more capable naturally aspirated Atkinson cycle engine with a high compression ratio, a Miller cycle engine, and a BEV with increased range. Cost assumptions relating to these technologies are

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[11] https://www.epa.gov/air-pollution-transportation#epa-publications.

[12] P2 hybrid technology uses a transmission-integrated electric motor placed between the engine and a gearbox or CVT, with a wet or dry separation clutch that is used to decouple the motor/transmission from the engine.

described further in the corresponding technology sections of the TSD. All technology costs have been updated to 2015 dollars.

A.3.1.2 Approach to Cost Reduction Through Manufacturer Learning

For some of the technologies considered in this analysis, manufacturer learning effects would be expected to play a role in the actual end costs. The “learning curve” or “experience curve” describes the reduction in unit production costs as a function of accumulated production volume. In theory, the cost behavior it describes applies to cumulative production volume measured at the level of an individual manufacturer, although it is often assumed—as EPA has done in past regulatory analyses—to apply at the industry-wide level, particularly in industries that utilize many common technologies and component supply sources. EPA believes there are indeed many factors that cause costs to decrease over time. Research in the costs of manufacturing has consistently shown that, as manufacturers gain experience in production, they are able to apply innovations to simplify machining and assembly operations, use lower cost materials, and reduce the number or complexity of component parts. All of these factors allow manufacturers to lower the per-unit cost of production (i.e., the manufacturing learning curve).

NAS recommended that the agencies “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.” (NAS pp. 7-23) EPA has conducted such a review under contract to ICF looking at learning in mobile source industries. The goal of the effort was to provide an updated assessment on learning and its existence in manufacturing industries. An extensive literature review was conducted and the most applicable and appropriate studies were chosen with the help of a subject matter expert (SME) that is one of the leading experts in this area.[13] EPA's intention was that the study would provide clear learning rates that could be applied in various mobile source manufacturing industries rather than the more general learning rates used in the past. That study was completed in September of 2015. In the Draft TAR, we noted that a peer review had been initiated and completed, but the subsequent final report was not completed in time for inclusion in the docket supporting the Draft TAR. That final report, which includes responses to the peer review is now completed and is contained in the docket supporting this Proposed Determination.[14] We discuss the report's findings in more detail in Chapter 2 of the TSD, and we continue to use the same approach to applying learning effects as we used in the Draft TAR.

A.3.1.3 Approach to Estimating Battery Costs

Battery cost is a large component of electrified vehicle cost. As in the 2012 FRM and the Draft TAR, EPA has used the BatPaC model[15] to estimate battery costs for electrified vehicles. Developed by Argonne National Laboratory (ANL) for the Vehicle Technologies Program of the U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy, the BatPaC model allows users to estimate the manufacturing cost of battery packs for various types

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[13] The SME was Dr. Linda Argote of Carnegie Mellon University.

[14] "Cost Reduction through Learning in Manufacturing Industries and in the Manufacture of Mobile Sources," Final Report and Peer Review Report, EPA-420-R-16-018, November 2016.

[15] Nelson, P.A. Gallagher, K.G., Bloom, I., and Dees, D.W., "Modeling the Performance and Cost of Lithium-Ion Batteries for Electric Drive Vehicles," Second Edition, Argonne National Laboratory, ANL-12/55 (December 2012).

of electrified powertrains given battery power and energy requirements as well as other design parameters.

In the 2015 NAS report (p. 4-25), the NAS committee endorsed the importance of the use of a bottom-up battery cost model such as BatPaC, further finding that "the battery cost estimates used by the agencies are broadly accurate" (Finding 4.4, p. 4-43). Since the publication of the 2012 FRM, BatPaC has been further refined and updated with new costs for some cathode chemistries and cell components, improved thermal management calculations, and improved accounting for plant overhead costs. Further changes were released in late 2015 and include additional chemistries, updated material costs, improved calculation of electrode thickness limits, and improved estimation of cost and energy requirements of certain manufacturing steps and material production processes.[16]

EPA received no public comments questioning the use of BatPaC as a component of the battery costing analysis. For this Proposed Determination assessment, EPA continues to use BatPaC in the same release version and in the same supporting role that it served in the Draft TAR. This has allowed us to update battery costs for electrified vehicles based on of the latest available input metrics to the BatPaC model and refinements to the method by which battery sizes are determined for a given driving range and performance targets. Key battery pack design parameters such as usable capacity and cell sizes have been reviewed and revised where appropriate to reflect trends in industry practice. These updates are detailed in the TSD.

A.3.1.4 Approach to Estimating Indirect Costs

To produce a unit of output, vehicle manufacturers incur direct and indirect costs. Direct costs include cost of materials and labor costs. Indirect costs are all the costs associated with producing the unit of output that are not direct costs – for example, they may be related to production (such as research and development [R&D]), corporate operations (such as salaries, pensions, and health care costs for corporate staff), or selling (such as transportation, dealer support, and marketing). Indirect costs are generally recovered by allocating a share of the costs to each unit of good sold. Although it is possible to account for direct costs allocated to each unit of good sold, it is more challenging to account for indirect costs allocated to a unit of goods sold. To make a cost analysis process more feasible, markup factors, which relate total indirect costs to total direct costs, have been developed. These factors are often referred to as retail price equivalent (RPE) multipliers.

Cost analysts and regulatory agencies (including both EPA and NHTSA) have frequently used these multipliers to predict the resultant impact on costs associated with manufacturers' responses to regulatory requirements. The best approach, if it were possible, to determining the impact of changes in direct manufacturing costs on a manufacturer's indirect costs would be to actually estimate the cost impact on each indirect cost element. However, doing this within the

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[16] Gallagher, K., Shabbir, A., Nelson, P., and Dees, D., "PHEV and EV Battery Performance and Cost Assessment," Argonne National Laboratory, presented at the 2015 U.S. DOE Vehicle Technologies Office Annual Merit Review and Peer Evaluation, June 9, 2015.

constraints of an agency's time or budget is not always feasible, or the technical, financial, and accounting information to carry out such an analysis may simply be unavailable.

To address this concern, EPA has worked with a contractor to develop modified multipliers for use in rulemakings.[17] These multipliers are referred to as indirect cost multipliers (or ICMs). In contrast to RPE multipliers, ICMs assign unique incremental changes to each indirect cost contributor as well as net income.

ICM = (direct cost + adjusted indirect cost) / (direct cost)

Developing the ICMs from the RPE multipliers requires developing adjustment factors based on the complexity of the technology and the time frame under consideration: the less complex a technology, the lower its ICM, and the longer the time frame for applying the technology, the lower the ICM. This methodology was used in the cost estimation for the recent light-duty MYs 2012-2016 and MYs 2017-2025 rulemaking and for the heavy-duty MYs 2014-2018 rulemaking. There was no serious disagreement with this approach in the public comments to any of these rulemakings. The ICMs for the light-duty context were developed in a peer-reviewed report from RTI International and were subsequently discussed in a peer-reviewed journal article.[18] Importantly, since publication of that peer-reviewed journal article, the agencies have revised the methodology to include a return on capital (i.e., profits) based on the assumption implicit in ICMs (and RPEs) that capital costs are proportional to direct costs, and businesses need to be able to earn returns on their investments.

Since their original development in February 2009, EPA and NHTSA made changes to both the ICM factors and to the method of applying those factors relative to the factors developed by RTI and presented in their reports. These changes have been described and explained in several rulemakings over the years, most notably the 2017-2025 FRM and the more recent Heavy-duty GHG Phase 2 rule (81 FR 73478 (Oct. 25, 2016)).

Although the Draft TAR analysis assessed indirect costs using both the ICM and RPE approaches, EPA has focused on the ICM approach for the Proposed Determination analysis, considering ICMs to be the better means of estimating indirect cost impacts resulting from regulatory changes. EPA believes that this stance is consistent with the support expressed by NAS in their 2015 report,[19] as well as several commenters on the Draft TAR. Comments from the American Council for an Energy-Efficient Economy (ACEEE), the Union of Concerned Scientists (UCS), and Environmental Defense Fund (EDF) all supported the use of ICMs. EPA has also performed a sensitivity analysis using RPEs instead of ICMs, as discussed in Section C.1.2 of this Appendix.

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[17] RTI International, "Automobile Industry Retail Price Equivalent and Indirect Cost Multipliers," February 2009; EPA-420-R-09-003; http://www.epa.gov/otaq/ld-hwy/420r09003.pdf.

[18] Rogozhin, A., et al., "Using indirect cost multipliers to estimate the total cost of adding new technology in the automobile industry," International Journal of Production Economics (2009), doi:10.1016/j.ijpe.2009.11.031.

[19] In the 2015 NAS study, the committee stated: "The committee conceptually agrees with the agencies' method of using an indirect cost multiplier instead of a retail price equivalent to estimate the costs of each technology since ICM takes into account design challenges and the activities required to implement each technology." (NAS Finding 7.1).

For this Proposed Determination, EPA is assessing indirect costs using the same ICMs as used in the Draft TAR, as shown in Table A.4. Near term values account for differences in the levels of R&D, tooling, and other indirect costs that will be incurred. Once the program has been fully implemented, some of the indirect costs will no longer be attributable to the standards and, as such, a lower ICM factor is applied to direct costs.

Table A.4 Indirect Cost Multipliers Used in this Analysis[20]

	2017-2025 FRM and this Draft TAR	
Complexity	Near term	Long term
Low	1.24	1.19
Medium	1.39	1.29
High1	1.56	1.35
High2	1.77	1.50

There are two important aspects to the ICM method employed by EPA. First, the ICM consists of two portions: a small warranty-related term and a second, larger term to cover all other indirect costs elements. The breakout of warranty versus non-warranty portions to the ICMs are presented in TSD 2.3.2.2.2. The latter of these terms does not decrease with learning and, instead, remains constant year-over-year despite learning effects which serve to decrease direct manufacturing costs. Learning effects were described in the previous section. The second important note is that all indirect costs are forced to be positive, even for those technologies estimated to have negative direct manufacturing costs.

Additional cost considerations were given to ICMs applied to mass reduction. The treatment of these costs is detailed in the TSD.

A.3.2 Effectiveness Methodology

In the Draft TAR, EPA reevaluated the effectiveness values for all technologies discussed in the MYs 2017-2025 light duty GHG Final Rulemaking (FRM), as well as prominent technologies that have emerged since then. Along with the vehicle benchmarking and full vehicle simulation process, EPA reviewed available data including the 2015 National Academy of Sciences report, confidential manufacturer estimates, automaker and supplier meetings, technical conferences, literature reviews, and press announcements regarding technology effectiveness. For this Proposed Determination, EPA has again reevaluated all the effectiveness values used in the Draft TAR to consider and incorporate where applicable updated information obtained since then. In most cases, multiple sources of information were considered in the process of determining the effectiveness values used in this Proposed Determination. This does not mean that every technology effectiveness has changed for the Proposed Determination. Only that effectiveness values were reevaluated and modified as deemed appropriate.

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[20] Rogozhin, A., et. al., “Using indirect cost multipliers to estimate the total cost of adding new technology in the automobile industry,” International Journal of Production Economics (2009); “Documentation of the Development of Indirect Cost Multipliers for Three Automotive Technologies,” Helfand, G., and Sherwood, T., Memorandum dated August 2009; “Heavy Duty Truck Retail Price Equivalent and Indirect Cost Multipliers,” Draft Report prepared by RTI International and Transportation Research Institute, University of Michigan, July 2010.

Full vehicle simulation modeling has been used in previous light-duty rules and in the Draft TAR to establish the effectiveness of technologies, and is regularly applied by vehicle manufacturers, suppliers, and academia to evaluate and choose alternative technologies to improve vehicle efficiency. EPAs continued use of this modeling approach assessment is also supported by both a 2010 and the 2015 studies published by the National Academy of Science – for example, in the 2015 report the NAS stated “The committee notes that the use of full vehicle simulation modeling in combination with lumped parameter modeling and teardown studies contributed substantially to the value of the agencies’ estimates of fuel consumption and costs, and it therefore recommends they continue to increase the use of these methods to improve their analysis".[21]

EPA created the Advanced Light-Duty Powertrain and Hybrid Analysis (ALPHA) tool to evaluate the Greenhouse Gas (GHG) emissions of Light-Duty (LD) vehicles. ALPHA is a physics-based, forward-looking, full vehicle computer simulation capable of analyzing various vehicle types with different powertrain technologies, showing realistic vehicle behavior. Having this tool available in-house allows EPA to make modifications as data are updated.

For this Proposed Determination, as in the Draft TAR, the ALPHA Model continues to play an important role in modeling of technologies. The ALPHA model has been developed and refined over several years and used in multiple rulemakings to evaluate the effectiveness of vehicle technology packages. Using ALPHA improves the transparency of the process and provides additional flexibility to allow consideration of the most recent technological developments and vehicle implementations of technologies. Input data for the ALPHA model has been created largely through benchmarking activities. Benchmarking is a commonly used technique that is intended to create a detailed characterization of a vehicle's operation and performance. For the purposes of developing ALPHA, and for establishing overall technology effectiveness, EPA has performed many benchmarking activities including measuring vehicle performance over the standard emission cycles and measuring system and component performance on various test stands.

Public comments on the Draft TAR included praise of EPA's development and use of the ALPHA model. The International Council on Clean Transportation (ICCT) noted, "EPA’s new physics-based ALPHA model offers a nice enhancement in modeling multiple technologies." The Union of Concerned Scientists also noted, "EPA extensively employed its own, freely accessible ALPHA full-vehicle modeling tool, which was extensively peer-reviewed and benchmarked against its work at its laboratory, which also resulted in numerous peer-reviewed publications. This laboratory analysis allowed for combinations of technologies not available on the road today to be analyzed, including both combinations of turbocharged engines with advanced transmissions and future high-compression ratio engines."

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[21] See Finding 8.7 and 10.12 and Recommendation 8.3 of “Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles published by the Committee on the Assessment of Technologies for Improving Fuel Economy of Light-duty Vehicles”; Phase 2; Board on Energy and Environmental Systems; Division on Engineering and Physical Sciences; National Research Council, ISBN 978-0-309-37388-3, 2015. See also Chapter 8 (page 118) of “Assessment of Fuel Economy Technologies for Light-Duty Vehicles”; Committee on the Assessment of Technologies for Improving Light-Duty Vehicle Fuel Economy; National Research Council; ISBN 978-0-309-15607-3, 2010.

The Alliance of Automotive Manufacturers, Global Automakers, and other stakeholders provided additional comment regarding inputs and assumptions used in the ALPHA Model, and the agencies' modeling approach in general. A full discussion of these comments is found in Chapter 2.3.3.3 of the TSD and other relevant chapters. Some key details are outlined below.

Comments related to the engine maps used in ALPHA, which stated that the maps were optimistic in nature, are addressed in TSD Chapter 2.3.4.1 (Engines: Data and Assumptions). Some comments also referred to "technical flaws" that were said to bias the results optimistically. One specific criticism in this respect expressed concern that the impact of other emissions regulations was not accounted for in the analyses. For example, the Alliance stated, "CO_2 and FE degradation associated with Tier 3 emissions control systems and the impact of more stringent evaporative emissions regulations" were not accounted for in the analyses. The Alliance also referred to the impact of CARB particulate matter (1 mg/mi) regulations on CO_2 and FE performance. EPA’s discussion of this comment regarding CO_2 emissions is found in Chapter 2.3.1.3 (Fuels) of the TSD, and discussion of the comment regarding evaporative and particulate emissions is found in Chapter 2.3.3.3 (ALPHA Vehicle Simulation Model).

The Alliance also made recommendations relating to the representation of accessory loads, and use of regular grade Tier 3 test fuel for future analysis. These comments are addressed in TSD Chapters 2.3.3.3.6 (Vehicle Component Vintage) and 2.3.1.3 (Fuels).

Another comment stated, "When adjusting engine size to maintain performance, EPA assumes that any resulting engine displacement will be available, maximizing the modeled benefits of various technologies. In practice, manufacturers have a limited number of engine displacements to choose from and will likely select the size of engine that maintains or improves performance."

Engine resizing for performance neutrality is a modeling approach that allows an overall fleet-wide estimation of CO_2 reduction while accounting for the effects of performance, as recommended by the 2015 NAS Report. EPA does not expect manufacturers to rigidly maintain performance, footprint, or any other characteristics of a specific vehicle for the duration of the rule. Rather, EPA anticipates that manufacturers will use the flexibility of the rule to balance a range of requirements, including the manufacturer’s estimation of the availability of engine displacements, when designing vehicles. A more detailed discussion of this topic is found in TSD Chapter 2.3.1.2 (Performance Assumptions).

The Alliance comments also criticized the use of 0 to 60 mile per hour acceleration time as the main metric EPA used to represent performance neutrality, and stated that top gear gradeability is another key metric that was omitted in the analysis. EPA’s discussion of this comment is found in TSD Chapter 2.3.4.2.2 (Effectiveness Values for TRX11 and TRX21), where we indicate that maintaining top gear at 75 mph up a grade, as AAM and Ford comments suggest, may not be appropriate for advanced eight-speed transmissions, where EPA testing has indicated downshifts regularly occur and are less noticeable to the driver.

The Alliance also recommended that EPA "incorporate and make readily available quality control parameters that can be used to verify the validity of model results in all output files." In response, the version of ALPHA used for this Proposed Determination generates .csv output files that contains over 150 columns of data and quality control parameters. In addition, since EPA is providing a runnable version of ALPHA on its website, any user can add additional quality control data as desired. TSD Chapter 2.3.3.3.3 (Energy Auditing) also contains a description of the energy flow auditing that describes another useful quality control component in ALPHA.

Appendix B Assessment of Consumer Impacts, Employment and Other Factors

B.1 Consumer Issues

B.1.1 Introduction

As part of the midterm evaluation, EPA must consider "the cost on the … purchasers of new motor vehicles" and "the practicability of the standards," as well as "the impact of the standards on … fuel savings by consumers."[22] Consistent with this requirement, EPA committed that it would examine "Costs, availability, and consumer acceptance of technologies to ensure compliance with the standards, such as vehicle batteries and power electronics, mass reduction, and anticipated trends in these costs."[23] Technologies and costs are examined in Sections A and C of this Proposed Determination Appendix; this section reviews issues affecting consumer acceptance of the technologies that can be used to meet the standards. With the program in effect since MY2012, this section focuses on the evidence to date on broader consumer impacts of vehicles subject to the standards.

In the Draft TAR, EPA found that the MY2025 standards may be met predominantly with advanced conventional gasoline vehicles; the combined penetration of strong hybrid electric vehicles (HEVs) and plug-in electric vehicles (PEVs) needed to meet the standards was projected to be only about 7 percent of expected fleet sales. A number of OEM commenters, as well as the Alliance of Automobile Manufacturers and Global Automakers, expressed concern that significantly higher levels of electrification will be needed to meet the standards. They point out that vehicle buyers have backed away from HEVs and PEVs as gasoline prices dropped, and raise questions about whether it will be possible to sell the numbers of HEVs and PEVs needed to be produced to meet the standards. Tesla, International Council on Clean Transportation, Nextgen Climate America, and Faraday Future, on the other hand, argue that the Draft TAR underestimates the likely sale of battery electric vehicles (BEVs) and consumer interest in them. As discussed in Section C, EPA continues to find that the standards can be met predominantly with advanced conventional gasoline vehicles. If so, then consumer acceptance issues hinge primarily on the acceptability of the technologies for advanced conventional gasoline vehicles. As we discuss below, technologies currently being used to meet the standards do not appear at this time to inhibit consumer acceptance. The types of technologies that we expect to be used to meet the MY2022-2025 standards are very similar to those being used today, such as advanced gasoline engines, higher speed transmissions, vehicle lightweighting, improved aerodynamics, stop-start, and low rolling resistance tires, all of which are penetrating very quickly into the fleet. Thus, we believe the evidence to date that these technologies do not appear to inhibit consumer acceptance would indicate that we would not expect to see significant issues with consumer acceptance of the 2022-2025 standards.

This section discusses a wide range of issues affecting consumers. Section B.1.2 provides a conceptual framework for assessing consumer impacts. Section B.1.3 discusses one potential measure of consumer acceptance, the effects of the standards on vehicle sales; as discussed there,

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[22] 40 CFR section 86.1818 (h) (1) (ii), (iii), and (iv).

[23] 77 Federal Register 62784.

it is difficult, if not impossible, to disentangle the effects of the standards on vehicle sales from the effects of macroeconomic or other conditions on sales. Section B.1.4 examines the relationship between fuel economy and other vehicle attributes. Section B.1.5 discusses consumer response to vehicles subject to the standards, both the existing fleet, and vehicles subject to the MY2022-25 standards. Finally, Section B.1.6 reviews evidence related to the effects of the standards on the affordability of new and used vehicles.

Overall, EPA's assessments indicate that, to date, there is little, if any, evidence that consumers have experienced adverse effects from the standards. Information provided by commenters either supports this conclusion or does not rely on current information or reasonable predictions of future impacts. Vehicle sales continue to be strong. Most likely these sales levels are not due to the standards, but rather to economic recovery from the 2008-2009 recession. Nevertheless, there is no evidence to suggest that the standards have impeded sales, and some evidence that the technologies being used to meet the standards provide ancillary benefits that may enhance consumers' acceptance of the vehicles. We have not found any evidence that the technologies used to meet the standards have imposed unavoidable "hidden costs" in the form of adverse effects on other vehicle attributes. Similarly, we have not identified significant effects on vehicle affordability to date. Given the lead times provided to automakers to achieve the MY2022-25 standards, and the evidence to date of consumer acceptance of technologies being used to meet the standards, EPA expects that any effects of the standards on the vehicle market will be small relative to market responses to broader macroeconomic conditions.

B.1.2 Conceptual Framework for Evaluating Consumer Impacts

In Appendix Section C, EPA estimates that fuel-saving technologies, in addition to reducing GHG emissions and improving energy security, will pay for themselves within a relatively short time period, and thus, in aggregate, ultimately save consumers money. It is important to emphasize that the purpose of the standards is to reduce GHG emissions. Any fuel savings that accrue to consumers are an ancillary benefit of the standards and are included in the benefit-cost analysis, to the extent that they would not occur in the absence of the standards.

Despite the expected net aggregate savings to consumers, development and uptake of energy efficiency technologies lag behind adoption that might be expected absent the standards based on a payback calculation. The implication is that private markets do not provide all the cost-effective energy-saving technologies identified by engineering analysis. The phenomenon is documented in many analyses of energy efficiency, and is termed the "energy paradox" or "energy efficiency gap."[24]

The observation of an energy efficiency gap in this context poses an economic conundrum. On the one hand, vehicle buyers are expected to gain significantly from the standards, as the increased cost of fuel-efficient cars is smaller than the fuel savings. Yet many of these technologies have been in some use for many years; financially savvy consumers could have sought vehicles with improved fuel efficiency, and automakers seeking those customers could have offered them. Assuming full information, perfect foresight, perfect competition, and financially rational consumers and producers, standard economic theory suggests that normal

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[24] Jaffe, A.B., and Stavins, R.N. (1994). "The Energy Paradox and the Diffusion of Conservation Technology." Resource and Energy Economics 16(2): 91–122.

market operations should have provided the private net gains to consumers, and the only benefits of the standards would be due to external benefits. If our analysis projects net private benefits that consumers have not realized in this perfectly functioning market, then, with the above assumptions, there must be additional costs of these private net benefits that are not addressed. This calculation assumes that consumers accurately predict and act on all the fuel-saving benefits they will get from a new vehicle, and that producers market products providing those benefits. The estimate of large private net benefits from the standards, then, suggests either that the assumptions noted above do not hold, or that EPA's analysis has missed some factor(s) tied to improved fuel economy that reduce(s) consumer welfare. This subsection discusses the economic principles underlying the assessment of impacts on consumer well-being due to the standards.

Some commenters dispute the finding that the standards provide net benefits. The Alliance of Automobile Manufacturers cites several studies, including by the Defour Group, which find significant welfare losses associated with the standards. The Defour Group cited these same studies in its comments on the MY2017-25 FRM.[25] We consider the same response to apply here in the (essentially identical) context of the MY2022-2025 standards. As we pointed out in the Response to Comments document for the 2017-25 FRM,[26] "These studies all use older estimates of technology and fuel costs than those used in this rule." Several of them focus on the use of a gasoline tax compared to fuel economy standards. EPA does not tax gasoline. In economic theory, a gasoline tax may have a number of advantages relative to standards, as these papers discuss. Because EPA does not tax gasoline, though, the relative merits of GHG standards versus a tax are not relevant to the MYs 2017-2025 standards. We note, though, that the studies cited note reasons that increased fuel economy standards may be desirable policies in the absence of gasoline taxes."

A number of hypotheses have been raised for the existence of the energy efficiency gap.[27] Unfortunately, the literature has not reached consensus on the underlying reasons for such a gap in the context of light-duty vehicles and what the role of government might be in addressing it. Some arise from market failures, such as lack of perfect information. Others point to behaviors on the part of consumers and/or firms that appear not to be in their own best interest (behavioral anomalies). Still others point to potential costs of the standards that are not reflected in EPA analyses, some of which are difficult to quantify. The Environmental Defense Fund and Consumer Federation of America (CFA) point to an efficiency gap for fuel-saving technologies; indeed, CFA discusses many potential failings affecting the market for fuel-saving technologies. Comments from Toyota (discussed more below, in the context of how consumer use future fuel savings in their purchase decisions) both implicitly support and deny the existence of the gap. Global Automakers says that EPA must be assuming that consumers' lack of demand for fuel

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[25] U.S. EPA (2012). "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards: EPA Response to Comments." EPA-420-R-12-017, pp. 18-20 to 18-29.

[26] U.S. EPA (2012). "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards: EPA Response to Comments." EPA-420-R-12-017, p. 18-74.

[27] Helfand, G., & Wolverton, A. (2011). "Evaluating the consumer response to fuel economy: A review of the literature." International Review of Environmental and Resource Economics *5*(2), 103-146; Allcott, H., & Greenstone, M. (2012). "Is there an energy efficiency gap?" Journal of Economic Perspectives 26(1), 3-28; Gillingham, K., and K. Palmer (2014). "Bridging the Energy Efficiency Gap: Policy Insights from Economic Theory and Empirical Evidence." Review of Environmental Economics and Policy 8(1): 18-38.

economy "is of no concern because the standards are good for customers." EPA, of course, does not have this assumption. How consumers account for fuel savings in their purchase decisions will affect their vehicle purchase decisions. As discussed in the following, EPA has reviewed the evidence on this issue, and, like the National Academy of Sciences, has not identified a clear finding on this accounting. Nevertheless, when consumers buy more efficient vehicles, they will experience fuel savings, even if they did not consider those savings in their purchase decisions.

On the consumer side, hypotheses for the efficiency gap include:

- Consumers might lack the information necessary to estimate the value of future fuel savings, not have a full understanding of this information even when it is presented, or not trust the presented information
- Consumers might be “myopic” and hence undervalue future fuel savings in their purchasing decisions
- Consumers may be accounting for uncertainty in future fuel savings when comparing upfront cost to future returns
- Consumers may consider fuel economy after other vehicle attributes and, as such, not optimize the level of this attribute (instead “satisficing” – that is, selecting a vehicle that is acceptable rather than optimal -- or selecting vehicles that have some sufficient amount of fuel economy)
- Consumers might be especially averse to the short-term losses associated with the higher prices of energy efficient products relative to the long-term gains of future fuel savings (the behavioral phenomenon of “loss aversion”)
- Consumers might associate higher fuel economy with inexpensive, less well designed vehicles
- When buying vehicles, consumers may focus on visible attributes that convey status or other benefits, such as size, and pay less attention to attributes such as fuel economy that typically do not visibly convey status. Toyota refers to this as the "good enough" approach, and argues for this as a source of the efficiency gap.
- Even if consumers have relevant knowledge, selecting a vehicle is a highly complex undertaking, involving many vehicle characteristics. In the face of such a complicated choice, consumers may use simplified decision rules
- Because consumers differ in how much they drive, they may already sort themselves into vehicles with different, but individually appropriate, levels of fuel economy in ways that an analysis based on an average driver does not identify
- Fuel-saving technologies may impose hidden costs -- adverse effects on other vehicle attributes

If vehicle buyers are doing a good job of getting their efficient amount of fuel economy, their willingness to pay for additional fuel savings, revealed in their purchase decisions, should approximately equal expected additional future fuel savings over the lifetimes of the vehicles--that is, a payback period of the full vehicle lifetime. A review of the literature sponsored by EPA looked at the range of estimates of the value of fuel economy in consumer purchase decisions in models of consumer vehicle purchase decisions; it found as many studies with undervaluation of fuel economy (that is, payback periods less than full vehicle lifetime) as there were studies with about-right or overvaluation (that is, payback periods equal to or exceeding vehicle lifetime).[28] The studies used in that review tended to emphasize modeling of vehicle purchase decisions rather than the role of fuel economy in those decisions. Some recent academic research has looked specifically at the question of the value of fuel economy.[29] Busse et al. (2013) and Sallee et al. (2016) find that consumers appear to buy fuel economy that does approximate fuel savings over the vehicle lifetime; Allcott and Wozny (2014) find in contrast that the willingness to pay for fuel economy is about 3/4 of the expected future fuel savings. Thus, consumers appear to take fuel economy into account when buying vehicles, but how precisely they do it is not yet clear.

In comments on the Draft TAR, Consumers Union provides results of a nationally representative survey in which 60 percent of respondents agreed with the statement, "I am willing to pay extra for a more fuel-efficient vehicle if I can recover the additional cost through lower fuel costs within 5 years." Consumer Federation of America claims that consumers are willing to accept a five-year payback on fuel savings, while also pointing out that that payback period does not account for various market failures. The Alliance of Automobile Manufacturers, Global Automakers, Toyota, Ford, and the National Automobile Dealers Association (NADA) argue instead for the assumption that consumers consider only 2-3 years of fuel savings in their purchase decisions. At the same time, NADA comments that "Customers appear to fairly accurately value fuel economy technologies and strategies relative to other vehicle attributes." As discussed above, an efficient evaluation would have consumers consider their expected lifetime fuel savings; they should in principle balance those savings with the costs of fuel-saving technologies, holding other vehicle attributes constant. (In the 2017-25 FRM, NADA commented that "at most, buyers value any fuel savings associated with the purchase of a new motor vehicle over a five-year period.")[30] NADA also cites survey data that 68 percent of respondents were willing to pay only $30 or less per month, or $360 per year, for a 17 mpg increase in fuel economy. Over five years, with a 5 percent interest rate, that $360/year willingness to pay has a present-value equivalent of $1,558, much more than EPA's current estimated technology costs of the MY2022-25 standards. Toyota argues that assessment of the paradox should use the highest incremental debt that a consumer faces, which is commonly that on credit cards. This assertion is puzzling, because most people who finance vehicle purchases use auto loans with much lower rates. Consumers using implicit interest rates higher than those they use to finance their vehicles is typically taken as implicit evidence of the existence of the efficiency gap.

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[28] Greene, David L. (2010). "How Consumers Value Fuel Economy: A Literature Review." EPA-420-R-10-008. Docket EPA-HQ-OAR-2010-0799-0711.

[29] Allcott, Hunt, and Nathan Wozny (2014). "Gasoline Prices, Fuel Economy, and the Energy Paradox." Review of Economics and Statistics 96: 779-795; Busse, Meghan R., Christopher R. Knittel, and Florian Zettelmeyer (2013). "Are Consumers Myopic? Evidence from New and Used Car Purchases." American Economic Review 103: 220-256; Sallee, James, Sarah West, and Wei Fan (2016). "Do Consumers Recognize the Value of Fuel Economy? Evidence from Used Car Prices and Gasoline Price Fluctuations." Journal of Public Economics 135: 61-73.

[30] National Automobile Dealers Association (2012). "Re: 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas (GHG) Emissions and Corporate Average Fuel Economy (CAFE)." Docket EPA-HQ-OAR-2010-0799-9575, p. 10. Docket EPA-HQ-OAR-2010-0799-9575.

Some of these commenters also assert that the 2015 National Academies of Sciences report on fuel economy technologies supports their assertion.[31] This is an incorrect claim; the NAS does not endorse any particular payback period. It concluded:

“How markets actually value increases in new vehicle fuel economy is critical to evaluating the costs and benefits of fuel economy and GHG standards. Unfortunately, the scientific literature does not provide a definitive answer at present. Academic studies that have analyzed the evidence on consumer willingness to pay for increased fuel economy are mixed, with some studies finding little evidence of undervaluation and others finding evidence of significant undervaluation. A range of theories and explanations is put forward for why consumers may undervalue fuel economy, and some have argued that what appears to be undervaluation may in some cases be differences in preferences and circumstances among consumers. Automobile manufacturers’ statements and survey evidence tend to support the view that consumers expect a quick payback for a vehicle with higher fuel economy, all else being equal. Survey evidence also indicates broad and consistent public support for raising fuel economy standards over the past 30 years."

"In the committee’s judgment, there is a good deal of evidence that the market appears to undervalue fuel economy relative to its expected present value, but recent work suggests that there could be many reasons underlying this, and that it may not be true for all consumers. Given the importance of this question to the rationale for regulatory standards and their costs and benefits, an improved understanding of consumer behavior about this issue would be of great value.” (p. 9-16)

Further, the NAS, in Finding 9.3, states that “The results of recent studies find that consumers' responses vary from requiring payback in only 2 to 3 years to almost full lifetime valuation of fuel savings” (p. 9-36). Thus, the 2-3 year payback period recommended by automakers in their comments appears to be the low end of a very wide range, and is not a consensus estimate of the payback period that consumers use in their vehicle purchase decisions.

After reviewing the same literature as the NAS, as discussed here, EPA agrees with the NAS that the role of fuel economy in consumer purchase decisions is not well understood, with estimates ranging from 2 years to the lifetimes of the vehicles.

Consumers cannot buy technologies that are not produced; some of the gap in energy efficiency may be explained from the producer's side. Two major themes arise on the producer side: the role of market structure and business strategy, and the nature of technological invention and innovation.

Light-duty vehicle production involves significant fixed costs, and automakers strive to differentiate their products from each other. These observations suggest that automakers, rather than meeting the stylized economic model of perfect competition, can act strategically in how they design and market products. In this context, the fuel economy of a vehicle can become a factor in product differentiation rather than a decision based solely on cost-effectiveness of a

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[31] National Research Council (2015). Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles. Washington, D.C.: The National Academies Press.

fuel-saving technology.[32] Product differentiation carves out corners of the market for different automobile brands. For instance, automakers may emphasize luxury characteristics in some vehicles to attract people with preferences for those characteristics, and they may emphasize cost and fuel economy for cost-conscious new entrants in the vehicle market. By separating products into different market segments, producers both provide consumers with goods targeted for their tastes, and may reduce competition among vehicle models, creating the possibility of greater profits. From the producer perspective, fuel economy is not necessarily closely related to the cost-effectiveness of the technologies to consumers, but rather is one of many attributes that manufacturers use to market their models to different consumer groups. As Fischer (2005) points out, this strategy can lead to inefficiencies in the market: an under-supply of fuel economy relative to what is cost-effective to consumers in some segments, and an over-supply of fuel economy in other sectors. The structure of the automobile industry thus may inefficiently allocate vehicle attributes--fuel economy among them--and help to explain the existence of an energy efficiency gap.

Chapter 4.1 of the TSD discusses the relationship between technological innovation and the standards, but a shortened discussion is relevant here. In particular, in the absence of standards, automakers are likely to invest in small improvements upon existing technologies ("incremental" technologies) that can be used to improve fuel economy or other vehicle attributes. On the other hand, they may be more hesitant to invest in "major" innovations in the absence of standards, for several reasons:

1) There may be first-mover disadvantages to investing in new technologies. Many manufacturers prefer to observe the market and follow other manufacturers rather than be the first to market with a specific technology. The "first-mover disadvantage" has been recognized in other research where the "first-mover" pays a higher proportion of the costs of developing technology, but loses the long-term advantage when other businesses follow quickly.[33] Toyota in its comments points out that there can be advantages to being a first mover, including "name recognition/improved public image, customer loyalty, halo effect for other products, and sometimes the opportunity to establish an entirely new market." EPA agrees that being a first mover can provide advantages as well as disadvantages. Our main point is that the disadvantages, if significant, may delay investment in new technologies.

2) There could be "dynamic increasing returns" to adopting new technologies, wherein the value of a new technology may depend on how many other companies have adopted the technology--for instance, creating multiple suppliers for a technology

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[32] Fischer, Carolyn (2005). "On the Importance of the Supply Side in Demand-Side Management." Energy Economics 27: 165-180; Blumstein, Carl, and Margaret Taylor (2013). "Rethinking the Energy-Efficiency Gap: Producers, Intermediaries, and Innovation." Energy Institute at Haas Working Paper WP 243; Houde, Sebastien, and C. Anna Spurlock (2015). "Do Energy Efficiency Standards Improve Quality? Evidence from a Revealed Preference Approach." Ernest Orlando Lawrence Berkeley National Laboratory Working Paper LBNL-182701.

[33] Blumstein, Carl and Margaret Taylor (2013). "Rethinking the Energy-Efficiency Gap: Producers, Intermediaries, and Innovation," Energy Institute at Haas Working Paper 243, University of California at Berkeley; Tirole, Jean (1998). The Theory of Industrial Organization. Cambridge, MA: MIT Press, pp. 400, 402. Docket EPA-HQ-OAR-2014-0827-0089.

should increase competition, improve quality, and reduce price. This could be due to network effects or learning-by-doing. In a network effects situation, the usefulness of the technology depends on others' adoption of the technology: e.g., a telephone is only useful if other people also have telephones. Learning by doing is the concept that the costs (benefits) of using a particular technology decrease (increase) with use. Both of these incentivize firms to pursue a "wait and see" strategy when it comes to adopting new technologies.[34]

3) There can be synergies when companies work on the same technologies at the same time.[35] Research among multiple parties can be a synergistic process: ideas by one researcher may stimulate new ideas by others, and more and better results occur than if the one researcher operated in isolation.[36] Collaboration between automotive companies or automotive suppliers does occur. For example, Ford and General Motors collaborated on a 10-speed transmission.[37] In 2013, Daimler, Ford, and Nissan teamed up to work on fuel cell vehicles.[38] In 2015 Toyota and Mazda "agreed to form a 'long-term partnership'" to collaborate on numerous advanced technologies, including plug-in hybrid and fuel cell systems and SKYACTIV gasoline and diesel technology.[39] Standards can promote research into low-CO_2 technologies that would not take place in the absence of the standards. Because all companies (both auto firms and auto suppliers) have incentives to find better, less expensive ways of meeting the standards, the possibilities for synergistic interactions may increase. Thus, the standards, by focusing all companies on finding more efficient ways of achieving the standards, may lead to better outcomes than if any one company operated on its own.

Thus, on both the producer and the consumer side, it is possible that various market and behavioral factors may impede the penetration of fuel-saving technology even when the

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[34] Popp, D., Newell, R.G., and Jaffe, A.B. (2010). "Energy, the environment and technological change." In Handbook of the Economics of Innovation 2nd ed. B.H. Hall, and N. Rosenberg, Elsevier; Vollebergh, Herman R.J., and Edwin van der Werf (2014). "The Role of Standards in Eco-Innovation: Lessons for Policymakers." Review of Environmental Economics and Policy 8(2): 230-248.

[35] Powell, Walter W., and Eric Giannella (2010). "Collective Invention and Inventor Networks," Chapter 13 in Handbook of the Economics of Innovation, Volume 1, ed. B. Hall and N. Rosenberg, Elsevier.

[36] Powell, Walter W., and Eric Giannella (2010). "Collective Invention and Inventor Networks," Chapter 13 in Handbook of the Economics of Innovation, Volume 1, edited by B. Hall and N. Rosenberg (Elsevier) discuss how a "collective momentum" has led uncoordinated research efforts among a diverse set of players to develop advances in a number of technologies (such as electricity and telephones). They contrast this view of technological innovation with that of proprietary research in corporate laboratories, where the research is part of a corporate strategy. Such momentum may result in part from alignment of economic, social, political, and other goals.

[37] Martinez, Michael. "2017 F-150 to feature new 10-speed transmission, engine." Detroit News, May 3, 2016, http://www.detroitnews.com/story/business/autos/ford/2016/05/03/powertrain-ten-speed-transmission/83882916/ , accessed 10/13/2016.

[38] Hetzner, Christiaan. "UPDATE 3-Daimler, Ford and Nissan team up on fuel cell cars." Reuters, January 28, 2013. http://www.reuters.com/article/2013/01/28/daimer-ford-nissan-idUSL5N0AX5QU20130128.

[39] Greimel, Hans. "Toyota, Mazda form partnership to share technologies, control cost challenges." Automotive News, May 13, 2015. http://www.autonews.com/article/20150513/OEM01/150519954?templa , accessed 10/13/2016.

technologies have short payback periods. If these factors are affecting the market for fuel economy, then it is possible that the standards may improve market conditions in ways that provide net benefits to consumers that would not happen in their absence. On the other hand, if the market for fuel-saving technology is operating efficiently--that is, buyers purchase as much fuel economy as will pay for itself over the vehicles' lifetimes, and producers offer that amount of fuel-saving technology--then neither manufacturers nor buyers will gain from providing more fuel-saving technologies. In the following sections, we discuss some of the evidence on how vehicle GHG standards have affected vehicle markets.

B.1.3 Effects of the Standards on Overall Vehicle Sales

B.1.3.1 Overview of the Vehicle Market

The annual Fuel Economy Trends Report monitors trends in the light-duty vehicle market.[40] As that report shows, and as several commenters point out, since MY2012, vehicle sales have increased every year, achieving record levels. At the same time that GHG emissions have achieved record low levels, vehicle footprint has dropped since its peak in 2014, horsepower has increased or stayed constant, and weight has been roughly constant. The car/truck mix in MY2015 is 43 percent, slightly higher than in MY2014 (41 percent) but below the MY2014 peak of 48 percent (p. 15).

It is difficult, if not impossible, to distinguish empirically the effects of the standards on vehicle sales and other characteristics from the impacts of macroeconomic or other forces on the auto market that occurred over the same timeframe. Figure B.1 graphs light-duty vehicle production[41] and gross domestic product (GDP) per capita from 2005-2015.[42] As this figure shows, production in the auto industry has had a pattern similar to GDP per capita: production fell with the reduction in economic activity in the 2009 recession, and has increased as the economy has recovered. The American Automotive Policy Council, in citing this recovery, notes that "U.S. auto sales increased by double digits from 2010 to 2014, even though GDP has grown by less than 3 percent each year;"[43] it projects sales to reach or exceed 17 million vehicles each year through 2016. A number of other factors are also likely to affect new vehicle production and sales, including fuel prices, demographic factors, and vehicle characteristics including but not limited to fuel economy.

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[40] U.S. EPA 2016. "Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016." EPA-420-R-16-010, https://www.epa.gov/sites/production/files/2016-11/documents/420r16010.pdf . Note that California's GHG standards began with MY2009 and includes a "deemed to comply" provision with the National Program for MY2012 and subsequent years.

[41] Vehicle production data represent production volumes delivered for sale in the U.S. market, rather than actual sales data. They include vehicles built overseas imported for sale in the U.S., and exclude vehicles built in the U.S. for export.

[42] Bureau of Economic Analysis. "Real gross domestic product per capita." BEA Account Code A939RXO, downloaded 2/10/2016; U.S. Environmental Protection Agency 2015. Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016. U.S. EPA-420-R-16-010, Office of Transportation and Air Quality. See "Sales Employment series 20161027.xlsx," Docket EPA-HQ-OAR-2016-0827.

[43] American Automotive Policy Council (2015). "State of the U.S. Automotive Industry: Investment, Innovation, Jobs, Exports, and America's Economic Competitiveness." http://americanautocouncil.org/sites/default/files/2015-AAPC-Economic-Contribution-Report%28FINAL%29.pdf.

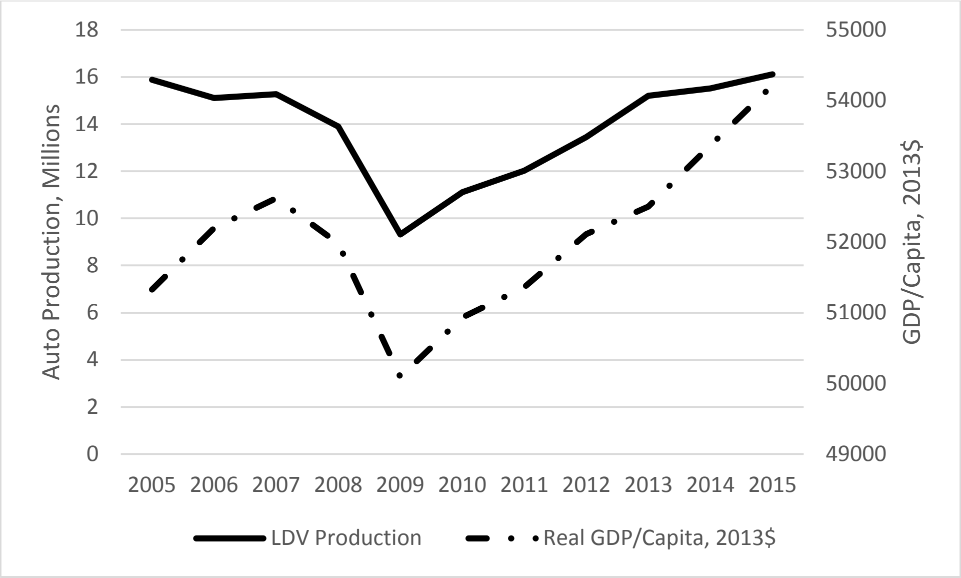

Figure B.1 Gross Domestic Product Per Capita and Vehicle Production, 2005-2015

Note: Gross Domestic Product per Capita data are from U.S. Bureau of Economic Analysis, Account Code A939RX (Real gross domestic product per capita); LDV production from U.S. EPA 2016. (See footnote 42).

B.1.3.2 Factors Affecting How the Standards Affect Total Sales

Predicting the effects of the standards on overall vehicle sales entails comparing two effects. On the one hand, the vehicles designed to meet the standards will become more expensive, which would, by itself, discourage sales. On the other hand, the vehicles will have improved fuel economy and thus lower operating costs due to significant fuel savings, which could encourage sales. Which of these effects dominates for potential vehicle buyers when they are considering a purchase will determine the effect on sales. Assessing the net effect of these two competing effects is uncertain, as it rests on how consumers consider fuel savings at the time of purchase and the extent to which manufacturers and dealers reflect technology costs in the purchase price. The empirical literature does not provide clear evidence on how much of the value of fuel savings consumers consider at the time of purchase (see further discussion in Section B.1.2), nor on how manufacturer costs are transmitted to prices. For these reasons, we did not quantify the impacts of the standards on vehicle sales when we developed the MY2022-25 standards in the 2012 FRM. Because the standards were not initially based on a quantified estimate of vehicle sales changes, we consider it appropriate to use the same qualitative approach for this Proposed Determination.

An additional source of uncertainty in the analysis is understanding what would happen in the absence of the standards. As discussed in Section B.1.2 , standard economic theory would suggest that, if automakers could profitably increase sales by adding more fuel-saving technologies to their vehicles, then manufacturers' profit motives would lead them to voluntarily add those technologies in the absence of the standards. If so, then the standards cannot provide improvements for the market for fuel efficiency; both automakers and vehicle buyers should be worse off (ignoring the external effects of the standards). As discussed in TSD Chapters 1 and 4.1, we assume, based on historical patterns, which automakers will not go beyond the MY2021 standards in the absence of the MY2022-25 standards. Overall vehicle sales would be expected to fall in this case. On the other hand, under the assumption that consumers consider around 5-6 years' worth of fuel savings in their vehicle purchase decisions and using our estimates of technology costs and future gas prices, the payback period analysis in Appendix Section C.2.4 suggests that aggregate vehicle sales could increase with more GHG-reducing technologies. Current estimates of the payback periods that consumers expect for fuel savings range from 2 years to essentially the lifetime of the vehicles (see Section B.1.2), so the 5-6 years' actual payback indicated by EPA's analysis is indeed well within this range.

Section B.1.2 discusses various hypotheses for why private markets have not led to the adoption of more fuel-saving technology with relatively short payback periods. This section discusses some of the mechanisms that may provide the potential for increases in vehicle sales due to the standards, arising from some of those hypotheses. These explanations focus on conditions where the standards stimulate investments that would not happen in their absence. The explanations posed below raise possibilities that the standards, by requiring all automakers to meet the standards, may lead to mutually beneficial outcomes that might not happen in their absence. Consumers would then have the opportunity to purchase vehicles that would not be available in the absence of the standards; if consumers consider at least as many years of fuel savings when buying new vehicles as the payback period for the new technologies, and if manufacturers would not have produced these vehicles in the absence of the standards, positive sales impacts could occur. The three possibilities we suggest for such outcomes are promotion of social learning, reduction of risk and uncertainty for manufacturers, and promotion of innovation.

B.1.3.2.1 Social Learning

For many years, fuel economy standards did not change (see the FRM Preamble III.D.1, 77 FR 62842).[44] Section B.1.2 raises the possibility that consumers historically therefore may not have focused on fuel economy, or may have found it difficult to do calculations involving the tradeoffs between fuel economy and increased vehicle costs, or may not have found vehicles with their preferred combination of fuel economy and other features. In recent years, though, increases in fuel economy standards and (temporarily) high fuel prices may have helped to focus consumer attention toward vehicle fuel economy. In addition, the fuel economy label, revised for MY2013, now has prominent information on fuel savings. These factors may contribute to consumers gaining experience with the benefits that accrue to them from owning and operating vehicles with greater fuel efficiency. Consumer households that include vehicles with a fairly wide range of fuel economy have an opportunity to learn about the value of fuel economy on their own. Consumer demand may be shifting towards such vehicles, not only because of increased availability, but also, possibly, because many consumers are learning about the value of purchases based not only on initial costs but also on the total cost of owning and operating a vehicle over its lifetime.

Comments from Consumers Union provide some suggestive support for this possibility. In a nationally representative telephone survey from June 2016,[45] respondents were asked what class

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[44] Car CAFE standards did not change from MYs 1990 through 2010. Truck CAFE standards did not change from MYs 1996 through 2004, and changed only 0.5 mpg cumulatively from MYs 1991 through 2004.

[45] Consumer Reports National Research Center (2016). "2016 Vehicle Fuel Economy Poll, Nationally Representative Telephone Survey. Docket EPA-HQ-OAR-0827-3997, p. 2.

of vehicle each currently owned, what class of vehicle each expected to buy next, and whether the respondent expected the next purchased vehicle to have better, about the same, or worse fuel economy. Although the proportion of people expecting to buy SUVs and pickups increased to 45 percent from the current ownership level of 37 percent, most--53 percent--expected better fuel economy in their next vehicle, and another 30 percent expected about the same fuel economy. When asked which attribute in their current vehicle has the most room for improvement, the largest number (32 percent) cited fuel economy, followed by purchase price, connectivity, and range. These findings imply that people are coming to expect better fuel economy in their next vehicles, even if they may shift from cars to SUVs and trucks.

The standards may increase sales by hastening this very type of consumer learning. Section B.1.5.2 discusses this phenomenon in the context of plug-in electric vehicles. As more consumers experience savings in time and expense from owning more fuel efficient vehicles, demand may shift further in the direction of vehicles with improved fuel economy and reduced GHG emissions mandated under the standards. This social learning can take place both within and across households, as consumers learn from one another. First and most directly, the time and savings associated with operating more fuel efficient vehicles may be more salient to individuals who own them, which might cause their subsequent purchase decisions to shift closer to minimizing the total cost of ownership over the lifetime of the vehicle. Second, this appreciation may spread across households through word of mouth, marketing and advertising, and other forms of communications. Third, as more motorists experience the time and fuel savings associated with greater fuel efficiency, the price of used cars may better reflect such efficiency, further reducing the cost of owning more efficient vehicles for the buyers of new vehicles (since the resale price may increase). If these induced learning effects are strong, the standards could potentially increase new vehicle sales over time.

The possibility that the standards could (after a lag for consumer learning) increase sales need not rest on the assumption that automobile manufacturers are failing to pursue profitable opportunities to supply the vehicles that consumers demand. In the absence of the standards, any individual auto manufacturer may not find it profitable to move toward more efficient vehicles to increase consumer learning because no individual company can fully internalize the potential future boost to demand. If one company were to make more efficient vehicles, counting on consumer learning to enhance demand in the future, that company would capture only a fraction of the extra sales so generated, because the learning at issue is not specific to any one company's fleet. Many of the extra sales could accrue to that company's competitors.

In other words, consumer learning about the benefits of fuel efficient vehicles may involve positive externalities (spillovers) from one company to the others.[46] These positive externalities may lead to benefits for manufacturers as a whole if they increase the demand for vehicles.

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[46] Industrywide positive spillovers of this type are hardly unique to this situation. In many industries, companies form trade associations to promote industry-wide public goods. For example, merchants in a given locale may band together to promote tourism in that locale. Antitrust law recognizes that this type of coordination can increase output.

B.1.3.2.2 Reduction in Risk and Uncertainty for Manufacturers

As discussed in Section B.1.2 , there appears to be a great deal of uncertainty about how consumers will respond to increases in fuel economy. Automakers may be cautious about adding more fuel-saving technology to vehicles if they are uncertain how buyers will respond. Even if they believe that buyers will respond positively, if a company is risk-averse, it may nevertheless hesitate to make the substantial major investments in new technologies and in research that would lead to increases in fuel economy across its fleet.[47] If a manufacturer invests substantially in fuel efficient technologies expecting higher consumer demand than realized, then the manufacturer has incurred the costs of investment but not reaped the benefits of those investments. On the other hand, if a manufacturer does not invest in fuel-efficient technologies, then the manufacturers may lose some sales in the short run if demand for fuel economy is higher than expected, but it still retains the option of investing in fuel-efficient technologies in the longer run. If its investments proved unsuccessful, the company might face substantial losses. Even if the probability of being unsuccessful is low, the manufacturer may nevertheless perceive the losses in that scenario as a substantial risk. If the investment proved successful, the company would, of course, take market share from other companies – but, if there are not brand-loyalty or other advantages to being first in the market with new fuel-saving technologies, only until the other auto companies caught up. In other words, for a risk-averse company, being a first mover may appear to have a greater downside risk than upside risk, even if the investment, on an expected-value basis, would pay off. If all companies are risk-averse, then they may all seek a strategy of waiting for some other company to be the first mover. In this case, caution about these major investments may lead to a lack of adoption of new technologies, in the absence of standards, consistent with the flat baseline assumption. The standards, by requiring that all companies act at the same time, remove the scenario of one company bearing all the risk.

In addition, there may be risk aversion on the consumer side. The simultaneous investment by all companies may also encourage consumer confidence in the new technologies. If only one company adopted new technologies, early adopters might gravitate toward that company, but early adopters tend to be a relatively small portion of the public. More cautious buyers, who are likely to be more numerous, might wait for greater information before moving away from well-known technologies. If all companies adopt advanced technologies at the same time, though, potential buyers may perceive the new technologies as the new norm rather than as a risky innovation. They may then be more willing to move to the new technologies. Simultaneous action required by the standards may change buyers' expectations (their reference points) for fuel economy, and investing in more fuel economy may seem less risky than in the absence of the standards.

As discussed more in Section B.1.2 , the standards, then, may reduce manufacturers' risk of making significant investments in fuel-saving technologies by requiring that all companies

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[47] Sunding, David, and David Zilberman, "The Agricultural Innovation Process: Research and Technology Adoption in a Changing Agricultural Sector," Chapter 4 in Handbook of Agricultural Economics, Volume 1, edited by B. Gardner and G. Rausser (Elsevier, 2001) (Docket EPA-HQ-OAR-2010-0799-12271) show how delaying adoption of a new technology in order to gain more information may be a more profitable activity than adopting a technology, even if it has positive net benefits, when a potential adopter is risk-averse.

produce more fuel-efficient vehicles. Under this outcome, it is possible for the standards to facilitate investment that would not happen in the absence of the standards, and vehicle sales could increase as a result of the standards.

B.1.3.2.3 Promotion of Innovation

Research among multiple parties can be a synergistic process: ideas by one researcher may stimulate new ideas by others, and more and better results occur than if the one researcher operated in isolation.[48] As noted above, collaboration between automotive companies or automotive suppliers does occur; for example, Ford and General Motors collaborated on a 10-speed transmission.[49] Toyota and Mazda announced a "long-term partnership" to collaborate on products and technologies, in which they might supply each other with advanced technologies.[50] One function that standards can serve is to promote research into low-CO_2 technologies that would not take place in the absence of the standards. Because all companies (both auto firms and auto suppliers) will have incentives to find better, less expensive ways of meeting the standards, the possibilities for synergistic interactions may increase. Thus, the standards, by focusing all companies on finding more efficient ways of achieving them, may lead to better outcomes than if any one company operated on its own. Section B.1.4 and Chapter 4.1.3 of the TSD further discuss the role of the standards in promoting innovation.

An additional aspect of the standards is the possibility of greater standardization.[51] As more companies adopt new technologies, the incentives increase for additional suppliers and more availability of after-market replacement parts; these suppliers would be likely to find ways to increase compatibility across vehicle types. For example, although battery electric vehicles (BEVs, which are popularly known simply as electric vehicles, or EVs) are not projected to be more than a few percent of the vehicles produced in response to the standards, their adoption depends on such factors as batteries and charging methods that are compatible across different companies. These are examples of “network externalities,” where use of a technology by one party has greater benefits if more people are also using the technology. In this case, just as the ability to buy gasoline from any station facilitates owning a gasoline-based vehicle, the ability to recharge an EV or get replacement parts easily facilitates ownership of an EV. In the absence of the standards, fewer companies would be pursuing this technology, and it would be considered a specialty product; the incentives to coordinate might be low. If EVs become more common, though, compatible infrastructure and batteries may become more desirable, as potential buyers

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[48] Powell, Walter W., and Eric Giannella, “Collective Invention and Inventor Networks,” Chapter 13 in Handbook of the Economics of Innovation, Volume 1, edited by B. Hall and N. Rosenberg (Elsevier, 2010) (EPA Docket EPA-HQ-OAR-2010-0799) discuss how a “collective momentum” has led uncoordinated research efforts among a diverse set of players to develop advances in a number of technologies (such as electricity and telephones). They contrast this view of technological innovation with that of proprietary research in corporate laboratories, where the research is part of a corporate strategy. Such momentum may result in part from alignment of economic, social, political, and other goals.

[49] Martinez, Michael. "2017 F-150 to feature new 10-speed transmission, engine." Detroit News, May 3, 2016, http://www.detroitnews.com/story/business/autos/ford/2016/05/03/powertrain-ten-speed-transmission/83882916/ , accessed 10/13/2016.

[50] Greimel, Hans. "Toyota, Mazda form partnership to share technologies, control cost challenges." Automotive News, May 13, 2015. http://www.autonews.com/article/20150513/OEM01/150519954?templa , accessed 10/13/2016.

[51] Vollebergh, Herman, and Edwin van der Werf (2014). "The Role of Standards in Eco-Innovation: Lessons for Policymakers." Review of Environmental Economics and Policy 8(2): 230-248.

are likely to be encouraged toward this technology if they can easily find places to charge batteries.

Thus, the standards may direct and promote innovation and standardization that would not happen in their absence. Such changes could reduce the cost increases associated with the standards and improve the qualities of the technologies, which could result in an increase in vehicle sales. Further, the certainty of the regulations reduces the costs of meeting them, because there will be more economies of scale and more learning curve benefits due to greater cumulative production of fuel-efficient technologies.

B.1.3.3 Assessing Impacts on Vehicle Sales

In the Draft TAR, EPA did not conduct a quantitative analysis of the effects of the standards on vehicle sales. As was discussed in Section B.1.3.1 , sales have increased to record levels during the same time period that the MY2012-16 standards came into effect. This increase is almost certainly due more to recovery from the Great Recession of 2008-2009 than to the effects of the standards. This trend suggests some of the challenges with modeling the effects of the standards. Conducting such an analysis requires some way to estimate the effects of the standards separately from all other changes happening in the auto market. In the analysis for the MY2012-16 standards, EPA conducted vehicle sales analyses by comparing the up-front costs of the vehicles with the present value of five years' worth of fuel savings; the direction of aggregate vehicle sales depended on whether up-front costs exceeded fuel savings (in which case sales would be expected to decline), or vice versa (in which case sales would be expected to increase).[52] Such an analysis depends heavily on the payback period that consumers consider in their vehicle purchases; as discussed in Section B.1.2 above, the evidence on this factor ranges widely, from 2 years to the lifetime of the vehicles. In part because of significant uncertainty over this factor, in the MY2017-25 FRM and in the Draft TAR, EPA presented a qualitative assessment of the effects of the standards on total sales, discussed in Section B.1.3.2 . Here, we continue with the qualitative approach.

In comments on the Draft TAR, the Alliance of Automobile Manufacturers (Alliance), Global Automakers, and several auto manufacturers criticize the agencies for not conducting a quantitative vehicle sales analysis for MYs 2022-25. Global Automakers points out that macroeconomic conditions are likely to be different in that time frame than from the present; EPA agrees, and expects that those effects are likely to influence vehicle sales more than the standards will. EPA has chosen for this Proposed Determination to continue with the qualitative approach that it used for setting the standards in the 2012 FRM, and in the Draft TAR, due to the significant uncertainties involved in conducting a quantitative analysis, as discussed in Section B.1.2 . In particular, there are two empirical challenges for which there is a paucity of literature. First, the literature generally does not speak to how manufacturer and dealer pricing decisions are made. Second, while EPA and NHTSA have used an elasticity of around -1 in past rulemakings to estimate sales impacts, this assumption is old (stemming from studies conducted two or more decades ago) and is a short run elasticity estimate, which may not be appropriate for standards that apply several years into the future. Because vehicles are a durable good, the long-

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[52] U.S. Environmental Protection Agency (April 2010). “Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards: Regulatory Impact Analysis.” EPA-420-R-10-009, Chapter 8.1.1, pp. 8-1 to 8-4.

run response of vehicles sales to a change in price may be lower than the short-run response. If so, any changes in sales would likely be overestimated, particularly in later years, if the short-run elasticity were used. In addition, large increases in sales of new vehicles likely imply an increase in scrappage or sales into the used vehicle market, which would change relative prices of new and used vehicles in ways that could influence sales but are difficult to estimate.

The Alliance, Fiat Chrysler Automobiles, Ford Motor Company, and the National Automobile Dealers Association (NADA) cite a recent report from the Center for Automotive Research (CAR) that estimates sales impacts of the standards ranging from an increase of 410,000 to a decrease of 3.7 million in MY2025.[53] TSD Chapter 4.2.1 provides a detailed review of the CAR report. As is discussed further in the TSD, this CAR report does not provide a sound basis for assessing vehicle sales or employment impacts due to serious flaws in its underlying assumptions and modeling methodology, as Isenstadt (2016) and Cooke (2016) point out.[54] Among the significant shortcomings of the modeling in the study are the following:

- As Isenstadt (2016) points out, the analysis uses cost estimates for the standards that are based not in technology cost estimates, but rather in a 25-year-old study of how to achieve CAFE standards by adjusting prices to affect sales.[55] EPA does not expect the auto industry to meet the standards through changing sales mix while holding technologies constant, as the CAR study's cost estimates do.
- The CAR report selectively reviews the literature for its claim of a 3-year payback period for fuel savings in consumer vehicle purchase decisions (Cooke 2016). As discussed in Section B.1.2 , the assumption that consumers consider only three years of fuel savings in their purchase decisions is close to the low end of a range of payback periods that, on the upper end, extends to the lifetimes of vehicles. If consumers put more weight on fuel savings than assumed in the CAR report, sales reported in its analysis would increase in more scenarios.
- The models that it uses to project future expenditures on vehicles do not address some potentially serious econometric concerns, such as the assumption that the average price of vehicles is based only on historic trends and not on market forces.
- The report provides two econometric models that estimate the effects of vehicle prices on total vehicle expenditures. One model finds that prices increase expenditures, while the other contradicts it, finding that prices decrease expenditures. The study uses both models for different purposes. If it reversed where the models

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[53] McAlinden, Sean, et al. (2016). "The Potential Effects of the 2017-2025 EPA/NHTSA GHG/Fuel Economy Mandates on the U.S. Economy." Center for Automotive Research http://www.cargroup.org/?module=Publications&event=View&pubID=143 , accessed 10/11/2016.

[54] Isenstadt, Aaron (2016). "The latest paper by the Center for Automotive Research is not what it thinks it is." International Council on Clean Transportation, http://www.theicct.org/blogs/staff/latest-paper-by-CAR-is-not-what-it-thinks-it-is , accessed 10/13/2016; Cooke, Dave (2016). "Déjà vu: Shoddy Economic Study Touted by Automakers Flaunts Facts." Union of Concerned Scientists, http://blog.ucsusa.org/dave-cooke/deja-vu-shoddy-economic-study-touted-by-automakers-flaunts-facts , accessed 10/19/2016.

[55] Greene, David (1991). "Short-Run Pricing Strategies to Increase Corporate Average Fuel Economy." Economic Inquiry 29(1): 101-114.

were used, the results would most likely show the standards increasing vehicle sales and employment.

- The report does not control consistently for inflation; it mixes nominal dollar values from a number of different years, and compares fuel savings in 2015 dollars with vehicle prices in 2025 dollars projected with inflation included.
- Its analysis of employment impacts is based only on the overstated impact on sales; it does not consider the positive employment impacts associated with producing and installing GHG-reducing technologies. In addition, the "multiplier" approach to employment analysis that it uses does not allow for the possibility that employment may shift from one sector to another rather than simply decrease.

For these and other reasons detailed in the TSD Chapter 4.2.1, EPA finds that the CAR analysis is unlikely to provide a sound estimate of the impacts of the MY2025 standards on vehicle sales.

Other commenters went so far as to maintain that EPA should not make a Proposed Determination until it could reliably quantitate the effects of the standards on vehicle sales. Neither the rules on the Midterm Evaluation, nor anything in Section 202(a)(1) of the Clean Air Act, requires such a quantitative determination. Nor is one needed as a matter of policy, any more than needed in promulgating the MY2017-2025 standards.[56] A reasonable qualitative assessment is preferable to a quantitative estimate lacking sufficient basis, or (due to uncertainties like those here) having such an enormous range as to be without substantial value. Thus, making quantitative estimates based on the entire range (from 2 years to the lifetime of the vehicle, as discussed in Section B.1.2) of estimates of the role of fuel economy in consumers' vehicle purchases would not produce reliable information about the impacts of the standards on vehicle sales. For that reason, we continue to assess this issue qualitatively as done in the 2017-2025 FRM and the Draft TAR.

The above discussion focuses on the effects of the standards on new vehicle sales. As already observed, the standards may also have an effect on the market for used vehicles, because people may switch between the new and used vehicle markets. As several commenters point out, the effect of the standards on the use and scrappage of older vehicles will be related to their effects on new vehicle prices, the fuel efficiency of new vehicle models, the fuel efficiency of used vehicles, and the total sales of new vehicles. If the value of fuel savings resulting from improved fuel efficiency to the typical potential buyer of a new vehicle outweighs the average increase in new models' prices, sales of new vehicles could rise, the used vehicle market may increase in volume as new vehicle buyers sell their older vehicles, and scrappage rates of used vehicles may increase slightly. This will cause both an influx of more efficient vehicles into the used vehicle market and an increase in the turnover of the vehicle fleet (i.e., the retirement of used vehicles and their replacement by new models), thus accentuating the anticipated effect of the standards on fleet-wide fuel consumption and CO_2 emissions. However, if potential buyers value future fuel savings resulting from the increased fuel efficiency of new models at less than the increase in their average selling price, sales of new vehicles will decline, the used vehicle market may decrease in volume as people hold onto their vehicles longer, and there will be a reduction in the

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[56] See 77 FR at 62912-14 and 62946-47.

rate at which used vehicles are retired from service. These effects will partly reduce the anticipated effects of the standards on fuel use and emissions.

Jacobsen and van Bentham (2013), using data on new and used vehicles from 1999-2009, provide one of the few studies of the used vehicle market. They find that more efficient vehicles were scrapped more quickly than less efficient vehicles, perhaps (especially during that time of the flat fuel economy standard) due to their being less valuable and thus less worth repairing.[57] It estimates leakage--that is, emissions reductions that do not occur due to the demand for used vehicles--of 13-16 percent as people hold onto used vehicles longer. We note that it relies on an estimated model of consumer vehicle choices that, as with most other models, has not been tested for out-of-sample validity or comparability with other models (see the discussion in Section B.1.3.4). Because the model is untested, and the substitution patterns among vehicles are likely to be different under the footprint-based standard, it is unclear how applicable the results of this paper are to this analysis.

Consumer, environmental, and investor organizations suggest that the standards can provide benefits to the auto industry as well as to vehicle buyers. Business for Innovative Climate and Energy Policy (BICEP) cites a study commissioned by Ceres that finds the domestic OEMs will be profitable even when gasoline is less than $2 per gallon.[58] That calculation assumes that OEMs can barely break even, which is unrealistic in the long run. It also estimates that those OEMs will be able to pass along the full estimate of $1353 compliance costs in going from MY2015 to MY2025 standards (2013$) for gasoline prices of $3 per gallon. The paper does not provide sufficient information to fully evaluate the analysis. It also points out that the standards provide long-term certainty that reduces the risk of major investments, and that the standards provide some insurance for the auto industry as well as vehicle buyers in case of higher fuel prices; EPA agrees with both these points.

The International Union, United Automobile, Aerospace & Agricultural Implement Workers of America (UAW) urge that the standards not provide incentives to move production overseas. Because both domestically produced vehicles and imported vehicles are subject to the same standards, EPA does not consider its standards to provide incentives related to location of production. The UAW also argues for flexibility of standards in response to changing market conditions; EPA considers the footprint-based standard to provide that flexibility. Allen County, Ohio's Board of Commissioners expresses concern that consumers will not be able to purchase vehicles that they want; EPA considers the footprint-based standard to reduce this concern.

The National Program light-duty vehicle standards, which went into effect in MY2012, are likely to have had some effect on vehicle sales. As the above discussion indicates, though, we have not identified a scientifically sound way to provide a quantitative estimate of the effect that the existing standards have had on sales. The most solid analysis would involve the ability to compare sales in a place not affected by the standards, with sales in a place identical to the first during the same time period, except where the standards are in effect. Because the standards are

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[57] Jacobsen, Mark (2013). "Evaluating U.S. Fuel Economy Standards in a Model with Producer and Household Heterogeneity." American Economic Journal: Economic Policy 5(2): 148-187.

[58] Baum, Alan, and Dan Luria (2016). "Economic Implications of the Current National Program v. a Weakened National Program in 2022-2025 for Detroit Three Automakers and Tier One Suppliers." Ceres Analyst Brief, https://www.ceres.org/files/analyst-brief-economic-effects-on-us-automakers-and-suppliers/at_download/file , accessed 10/17/2016.

national in scope, such a comparison is not possible. Alternatively, it may be possible to examine how sales have changed as the standards have tightened, but it would be necessary to control for all other factors, such as macroeconomic conditions, that affect sales. But it is clear from empirical evidence that the standards have not prevented the automobile market from recovering to pre-recession sales levels--indeed, to record sales levels. The next section further explains our concerns with quantitative modeling of the impacts of the standards.

B.1.3.4 Consumer Vehicle Choice Modeling

In addition to their effect on overall sales and production, the standards could affect the mix of vehicles sold. Consumer vehicle choice models estimate what vehicles consumers buy based on vehicle and consumer characteristics. In principle, such models could provide a means of examining the effects of the standards on both overall vehicle sales and the mix of vehicles sold. Because the standards are based on the footprints of vehicles, shifts in the mix of vehicles sold do not necessarily affect automakers' ability to meet the standards, but they could affect total GHGs emitted. Whitefoot and Skerlos (2012), for example, use a vehicle choice model combined with producer cost estimates to argue that the footprint-based standard provides some incentive for automakers to increase the size of vehicles in order to face a less stringent standard, and higher GHG emissions.[59] As discussed in Chapter 3 of the Draft TAR, the average footprint of vehicles has increased slightly since the standards have been implemented. As with sales, this effect is potentially confounded by a number of factors, such as previous trends, dropping gasoline prices and increasing consumer income that changes the mix of vehicles purchased.

In the 2017-25 LDV GHG RIA (Chapter 8.1.2), EPA provided an extensive discussion of consumer vehicle choice modeling as a way to estimate the effects of GHG/fuel economy standards on vehicle purchase decisions.[60] In that discussion, EPA found that, despite an extensive literature of consumer choice models, few researchers have compared estimates of key model parameters with those of others' models, and there have been few efforts to test the forecasting ability of those models. As a start to addressing this gap in the literature, EPA had commissioned a study of the findings of these models on the role of fuel economy in consumer vehicle purchases and found highly varied results.[61] At the time, EPA concluded that the science of these models was not adequately developed for use in policy-making.

Recent papers have done some work on the predictive abilities of consumer choice models. Haaf et al. (2014) use data from MY2004-6 vehicles to estimate a number of different

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[59] Whitefoot, Kate S., and Steven J. Skerlos (2012). "Design incentives to increase vehicle size created from the U.S. footprint-based fuel economy standards." Energy Policy 41: 402-411. While EPA considers the concept of the Whitefoot and Skerlos analysis to have some potential merits, it is also important to note that, among other things, the authors assumed different inputs than EPA (and NHTSA) actually used in the MYs 2012-2016 rule regarding the baseline fleet, the cost and efficacy of potential future technologies, and the relationship between vehicle footprint and fuel economy. Changes in any of the underlying assumptions is likely to lead to different analytical results, and possibly different implications for agency action.

[60] See also Helfand, Gloria, and Ann Wolverton (2011). "Evaluating the Consumer Response to Fuel Economy: A Review of the Literature." International Review of Environmental and Resource Economics 5: 103-146.

[61] Greene, David L. (2010). "How Consumers Value Fuel Economy: A Literature Review." EPA Report EPA-420-R-10-008, http://www.epa.gov/otaq/climate/regulations/420r10008.pdf .

econometric models, and test their predictions against MY2007 and 2010 vehicle sales.[62] They conclude that "the models we construct are fairly poor predictors of future shares." They find that a "static" model assuming constant market shares–that is, using current-year market shares rather than a model--outperformed their estimated models for MY2007, while some attribute-based models predicted better for MY2010. Haaf et al. (2016) examines some of the methods commonly used for modeling vehicle choice, and finds that the method used in a number of academic papers (using instrumental variable) may have less accurate forecasts than another method, using alternative-specific constants.[63] Raynaert (2014) developed a structural model of vehicle supply and demand in Europe, using data from 1998-2007; he then compared sales-weighted aggregate predictions from the model for MY2011 to actual outcomes.[64] He finds close agreement on aggregate market outcomes: in a period where actual emissions dropped 14 percent, his estimates for emissions differed from the observed values by 2.3 percent. Weight, footprint, and the share of diesel also had discrepancies of 3 percent or less; price/income and horsepower differed by under 10 percent. He implies, without detailed information, that the model nevertheless does not predict market shares or total sales very well. These papers leave questions unanswered about the ability of consumer vehicle choice models to predict sales and fleet mix.

As part of its exploration of vehicle choice modeling, EPA commissioned the development of a vehicle choice model from David Greene and Changzheng Liu of Oak Ridge National Laboratory (Greene and Liu 2012).[65] This model, described in the 2017-2025 RIA (Chapter 8.1.2.8), is designed with a straightforward purpose: to estimate, for a predetermined fleet (the reference fleet, described in TSD Chapter 1), the effects of changes in only fuel economy and price on vehicle sales and class mix. The model calculates a sales response to a change in the "effective price" for each vehicle, where the effective price combines any change in up-front cost with a portion of the future fuel savings (see Greene and Liu 2012, footnote 65, for details). That portion of future fuel savings depends on user inputs for factors including the price of fuel, the number of years of fuel savings that a buyer considers (the payback period), and the discount rate. It is intended for use in policy analyses of vehicle GHG/fuel economy regulations, and not to predict changes in the vehicle market associated with macroeconomic shifts or changes in demographic factors.

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[62] Haaf, C.G., J.J. Michalek, W.R. Morrow, and Y. Liu (2014). "Sensitivity of Vehicle Market Share Predictions to Discrete Choice Model Specification." Journal of Mechanical Design 136: 121402-121402-9.

[63] Haaf, C.G., W.R. Morrow, I.M.S. Azevedo, E.M. Feit, and J.J. Michalek (2016). "Forecasting light-duty vehicle demand using alternative-specific constants for endogeneity correction versus calibration." Transportation Research Part B 84: 182-210.

[64] Raynaert, Mathias (2014). "Abatement Strategies and the Cost of Environmental Regulation: Emission Standards on the European Car Market." KU Leuven Center for Economic Studies Discussion Paper Series DPS14.31.

[65] Oak Ridge National Laboratory (2012). "Consumer Vehicle Choice Model Documentation." EPA-420-B-12-052, http://www.epa.gov/otaq/climate/documents/420b12052.pdf ; Systems Research and Applications International, Inc. (2012). "Peer Review for the Consumer Vehicle Choice Model and Documentation." EPA-420-R-12-013, http://www.epa.gov/otaq/climate/documents/420r12013.pdf .

As part of our ongoing study of vehicle choice models, EPA has put the model through a variety of tests intended to understand it better.[66] One group of tests involved examining the sensitivity of the model to changes in parameters, including the role of fuel economy in consumer purchase decisions, the discount rate, model elasticities, and the initial vehicle fleet.

- First, we examined the effects of a 20 percent improvement in fuel economy[67] for all vehicles; in response, total sales increased about 5 percent, with higher sales increases going for some of the larger, less fuel-efficient vehicles. If poor fuel efficiency would otherwise reduce the interest of buyers in those vehicles, then improving their fuel economy may disproportionately improve their sales.
- Next, we varied the payback period–the number of years of fuel savings that a vehicle buyer might consider in the purchase decision–from 1 to 7 years. Total sales increased by less than 1 percent for every additional year of payback period, suggesting that modeling results are not highly sensitive to this parameter.
- Similarly, varying the discount rate (used to calculate the value of future fuel savings) from 2 to 10 percent changed total sales by less than 1 percent, suggesting insensitivity to this parameter as well.
- When demand elasticities (percent change in sales in response to a one percent change in effective price) for all classes in the model are increased by 50 percent, total sales increase 7 percent, compared to 5 percent in the baseline case; if the elasticity of only one class is changed, total sales are virtually unaffected, though sales in the class that had the elasticity change increased by about 5 percent.
- Finally, we experimented with increasing the number of vehicles in the initial fleet by 50 percent (both uniformly for all vehicles and for one vehicle class at a time), to test sensitivity to assumptions about that baseline fleet. The sales response with a larger fleet to the 20 percent change in fuel economy was approximately proportional: just as sales in the initial case increased 4.9 percent in response to the changes in fuel economy, sales with the larger fleet increased 4.9 percent. Changing the size of individual classes also had very little effect on market shares, because they all increased proportionally.

In sum, these tests showed that the results of the model are not highly sensitive to any of these parameters. Thus, imprecision in the initial fleet or these other factors is not likely to have a major effect on the model's predictions of vehicle sales and fleet mix. It also suggests that changing the fuel economy and price in the model may not lead to very large changes in sales and fleet mix. Of course, this series of tests does not provide insight into whether its predictions are accurate.

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[66] Helfand, Gloria, Changzheng Liu, Marie Donahue, Jacqueline Doremus, Ari Kahan, and Michael Shelby (2015). "Testing a Model of Consumer Vehicle Purchases." EPA-420-D-15-011, https://nepis.epa.gov/Exe/ZyPDF.cgi/P100NNOZ.PDF?Dockey=P100NNOZ.PDF.

[67] In the model, sales change in response to an effective price that combines the up-front cost with a share of future fuel savings. Increasing fuel economy thus has the opposite effect of increasing price; the former reduces the effective price, while the latter increases it. We used the 20 percent increase in fuel economy as a fairly large change, especially because it is not offset by any price increase.

A second exercise examined the model's ability to predict sales. It should be noted that the model is not intended to predict future sales or fleet mix. To do so would require inclusion of factors such as macroeconomic conditions and demographic shifts that affect sales; EPA's model was not designed to include those factors. As noted above, the model is intended to take as a given the without-standards fleet (i.e. the reference fleet), and to estimate the effects of changes in price and fuel economy on sales and class shifts, as a way of focusing specifically on the effects of GHG policy on the reference fleet. For that reason, testing the model by using it to predict sales in a different year is beyond the model's design capabilities. We conducted this test, nevertheless, as an initial attempt to test whether the model's results reflect actual consumer behavior.

In this test, we calibrated the model to MY2008 vehicle sales, calculated the difference in vehicles' fuel economy and price between MY2008 and MY2010 (another year for which we had the specific vehicle data needed for this analysis), used the model to estimate responses to the changes in MY2010 fuel economy and price, and compared the MY2010 predictions to actual MY2010 sales. The model did not predict sales or market shares well. The model predicted an increase in total sales when actual sales decreased. For market shares, similar to the near-term results in Haaf et al. (2014), using actual market shares from MY2008–i.e., not using a model – had better predictions than using the model. These poor predictions are not surprising, given that MY2010 sales reflect the Great Recession, a significant factor that the model was not designed to address. We do not consider these results a demonstration that the model does not perform well; rather, it indicates the difficulty of testing the predictive abilities of this model as it is designed.

The Alliance, the National Automobile Dealers Association, Fiat Chrysler, and Toyota request that EPA develop a consumer vehicle choice model that includes macroeconomic and demographic factors, in order to predict sales as well as changes in fleet mix. For instance, the Alliance comments that "Customer choice is complex; for over 100 years automakers have attempted to understand and predict it, but nonetheless, it is important to work to get the best possible insight on this tricky issue."[68] EPA agrees that the issue is complex. As documented above, current public research on vehicle choice modeling does not inspire confidence in the use of these models. Both Haaf et al. and EPA's analysis suggest that using a vehicle choice model may provide more error than using current market shares; EPA believes that using a model that may increase error will not provide useful information. Automakers do not provide suggestions for methods that may be more successful in their predictive abilities. Indeed, their own comment cited above ("for over 100 years") suggests the industry has confronted the same issues EPA identifies here.

Toyota specifically criticizes the EPA model for focusing only on price and fuel economy. We agree that such a model will not be useful for forecasting a future fleet, but that was not the purpose of the model. EPA's interest is in estimating the effects of the standards from a reference fleet. The reference fleet is discussed in Chapter 1 of the TSD. EPA has used independent projections of fleet mix and total volume by IHS-Polk and EIA, which consider

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[68] Alliance of Automobile Manufacturers (2016). "Alliance of Automobile Manufacturers Comments on Draft Technical Assessment Report: Midterm Evaluation of Light-Duty Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-25." Docket EPA-HQ-OAR-2015-0827-4089, p. 107.

macroeconomic factors, to develop its reference case. Our model then focuses on the vehicle characteristics, price and fuel economy, where the standards will have their most significant effects. We note that developing a more complex model would require testing and validation of more combinations of parameters than those in the simple model. Section B.1.4 below and TSD Chapter 4.1.5 discuss research that EPA has conducted on consumer willingness to pay for vehicle attributes, key parameters in a more complex model; as those discussions indicate, those values range too widely to be useful for policy analysis. Based on the existing literature, there is little evidence to date that more complex models will enhance decision-making.

At this point, then, EPA is not using this or another vehicle choice model in its current modeling work. What little research that has been conducted on model validation suggests that not using a model may produce better results than using a model. In addition, the models in the academic literature indicate extremely wide ranges for willingness to pay for key vehicle characteristics. The evidence to date suggests that the science of vehicle choice modeling is not robust enough to provide useful policy advice.

B.1.4 Relationship between Fuel Economy and Other Vehicle Attributes

Chapter 4.1.3 of the Draft TAR and Chapter 4.1 of the TSD discuss the relationship between fuel economy and other vehicle attributes, such as performance or handling. As discussed in TSD Chapters 1 and 2.3, EPA uses as a baseline the vehicle fleet in 2015, with only GHG emissions and cost expected to change for each vehicle model. This assumption does not allow for changes in vehicle attributes that would take place in the absence of the standards. Comments from the Alliance of Automobile Manufacturers, National Automobile Dealers Association, Resources for the Future, Simmons and Tyner, and Global Automakers raise concerns about tradeoffs between improved fuel economy and other vehicle attributes, such as vehicle power or size. If the standards were not in place, they argue, other vehicle attributes might be enhanced in the future, and EPA should develop a reference fleet including those enhancements. Other commenters, such as the International Council for Clean Transportation, point out that some technologies have ancillary benefits--for instance, lightweighting produces "better ride, handling, braking, performance and payload and tow capacity." In Congressional testimony, ICCT adds that it is "not appropriate" that EPA assigned the costs of lightweighting to GHG reductions without accounting for the consumer benefits (p. 19).[69] ICCT, in that testimony, points out that gasoline direct injection, variable valve timing, variable valve list, and cooled EGR also improve both performance and efficiency; advanced transmissions have improved vehicle launch, better acceleration, and quieter operation on the highway in addition to improved fuel efficiency.

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[69] German, John (2016). "Statement of John German, Senior Fellow, International Council on Clean Transportation before the Subcommittee on Commerce, Manufacturing, and Trade and the Subcommittee on Energy and Power, Committee on Energy and Commerce, U.S. House of Representatives, Midterm Review and an Update on the Corporate Average Fuel Economy Program and Greenhouse Gas Emissions Standards for Motor Vehicles." http://docs.house.gov/meetings/IF/IF17/20160922/105350/HHRG-114-IF17-Wstate-GermanJ-20160922.pdf , accessed 11/8/2016.

As discussed in TSD Chapters 2.3 and 4.1, EPA continues to use a static reference case, in which we hold all vehicle characteristics, other than GHG emissions and cost, constant.[70] That is, we reject the idea suggested by Resources for the Future that it is appropriate to extrapolate trends in power over time in the reference case, and use estimated tradeoffs between fuel economy and power to estimate a fleet in the absence of the standards. We provide several reasons to justify our use of the static baseline. First, it is possible for automakers to continue to improve some other vehicle attributes, such as infotainment systems, in the absence of the standards. Second, EPA believes that the standards are contributing to innovation and adoption that would not have happened in the absence of the standards. In some cases, that innovation has contributed both to reduced GHG emissions and to improvements in other vehicle characteristics. For instance, Ford points out that the MY2015 F-150, with high-strength steel frame and high-strength, aluminum alloy body, provides better towing and hauling in addition to reduced GHG emissions. If that significant effort in lightweighting would not have happened in the absence of the standards, then the standards have led to all those improvements. Third, various researchers have conducted statistical analyses to estimate tradeoffs among fuel economy, power, and weight.[71] As discussed in detail in TSD Chapter 4.1.2, these studies appear to have statistical flaws that reduce their usefulness in projecting future trends. Chapter 2.3.3.2.1 of the TSD presents evidence that advanced technologies appear to have changed the relationship between acceleration and fuel economy. Fourth, EPA is not convinced that power would in fact continue to increase at the same pace over time in the absence of the standards. In a survey conducted for DOE's National Renewable Energy Laboratory, only 9 percent of respondents wanted more power in their vehicles; 66 percent were satisfied with current levels, 17 percent said that they don't care about power, and 1 percent wanted less power.[72] The Alliance of Automobile Manufacturers, in a survey of vehicle buyers in California and the Northeastern U.S., asked, "When buying or leasing a vehicle how important is the following factor to you?" Performance-related metrics, such as "Fun to drive" and "Has a powerful engine" scored between 2.99 and 3.35 on a scale from 1 ("Not at all") to 5 (One of the most), below reliability (4.4), safety (4.4), and fuel economy (3.9).[73] The Natural Resources Defense Council (NRDC) points out that the market shift from truck-based SUVs to car-based crossover utility vehicles suggests that automakers may also indicate less interest in performance than has previously been assumed. Indeed, zero-to-sixty acceleration time, another measure of performance, cannot decrease continually without hitting physically impossible speeds. In light of these concerns, EPA maintains the static baseline in its modeling.

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[70] Costs include any expenditures needed to maintain other vehicle attributes. For instance, downsizing an engine would reduce a vehicle's horsepower. The cost estimates include the cost of a turbocharger to bring performance back to the baseline level.

[71] Knittel, C. R. (2011). “Automobiles on Steroids: Product Attribute Trade-Offs and Technological Progress in the Automobile Sector.” American Economic Review 101(7): pp. 3368–3399, Docket EPA-HQ-OAR-2010-0799-11946; Klier, T. and Linn, J. (2016). “The Effect of Vehicle Fuel Economy Standards on Technology Adoption.” Journal of Public Economics 133: 41-63; McKenzie, D. and Heywood, J. B. (2015). “Quantifying efficiency technology improvements in U.S. cars from 1975-2009.” Applied Energy 157: 918-928; Wang, Y. (2016). “The Impact of CAFE Standards on Automobile Innovation in the US.” Working paper.

[72] National Renewable Energy Laboratory (2015). "Consumer Views towards Willingness to Pay, PEV Range, and Fuel Economy." ORC Study #724328, August 6-9, 2015.

[73] Bainwol, Mitch (2016). "Consumers and Fuel Economy." CAR Management Briefing Seminars, http://www.cargroup.org/assets/speakers/presentations/370/bainwol2.pdf , accessed 11/3/2016.

The Union of Concerned Scientists, NRDC, and American Council for an Energy-Efficient Economy take a very different stance that EPA should use the performance characteristics of the reference fleet from the MY2017-25 FRM. In their view, automakers could have used improvements in performance in the last few years instead to reduce GHG emissions; automakers themselves are increasing the costs of the standards by investing in performance. EPA instead is using the most recent baseline fleet to develop its reference fleet.

Achates Power, Blue-Green Alliance, Business for Innovative Climate and Energy Policy, Coalition for Clean Air, Exa Corporation, the National Association of Clean Air Agencies, the Northeast States for Coordinated Air Use Management, NRDC, and Environmental Entrepreneurs support the idea that the standards promote innovation. Toyota agrees with this possibility, but considers the program not to have succeeded in doing so. American Petroleum Institute and Manufacturers of Emission Controls Association (MECA) encourage EPA "to refrain from picking technology winners and losers." In response, we note that the standards are performance-based to avoid picking winners and losers. The Alliance of Automobile Manufacturers points out that the industry innovates in many ways. EPA agrees; it is a strength of the standards that automakers may respond (and have responded) in diverse ways. The Alliance raises concerns that patents may protect some innovations; EPA agrees that in principle patent protection may limit the application of certain technologies, but it does not appear to have limited availability of applications to date. Patent holders may license their innovations for others to use. The Alliance considers innovations in new features, such as connectivity, to compete with fuel efficiency for incremental customer spending. EPA disagrees that such features need to be traded off, because the efficiency technologies are the only features that provide fuel savings that pay for themselves. BorgWarner, Ford, Global Automakers, and MECA point out that program flexibilities such as averaging, banking, and trading encourage early compliance and broader adoption of new technologies, but express concerns that limits on off-cycle credits may limit innovation. As discussed in Section B.3.4 , below, EPA seeks verifiable emissions reductions for off-cycle credits to ensure reductions in GHG emissions.

Resources for the Future argues that EPA confuses innovation--development of new technologies--with adoption of existing technologies, and argues that existing research is based on adoption of existing technologies. It criticizes EPA for claiming that the standards promote innovation when they instead promote adoption. This is a puzzling argument, because the studies of these tradeoffs are not capable of distinguishing between innovation and adoption. In those studies, advances in technology are measured as the ability of vehicles, over time, to have simultaneous improvements in fuel economy, power, and weight; these studies cannot identify why those changes occur. EPA's technology and cost analysis is based primarily on technologies that already exist, with a cost adjustment for learning over time. As discussed in Section Appendix A , automakers are both developing new technologies and making wider use of existing efficiency technologies. Performance-based standards provide flexibility to automakers to choose technology combinations that best advance their product plans.

For these reasons, EPA has continued holding other vehicle attributes constant. As this discussion has shown, EPA agrees with some commenters that it is possible that the standards could lead to opportunity costs in terms of reduced power or other adversely affected vehicle attributes. These adverse effects are not a necessary consequence of the standards: EPA has included the costs of avoiding adverse effects in its estimates. At the same time, as in the case of the Ford F-150, the standards could induce major innovations that may be used in part to mitigate those opportunity costs, and that may in addition lead to ancillary benefits to consumers. If vehicle attributes do change in response to the standards, either as benefits or costs, it would be desirable to reflect these changes in the benefit-cost analysis of the standards. Measuring the net effect on consumer impacts requires estimates of the values of these attributes to consumers.

The most common sources of estimates of willingness to pay for these attributes are models, such as those discussed in Section B.1.3.4 , developed to understand vehicle purchase decisions. These studies quantitatively estimate the role of various vehicle characteristics, such as size, power, and fuel economy, in those purchase decisions. The parameters estimated for these characteristics can usually be used to derive estimates of the value–the willingness to pay (WTP)--of each attribute to consumers. It is common in this literature, though, for the researchers themselves not to have done the WTP calculation. In a 1988 study, Greene and Liu[74] reviewed the literature to that time; they found, “The dispersion of estimated attribute values both within and across models is striking,” varying by factors of 5 to 10 or more; for performance, they considered the variation “wild. from -$8 to $4,081 per 0.01 cubic inches per pound.” To our knowledge, there has not been a study since that time that has done a comprehensive review of consumers’ willingness to pay for vehicle attributes.[75]

To better understand the market implications of changes in other vehicle attributes, EPA has commissioned an assessment of the willingness to pay (WTP) for a wide range of vehicle attributes, such as fuel economy, performance, size, and comfort. The goal is to determine whether there are robust WTP values that could be used for monetizing at least some of the opportunity costs and ancillary benefits. This study estimates the WTP for attributes from published models of vehicle demand.[76] Though the results are not yet peer reviewed, and should thus be considered preliminary, they generally indicate a lack of consensus in the existing literature for WTP values. For instance, even after dropping a few extreme outliers, estimates of the WTP for a reduction in 0-to-60 acceleration time range from about -$1,000 to over $2,000 per second. See Chapter 4.1.5 of the TSD for more detail. Sources of variation include the time span of the data used in each study, the sources of the data, the methods used to estimate the effect of acceleration on demand, other characteristics included in each study, and the metric used for acceleration. For other attributes studied, including various measures of comfort, fuel type, size, range, and fuel cost, the variation is often wider. This high variation does not currently provide clear guidance for estimating the costs or benefits associated with changes in other vehicle attributes due to the standards.

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[74] Greene, David, and Jin-Tan Liu (1988). “Automotive Fuel Economy Improvements and Consumers’ Surplus.” *Transportation Research A* 22A(3): 203-218. Docket EPA-HQ-OAR-2010-0799-0703.

[75] Greene, David (2010). “How Consumers Value Fuel Economy: A Literature Review.” EPA-420-R-10-008, Docket EPA-HQ-OAR-2010-0799-0 conducted a review of consumers’ willingness to pay for one attribute, fuel economy, and found wide ranges of values.

[76] Greene, David, Anushah Hossein, and Robert Beach (2016). "Consumer Willingness to Pay for Vehicle Attributes: What is the Current State of Knowledge?" RTI International Final Report, Work Assignment 4-11, EPA Contract EP-C-11-045.

B.1.5 Consumer Response to Vehicles Subject to the Standards

B.1.5.1 Recent New Vehicles

B.1.5.1.1 Sales

One measure of consumer response to the vehicles subject to the standards is the effects of the standards on vehicle sales. As discussed in Section B.1.3.3 , it is difficult to separately identify the effects of the standards on vehicles sales from the effects of recovery from recession using currently available data and methods. It at least appears that the standards did not prevent recovery of auto sales from the recession, but it is not possible to say whether the standards helped or hindered that recovery.

B.1.5.1.2 Evaluations from Professional Auto Reviewers

Another way that EPA is examining the effects of the standards on new vehicles is through analysis of the evaluations that professional auto reviewers give to fuel-saving technologies.[77] Auto reviews are a readily available and public source of information about the advantages and disadvantages of new vehicle models. We have focused on professional automobile reviews because professional reviewers have experience evaluating vehicle technologies and are expected to identify any potential drawbacks to consumers (i.e., hidden costs) if they exist. Although reviewers may not respond to vehicle technologies in the same way that vehicle owners will, it seems reasonable to expect that, if there are significant problems for particular technologies, reviewers will comment on them.

Initially, EPA commissioned RTI International to conduct a content analysis of auto reviews for MY2014 vehicles from six major websites that conduct professional auto reviews: Automobile Magazine, Auto Trader, Car and Driver, Consumer Reports, Edmunds, and Motor Trend.[78] Content analysis is a research technique that breaks text into pre-defined sub-units that can be categorized and analyzed into specified definitional codes.[79] Staff at RTI read each auto review from a professional reviewer (reader reviews or comments were not included in the study) and coded each mention of specific fuel-saving technologies for whether the reviewer evaluated it as positive, negative, or neutral. In addition, they coded mentions of a number of operational characteristics, such as handling, acceleration, and noise. The initial dataset included

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[77] Helfand, Gloria, Michael McWilliams, Kevin Bolon, Lawrence Reichle, Mandy Sha, Amanda Smith, and Robert Beach (2016). “Searching for Hidden Costs: A Technology-Based Approach to the Energy Efficiency Gap in Light-Duty Vehicles.” Energy Policy 98: 590-606, http://dx.doi.org/10.1016/j.enpol.2016.09.014.

[78] Sha, Mandy, and Robert Beach (2015). “Content Analysis of Professional Automotive Reviews.” Final Report, Work Assignment 3-01, EPA Contract Number EP-C-11-045; Helfand, Gloria, Michael McWilliams, Kevin Bolon, Lawrence Reichle, Mandy Sha, Amanda Smith, and Robert Beach (2016). "Searching for Hidden Costs: A Technology-Based Approach to the Energy Efficiency Gap in Light-Duty Vehicles." Energy Policy 98: 590-606, http://dx.doi.org/10.1016/j.enpol.2016.09.014.

[79] There are many descriptions of content analysis and its evolution as a research methodology; see Helfand et al. (2016), footnote 77, for background and citations.

1023 reviews. After further review of the data, the final set includes 1,003 separate reviews, containing 3,535 separate evaluations of various fuel-saving technologies.[80]

Table B.1 shows the results aggregated to the review level.[81] For each technology, positive evaluations exceed negative evaluations. Indeed, in the aggregate, negative evaluations are less than 20 percent of the totals. Even the most negatively reviewed technologies–continuously variable transmissions (51 percent positive) and stop-start (59 percent positive)–have majority positive evaluations. These results suggest that it is possible to implement these technologies without significant hidden costs. The NAS report suggests a similar conclusion: "'It is not technology per se that generates new problems, but rather its integration and execution,' Neal Oddes, Director of Product Research and Analysis at J.D. Power, noted (Janes 2013), an observation that could be made for some of the fuel-saving technologies being launched today" (p. 9-21).

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[80] The initial dataset inadvertently contained reviews of 15 vehicles not subject to the standards, primarily medium-duty trucks that had not previously been eliminated. In addition, due to issuance of a notice of violation about the compliance of some Volkswagen diesel engines with emissions standards, we dropped 5 reviews of those vehicles.

[81] Each review could contain mentions of more than one technology, or even multiple mentions of the same technology. The review-level results aggregate all like mentions of a technology in one review. For instance, if a review contains 3 positive mentions of turbocharging, the review-level results count them as 1 positive mention. If the review contains 3 positive mentions and 1 negative mention, at the review level these are counted as 1 positive and 1 negative mention. The data were analyzed both at the level of individual codes, and aggregated to review. With the results very similar, we here focus on the review-level results. See Helfand et al. (2016), footnote 77, for more detail, including code-level results.

Table B.1 Efficiency Technology's Positive, Negative, or Neutral Evaluations by Auto Reviews

Efficiency Technology Categories		Coding Level	Negative		Neutral		Positive		Total
Active Air Dam		Active air dam	-	-	-	-	6	100%	6
Active Grill Shutters		Active grill shutters	-	-	-	-	1	100%	1
Active Ride Height		Active ride height	-	-	1	33%	2	67%	3
Electric Assist or Low Drag Brakes		Electric assist or low drag brakes	1	14%	3	43%	3	43%	7
Lighting - LED		Lighting-LED	1	5%	2	10%	17	85%	20
Low Rolling Resistance Tires		Low rolling resistance tires	4	24%	5	29%	8	47%	17
Mass Reduction		Mass reduction	-	-	9	12%	65	88%	74
Passive Aerodynamics		Passive aerodynamics	4	10%	7	18%	29	73%	40
Powertrain	Engine	Cylinder deactivation	1	3%	4	11%	30	86%	35
		Diesel	7	12%	9	15%	44	73%	60
		Electronic power steering	45	22%	42	20%	121	58%	208
		Full electric	2	9%	6	27%	14	64%	22
		GDI	6	9%	6	9%	54	82%	66
		General Engine	104	16%	95	15%	443	69%	642
		Hybrid	16	23%	10	14%	45	63%	71
		Plug-in hybrid electric	4	14%	6	21%	18	64%	28
		Stop-start	14	27%	7	14%	30	59%	51
		Turbo-charged	20	9%	23	10%	180	81%	223
	General Powertrain	General Powertrain	8	8%	19	18%	78	74%	105
	Transmission	CVT	35	31%	20	18%	57	51%	112
		DCT	16	24%	10	15%	42	62%	68
		General Transmission	30	18%	26	16%	108	66%	164
		High speed automatic	60	14%	81	20%	273	66%	414
		Total	378	16%	391	16%	1,668	68%	2,437

Further evaluation of the data involves looking at correlations between evaluations of each technology and a range of operational characteristics (handling, acceleration, noise, etc.). In particular, this evaluation assesses how the technologies are related to negative evaluations of these characteristics. If adoption of these technologies produces hidden costs (i.e. involves tradeoffs with other vehicle attributes valued by consumers), the research premise is that the technologies should be positively correlated with negative evaluations of operational characteristics. The results do not reveal much evidence of such correlation. When correlations exist, often they are not statistically robust; their statistical significances change depending on what covariates are considered. For instance, seven technologies have at least one statistically significant correlation with the characteristic of acceleration capability in six versions of the model, but only one (continuously variable transmissions) has a statistically significant correlation across all six model versions (its existence is correlated with negative effects on acceleration capability). At the same time, in five of six models, the existence of stop-start technology is significantly associated with reduced probability of negative evaluations of acceleration capability. Indeed, across all characteristics, there are more instances of fuel-saving technologies associated with lower probabilities of negative evaluations of characteristics than with increased negative evaluations. In addition, negative evaluations of characteristics are more likely if the technology itself has a negative evaluation--in other words, it seems that a bad implementation of the technology is associated with bad characteristics, rather than there being some inherent problem in the technology. If it is possible to implement a technology to avoid hidden costs, as these data suggest, then automakers should be able to improve implementation over time; in such a circumstance, any problems with hidden costs may be temporary.

Since then, EPA has repeated this analysis for MY2015 vehicles.[82] This analysis used the same method as the MY2014 analysis, with the exception that it included an additional website, Cars.com, which has a substantial number of viewers. Table B.2 reports the results aggregated to the review level for MY2015 vehicles. Similar to the results of MY2014 vehicles, positive evaluations exceed negative evaluation for each technology. Some technologies have limited samples in MY2014 or MY2015 data, such as plug-in hybrid electric, full electric, passive aerodynamics, and low resistance tires, and thus the results might not be well represented. We combine the two datasets and report the results aggregated to the review level in Table B.3. Given a larger sample size, the results are more creditable for those technologies that had small sample size in each model year. The results indicate that, for all technologies reviewed, positive evaluations outnumber negative evaluations, and the conclusion is consistent to the results only using MY2014 data.

As with the MY2014 data, we further analyzed the data to look for associations between operational characteristics and the technologies. In particular, we examined whether negative evaluations of operational characteristics--hidden costs--are correlated with the presence of the efficiency technologies. Table B.4 summarizes, at a very high level, the results of numerous tests of the relationship between each technology and each operational characteristic. In the table, a positive, statistically significant coefficient indicates that the existence of a technology is correlated with the likelihood of hidden costs; a negative coefficient indicates that the presence of the technology is associated with a reduced probability of hidden costs. As the row labels show, we explored different controls on the regressions, to check for consistency of results. The results indicate that, out of 462 possible combinations of 22 operational characteristics and 21 technologies, only about 25 percent or fewer of the combinations have a statistically significant relationship.[83] This is not surprising; for instance, LED lights are not expected to be associated with handling or acceleration. Of the roughly 100 statistically significant coefficients across the

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[82] Sha, Mandy, and Robert Beach (May 2016). "Content Analysis of Professional Automotive Reviews: Model Year 2015, Work Assignment 4-08 Final Report." RTI International; Huang, Hsing-Hsiang, and Gloria Helfand (2016). "Content Analysis of Auto Reviews using MY2014 and MY2015 Data." U.S. EPA Office of Transportation and Air Quality, Memorandum to Docket.

[83] We exclude the General Engine, Transmission, and Powertrain categories because they are not specifically fuel-saving technologies.

different specifications, about 4 out of 5 are negative, indicating that the technology is associated with a lower probability of hidden costs. In other words, the probability of obtaining a negative evaluation of operational characteristics is lower in the presence of fuel-saving technologies, is substantially greater than fuel-saving technologies being correlated with increased likelihood of hidden costs. That is, the use of fuel-saving technologies is more consistently associated with positive or neutral evaluations of characteristics than with negative characteristics.

TSD Chapter 4.2.2 provides greater detail about these combined results.

Table B.2 Efficiency Technology's Positive, Negative, or Neutral Evaluations by Auto Reviews for MY2015 Vehicles

Efficiency Technology Categories		Coding Level	Negative		Neutral		Positive		Total
Fuel Cell		Fuel Cell	-	-	-	-	1	100%	1
Active Air Dam		Active air dam	0	-	0	-	0	-	0
Active Grill Shutters		Active grill shutters	1	14%	0	0%	6	86%	7
Active Ride Height		Active ride height	0	-	0	-	0	-	0
Electric Assist or Low Drag Brakes		Electric assist or low drag brakes	0	0%	0	0%	2	100%	2
Lighting - LED		Lighting-LED	0	0%	1	4%	25	96%	26
Low Rolling Resistance Tires		Low rolling resistance tires	4	31%	1	8%	8	62%	13
Mass Reduction		Mass reduction	3	6%	2	4%	43	90%	48
Passive Aerodynamics		Passive aerodynamics	2	11%	0	0%	17	89%	19
Powertrain	Engine	Cylinder deactivation	4	16%	3	12%	18	72%	25
		Diesel	5	28%	2	11%	11	61%	18
		Electronic power steering	22	14%	19	12%	116	74%	157
		Full electric	0	0%	3	15%	17	85%	20
		GDI	4	6%	6	9%	55	85%	65
		General Engine	117	16%	84	12%	509	72%	710
		Hybrid	10	21%	5	11%	32	68%	47
		Plug-in hybrid electric	4	22%	3	17%	11	61%	18
		Stop-start	15	31%	9	19%	24	50%	48
		Turbo-charged	43	13%	35	10%	264	77%	342
	General Powertrain	General Powertrain	27	22%	13	10%	84	68%	124
	Transmission	CVT	38	30%	14	11%	75	59%	127
		DCT	18	17%	10	10%	77	73%	105
		General Transmission	50	33%	24	16%	78	51%	152
		High speed automatic	96	20%	76	16%	310	64%	482
		Total	463	18%	310	12%	1,783	70%	2,556

Table B.3 Efficiency Technology's Positive, Negative, or Neutral Evaluations by Auto Reviews for Combined MY2014-2015 Data

Efficiency Technology Categories		Coding Level	Negative		Neutral		Positive		Total
Fuel Cell		Fuel Cell	0	0%	0	0%	1	100%	1
Active Air Dam		Active air dam	0	0%	0	0%	6	100%	6
Active Grill Shutters		Active grill shutters	1	13%	0	0%	7	88%	8
Active Ride Height		Active ride height	0	0%	1	33%	2	67%	3
Electric Assist or Low Drag Brakes		Electric assist or low drag brakes	1	11%	3	33%	5	56%	9
Lighting - LED		Lighting-LED	1	2%	3	7%	42	91%	46
Low Rolling Resistance Tires		Low rolling resistance tires	8	27%	6	20%	16	53%	30
Mass Reduction		Mass reduction	3	2%	11	9%	108	89%	122
Passive Aerodynamics		Passive aerodynamics	6	10%	7	12%	46	78%	59
Powertrain	Engine	Cylinder deactivation	5	8%	7	12%	48	80%	60
		Diesel	12	15%	11	14%	55	71%	78
		Electronic power steering	67	18%	61	17%	237	65%	365
		Full electric	2	5%	9	21%	31	74%	42
		GDI	10	8%	12	9%	109	83%	131
		General Engine	221	16%	179	13%	952	70%	1,352
		Hybrid	26	22%	15	13%	77	65%	118
		Plug-in hybrid electric	8	17%	9	20%	29	63%	46
		Stop-start	29	29%	16	16%	54	55%	99
		Turbo-charged	63	11%	58	10%	444	79%	565
	General Powertrain	General Powertrain	35	15%	32	14%	162	71%	229
	Transmission	CVT	73	31%	34	14%	132	55%	239
		DCT	34	20%	20	12%	119	69%	173
		General Transmission	80	25%	50	16%	186	59%	316
		High speed automatic	156	17%	157	18%	583	65%	896
		Total	841	17%	701	14%	3,451	69%	4,993

Table B.4 Summary of Estimation Results Using Linear Probability Model for MY2014-15 Data using Different Specification

Specification (Dependent variable: Indicator variable = 1 if obtaining negative evaluation on an operational characteristics; otherwise 0)	Number of Statistically Significant Positive Coefficients	Number of Statistically Significant Negative Coefficients
MY2014 data with class, make, and website fixed effects	15	62
MY2015 data with class, make, and website fixed effects	19	79
Combined data with class, make, and website fixed effects	19	95
Combined data with class, make, website, year, website-by-year, and class-by-year fixed effects	24	81
Combined data with class, make, website, year, website-by-year, and make-by-year fixed effects	25	83
Combined data with class, make, website, year, website-by-year, class-by-year, and make-by-year fixed effects	24	75

These findings on the relationship of technologies to hidden costs or hidden benefits have some limitations. They appear sensitive to how the analysis is done, and the magnitudes are often small. Perhaps more importantly, it is not possible to determine whether the technologies themselves cause these effects, or whether these associations are due to the vehicles in which the technologies are installed. For instance, perhaps stop-start was put in vehicles that would have had better acceleration even without it. As a result, this research is not able to disprove the possibility of hidden costs (or benefits).

In addition, this research cannot determine what, if any, additional costs may have been incurred to mitigate problems with the technologies. It is possible that manufacturers, knowing of potential tradeoffs (or synergies) associated with a particular technology, modified more than just the fuel saving aspect of the vehicle. For instance, if it is well known that a particular fuel efficient technology reduces power, an auto manufacturer may add features to the vehicle to neutralize this tradeoff before rolling the vehicle out to the consumer. As previously stated, EPA has included in its costs the estimated costs of maintaining vehicle performance and utility. We have not included estimates of effects on other attributes, either positive or negative, in part because of the difficulties of identifying and measuring these effects, and in part due to the wide ranges of estimates for the values of other attributes.

Note that this research examines how professional auto reviewers respond to these technologies, rather than how vehicle buyers respond. If the public tends to be more critical than the reviewers, these results may understate negative consumer response. In addition, reviewers spend much less time with any one vehicle than a vehicle owner; something that a reviewer may not notice in a few hours of test driving may become significant to an owner over time. On the other hand, we expect professional auto reviewers, as experts, to be aware of vehicle characteristics and technologies more than the general public. Thus, consumer response to these technologies may be either more or less critical than reviewer response.

In comments on the Draft TAR, Global Automakers suggests that it is "without support" that implementation may be the cause of poor evaluations. We disagree that the finding lacks support. As discussed in Helfand et al. (2016), we base this finding on two factors. First, the majority of uses of each technology received positive evaluations. It thus seems possible to implement each of technologies well. Secondly, as discussed above, we looked for correlations between operational characteristics and the existence of each technology, as well as correlations between operational characteristics and badly reviewed technologies. The latter had more correlations. One interpretation of this result is that poorly implemented technologies are associated with more problems than the existence of the technology. In addition, TSD Chapter 4.2.2 provides evaluation results for each technology for each manufacturer; the figures show that the proportions of negative evaluations for specified technologies vary across manufacturers. For instance, for stop-start technology, 50 percent and 36 percent of the evaluations are negative for Subaru and BMW, respectively, while Chevrolet, Ford, Honda, and Toyota have zero negative evaluations. These findings suggest, though they do not prove, differences in implementation across manufacturers. As Helfand et al. (2016) and we emphasize, this work is not conclusive. We nevertheless believe that, if there were technologies with significant inherent problems, this method would have found evidence of those problems.

The Alliance of Automobile Manufacturers raises several questions about the analysis, which we respond to here:

- Do the reviewers represent customers' views of the technologies? As discussed above, we do not have evidence of the relationship between customers' and reviewers' views of the technologies, except that potential vehicle buyers use these websites. As discussed in Helfand et al. (2016), the sites chosen were specifically those that people use frequently; if the sites do not provide insights that potential buyers consider useful, they would probably not be used so frequently. We note that automakers cite some of the same sources in their marketing materials: for instance, Chevrolet, on its website, positions several of its vehicles in front of a wall with awards from companies including Car & Driver;[84] Ford points out its awards from Edmunds.com;[85] Fiat Chrysler highlights that AutoTrader.com named its MY2015 Chrysler 200 a "Must Test Drive vehicle."[86] We expect that these reviews help potential buyers form expectations about the vehicles.

- Do the reviews disproportionately reflect performance vehicles? Helfand et al. (2016) discusses the vehicles in the reviews. At the make level, the number of reviews is approximately proportional to the number of models offered, but it is not proportional to sales. In the regression analyses, we controlled for make, vehicle class, and website (and year, in the merged dataset), in order to avoid the effects of those characteristics on the results.

- For a number of the technologies, the sample sizes were small, which may reduce the ability to identify statistically significant relationships between technologies and operational characteristics. We agree that small sample sizes make it harder to identify such relationships. In part for that reason, as discussed above, we conducted a new analysis for MY2015 vehicles. In the pooled sample, 46 percent of

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[84] "Chevy's Innovative Vehicle Features." http://www.chevrolet.com/features-and-awards.html, accessed 10/17/2016.

[85] "Ford Mustang, F-150 Take Home Most Popular on Edmunds.com Awards." https://media.ford.com/content/fordmedia/fna/us/en/news/2016/01/04/ford-mustang-f150-take-home-most-popular-on-edmunds-com.html , accessed 10/17/2016.

[86] "Chrysler 200 Ratings." http://www.chrysler.com/en/awards/ , accessed 11/3/2016.

technologies have sample sizes greater than 100 evaluations (which, of course, is itself an arbitrary value); almost 80 percent of technologies have more than 30 evaluations. If some technologies had problems inherent in their use, we expect that these sample sizes would be sufficient to identify them.

- Are there still problems if a large proportion, though less than 50 percent, of evaluations are negative? We agree that bad reviews of any vehicle technology, or vehicle, suggest problems that automakers may need to address. The question that this study raised was whether such problems are unavoidable, or whether it is possible for automakers to fix the problems. Our analysis suggests that it is possible to use any of the technologies in a way that achieves positive or neutral ratings. We would expect this result: automakers would be expected to minimize problems, and to use technologies that work well in each model. Though some specific vehicles may have problems yet to be solved, the findings for other vehicles suggest that it is possible to solve them.
- With the standards increasing in stringency each year, might lead times be insufficient to vet or improve technologies, and for consumers to accept the technologies? As discussed in Appendix Section C.1 , EPA projects that the standards may be met mostly using advanced gasoline engines, which reduces problems with consumer acceptance since most of these technologies are already in some portion of the fleet today, and will become more widespread by 2025. The standards were developed taking lead time into consideration.

Fiat Chrysler (FCA) mischaracterizes the study as citing "automotive journalists" writing "automotive enthusiast articles." As discussed in Helfand et al. (2016), the analysis specifically used auto reviews (not news stories) from websites that received high numbers of views. That article discusses the benefits and limitations of this approach. In addition to raising the Alliance's questions about whether the reviewers' opinions reflect those of vehicle owners and a possible emphasis on performance vehicles (see above responses), FCA points out that the analysis does not indicate magnitude of the problem. As discussed in Helfand et al., this was an analytical choice, to reduce any bias that might result from different evaluation styles of reviewers. Some reviewers may be more enthusiastic in style than others; by limiting coding to positive, neutral, and negative, the study reduced the influence of different writing styles. We agree that the study does not indicate magnitudes. Finally, FCA points out that the negative reviews could be associated with various operational characteristics, such as feel or performance. We agree; Helfand et al. (2016) details its analysis of associations between the technologies and the operational characteristics. It found more positive associations with the existence of the technologies than negative associations, and there were more negative associations with negatively reviewed technologies than with the existence of the technologies. The above discussion provides similar results for the pooled MY2014-2015 data. As noted, Helfand et al. use this evidence to suggest that it is possible to implement these technologies well. If it is possible, the authors expect that automakers will improve their implementation over time.

B.1.5.1.3 Consumer Responses to New Vehicles

Another potential source of information on consumer response to vehicles subject to the GHG and fuel economy standards can come from survey research on consumer response to new vehicles. Consumers Union analyzed the relationship between its tested fuel economy values and responses on consumer satisfaction from Consumer Reports (CR) members who owned a tested vehicle.[87] It finds a statistically significant positive correlation between rated fuel economy and overall satisfaction with the vehicles, controlling for year, mechanical problems, price, acceleration, and CR's Road Test Score. It also finds a positive correlation between individually reported fuel economy and overall satisfaction.

Some market research firms conduct surveys of new vehicle buyers. These surveys, typically conducted a few months after purchase of a new vehicle, ask the buyer's views on a wide range of vehicle attributes. Several commenters encourage EPA to utilize such materials in its evaluation. Toyota, the Alliance of Automobile Manufacturers, and Fiat Chrysler specifically claim, incorrectly, that one company is endorsed by the NAS; instead, NAS commented that, "The most reliable information about consumer preferences comes from surveys of drivers who have made a recent new car purchase," and cite the one company as an example.[88] The Alliance, Global Automakers, the National Automobile Dealers Association, and Fiat Chrysler cite findings from Strategic Vision, one company that conducts these surveys, that fuel economy may not be the primary consideration in consumers' vehicle purchase decisions. While it is likely that lower fuel prices are a major factor in this result, it is possible that standards have also contributed to this finding: the vehicles with attributes that they seek are now more efficient. The National Academy of Sciences, in reviewing a number of surveys of the role of fuel economy in vehicle purchases, observes that "while consumers value fuel economy, they do so in the context of other attributes they also value."[89] As discussed in Section B.1.2 , EPA and the NAS find that the role of fuel economy in consumer purchase decisions is not well understood. Though these commenters appear to have access to at least one of these sets of survey results, they do not otherwise provide insights from these results on consumer response to vehicles subject to the standards.

B.1.5.2 MY2022-25 Vehicles

To date, we have not found evidence that the standards have posed significant obstacles to consumer acceptance: vehicle sales are very strong, and we have not found evidence of inherent "hidden costs" of the technologies to vehicles, at the same time that the auto industry as a whole has over-complied with the standards (see the Proposed Determination document Section I.A).[90] As the standards continue to become more stringent, though, there will be both greater application of existing technologies to new vehicles, and new or improved technologies are

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[87] Hazel, Malcolm, Michael Saccucci, Keith Newsom-Stewart, and Martin Romm (2016). "Investigation of Relationship between Fuel Economy and Owner Satisfaction." Consumers Union, http://consumersunion.org/research/investigation-of-relationship-between-fuel-economy-and-owner-satisfaction/ , accessed 11/3/2016.

[88] National Research Council (2015). Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles. Washington, D.C.: The National Academies Press, 9-26.

[89] National Research Council (2015). Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles. Washington, D.C.: The National Academies Press, 9-28.

[90] Design elements of program, such as targeting emissions rather than specific technologies, averaging and banking credits, and allowing credit trades, are intended to and are expected to have facilitated compliance by providing manufacturers with great flexibility in meeting the standards.

likely to be developed. As discussed in Section B.1.3.2.3 and TSD Chapter 4.1, these standards themselves may be contributing to innovation that would not have happened in their absence. As a result, it is difficult to extrapolate to future technologies from findings related to existing ones.

There is, of course, uncertainty about which technologies will be necessary (or which will be selected by individual OEMs) to achieve the MY2022-25 standards. In SectionC.1.1.3 , EPA projects that the standards can be achieved primarily with gasoline vehicles; it estimates only about 2 percent penetration of strong hybrids, 2 percent of plug-in hybrid-electric vehicles, and 3 percent of battery electric vehicles (BEVs). The NAS also expects the spark-ignition gasoline engine to dominate the auto market through, and beyond, 2025.[91] For these vehicles, the effects of the standards on consumer acceptance depend on the costs, effectiveness, and potential tradeoffs or synergies of those technologies with other attributes; there is already an established infrastructure for fuel availability. If the standards can be achieved primarily with greater penetration of existing technologies, we have no evidence of significant problems for consumer acceptance. On the other hand, if the standards can be achieved only with increased utilization of new technologies, these new technologies could raise the possibility of new challenges.

As discussed in Appendix Section Appendix A , many of the automakers expressed concern in their comments on the Draft TAR that more electrification will be needed than EPA estimated. They point out that sales of hybrid (HEV) and plug-in electric vehicles (PEV) has dropped with current low gasoline prices. With gasoline prices not expected to rise rapidly in the time frame of the Midterm Evaluation, they are concerned that they will not be able to sell the vehicles needed to meet the standards. Tesla, International Council on Clean Transportation, Nextgen Climate America, and Faraday Future, in contrast, suggest that consumer acceptance of electrified vehicles is rising rapidly, especially with longer-range PEVs becoming less expensive. Tesla suggests that EPA should tighten the standards, to encourage both advanced gasoline technologies and PEVs. Faraday Future and Consumer Federation of America cite survey evidence that interest is growing in PEVs, especially among young people. The International Council on Clean Transportation points out that the prospects for PEVs have improved in recent years, and that many companies are deploying this technology. Nextgen Climate America says that PEVs can offer greater benefits than assumed in the Draft TAR. The National Association of Clean Air Agencies points to rapid growth in sales of hybrid and electric vehicles in the states that have adopted California's Zero Emission Vehicle program, as well as other states.[92]

Section IV.3 of the Proposed Determination document and Section C.1.1.3 finds, consistent with the NAS and the Draft TAR, that only low levels of electrification are needed to meet the standards. The standards give automakers flexibility in how to meet the standards; they may choose more electrification than EPA projects, or they may use advanced conventional gasoline technology and avoid many of the concerns with a change to electrified vehicles.

Some auto industry comments argue that reduced sales of HEVs in response to lower fuel prices reflect the difficulty of meeting the standards. As Section Appendix A discusses, many gasoline technologies are reducing fuel consumption and GHG emissions without the use of

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[91] National Research Council (2015). Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles. Washington, D.C.: The National Academies Press, p. S-4.

[92] Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont have adopted the California Zero Emission Vehicle program.

strong hybrid technology; indeed, some conventional vehicles have fuel economy and GHG emissions approaching the levels of HEVs. Moreover, thus far in the first four years of the program, the industry has outperformed the standards, as summarized in the Proposed Determination Document Section I.A, and did so with minimal levels of electrification.

EPA has, however, carefully analyzed the issue of consumer acceptance of electrified vehicles. The following discussion focuses on consumer acceptance of PEVs (and fuel-cell electric vehicles, FCEVs) in particular because they require different fueling infrastructures. As noted above, some states, led by California, are requiring greater use of PEVs and FCEVs for meeting state air quality and greenhouse gas targets, and these vehicles are also included in automaker fleets that are subject to the National Program. If BEVs become a more important part of the compliance strategy for the 2022-2025 standards, then their unique features--in particular, the need for infrastructure and the associated concerns over vehicle range, as well as differences (many positive) in other attributes--are likely to have an effect on consumer acceptance.

The National Program standards are performance-based; there is no mandate under the National Program for any manufacturer to use any particular kind of technology, or for any consumer to choose, any particular kind of vehicle. If the variety of vehicles in the conventional fleet does not shrink, the availability of PEVs should not reduce consumer welfare compared to a fleet with no PEVs: increasing options should not reduce consumer well-being, because other existing options still are available. An individual consumer will buy a PEV only if the price and characteristics of the vehicle make it more attractive to her than other vehicles. Global Automakers points out the "unprecedented range" of currently available fuel-efficient vehicles, including conventional and advanced technologies. Already, many current PEV options are versions of gasoline-only vehicles, for example, the Fiat 500e, all of Ford's PEV products, and the Volkswagen e-Golf. The forthcoming Hyundai Ioniq will be offered as a conventional hybrid, plug-in hybrid, and all-battery electric vehicle, allowing consumers to choose the degree of electrification best suited to their needs. Similarly, Mercedes, Volvo, and BMW are offering plug-in hybrid versions of existing and new models.

On the other hand, if the only compliance path available to automakers involves more use of PEVs than markets would normally support (in the absence of government incentives), then achieving the standards may lead automakers and dealers to encourage the market for PEVs by providing incentives for PEV purchase sufficient to meet the standards. This encouragement can come in various forms--for instance, through marketing and advertising, through sales incentives, or through increased education about PEVs to potential buyers to increase consumer familiarity with the technology. Automakers may also cross-subsidize sales as they have long been able to do to meet fleet average standards; in this case using higher prices on conventional vehicles to support lower prices on PEVs, to increase sales of PEVs relative to gasoline vehicles beyond levels that markets would support in the absence of the standards. Cross-subsidization would be expected to reduce auto industry profits. Global Automakers commented that it considers cross-subsidization infeasible. The Center for Biological Diversity, on the other hand, in noting market shifts toward increased truck/SUV sales, states that "light trucks are the most profitable and have a wide profit margin," which suggests that automakers already use different pricing strategies for different segments.

If consumers are willing to purchase PEVs (and other low-GHG-emitting vehicles) at prices that provide adequate profits to manufacturers, then consumer acceptance is sufficient to maintain a functioning auto market. As discussed in Chapter 3.1.5 of the Draft TAR, PEVs were estimated to be about 1.1 percent of MY2015 sales. Chapters 2.2.4.4.5 and 2.2.4.4.6 of the TSD discusses these technologies and the technological advances being made. As those chapters relate, the PEV market is evolving rapidly, with expected increases in model diversity, vehicle range, decreased costs, and expansion of infrastructure (see Section B.3.2). Although PEV range is often cited as a concern for consumer acceptance, it should be noted that PEVs have some desirable characteristics relative to gasoline vehicles, including higher low end torque, potentially higher acceleration, lower operating costs, and the convenience of refueling by plugging in at home.[93] Consumer acceptance of these vehicles will depend on the degree of all these factors, plus the differences in attributes, both positive and negative, of PEVs relative to gasoline vehicles. Additionally, many automakers have announced moderately priced BEVs with longer ranges, and various public and/or private initiatives continue to increase investments in public and workplace infrastructure that will further alleviate concerns about range.

While concerns over range and cost are often cited as primary obstacles to PEV adoption, lack of awareness and understanding of PEVs, perhaps including misunderstanding, itself creates another barrier to adoption.[94] A 2015 survey by the National Renewable Energy Laboratory (NREL) of over 1,000 U.S. households found that less than half of the respondents could name a specific PEV model, despite being available on the market for over four years.[95] Using this same measure, awareness levels were even lower in a 2015 University of California, Davis survey of 5,600 households that purchased a new vehicle after 2008.[96]

The National Academy of Sciences Committee on Overcoming Barriers to Electric-Vehicle Deployment[97] notes that many people consider PEVs, as new technologies, to involve uncertainty and risk compared to gasoline vehicles, and thus are hesitant to consider them. It cites as barriers "the limited variety and availability of PEVs; misunderstandings concerning range of PEVs; difficulties in understanding electricity consumption, calculating fuel costs, and determining charging infrastructure needs; complexities of installing home charging; difficulties in determining the 'greenness' of the vehicle; lack of information on incentives; and lack of knowledge of unique PEV benefits" (p. 47).

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[93] The Tesla Model S, an all-electric vehicle, for instance, has regularly been achieving top ratings from standard auto reviewers for its handling and power. DeMorro, Christopher (2015). "How Many Awards Has Tesla Won? This Infographic Tells Us. Clean Technical" http://cleantechnica.com/2015/02/18/many-awards-tesla-won-infographic-tells-us/.

[94] Consumer Federation of America (2015). "Knowledge Affects Consumer Interest in EVs, New EVs Guide to Address Info Gap." http://consumerfed.org/press_release/knowledge-affects-consumer-interest-in-evs-new-evs-guide-to-address-info-gap/ , accessed 3/15/16.

[95] Singer, Mark (2016). "Consumer Views on Plug-In Electric Vehicles -- National Benchmark Report." U.S. Department of Energy, National Renewable Energy Laboratory Technical Report NREL/TP-5400-65279, http://www.afdc.energy.gov/uploads/publication/consumer_views_pev_benchmark.pdf.

[96] K. Kurani, N. Caperello, J. TyreeHageman; New Car Buyers' Valuation of Zero-Emission Vehicles: California, March 2016, http://www.arb.ca.gov/research/apr/past/12-332.pdf.

[97] National Research Council (2015). Overcoming Barriers to Deployment of Plug-In Electric Vehicles. Washington, D.C.: National Academies Press.

Some studies suggest that experience with the technology increases acceptance.[98] Consumer Federation of America cites survey evidence that people who know more about PEVs are more likely to express an intention to purchase. Yet, if people view PEVs as risky and are thus reluctant to try them, then it will be difficult for them to gain experience that would make them more comfortable with the technology.

The NAS Committee discusses the role of auto dealers in helping consumers to understand PEVs. It notes PEV buyers' dissatisfaction with the dealer experience, greater than that of buyers of conventional vehicles.[99] It cites evidence that salespeople are not very knowledgeable about PEVs, and may not get adequate financial incentives for the extra time that PEV buyers may require. Many dealers have no or few PEVs in their stock. At most dealerships the explanation for not having PEVs in stock is "high demand" for the vehicles; the second-most common explanation, in contrast, is a "lack of consumer interest" (p. 52). These problems with consumers' experiences with PEV dealers may contribute to the slow adoption of PEVs in the market.

For a small segment of the public, PEVs already are suitable for their purposes. As the technology of PEVs evolves, especially as range and fueling infrastructure expand, it is likely that a larger segment could find PEVs suitable. As the NAS Committee notes, these issues arise with adoption and diffusion of many new technologies, and are not unique to PEVs. Overcoming these barriers, it argues, will require both public policy incentives and methods to promote consumer experience with them. As noted, some research suggests that some perceived barriers, such as concerns over charging, may become smaller with experience, while some perceived advantages may be strengthened.[100] Thus, consumer acceptance of PEVs may depend, not only on technological advances, but also on the feedback loop associated with other consumers purchasing PEVs.

B.1.6 Impacts of the Standards on Vehicle Affordability

Because the standards are expected to increase the up-front costs of new vehicles, with the fuel savings that recover those costs coming over time, questions have arisen in comments about the effects of the standards on affordability. EPA presented discussions of affordability in both the 2012 FRM (77 FR 62950-2) and in the Draft TAR (Chapter 6.5). FCA claims that EPA has not defined affordability. The TSD, Chapter 4.3.1, presents an extensive literature review on

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[98] Buhler, Franziska, Peter Cocron, Isabel Neumann, Thomas Franke, and Josef F. Krems (2014). "Is EV Experience Related to EV Acceptance? Results from a German Field Study." Transportation Research Part F 25: 34-49; Dudenhoffer (2013). "Why Electric Vehicles Failed." Journal of Management Control 24:95-124; Singer, Mark (2016). Consumer Views on Plug-in Electric Vehicles -- National Benchmark Report. National Renewable Energy Laboratory Technical Report NREL/TP-5400-65279.

[99] Cahill, E., J. Davies-Shawhyde, and T. Turrentine. 2014. “Zero-emission Vehicles and Retail Innovation in the U.S. Automotive Sector: An Exploration of the Consumer Purchase Experience for Plug-in Electric Vehicles.” University of California, Davis Institute of Transportation Studies Working Paper, August 2014, cited in National Research Council (2015). Overcoming Barriers to Deployment of Plug-In Electric Vehicles. Washington, D.C.: National Academies Press.

[100] Buhler, Franziska, Peter Cocron, Isabel Neumann, Thomas Franke, and Josef F. Krems (2014). "Is EV Experience Related to EV Acceptance? Results from a German Field Study." Transportation Research Part F 25: 34-49.

affordability; as that discussion shows, affordability is not a well-defined concept in existing literature. To make its examination more concrete, EPA has focused on four aspects of affordability: the effects of the standards on lower-income households, on the used vehicle market, on whether access to credit may limit consumers' ability to purchase new vehicles, and on the availability of low-priced vehicles. Further detail may be found in the TSD, Chapter 4.3.

B.1.6.1 Effects on Lower-Income Households

We begin by examining the effects of the standards separately for lower- and higher-income households. Some commenters argue that the standards are regressive--that is, they have more severe impacts on low-income households than on higher-income households--while others argue that the standards have the opposite effect (i.e., they are progressive). The Alliance of Automobile Manufacturers (Alliance) and the National Automobile Dealers Association (NADA) cite Jacobsen (2013) for the regressivity of the standards.[101] Jacobsen's finding of regressivity is based on a flat standard (i.e., not an attribute-based standard); because a flat standard provides incentives for small, efficient vehicles, lower-income households have lower benefits because vehicles are smaller than they would otherwise desire. On the other hand, comments from Levinson and Killeen at Georgetown University argue that the footprint-based standards are more regressive than flat standards because they provide incentives for bigger, more expensive vehicles. Unlike Jacobsen, the evidence offered by Levinson and Killeen does not consider consumer tastes for larger vehicles. These results, combined, suggest that the footprint-based standard, which is intended to maintain fleet size diversity valued by consumers, may mitigate any regressivity of the standards.

In contrast, Greene and Welch at the University of Tennessee provide an analysis indicating that the standards are progressive--that is, they help low-income households more than they help higher-income households.[102] Using Consumer Expenditure Survey data, they find that fuel economy improvements reduced expenditures on fuel for all income groups. Though higher-income groups benefit more in absolute expenditures, lower-income households benefit more as a percent of income. Similarly, they find, when the costs of fuel-saving technology are included, that all income groups gain from the technologies; savings relative to income decreases, indicating progressivity; and the highest total dollar savings go to middle-income households. They do not consider these results definitive. Consumer Federation of America also finds that lower income households benefit more than average consumers, not only because operating costs are more important than purchase price in their total costs of driving, but also because they live in areas most affected by the environmental and public health effects of driving. We note that these standards only indirectly affect conventional vehicle emissions, through the rebound effect and through reductions in refinery emissions.

The Alliance points out the importance of access to transportation for low-income households for economic mobility. EPA agrees this is an important issue. At the same time, as discussed in the TSD Chapter 4.3.1, there is no commonly accepted definition of an acceptable level of access

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[101] Jacobsen, Mark (2013). "Evaluating U.S. Fuel Economy Standards in a Model with Producer and Household Heterogeneity." American Economic Journal: Economic Policy 5(2): 148-187.

[102] Greene, David, and Jilleah Welch (2016). "The Impact of Increased Fuel Economy for Light-Duty Vehicles on the Distribution of Income in the United States." University of Tennessee Baker Center Report 5:16, Docket EPA-HQ-OAR-2015-0827-4311.

to transportation to which everyone should be entitled. Access to transportation does not only involve vehicles; it also may involve access to housing in locations with jobs, mass transit, and other forms of mobility.

We use the Consumer Expenditure Survey for the years 2007-2015 in our analysis of this issue. For details on the analysis, including the weighting procedures, see the TSD Chapter 4.3.3. The income variable we examine is total household income before taxes. In the Draft TAR, we used after-tax income; we now believe it is more appropriate to use before-tax income because before-tax income is more typically used in analyses involving the CES data, and because the after-tax income series changed definitions during the years of our analysis (see TSD Chapter 4.3.3). We classify households with before-tax incomes below the weighted median as "lower income," and the other half of households are considered "higher income." For example, the weighted median in 2015 was $50,000, in 2015$.

As we pointed out in the Draft TAR (Chapter 6.5.1), lower-income households are not the primary market for new vehicles. Figure B.2 shows expenditures on new vehicles for lower-income households, as well as for higher-income households; it also includes median before-tax income. Lower-income households spend far less on new vehicles than do higher-income households. Greene and Welch (2016), using income quintiles, find similarly that lower-income households spend less on new (and used) vehicles than higher-income households.[103]

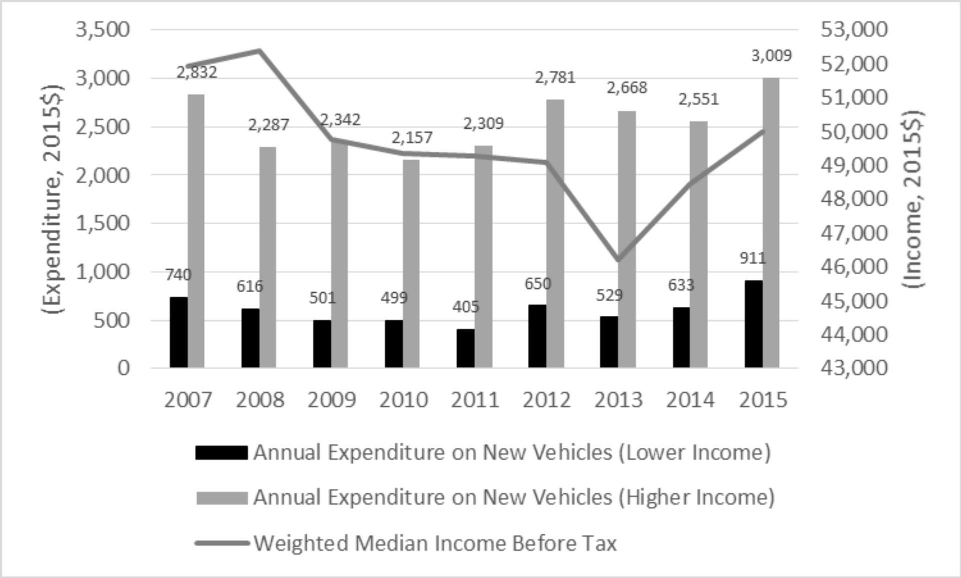

Figure B.2 Median Income and Annual Expenditure on New Vehicles for Lower and Higher Income Households

Figure B.3 shows the proportion of lower- and higher-income households that bought vehicles. A small proportion of households buy a vehicle, either new or used, in any one year. While a higher proportion of both income groups buy used vehicles than new vehicles, lower-income households buy fewer of both. Perhaps worth noting in this chart is that the proportion

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[103] Greene, David, and Jilleah Welch (2016). "The Impact of Increased Fuel Economy for Light-Duty Vehicles on the Distribution of Income in the United States." University of Tennessee Baker Center Report 5:16, Docket EPA-HQ-OAR-2015-0827-4311.

of households buying vehicles, either new or used, has increased, albeit slightly, since 2012, when the National Program began. As with sales, discussed in Section B.1.3.1 , this increase is likely to be due more to economic recovery than to the National Program.

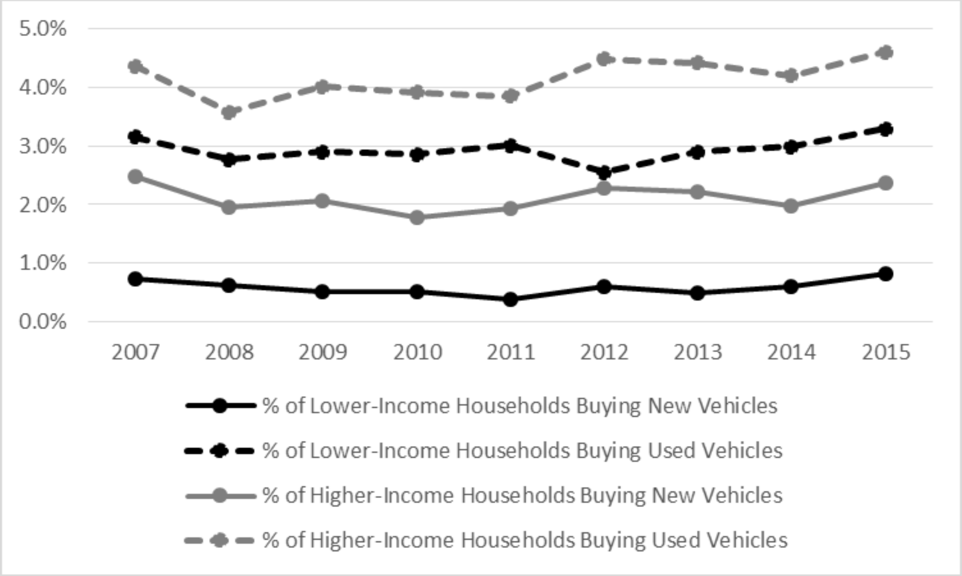

Figure B.3 Percentage of Lower-Income and Higher-Income Households Buying New and Used Vehicles

Figure B.4 compares annual expenditures on new vehicles, used vehicles, and fuel for lower-income households in Panel A, and higher-income households in Panel B. As Consumer Federation of America has pointed out, lower-income households spend more on gasoline than they do on either new or used vehicles, and they spend more on used vehicles than they do on new vehicles. Higher-income households spend more on new than on used vehicles; in 2015, their expenditures on fuel approximately equaled expenditures on new and used vehicles. In addition, household expenditures on gasoline and motor oil fluctuates more than its expenditures on new and used vehicles. This suggests that households may face more uncertainty due to changes in fuel prices than they do due to changes in vehicle prices. Greene and Welch estimate that increased fuel economy decreased fuel expenditures by about 30 percent between 1980 and 2014, with most of that reduction before the mid-1990s; they attribute almost flat expenditures since then to the increase in the proportion of light trucks over time.[104] They observe that lower-income households lag behind higher-income households in getting these reductions, because it takes time for the more efficient vehicles to become part of the used vehicle market.

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[104] Greene, David, and Jilleah Welch (2016). "The Impact of Increased Fuel Economy for Light-Duty Vehicles on the Distribution of Income in the United States." University of Tennessee Baker Center Report 5:16, Docket EPA-HQ-OAR-2015-0827-4311.

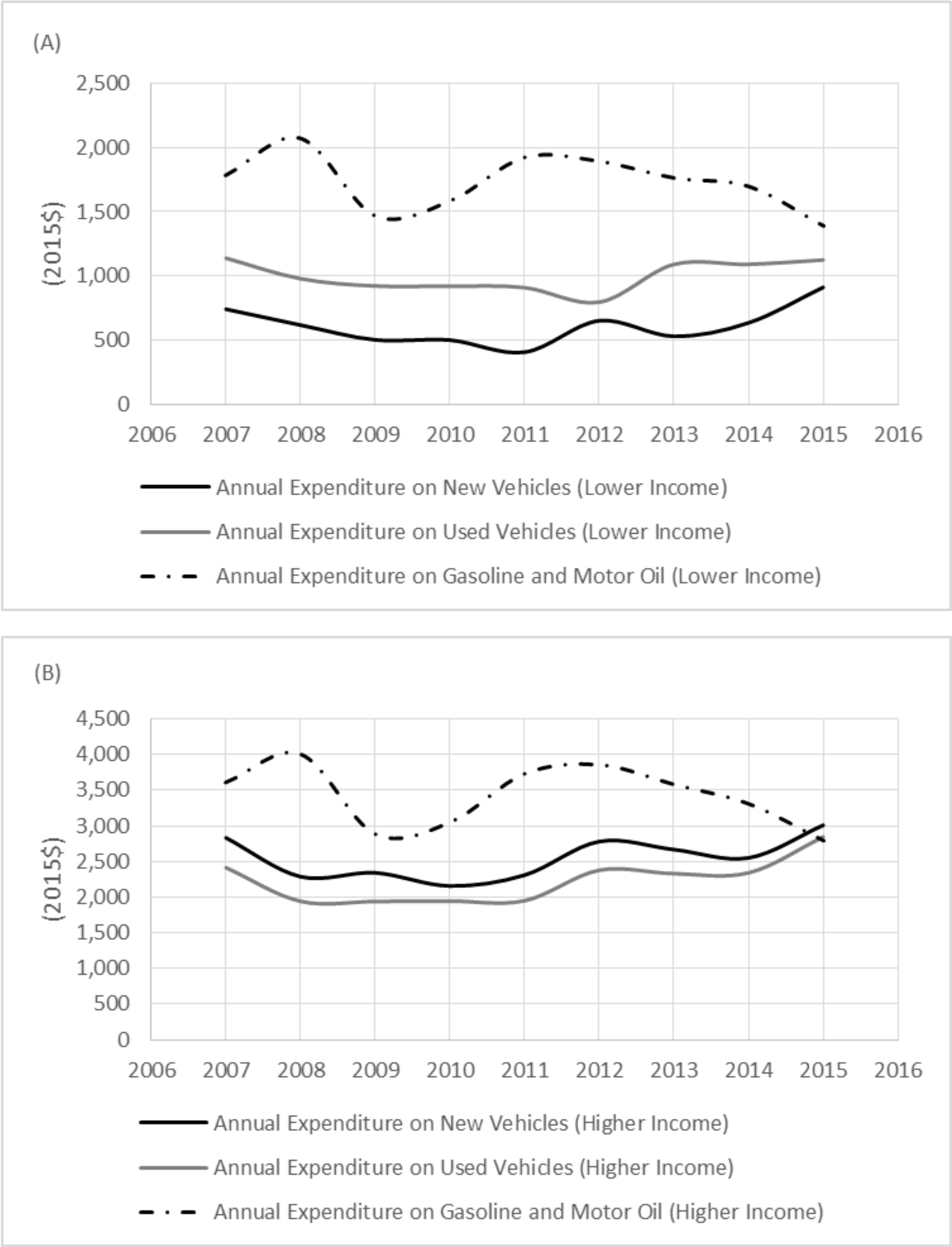

Figure B.4 Annual Expenditure on Vehicles and Gasoline for Lower-Income Households and Higher-Income Households

These data suggest that lower-income households are more affected by the impact of the standards on the used vehicle market than on the new vehicle market.

B.1.6.2 Effects on the Used Vehicle Market

The effect of the standards on the used vehicle market will be related to its effects on new vehicle prices, the fuel efficiency of new vehicle models, the fuel efficiency of used vehicles, and the total sales of new vehicles. If the consumer value of fuel savings resulting from improved fuel efficiency outweighs the average increase in new models' prices to potential buyers of new vehicles, sales of new vehicles could rise, and the used vehicle market may increase in volume as new vehicle buyers sell their older vehicles. In this case, used vehicle buyers, including lower-income households, are likely to benefit from the increased inventory of used vehicles. However, if potential buyers value future fuel savings resulting from the increased fuel efficiency of new models at less than the increase in their selling prices, sales of new vehicles may decline, and the used vehicle market may see price increases as people hold onto their vehicles longer.

Jacobsen and van Bentham (2015) look at the effect of fuel prices and fuel standards on the used vehicle market.[105] They argue that the increased price of new vehicles subject to the standards will decrease new vehicle sales, and increase sales and prices in the used vehicle market. As people switch to used vehicles, the greenhouse gas benefits of more efficient new vehicles will be reduced. The Alliance and Fiat Chrysler cite this result in their claim that lower-income households will face higher fuel costs because of the standards. The results of that paper depend on the standards depressing new vehicle sales.[106] As discussed in Section B.1.3.3 , we have not estimated the effects of the standards on new vehicle sales due to great uncertainties in key parameters, such as consumer willingness to pay for improved fuel economy. It is thus not clear whether the results from Jacobsen and van Bentham are relevant to these standards.

Greene and Welch (2016), cited above, find that used vehicle prices depreciate faster than use of vehicles. Because price depreciates faster than miles used, the payback period for a used vehicle should be shorter than for a new vehicle. This finding is consistent with Consumer Federation of America's (CFA) statements that owners of used vehicles will have higher mileage and lower operating costs. Because low-income households disproportionately buy used vehicles, CFA expects that those households will capture a disproportionate share of fuel savings from resold vehicles.

Figure B.5 presents data from the Consumer Price Index for used[107] and new vehicles.[108] Each series has been adjusted to a year 2015 reference base with underlying prices in 2015$ (using price deflators for GDP[109]) so that numbers on the *y*-axis represent the percentage difference from price levels in 2015 (in 2015$). Used vehicle prices have decreased since 1995,

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[105] Jacobsen, Mark, and Arthur van Bentham (2015). "Vehicle Scrappage and Gasoline Policy." American Economic Review 105: 1312-1338.

[106] The applicability of their empirical analysis is limited due to their use of pre-2009 data (including cost data from 2002) and a flat (not footprint-based) standard, among other assumptions.

[107] U.S. Bureau of Labor Statistics. "Consumer Price Index for All Urban Consumers: Used cars and trucks [CUSR0000SETA02]," retrieved from FRED, Federal Reserve Bank of St. Louis, https://research.stlouisfed.org/fred2/series/CUSR0000SETA02, accessed 3/23/2016; see "Annual used and new CPI price index with GDPdeflator," Docket EPA-HQ-OAR-2015-0827-0797.

[108] U.S. Bureau of Labor Statistics. "Consumer Price Index for All Urban Consumers: New vehicles [CUSR0000SETA01]," retrieved from FRED, Federal Reserve Bank of St. Louis, https://research.stlouisfed.org/fred2/series/CUSR0000SETA01, accessed 3/23/2016; see "Annual used and new CPI price index with GDP deflator," Docket EPA-HQ-OAR-2015-0827-0797.

[109] U.S. Department of Commerce, Bureau of Economic Analysis. "Table 1.1.9 Implicit Price Deflators for Gross Domestic Product," http://www.bea.gov/iTable/iTable.cfm?ReqID=9&step=1#reqid=9&step=3&isuri=1&903=13, accessed 3/23/2016; see "Annual used and new CPI price index with GDP deflator," Docket EPA-HQ-OAR-2015-0827-0797.

and have varied in a small range between 2008 and 2015. As the Alliance comments, the used car price index closely follows the new car price index, although used car prices have more volatility across all years. Both price trends are generally downward, with new vehicle prices approximately flat since about 2008. Generally, then, it appears that neither new nor used vehicle prices appear to have increased in recent years.

The Alliance comments include a paper from the Defour Group which argues that this chart is inaccurate, that price trends are increasing.[110] Fiat Chrysler also points to increasing average vehicle prices. If the trends are not adjusted to account for overall inflation, this is true, but EPA, following standard practice, removes the effects of inflation from its analyses. We also note that this price index does not control for changes in sales mix. People may be choosing more expensive vehicles as incomes increase, rather than vehicles themselves becoming more expensive. As Fiat Chrysler points out, people are buying more SUVs and pickups, and fewer (and less expensive) small cars; that change in fleet mix itself will push average prices higher. The Defour Group paper also points out that the use of these price trends understates effects on the used vehicle market, because the BLS series is limited to used vehicles up to 7 years old. For older vehicles, it argues, prices have increased relative to newer vehicle prices between 2000 and 2014. As the comment suggests, this effect appears to be due to the improved dependability and durability of vehicles; those improvements would be expected to increase the prices of older vehicles. No evidence is provided that the standards played a role in that change.[111]

Mannheim Consulting indicates that volumes at used auto auctions have increased steadily from 2011-2015, with relatively small fluctuations in its value index during that time.[112] These suggest that the increase in new vehicle sales since the recession ended (see Section B.1.3.1) has had the expected positive effect on used vehicle volumes; price reflects "strong new vehicle pricing, exceptional credit conditions, higher employment levels, record job stability, and the often overlooked factor of increased dealership operating efficiencies" (Mannheim Consulting, p. 15). The average loan payment for used vehicles, in nominal terms, increased by $6/month between 2014 and 2015;[113] in constant dollars, the payment is approximately constant, at $350/month. This observation again does not suggest great movement in overall used vehicle prices. Additionally, trends in the new vehicle market, supply of used vehicles, and changing consumer preferences may even result in used prices falling for certain market segments; January 2016 used vehicle prices for compact and luxury cars fell relative to the prior year, while prices for used pickups increased.[114] As with the effects of the standards on new vehicle sales, it is

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[110] Walton, Tom, and Dean Drake (2016). "The Impact of Future Fuel Economy Standards on Low Income Households." Docket EPA-HQ-OAR-2015-0827-4089, Attachment 11.

[111] National Automobile Dealers Association (2015), "How Better Quality is Affecting Used Vehicle Demand," Quarter Three, 2015, at http://nhada.com/docs/NADA_Q3_WhitePaper.pdf, accessed 10/20/2016.

[112] Mannheim (2016). "Used Car Market Report." http://www.manheim.com/content_pdfs/products/UCMR-2016.pdf?WT.svl=m_prod_consulting_latestupdates_button_2016 , accessed 2/11/2016.

[113] Zabritski, Melinda (2015). "State of the Automotive Finance Market Second Quarter 2015." Experian Automotive, http://www.experian.com/assets/automotive/white-papers/experian-auto-2015-q2.pdf?WT.srch=Auto_Q22015FinanceTrends_PDF , accessed 9/25/2015.

[114] Mannheim (2016). "Mannheim Used Vehicle Value Index." https://www.manheim.com/content_images/content/ManheimUsedVehicleValueIndex-BarGraph0116.jpg , accessed 3/15/16.

possible that the GHG/fuel economy standards have had some influence on these trends, but their effect is likely swamped by the effects of the economic recovery.

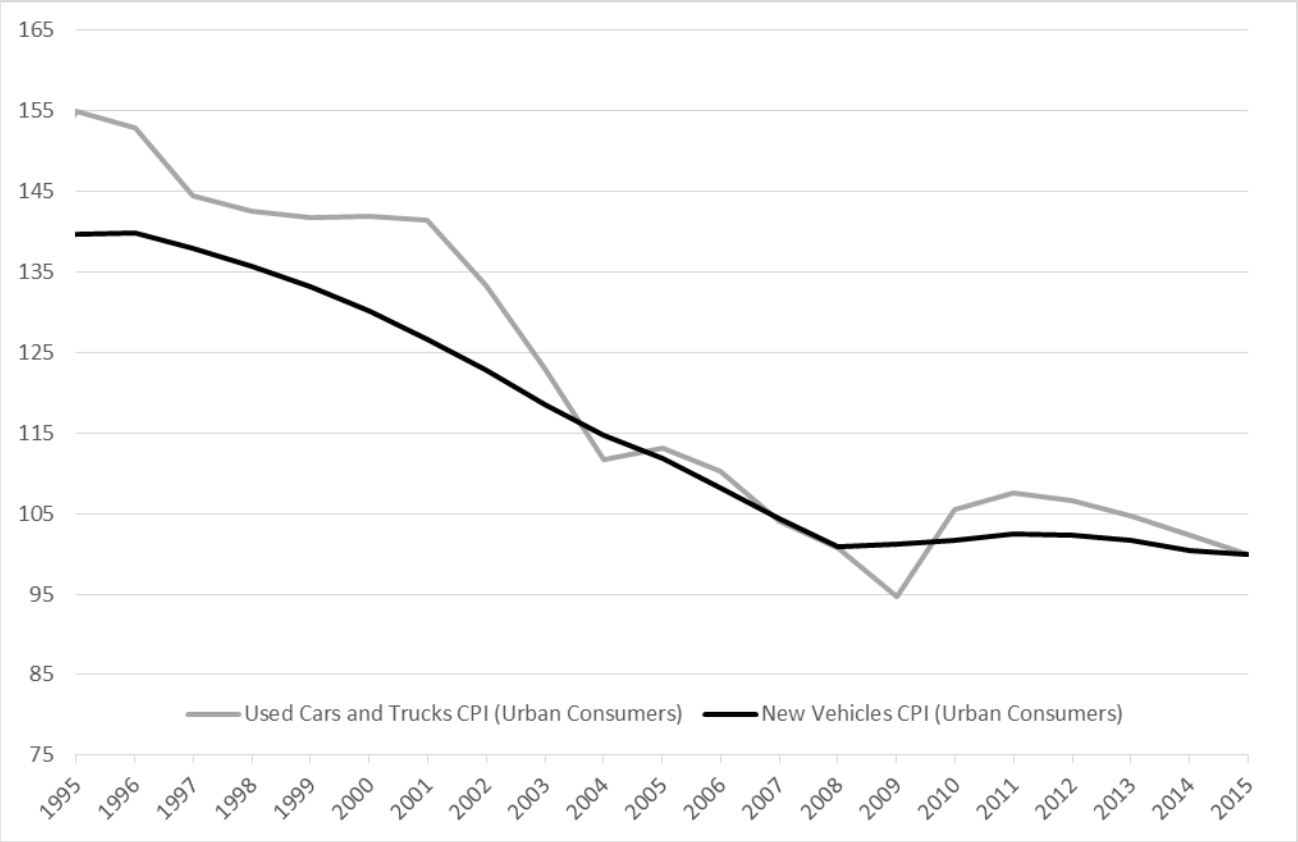

Figure B.5 Used and New Car Consumer Price Index, 2015=100 (2015$).

A recent Heritage Foundation analysis[115] by Furth and Kreutzer (2016) cites a similar set of price trends to argue that prices of new vehicles are higher by larger amounts (up to $7100) than they would be if they had followed trends before 2009, trends in furnishings and durable household equipment, or trends in vehicle prices in the United Kingdom or in Australia. It implies that the standards created this divergence between the previous trend and current prices. This change in the price trend is unlikely to be due only, or even primarily, to the standards. These price trends are based on the vehicles that people are buying, not on a constant vehicle model; that is, if people are switching from less expensive to more expensive vehicles, then price trends would increase, even if the prices of individual vehicles had stayed constant. As discussed in Chapter 3.1.4 of the Draft TAR, fleet mix has been changing during this time, with sales of SUVs and pickup trucks higher than the estimates in the 2012 final rule. For instance, the share of the fleet that is car (sedan) and not car SUV, truck SUV, pickup, or minivan went from 61

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[115] Furth, Salim, and David W. Kreutzer (2016). "Fuel Economy Standards are a Costly Mistake." The Heritage Foundation Backgrounder. http://www.heritage.org/research/reports/2016/03/fuel-economy-standards-are-a-costly-mistake, downloaded 5/20/2016.

percent in MY2009 to 49 percent in MY2014.[116] To the extent that the latter vehicles are more expensive than car sedans, the change in sales mix will have affected the trend. Note as well that the price trend changes in 2008, at the start of the Great Recession, before the standards went into effect for MY2012.[117] Without a good way to separate effects on prices due to the standards from other factors affecting prices, the Furth and Kreutzer (2016) assessment does not provide a sound basis for estimating the effects of the standards on vehicle prices.

The benefits of the standards for buyers of used vehicles, as with new vehicle buyers, will depend on two countervailing effects from the improvement in fuel economy: the increased cost of the used vehicles attributed to fuel-saving technologies, and the savings in fuel costs over time. Depreciation of new vehicle prices reduces the cost of the additional fuel economy for used vehicle buyers. On the other hand, because older vehicles are used less on average than new vehicles, the fuel savings will accrue more slowly. The Alliance's Defour Group paper, based on the assumption of significant increases in used vehicle prices, argues that used vehicle prices will increase faster than the fuel savings. Greene and Welch present findings that vehicle prices depreciate at a somewhat faster rate than the decrease in VMT.[118] If so, then the payback period for used vehicles should become shorter with reduced fuel consumption, because the up-front cost will decrease faster than fuel savings.

B.1.6.3 Effects on Access to Credit

Even though projected fuel savings are expected to outweigh increased vehicle costs, some concerns have been raised about whether higher vehicle prices may exclude prospective consumers from the new vehicle market through effects on consumers’ ability to finance vehicles. If lenders focus on the amount of the vehicle loan, the person’s current debt, and the person’s income when issuing loans, and do not consider the reduced operating costs associated with fuel savings, then the higher up-front costs of the new vehicles subject to the standards could reduce buyers’ ability to get loans (holding down payments constant). Thus, if lenders do not take fuel savings into account in providing some loans, households that are borrowing near the limit of their abilities to borrow may either have to change what vehicles they buy (including possibly switching from new to used vehicles), or defer buying vehicles.

The financing market appears to be evolving, apparently in response to consumers buying more expensive vehicles, among other factors. One way that the loan market appears to be

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[116] U.S. EPA (2015). "Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975-2015," EPA-420-S-15-001, Appendix D, Docket EPA-HQ-OAR-2015-0827-0041.

[117] Further evidence that these price trends are not due to the standards is found in comparing the trend in the United Kingdom (UK) with the trends in France, Germany, and Italy reported by Furth and Kreutzer (2016). The UK has a fairly steady, steep decrease in prices from 1999 to 2015, while France, Italy, and Germany have much flatter price trends; France and Italy show small decreases followed by a small upturn, while Germany has a steady but small decrease. All these countries are in the European Union, which provides a common set of standards for all countries. If standards alone were driving price trends, then these countries should all see similar trends. Instead, even if the France, Italy, and Germany patterns are similar, the UK pattern is very different. Thus, vehicle standards alone do not seem to be driving price trends.

[118] Greene, David, and Jilleah Welch (2016). "The Impact of Increased Fuel Economy for Light-Duty Vehicles on the Distribution of Income in the United States." University of Tennessee Baker Center Report 5:16, Docket EPA-HQ-OAR-2015-0827-4311.

evolving is that the available term length of auto loans has increased. The average new car loan in mid-2015 has a record repayment period of 67 months, and 29 percent of loans were for 73-84 months.[119] While interest rates have been low by historic standards since the recession, longer loans typically reduce (or keep constant) the monthly payments that consumers make, though with more payments required and perhaps higher interest rates. Though these longer terms may ease consumers' abilities to buy more expensive vehicles than they otherwise would, they increase the chances that a vehicle owner may end up "under water"--that is, with a vehicle worth less than the amount that the buyer still owes. In addition, the number of new vehicles being leased has increased, from 19 percent in 2010 to 27 percent in 2015.[120] These changes show an evolving financing market, though why the market is evolving is not clear: it may be that vehicles have become more expensive, or it may be that consumers are choosing more expensive vehicles, or that consumer preferences toward ownership are changing. Any link between these changes and the standards is speculative.

Another market innovation suggests that parts of the loan market take fuel savings into account in the lending decision. Some lenders currently give discounts for loans to purchase more fuel-efficient vehicles.[121] An internet search on the term “green auto loan” produced more than 60 lending institutions that provide reduced loan rates for more fuel-efficient vehicles.[122] A third of credit unions responding to a recent survey offered some type of green auto loan.[123] It seems that some auto loan makers incentivize the financing of more fuel-efficient vehicles. The Alliance of Automobile Manufacturers and the Association of Global Automakers argue that these programs are not incorporating future fuel savings into the loan decision, but rather are ways to attract particular applicants. EPA agrees that green auto loans do not explicitly factor fuel savings into the calculation. Indeed, it would be difficult or impossible to do that calculation, because it would require knowing what the fuel expenditures would be for the vehicle that the consumer otherwise would have purchased. We also agree that lending institutions may have multiple motives for offering these incentives. Nevertheless, they do provide a means to mitigate the effects of higher up-front costs on borrowers.

The Alliance and Toyota ask us to consider how macroeconomic factors, such as the slowdown in the growth of disposable income and changes in interest rates, will affect affordability. Lower income and higher interest rates are likely to suppress vehicle sales. The

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[119] Zabritski, Melinda (2015). "State of the Automotive Finance Market Second Quarter 2015." Experian Automotive, http://www.experian.com/assets/automotive/white-papers/experian-auto-2015-q2.pdf?WT.srch=Auto_Q22015FinanceTrends_PDF , accessed 9/25/2015; Gardner, Greg (2015). "New-car loans keep getting longer." USA Today June 1, 2015, http://www.usatoday.com/story/money/cars/2015/06/01/new-car-loans-term-length/28303991/ , downloaded 9/25/2015.

[120] Zabritski, Melinda (2015). "State of the Automotive Finance Market Second Quarter 2015." Experian Automotive, http://www.experian.com/assets/automotive/white-papers/experian-auto-2015-q2.pdf?WT.srch=Auto_Q22015FinanceTrends_PDF , accessed 9/25/2015.

[121] See, for instance, Ladika, Susan (2009). “’Green auto loans offer lower rates,” Bankrate.com, http://www.bankrate.com/finance/auto/green-auto-loans-offer-lower-rates-1.aspx, accessed 7/29/15, Docket EPA-HQ-OAR-2010-0799-11829.

[122] Huang, Hsing-Hsiang, and Gloria Helfand (2016). "Lending institutions that provide discounts for more fuel-efficient vehicles." U.S. EPA Office of Transportation and Air Quality, Memorandum to Docket.

[123] Baumhefner, Max (2013). “Why Can’t Your Loan be as Green and Efficient as Your Vehicle?” Natural Resources Defense Council, http://switchboard.nrdc.org/blogs/mbaumhefner/why_cant_your_loan_be_as_green.html, accessed 7/29/2015.

relevant question for the light-duty GHG standards is whether the effects of the standards are likely to be different in such a scenario. NADA argues that access to credit limits consumer ability to purchase vehicles regardless of fuel savings. As discussed here, adaptations in the loan market, such as extended loan periods and green auto loans, can help to mitigate these effects. Regardless, EPA considers the effects of the standards on vehicle sales to be small relative to effects such as reduced income growth and higher interest rates in the economy.

Ford commented that the Draft TAR did not comprehensively analyze the effects of the standards on credit availability, though it did not provide any data to inform such analysis, nor did it provide suggestions for what additional analyses EPA should conduct. As discussed in the Draft TAR Chapter 6.5.3, we in fact closely examined the question of whether the debt-to-income ratio (DTI) is an impassible obstacle for lending, because of the importance of the DTI in determining access to credit. To determine whether the DTI threshold is rigid, we used CES data across 2007-2015 to identify households with over 36 percent DTI in order to gauge whether exceeding this threshold precludes households from being able to finance a vehicle purchase. We chose this threshold based on guidance from online sources stating that lenders prefer to give loans to consumers who have a DTI under 36 percent.[124] Figure B.6 presents the results. Between 2007 and 2015, on average 28 percent of lower-income households and 7 percent of higher-income households with a DTI of over 36 percent, that purchased at least one new vehicle, financed their car purchases. The results are similar using the 40 percent DTI as the threshold. This suggests that it is possible to obtain a loan for a new vehicle even with a DTI over the assumed thresholds. Thus, if increases in vehicle prices push some households over the 36 or 40 percent DTI, it nevertheless may be possible for them to get loans.

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[124] See Bankrate (2015). “Debt-to-income ratio calculator,” Bankrate.com, http://www.bankrate.com/calculators/mortgages/ratio-debt-calculator.aspx; Keythman, Bryan (2015). "What is the 28/36 Rule of Debt Ratio?" http://budgeting.thenest.com/28-36-rule-debt-ratio-22412.html; Zillow (2015). “Debt-to-income calculator,” Zillow.com, http://www.zillow.com/mortgage-calculator/debt-to-income-calculator/.

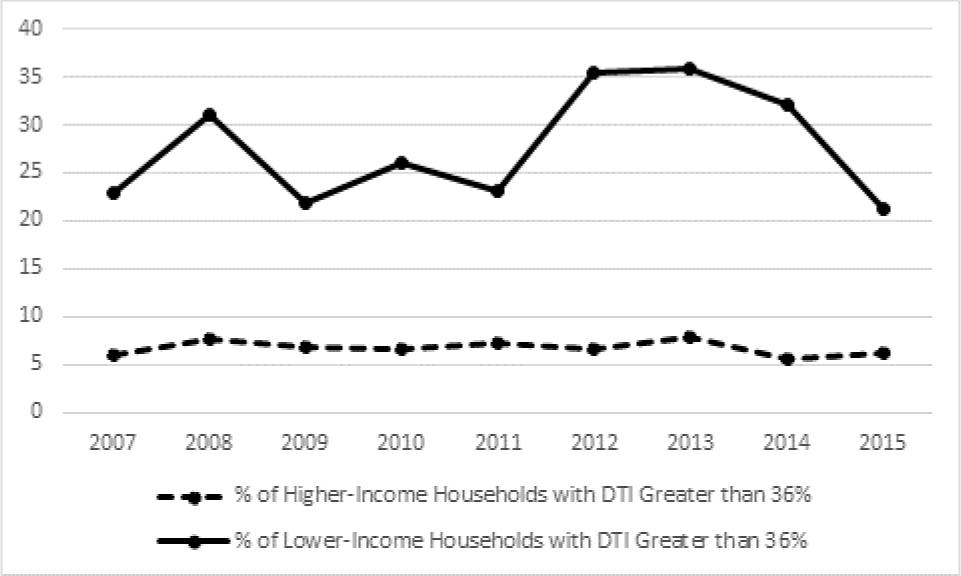

Figure B.6 Percentage of Households Buying at Least One New Vehicle with Financing who had Debt-to-Income Ratio (DTI) Greater than 36 Percent

B.1.6.4 Effects on Low-Priced Cars

Low-priced vehicles may be considered an entry point for people into buying new vehicles instead of used ones; automakers may seek to entice people to buy new vehicles through a low price point, perhaps to build brand loyalty for future, more profitable sales.[125] In comments on the MY2017-25 LD GHG rule, concerns were raised that the standards would increase the cost of low-priced vehicles sufficiently to eliminate this segment. To examine this question, in the Draft TAR we used WardsAuto datasets[126] to explore low-priced new car models over time. Low-priced new models–in particular, those with manufacturer's suggested retail price (MSRP) of less than $15,000 (in 2015$) for the base version—continue to exist in the automobile market. As shown in Figure B.7, the number of new car models offered with an MSRP of under $15,000 (2015$) is not large, but automakers to date have been able to preserve the number of offerings in this segment.

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[125] Deep, Said (1999). "Small in Stature, Big in the Market-Why automakers maintain their small-car focus." Wards Auto, http://wardsauto.com/news-analysis/small-stature-big-market-why-automakers-maintain-their-small-car-focus, accessed 6/16/2016.

[126] Ward's Automotive. '07 [and subsequent, to 2015] Model Year U.S. Car and Light Truck Specifications and Prices. Accessed 6/16/2015: http://wardsauto.com/data-center see Cassidy, Alecia, Geoffrey Burmeister, and Gloria Helfand. "Impacts of the Model Year 2017-25 Light-Duty Vehicle Greenhouse Gas Emission Standards on Vehicle Affordability." Working paper, docket EPA-HQ-OAR-2015-0827.

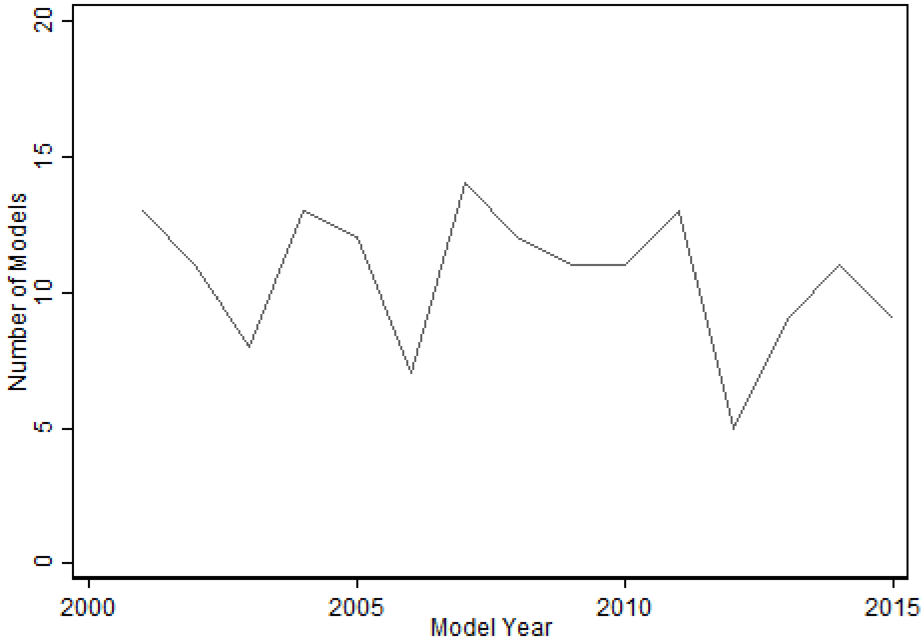

Figure B.7 Number of <$15,000 Car Models Available, from Ward's Automotive Data

Figure B.8 shows the MSRP for the least expensive of all new cars available (2015$). During the period 2001-2015, this price has risen, suggesting that the very least expensive new cars have become more expensive.

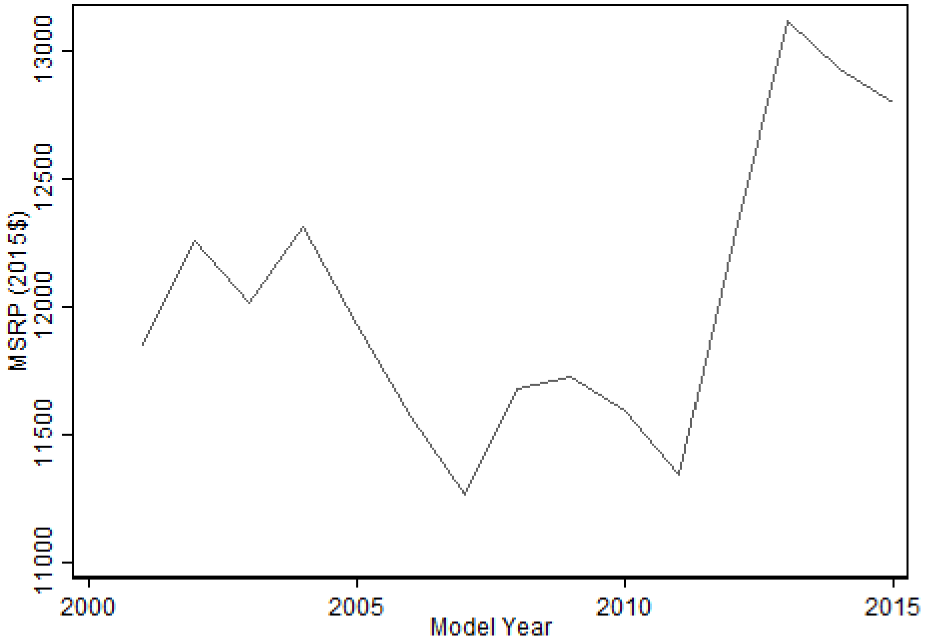

Figure B.8 Minimum MSRP of All Car Models Available, from Ward's Automotive Data

Note that the lowest prices were observed in the years surrounding the recession. In the past, not only was the low-priced vehicle segment a way to encourage first-time new vehicle purchasers, but it also tended to include more fuel-efficient vehicles that assisted automakers in achieving CAFE standards.[127] The footprint-based standards, by encouraging improvements in GHG emissions and fuel economy across the vehicle fleet, reduce the need for low-priced vehicles to be a primary means of compliance with the standards. This change in incentives for the marketing of this segment may contribute to the increases in the prices of vehicles previously in this category. In addition, these vehicles appear to be gaining more content, such as improved entertainment systems and electric windows; they may be developing an identity as a desirable market segment without regard to their previous purpose in enabling the sales of less efficient vehicles and compliance with CAFE standards.[128] For instance, the Nissan Versa, the lowest-priced vehicle since MY2011, added Bluetooth, audio controls on the steering wheel, and speed-sensitive volume control in MY2015. It may be that the small, fuel-efficient vehicles previously sold with low prices are evolving to fit consumer demand that prefers content to low prices.

In sum, the low-priced vehicle segment still exists. Whether it continues to exist, and in what form, may depend on the marketing plans of manufacturers: whether benefits are greater from

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[127] See, for example, Austin, David, and Terry Dinan (2005). “Clearing the Air: The Costs and Consequences of Higher CAFE Standards and Increased Gasoline.” Journal of Environmental Economics and Management 50(3): 562—82; and Kleit, Andrew N. (2004). "Impacts of Long-Range Increases in the Fuel Economy (CAFE) Standard." Economic Inquiry 42(2): 279—294.

[128] Cassidy, Alecia, Geoffrey Burmeister, and Gloria Helfand (2015). "Impacts of the Model Year 2017-25 Light-Duty Vehicle Greenhouse Gas Emission Standards on Vehicle Affordability." Working paper, docket EPA-HQ-OAR-2015-0827.

offering basic new vehicles to first-time new-vehicle buyers, or from making small vehicles more attractive by adding more desirable features to them.

B.1.6.5 Conclusion

It is difficult to assess the effects of the LDV GHG standards on vehicle affordability, due to both challenges in defining affordability, and difficulties in separating the effects of the standards from other market changes. Because lower-income households are likely to buy used vehicles, the effects of the standards on lower-income households depend on its effects in both the new and used vehicle markets. In the used vehicle market, used vehicle prices do not appear to be increasing. The effects of the standards on access to sufficient financing to purchase a new vehicle may not be large: there continue to be loan discounts for fuel-efficient vehicles, and people with high debt-to-income ratios appear able to get loans. The low-priced vehicle segment still exists, though perhaps changing in terms of content features provided by automakers for this segment. In sum, if the standards thus far have affected vehicle affordability, they have not had significant visible effects. In addition, there appear to be market adjustments, such as ongoing changes in the finance market that may mitigate some of any adverse effects. In the MY2022-2025 time frame, the primary effects on affordability of vehicle sales are still likely to be due to broader macroeconomic factors, such as economic activity and overall employment; any impacts of the standards are likely to be secondary to those broader economic factors.

This assessment has focused on the effects of the standards on purchase affordability of vehicles–that is, whether they become more difficult to purchase because of the increase in up-front costs. The vehicles will also become less expensive to operate, due to fuel savings from more fuel-efficient technologies. The reduced operating costs from fuel savings over time are still expected to exceed the increase in up-front vehicle costs, as discussed further in SectionC.2.4 , as a further mitigation of any effects on vehicle affordability.

B.2 Employment Impacts

B.2.1 Introduction

The Presidential Memorandum that requested development of the National Program sought a program that would “strengthen the [auto] industry and enhance job creation in the United States.”[129] Executive Order 13563, “Improving Regulation and Regulatory Review” (January 18, 2011), states, “Our regulatory system must protect public health, welfare, safety, and our environment while promoting economic growth, innovation, competitiveness, and job creation.”[130] In addition, the 2017-25 final rule lists "Impacts on employment, including the auto sector" as one of the factors to be considered in the Midterm Evaluation, and the regulations cite "the impact of the standards on the automobile industry" as one of the factors the Administrator must consider in making her determination on the appropriateness of the standards.[131] EPA is accordingly providing this discussion of the potential employment effects of the standards. This

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[129] President Barack Obama. “Presidential Memorandum Regarding Fuel Efficiency Standards. The White House, Office of the Press Secretary, May 21, 2010. http://www.whitehouse.gov/the-press-office/presidential-memorandum-regarding-fuel-efficiency-standards.

[130] President Barack Obama. "Executive Order 13563 of January 18, 2011: Improving Regulation and Regulatory Review." Federal Register 76(14) (January 21, 2011): 3821-3823.

[131] 77 Federal Register 62784.

section begins with an overview of employment in the auto industry in recent years, and then discusses estimating the employment effects of the standards. While the 2022-2025 standards may have some effect on employment in the auto sector, this effect is likely to be small enough that it cannot be distinguished from macroeconomic and other factors affecting auto sector employment.

B.2.2 Employment in the Auto Sector in Recent Years

Figure B.9 shows employment in three segments of the U.S. auto industry from 2005 through 2016 Motor Vehicles; Motor Vehicle Parts; and Automobile Dealers. The Motor Vehicle sector itself, which includes the major manufacturers, employs the fewest people of these three sectors; Motor Vehicle Parts, suppliers to the auto industry, employs roughly two to three times as many people, and the Automobile Dealers sector employs more than the sum of the manufacturing and parts sectors.

As this chart shows, in all three segments, employment was decreasing before the recession began in 2009, and has been increasing in recent years with recovery from the recession. Auto dealers had a smaller percentage decrease than Motor Vehicles or Motor Parts, though all have recovered back to employment levels of 2007-2008 by 2014.

Figure B.9 includes vehicle sales[132] during this period (see also Section B.1.3.1); it shows a similar overall pattern of decrease followed by increase, though sales have increased more rapidly on a percentage basis than employment since 2009 (see Figure B.10). The similarities in the patterns for sales and employment suggest, unsurprisingly, that one of the key drivers of employment in auto-related sectors is vehicle production. Indeed, the American Automotive Policy Council cites a prediction from the Center for Automotive Research that auto employment will increase by more than a third from 2011 to 2016, as production of vehicles in the U.S. increases from 5.8 million in 2009 to at least 11.5 million vehicles in 2016,[133] and total sales reached a record high of 17.5 million in 2015.[134] The differences in changes in magnitude for employment compared to sales may be due to a number of factors; one of those factors may be changes in the production process and in productivity; another factor might be the GHG/fuel economy standards.

The effects of the standards on employment are difficult to identify. As Section B.1.3.1 discusses, it is difficult, if not impossible, to disentangle the effects of the standards on vehicle production (or employment) from changes in other factors, especially the state of the macroeconomy. Figure B.10 shows the same employment sectors and production as in Figure B.9, now indexed to show each value as a percent of its value in 2005; it also includes Gross Domestic Product (GDP) per capita.[135] This figure suggests that auto sector production and

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[132] Vehicle production data represent production volumes delivered for sale in the U.S. market, rather than actual sales data. They include vehicles built overseas imported for sale in the U.S., and exclude vehicles built in the U.S. for export.

[133] American Automotive Policy Council (2015). "State of the U.S. Automotive Industry: Investment, Innovation, Jobs, Exports, and America's Economic Competitiveness." http://americanautocouncil.org/sites/default/files/2015-AAPC-Economic-Contribution-Report%28FINAL%29.pdf.

[134] Woodall, Bernie (2015). "U.S. Auto Sales in 2015 Set Record after Strong December." Reuters, http://www.reuters.com/article/us-usa-autos-idUSKBN0UJ1C620160105 , accessed 2/12/2016.

[135] Graphing in this way facilitates comparison of percentage changes in the data series compared to 2005.

employment declined earlier and more deeply than the economy as a whole, and rebounded more vigorously.

Chapter 7 of the Draft TAR included a discussion of the effects of the standards on employment in the automotive and directly related sectors (e.g., the parts sector). It did not quantify the overall net effects of the standards on U.S employment, nor did it quantify the effects of the standards on vehicle sales. Thus, it did not quantify the effects of employment changes in these sectors due to changes in vehicle sales. It did provide partial estimates of the effects of increased expenditures on employment in these sectors: some of those increased expenditures would be on labor. Those estimates were provided to suggest the magnitude of employment impacts, even though they were only one pathway through which employment in these sectors would be affected. It estimated increases on the order of 1200 to 11,800 jobs in 2025 due to those expenditures, with the range dependent on whether the increased expenditures occurred in the light duty vehicle manufacturing sector or the parts sector. Given levels of employment in the auto sector in 2016, this increase would be 1 percent or less of employment in the auto sector, and it does not account for any effects of the standards on vehicle sales. As Figure B.9 and Figure B.10 suggest, employment is likely to vary much more than 1 percent due to macroeconomic factors. Thus, while the MY2012-16 standards are likely to have had some effect on employment in the auto sector, this effect is likely to have been small enough that it cannot be distinguished from other factors affecting auto sector employment. In addition, the standards are not expected to have had any notable inflationary or recessionary effect.

Figure B.9 Auto Sector Employment and Production[a]

Note:

[a] Employment data are from http://www.bls.gov/iag/tgs/iagauto.htm. Production data are for model years, from U.S. EPA (2016). Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016. U.S. EPA-420-R-16-010. Note that 2016 production data are projected, not actual, values.

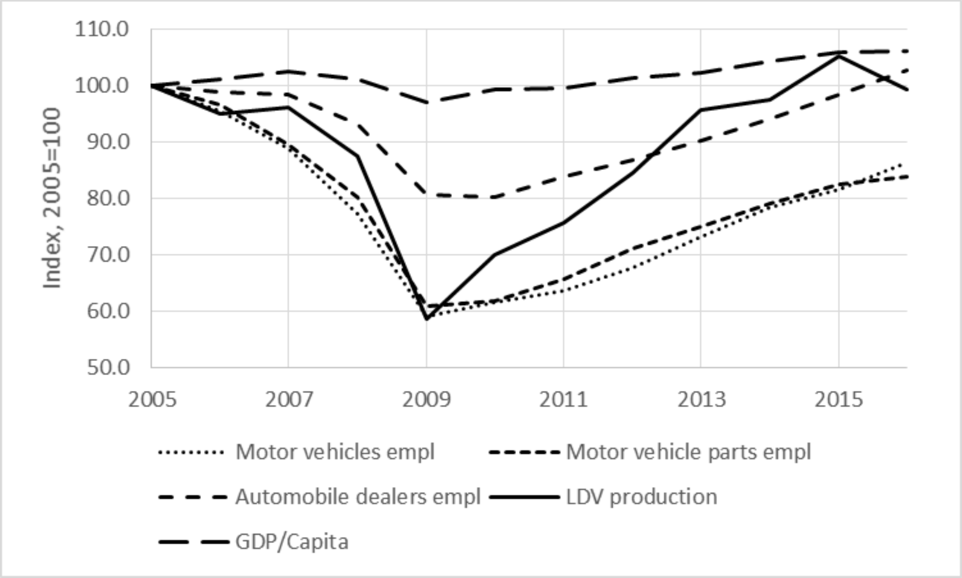

Figure B.10 Indexed Auto Sector Employment and Production, and Gross Domestic Product (GDP) per Capita,[a] 2005 = 100 for all data series.

Note:
[a] Employment data are from http://www.bls.gov/iag/tgs/iagauto.htm. Production data are for model years, from U.S. EPA (2015). Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2015. U.S. EPA-420-R-15-001. Note that 2015 production data are projected, not actual, values.

B.2.3 Current State of Knowledge of Employment in the Automotive Sector Based on the Peer-Reviewed Literature

As suggested in the previous section, the employment effects of environmental regulation are difficult to disentangle from other economic changes and business decisions that affect employment, over time and across regions and industries. In light of these difficulties, we look to economic theory to provide a constructive framework for approaching these assessments and for better understanding the inherent complexities in such assessments.

If the U.S. economy is at full employment, even a large-scale environmental regulation is unlikely to have a noticeable impact on aggregate net employment.[136] Instead, labor would primarily be reallocated from one productive use to another, and net national employment effects from environmental regulation would be small and transitory (e.g., as workers move from one job to another).[137]

Affected sectors may experience transitory effects as workers change jobs. Some workers may retrain or relocate in anticipation of new requirements or require time to search for new

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[136] Full employment is a conceptual target for the economy where everyone who wants to work and is available to do so at prevailing wages is actively employed. The unemployment rate at full employment is not zero.

[137] Arrow et al. (1996). "Benefit-Cost Analysis in Environmental, Health, and Safety Regulation: A Statement of Principles." American Enterprise Institute, The Annapolis Center, and Resources for the Future. Docket EPA-HQ-OAR-2014-0827-0073. See discussion on bottom of p. 6. In practice, distributional impacts on individual workers can be important, as discussed later in this section.

jobs, while shortages in some sectors or regions could bid up wages to attract workers. These adjustment costs can lead to local labor disruptions. Although the net change in the national workforce is expected to be small, localized reductions in employment may adversely impact individuals and communities just as localized increases may have positive impacts.

If the economy is operating at less than full employment, economic theory does not clearly indicate the direction or magnitude of the net impact of environmental regulation on employment; it could cause either a short-run net increase or short-run net decrease.[138] An important research question is how to accommodate unemployment as a structural feature in economic models. This may be important in assessing large-scale regulatory impacts on employment.[139] The Alliance of Automobile Manufacturers and the National Automobile Dealers Association recommend the use of multipliers for employment impacts. These multipliers estimate the effects in the broader macroeconomy of impacts in the regulated sector, by using constant values for the number of additional workers in the broader economy per worker in, for instance, the auto sector. Multiplier effects are based on the assumption that there is an infinite supply of workers ready to join (or leave) the labor force. At the national level, these effects may exist when the economy is not at full employment, as there are available workers who are ready for employment. As discussed above, when the economy is at full employment, the effects of regulation will be primarily to shift employment toward different sectors, rather than to create or reduce national employment. As a result, multiplier effects are not meaningful for understanding employment impacts of federal regulations in a full-employment economy. Because of the difficulties in knowing the state of the macroeconomy in the future, we do not use multiplier effects for national level employment impact analyses.

Environmental regulation may also affect labor supply. In particular, pollution and other environmental risks may impact labor productivity or employees' ability to work.[140] While the theoretical framework for analyzing labor supply effects is analogous to that for labor demand, it is more difficult to study empirically. There is a small emerging literature described in the next section that uses detailed labor and environmental data to assess these impacts.

B.2.3.1 Regulatory Effects at the Firm Level

Neoclassical microeconomic theory provides insights into how profit-maximizing firms adjust their use of productive inputs in response to changes in their economic conditions.[141] Berman and Bui (2001, pp. 274-75) model two components that drive changes in firm-level labor

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[138] Schmalensee, Richard, and Robert N. Stavins. "A Guide to Economic and Policy Analysis of EPA's Transport Rule." White paper commissioned by Excelon Corporation, March 2011. Docket EPA-HQ-OAR-2014-0827-0071.

[139] Klaiber, H. Allen, and V. Kerry Smith (2012). "Developing General Equilibrium Benefit Analyses for Social Programs: An Introduction and Example." Journal of Benefit-Cost Analysis 3(2). Docket EPA-HQ-OAR-2014-0827-0085.

[140] Graff Zivin, J., and M. Neidell (2012). "The Impact of Pollution on Worker Productivity." American Economic Review 102: 3652-3673. Docket EPA-HQ-OAR-2014-0827-0092.

[141] Layard, P.R.G., and A. A. Walters (1978). Microeconomic Theory (McGraw-Hill, Inc.), Chapter 9, "The Derived Demand for Factors." Docket EPA-HQ-OAR-0827-0086.

demand: output effects and substitution effects.[142] Regulation can affect the profit-maximizing quantity of output by changing the marginal cost of production. If regulation causes marginal cost to increase, it will place upward pressure on output prices, leading to a decrease in the quantity demanded, and resulting in a decrease in production. The output effect describes how, holding labor intensity constant, a decrease in production causes a decrease in labor demand. As noted by Berman and Bui, although many assume that regulation increases marginal cost, it need not be the case. A regulation could induce a firm to upgrade to less polluting and more efficient equipment that lowers marginal production costs, or it may induce use of technologies that may prove popular with buyers or provide positive network externalities (see Chapter 6.3 for discussion of this effect). In such a case, output could increase.

The substitution effect describes how, holding output constant, regulation affects labor-intensity of production. Although increased environmental regulation may increase use of pollution control equipment and energy to operate that equipment, the impact on labor demand is ambiguous. For example, equipment inspection requirements, specialized waste handling, or pollution technologies that alter the production process may affect the number of workers necessary to produce a unit of output. Berman and Bui (2001) model the substitution effect as the effect of regulation on pollution control equipment and expenditures required by the regulation and the corresponding change in labor-intensity of production.

In summary, as output and substitution effects may be positive or negative, theory alone cannot predict the direction of the net effect of regulation on labor demand at the level of the regulated firm. Operating within the bounds of standard economic theory, however, empirical estimation of net employment effects on regulated firms is possible when data and methods of sufficient detail and quality are available. The literature, however, illustrates difficulties with empirical estimation. For example, studies sometimes rely on confidential plant-level employment data from the U.S. Census Bureau, possibly combined with pollution abatement expenditure data that are too dated to be reliably informative. In addition, the most commonly used empirical methods do not permit estimation of net effects.

B.2.3.2 Regulatory Effects at the Industry Level

The conceptual framework described thus far focused on regulatory effects on plant-level decisions within a regulated industry. Employment impacts at an individual plant do not necessarily represent impacts for the sector as a whole. The approach must be modified when applied at the industry level.

At the industry level, labor demand is more responsive if: (1) the price elasticity of demand for the product is high, (2) other factors of production can be easily substituted for labor, (3) the supply of other factors is highly elastic, or (4) labor costs are a large share of total production

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[142] Berman, E. and L. T. M. Bui (2001). "Environmental Regulation and Labor Demand: Evidence from the South Coast Air Basin." Journal of Public Economics 79(2): 265-295. Docket EPA-HQ-OAR-2014-0827-0074. Berman and Bui also discuss a third component, the impact of regulation on factor prices, but conclude that this effect is unlikely to be important for large competitive factor markets, such as labor and capital. Morgenstern, Pizer and Shih (2002) use a very similar model, but they break the employment effect into three parts: 1) a demand effect; 2) a cost effect; and 3) a factor-shift effect. Docket EPA-HQ-OAR-2014-0827-0088.

costs.[143] For example, if all firms in an industry are faced with the same regulatory compliance costs and product demand is inelastic, then industry output may not change much, and output of individual firms may change slightly.[144] In this case, the output effect may be small, while the substitution effect depends on input substitutability. Suppose, for example, that new equipment for GHG emissions reductions requires labor to install and operate. In this case, the substitution effect may be positive, and with a small output effect, the total effect may be positive. As with potential effects for an individual firm, theory cannot determine the sign or magnitude of industry-level regulatory effects on labor demand. Determining these signs and magnitudes requires additional sector-specific empirical study. For environmental rules, much of the data needed for these empirical studies is not publicly available.

In addition to changes to labor demand in the regulated industry, net employment impacts encompass changes in other related sectors. For example, the standards are expected to increase demand for fuel-saving technologies. This increased demand may increase revenue and employment in the firms supporting this technology. At the same time, the regulated industry is purchasing the equipment, and these costs may impact labor demand at regulated firms. Therefore, it is important to consider the net effect of compliance actions on employment across multiple sectors or industries.

Affected sectors may experience transitory effects as workers change jobs. Some workers may retrain or relocate in anticipation of new requirements or require time to search for new jobs, while shortages in some sectors or regions could bid up wages to attract workers. These adjustment costs can lead to local labor disruptions. Although the net change in the national workforce is expected to be small, localized reductions in employment may adversely impact individuals and communities just as localized increases may have positive impacts.

To summarize, economic theory provides a framework for analyzing the impacts of environmental regulation on employment. The net employment effect incorporates expected employment changes (both positive and negative) in the regulated sector and elsewhere. Labor demand impacts for regulated firms, and also for the regulated industry, can be decomposed into output and substitution effects which may be either negative or positive. Estimation of net employment effects for regulated sectors is possible when data of sufficient detail and quality are available. Finally, economic theory suggests that labor supply effects are also possible. In the next section, we discuss the empirical literature.

B.2.3.3 Peer-Reviewed Literature

In the labor economics literature there is an extensive body of peer-reviewed empirical work analyzing various aspects of labor demand, relying on the above theoretical framework.[145] This work focuses primarily on the effects of employment policies, e.g. labor taxes, minimum wage,

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[143] Ehrenberg, Ronald G., and Robert S. Smith (2000). Modern Labor Economics: Theory and Public Policy (Addison Wesley Longman, Inc.), p. 108. Docket EPA-HQ-OAR-2014-0827-0077.

[144] This discussion draws from Berman, E. and L. T. M. Bui (2001). "Environmental Regulation and Labor Demand: Evidence from the South Coast Air Basin." Journal of Public Economics 79(2): 265-295, p. 293. Docket EPA-HQ-OAR-2014-0827-0074.

[145] Hamermesh (1993). Labor Demand (Princeton, NJ: Princeton University Press), Chapter 2. Docket EPA-HQ-OAR-2014-0827-0082.

etc.[146] In contrast, the peer-reviewed empirical literature specifically estimating employment effects of environmental regulations is very limited. Several empirical studies, including Berman and Bui (2001),[147] Morgenstern, Pizer and Shih (2002),[148] Gray et al (2014),[149] and Ferris, Shadbegian and Wolverton (2014)[150] suggest that net employment impacts may be zero or slightly positive but small even in the regulated sector. Other research suggests that more highly regulated counties may generate fewer jobs than less regulated ones.[151] However, since these latter studies compare more regulated to less regulated counties, they overstate the net national impact of regulation to the extent that regulation causes plants to locate in one area of the country rather than another. List et al. (2003)[152] find some evidence that this type of geographic relocation may be occurring. Overall, the peer-reviewed literature does not contain evidence that environmental regulation has a large impact on net employment (either negative or positive) in the long run across the whole economy.

Analytic challenges make it very difficult to accurately produce net employment estimates for the whole economy that would appropriately capture the way in which costs, compliance spending, and environmental benefits propagate through the macro-economy. Quantitative estimates are further complicated by the fact that macroeconomic models often have very little sectoral detail and usually assume that the economy is at full employment. EPA is currently in the process of seeking input from an independent expert panel on modeling economy-wide impacts, including employment effects. For more information, see: http://yosemite.epa.gov/sab/sabproduct.nsf/0/07E67CF77B54734285257BB0004F87ED?OpenDocument.

B.2.4 Employment Impacts in the Motor Vehicle and Parts Manufacturing Sector

Here we describe estimated changes in employment in the motor vehicle, trailer, and parts (hence, motor vehicle) manufacturing sectors associated with the MY2022-2025 standards. We

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[146] Ehrenberg, Ronald G., and Robert S. Smith (2000). Modern Labor Economics: Theory and Public Policy, Addison Wesley Longman, Inc., Chapter 4. Docket EPA-HQ-OAR-2014-0827-0077.

[147] Berman, E. and L. T. M. Bui (2001). "Environmental Regulation and Labor Demand: Evidence from the South Coast Air Basin." Journal of Public Economics 79(2): 265-295. Docket EPA-HQ-OAR-2014-0827-0086.

[148] Morgenstern, Richard D., William A. Pizer, and Jhih-Shyang Shih (2002). "Jobs Versus the Environment: An Industry-Level Perspective." Journal of Environmental Economics and Management 43: 412-436. Docket EPA-HQ-OAR-2014-0827-0088.

[149] Gray, Wayne B., Ronald J. Shadbegian, Chunbei Wang, and Merve Meral (2014). "Do EPA Regulations Affect Labor Demand? Evidence from the Pulp and Paper Industry." Journal of Environmental Economics and Management 68: 188-202. Docket EPA-HQ-OAR-2014-0827-0080.

[150] Ferris, Ann, Ronald J. Shadbegian and Ann Wolverton (2014). "The Effect of Environmental Regulation on Power Sector Employment: Phase I of the Title IV SO2 Trading Program." Journal of the Association of Environmental and Resource Economists 1(4): 521-553. Docket EPA-HQ-OAR-2014-0827-0078.

[151] Greenstone, M. (2002). "The Impacts of Environmental Regulations on Industrial Activity: Evidence from the 1970 and 1977 Clean Air Act Amendments and the Census of Manufactures." Journal of Political Economy 110(6): 1175-1219, Docket EPA-HQ-OAR-2014-0827-0081; Walker, Reed. (2011). "Environmental Regulation and Labor Reallocation." American Economic Review: Papers and Proceedings 101(3): 442-447, Docket EPA-HQ-OAR-2014-0827-0091.

[152] List, J. A., D. L. Millimet, P. G. Fredriksson, and W. W. McHone (2003). "Effects of Environmental Regulations on Manufacturing Plant Births: Evidence from a Propensity Score Matching Estimator." The Review of Economics and Statistics 85(4): 944-952. Docket EPA-HQ-OAR-2014-0827-0087.

focus on the motor vehicle manufacturing sector because it is directly regulated by the GHG/fuel economy standards, and because it is likely to bear most of any employment changes due to the standards. We include discussion of effects on the parts manufacturing sector, because the motor vehicle manufacturing sector can either produce parts internally or buy them from an external supplier, and we do not have estimates of the likely breakdown of effort between the two sectors.

We follow the theoretical structure of Berman and Bui [153] of the impacts of regulation in employment in the regulated sectors. In Berman and Bui's (2001, p. 274-75) theoretical model, as described above, the change in a firm's labor demand arising from a change in regulation is decomposed into two main components: output and substitution effects. As the output and substitution effects may be both positive, both negative, or some combination, standard neoclassical theory alone does not point to a definitive net effect of regulation on labor demand at regulated firms.

In their comments on the Draft TAR, Business for Innovative Climate and Energy Policy claims that the standards create jobs through its benefits to the auto sector. It cites a report from Ceres, discussed in Section B.1.3.3 ,[154] that finds that automakers will be profitable even with gasoline prices below $2 per gallon. As explained above, EPA expects that the auto industry needs a higher standard for profitability than simple break-even over time. The Lima Auto Task Force expresses concern over the effects of the standards on employment.

The Alliance of Automobile Manufacturers argues that EPA has not fulfilled its obligation to consider employment impacts because it did not quantify the impacts on employment due to changes in vehicle sales (the output effect, described below) in the Draft TAR. As explained in Section B.1.3.3 , EPA considers estimates of the effects of the standards on sales to be so highly uncertain that quantifying them may not provide useful policy insight; without an adequate way to estimate those effects, it is not possible to estimate the output effect. We repeat both that the Midterm Evaluation requirements do not require such a quantified analysis, and that EPA views it preferable to consider an issue with reliable qualitative information than unhelpfully wide-ranging quantified estimates. The Alliance and the National Automobile Dealers Association (NADA) cite the report from the Center for Automotive Research (CAR), discussed in Section B.1.3.3 and Chapter 4.2.1 of the TSD that estimates employment impacts in the auto sector ranging from an increase of 34,000 to a decrease of 237,000 jobs in 2027.[155] This analysis is based only on the output effect--the effect of the standards on vehicle sales. As discussed in Section B.1.3.3 and TSD Chapter 4.2.1, EPA considers the sales estimates from the CAR report to be highly flawed, and thus does not have confidence in its estimates of the output effect. It claims that the output effect dominates the substitution effect because "any so-called creation of employment because of higher mandated FE [fuel economy] technology content is exceeded by even greater revenue loss due to lower sales." EPA does not understand what the magnitude of

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[153] Berman, E. and L. T. M. Bui (2001). "Environmental Regulation and Labor Demand: Evidence from the South Coast Air Basin." Journal of Public Economics *79*(2): 265-295. Docket EPA-HQ-OAR-2014-0827-0086.

[154] Baum, Alan, and Dan Luria (2016). "Economic Implications of the Current National Program v. a Weakened National Program in 2022-2025 for Detroit Three Automakers and Tier One Suppliers." Ceres Analyst Brief, https://www.ceres.org/files/analyst-brief-economic-effects-on-us-automakers-and-suppliers/at_download/file , accessed 10/17/2016.

[155] McAlinden, Sean, et al. (2016). "The Potential Effects of the 2017-2025 EPA/NHTSA GHG/Fuel Economy Mandates on the U.S. Economy." Center for Automotive Research http://www.cargroup.org/?module=Publications&event=View&pubID=143 , accessed 10/11/2016.

asserted revenue loss indicates about the relative magnitudes of the output and substitution effects. Regardless, as discussed previously, it considers the estimated revenue losses in this CAR report to be significantly flawed and unreliable.

In contrast, the BlueGreen Alliance points out the high levels of employment in the motor vehicle and parts industry, as well as in the dealers' sector, and cite studies claiming increases in manufacturing employment of 50,000 to 100,000 by 2025-2030 as a result of the standards. It also points out that "proactive manufacturing policy" for the auto industry promotes employment in this sector. The Natural Resources Defense Council (NRDC) cites a study from 2011 that found more than 150,000 U.S. jobs associated with reducing vehicle fuel consumption, and points out that weakening the standards will put those jobs at risk. NRDC also argues that there is potential for job growth in other sectors due to fuel savings stimulating the broader economy. EPA agrees with these latter general comments that the standards may increase employment, especially in production of GHG-reducing technologies, though it does not endorse these specific estimates.

Following the Berman and Bui framework for the impacts of regulation on employment in the regulated sector, we consider two effects for the motor vehicle sector: the output effect and the substitution effect.

B.2.4.1 The Output Effect

The output effect measures the effect on employment due to new vehicle sales only. If vehicle sales increase, then more people will be required to assemble vehicles and their components. If vehicle sales decrease, employment associated with these activities will decrease. The effects of the MY2022-25 standards on vehicle sales thus depend on the perceived desirability of the new vehicles relative to other transportation options. On one hand, these standards will increase vehicle costs; by itself, this effect would reduce vehicle sales. In addition, while adverse effects on other vehicle characteristics would also decrease sales, there is currently no evidence of systematic adverse effects of fuel-saving technologies (see Section B.1.5.1.2). On the other hand, these standards will reduce the fuel costs of operating the vehicles; by itself, this effect would increase vehicle sales, especially if potential buyers have an expectation of increasing fuel prices. EPA has not made an estimate of the effects of the standards on vehicle sales (see Section B.1.3.3).

B.2.4.2 The Substitution Effect

The substitution effect includes the impacts on employment due to the changes in technologies needed for vehicles to meet the standards, separate from the effect due to vehicle sales (that is, as though holding output constant). This effect includes both changes in employment due to incorporation of abatement technologies and overall changes in the labor intensity of manufacturing. We here capture these effects using estimates of the historic share of labor as a part of the cost of production, which we then extrapolate to provide future estimates of the share of labor as a cost of production. When these shares are multiplied by the change in the cost of production, they approximate the change in labor associated with the cost increases associated with the standards. We present estimates for this effect to provide a sense of the order of magnitude of expected impacts on employment, which we expect to be small in the automotive sector, and to repeat that regulations may have positive as well as negative effects on employment.

In the Draft TAR (Chapter 7.4.2), we estimated this effect using the ratio of workers to each $1 million of expenditures in that sector. Though, as noted above, we received comments critical of our not quantifying the output effect, we did not receive comments on this approach to the substitution effect. The use of these ratios has both advantages and limitations. It is often possible to estimate these ratios for quite specific sectors of the economy: for instance, it is possible to estimate the average number of workers in the light-duty vehicle manufacturing sector per $1 million spent in the sector, rather than use the ratio from another, more aggregated sector, such as motor vehicle manufacturing. As a result, it is not necessary to extrapolate employment ratios from possibly unrelated sectors. On the other hand, these estimates are averages for the sectors, covering all the activities in those sectors; they may not be representative of the labor required when expenditures are required on specific activities, or when manufacturing processes change sufficiently that labor intensity changes. For instance, the ratio for the motor vehicle manufacturing sector represents the ratio for all vehicle manufacturing, not just for emissions reductions associated with compliance activities. In addition, these estimates do not include changes in sectors that supply these sectors, such as steel or electronics producers. They thus may best be viewed as the effects on employment in the auto sector due to the changes in expenditures in that sector, rather than as an assessment of all employment changes due to these changes in expenditures. In addition, this approach estimates the effects of increased expenditures while holding constant the labor intensity of manufacturing; it does not take into account changes in labor intensity due to changes in the nature of production. This latter effect could either increase or decrease the employment impacts estimated here.[156]

Some of the costs of these standards will be spent directly in the motor vehicle manufacturing sector, but it is also likely that some of the costs will be spent in the motor vehicle parts manufacturing sector. The analysis here draws on estimates of workers per $1 million of expenditures for both of these sectors.

There are several public sources for estimates of employment per $1 million expenditures. The U.S. Bureau of Labor Statistics (BLS) provides its Employment Requirements Matrix (ERM),[157] which provides direct estimates of the employment per $1 million in sales of goods in 202 sectors. The values considered here are for Motor Vehicle Manufacturing (NAICS 3361) and Motor Vehicle Parts Manufacturing (NAICS 3363) for 2014.

The U.S. Census Bureau provides both the Annual Survey of Manufacturers[158] (ASM) and the Economic Census (EC). The ASM is a subset of the Economic Census, based on a sample of establishments; though the Census itself is more complete, it is conducted only every 5 years, while the ASM is annual. Both include more sectoral detail than the BLS ERM: for instance, while the ERM includes the Motor Vehicle Manufacturing sector, the ASM and EC have detail at the 6-digit NAICS code level (e.g., light truck and utility vehicle manufacturing). While the

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[156] As noted above, Morgenstern et al. (2002) (Docket EPA-HQ-OAR-2014-0827-0088) separate the effect of holding output constant into two effects: the cost effect, which holds labor intensity constant, and the factor shift effect, which estimates those changes in labor intensity.

[157] http://www.bls.gov/emp/ep_data_emp_requirements.htm; see "Substitution Effect Employment Impacts calculation," Docket EPA-HQ-OAR-2015-0827.

[158] http://www.census.gov/manufacturing/asm/index.html; see "Substitution Effect Employment Impacts calculation," Docket EPA-HQ-OAR-2015-0827.

ERM provides direct estimates of employees/$1 million in expenditures, the ASM and EC separately provide number of employees and value of shipments; the direct employment estimates here are the ratio of those values. The values reported are for Motor Vehicle Manufacturing (NAICS 3361), Automobile and Light Duty Motor Vehicle Manufacturing (NAICS 33611), and Motor Vehicle Parts Manufacturing (NAICS 3363), for 2014 for the ASM and 2012 for the EC.

The values used here are adjusted to remove the employment effects of imports through use of a ratio of domestic production to domestic sales of 0.663.[159]

Table B.5 provides the values, either given (BLS) or calculated (ASM and EC) for employment per $1 million of expenditures in 2014 (2012 for EC) the most recent values available, all adjusted to 2015 dollars using the Bureau of Economic Analysis's Implicit GDP Price Deflators.[160] Although the ASM appears to provide slightly higher values than the ERM, the different data sources provide similar patterns for the estimates for the sectors.

Table B.5 Employment per $1 Million Expenditures (2015$) in the Motor Vehicle Manufacturing Sector[a]

Source	Sector	Ratio of workers per $1 million expenditures	Ratio of workers per $1 million expenditures, adjusted for domestic vs. foreign production
BLS ERM	Motor vehicle mfg (3361)	0.38	0.25
BLS ERM	Motor vehicle parts mfg (3363)	1.67	1.10
ASM	Motor vehicle mfg (3361)	0.57	0.38
ASM	Automobile and light duty motor vehicle mfg (33611)	0.52	0.35
ASM	Automobile mfg (336111)	0.61	0.41
ASM	Motor vehicle parts mfg (3363)	2.03	1.34
EC	Motor vehicle mfg (3361)	0.58	0.38
EC	Automobile and light duty motor vehicle mfg (33611)	0.53	0.35
EC	Automobile mfg (336111)	0.61	0.41
EC	Motor vehicle parts mfg (3363)	2.07	1.37

Note:
[a] BLS ERM refers to the U.S. Bureau of Labor Statistics' Employment Requirement Matrix, 2014 values. ASM refers to the U.S. Census Bureau's Annual Survey of Manufactures, 2014 values. EC refers to the U.S. Census Bureau's Economic Census, 2012 values. These are the most recent data available.

Over time, the amount of labor needed in the motor vehicle industry has changed: automation and improved methods have led to significant productivity increases. The BLS ERM, for

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[159] To estimate the proportion of domestic production affected by the change in sales, we use data from WardsAuto for total car and truck production in the U.S. compared to total car and truck sales in the U.S. Over the period 2006-2015, the proportion averages 66.3 percent. From 2012-2015, the proportion average is slightly higher, at 69.2 percent.

[160] At the time of access, the EC data was only available by 2-, 3-, or 6-digit NAICS industry code. To construct the 4- and 5-digit numbers, we separately summed total employees and total expenditure for each 6-digit subcategory.

instance, provided estimates that, in 1997, 1.06 workers in the Motor Vehicle Manufacturing sector were needed per $1 million, but only 0.38 workers by 2014 (in 2015$).[161] Because the ERM is available annually for 1997-2014, we used these data to estimate productivity improvements over time. We regressed logged ERM values on a year trend for the Motor Vehicle Manufacturing and Motor Vehicle Parts Manufacturing sectors. We used this approach because the coefficient describing the relationship between time and productivity is a direct measure of the average percent change in productivity per year. The results suggest a 6.6 percent per year productivity improvement in the Motor Vehicle Manufacturing Sector, and a 4.9 percent per year improvement in the Motor Vehicle Parts Manufacturing Sector.

We then used the regression results to project the number of workers per $1 million through 2025. We calculated separate sets of projections (adjusted to 2015$) for both the BLS ERM data as well as the EC and ASM for all sectors discussed above. The BLS ERM projections were calculated directly from the fitted regression equations since the regressions themselves used ERM data. For the ASM and EC projections, we used the ERM's ratio of the projected value in each future year to the projected value in 2014 for the ASM and 2012 for the EC (the base years in our data) to determine how many workers will be needed per $1 million of 2015$. In other words, we apply the projected productivity growth estimated using the ERM data to the ASM and EC numbers.

Finally, to simplify the presentation and give a range of estimates, we compared the projected employment among the sectors for the ERM, EC, and ASM, and we provide here only the maximum and minimum effects in each year across all sectors. We provide the range rather than a point estimate because of the inherent difficulties in estimating employment impacts; the range gives an estimate of the expected magnitude. The details of the calculations may be found in the docket. The Motor Vehicle Parts Manufacturing Sector value from the ASM provides the maximum employment estimates per $1 million; the Motor Vehicle Manufacturing Sector value from the ERM provides the minimum estimates.

Section C.1 of this Appendix discusses the vehicle cost estimates developed for the standards. The final step in estimating employment impacts is to multiply costs (in $ millions) by workers per $1 million in costs, to estimate employment impacts in the regulated and parts manufacturing sectors. Table B.6 presents the projected reference case costs and the corresponding minimum and maximum estimated employment impacts. For each year, additional ranges in parentheses are included that reflect estimates from projections using high and low fuel price scenarios.[162] Increased costs of vehicles and parts, by itself, and holding labor intensity constant, would be expected to increase employment between 2021 and 2025 by a few hundred to perhaps 12,000. We note again that these estimates are only for substitution-effect employment; it omits effects on total employment due to changes in vehicle sales, because we have not quantified an effect on vehicle sales.

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[161] http://www.bls.gov/emp/ep_data_emp_requirements.htm; this analysis used data for sectors 80 (Motor Vehicle Manufacturing) and 82 (Motor Vehicle Parts Manufacturing) from "Chain-weighted (2009 dollars) real domestic employment requirements tables;" see "Substitution Effect Employment Impacts calculation," Docket EPA-HQ-OAR-2015-0827.

[162] As discussed in Section C, the costs for the reference fuel price scenario do not necessarily fall between those of the high and low fuel price scenarios, because fuel prices are not the only difference in the scenarios; they differ in assumptions about the vehicle fleet as well.

While we estimate employment impacts, measured in job-years, beginning with program implementation, some of these employment gains may occur earlier as vehicle manufacturers and parts suppliers hire staff in anticipation of compliance with the standards. A job-year is a way to calculate the amount of work needed to complete a specific task. For example, a job-year is one year of full-time work for one person.

Table B.6 Partial Employment Impact due to Substitution Effect of Increased Costs of Vehicles and Parts, in Job-years[a]

Year	Costs (Millions of 2015$)	Minimum Employment Due to Substitution Effect (ERM estimates, expenditures in the Motor Vehicle Mfg Sector)	Maximum Employment Due to Substitution Effect (ASM estimates, expenditures in the Parts Sector)
2021	$2,334 ($2,266 - $2,508)	200 (200 - 300)	2,200 (2,200 - 2,400)
2022	$5,269 ($5,140 - $5,638)	500 (500 - 600)	4,800 (4,700 - 5,100)
2023	$8,308 ($8,198 - $8,833)	800 (800 - 800)	7,200 (7,100 - 7,600)
2024	$11,298 ($10,983 - 11,940)	1,000 (1,000 - 1,000)	9,300 (9,000 - 9,800)
2025	$14,375 ($13,607-15,266)	1,200 (1,100 - 1,300)	11,300 (10,700 - 12,000)

Note:
[a] Numbers in parentheses reflect the estimates derived from scenarios with high and low fuel prices.

B.2.4.3 Summary of Employment Effects in the Motor Vehicle Sector

The overall effect of the standards on motor vehicle sector employment depends on the relative magnitude of the output effect and the substitution effect. Because we do not have quantitative estimates of the output effect, and only a partial estimate of the substitution effect, we cannot reach a quantitative estimate of the overall employment effects of the standards on auto sector employment or even whether the total effect will be positive or negative.

The Urban Air Initiative mentions the benefits to the economy, including employment, associated with reduced fuel consumption. Environmental Defense Fund points out that more efficient vehicles make the auto industry less vulnerable to unanticipated changes in fuel prices, and thus reduce changes in employment. The International Union, United Automobile, Aerospace & Agricultural Implement Workers of America (UAW) seeks to avoid incentives in the program that might shift production overseas. The standards are not expected to provide incentives for manufacturers to shift employment between domestic and foreign production. This is because the standards will apply to vehicles sold in the U.S. regardless of where they are produced. WardsAuto data suggest that the current share of domestic production for cars and trucks is very similar to the share in 2006: 66 percent in 2006, and 68 percent in 2015.

If production overseas already involved increased expertise in satisfying the requirements of the standards, there may be some initial incentive for foreign production, but meeting the standards may lead to increased opportunities for domestic production to sell in other markets. To the extent that the requirements of these standards might lead to installation and use of technologies that other countries may seek now or in the future, developing this capacity for domestic production now may provide some additional ability to serve those markets. Business for Innovative Climate and Energy Policy, Environmental Entrepreneurs, the Natural Resources Defense Council, and Consumer Federation of America all argue that the standards promote the global competitiveness of the U.S. auto industry in a world where vehicle efficiency and GHG standards are tightening, by promoting development and sales of vehicles that customers elsewhere in the world will favor.

B.2.4.4 Motor Vehicle Parts Manufacturing Sector

Some vehicle parts are made in-house and would be included directly in the regulated sector. Others are made by independent suppliers and are not directly regulated, but they will be affected by the standards as well. The parts manufacturing sector will be involved primarily in providing “add-on” parts, or components for replacement parts built internally. If demand for these parts increases due to the increased use of these parts, employment effects in this sector are expected to be positive. If the output effect in the regulated sectors is significantly negative enough, it is possible that demand for other parts may decrease. As noted, EPA does not predict a magnitude or direction for the output effect.

The Aluminum Association points to increases in its employment as it has expanded automotive aluminum body sheet manufacturing. The aluminum sector is not explicitly in the estimates provided of motor vehicle parts manufacturing. We also note that expanded use of aluminum may come at the expense of other materials. EPA did not receive comments on losses in other manufacturing-related sectors.

B.2.5 Employment Impacts in Other Affected Sectors

B.2.5.1 Effects on Employment for Auto Dealers

The effects of the standards on employment for auto dealers depend principally on the effects of the standards on light duty vehicle sales: increases in sales are likely to contribute to employment at dealerships, while reductions in sales are likely to have the opposite effect. As discussed in Section B.1.3 , EPA does not estimate the effects of the standards on vehicle sales. In addition, auto dealers may be affected by any changes in maintenance and service costs. Increases in those costs are likely to increase labor demand in dealerships, and reductions are likely to decrease labor demand.

Concerns have been raised about consumer acceptance of technologies used to meet the standards, though these effects do not seem significant to date (see Section B.1.5). Auto dealers may play a major role in explaining the merits and disadvantages of these new technologies to vehicle buyers. This additional role may also affect employment levels at dealers.

B.2.5.2 Effects on Employment for Fuel Suppliers

In addition to the effects on the auto manufacturing and parts sectors, the standards result in changes in fuel use that lower GHG emissions.

Expected petroleum fuel consumption reductions can be found in SectionC.2 . While this reduced consumption represents fuel savings for purchasers of fuel, it represents a loss in value of output for the petroleum refinery industry, fuel distributors, and gasoline stations. The loss of expenditures to petroleum fuel suppliers throughout the petroleum fuel supply chain, from the petroleum refiners to the gasoline stations, is likely to result in reduced employment in these sectors. Securing America's Future Energy (SAFE) points out that falling oil prices have contributed to workers losing jobs in the energy sector. In contrast, when oil prices are high, the auto industry loses jobs. SAFE implies that jobs in the U.S. are vulnerable to oil price shocks regardless of the direction of the shock.

Because the fuel production sector is material-intensive, the employment effect is not expected to be large.[163] Although gasoline stations will sell less fuel, the fact that many provide other goods, such as food and car washes, moderates losses in this sector. In addition, it may be difficult to distinguish these effects from other trends, such as increases in petroleum sector labor productivity that may also lower labor demand.

Auto manufacturers may choose to meet the standards through alternatively-fueled vehicles, such as those that use electricity, hydrogen, or compressed natural gas (CNG), though EPA does not project large use of these vehicles. Such fuels may require additional infrastructure, such as electricity charging locations or hydrogen fueling stations (see Section B.3.2). Providing this infrastructure will require some increased employment. In addition, the production of these fuels is likely to require some additional labor. The National Propane Gas Association, for instance, in supporting use of propane, point out that it has an established network of suppliers, and suggests it might increase employment with more use of propane. We did not receive comments on employment impacts from other fuel suppliers. We have insufficient information at this time to predict whether the increases in labor associated with increased infrastructure provision and generation for production of other fuels will be greater or less than the employment reductions associated with reduced demand for petroleum fuels.

B.2.5.3 Effects on Employment due to Impacts on Consumer Expenditures

As a result of these standards, consumers will likely pay higher up-front costs for the vehicles, but they are expected to recover those costs in a fairly short payback period (see SectionC.2.4). As a result, consumers are expected to have additional money to spend on other goods and services, though the timing for access to that additional money depends on the payback period and whether the consumer borrows money to buy the vehicle. These increased expenditures could support employment in those sectors where consumers spend their savings.

These increased expenditures will occur in the years in which the fuel savings exceed expenditures on the up-front costs. If, on the one hand, the economy is at full employment during that time, any change in consumer expenditures would primarily represent a shift in employment among sectors. If, on the other hand, the economy has substantial unemployment, these expenditures would contribute to employment through increased consumer demand.

B.2.6 Summary

The primary employment effects of these standards are expected to be found in several key sectors: auto manufacturers, auto parts manufacturing, auto dealers, fuel production and supply, and consumers (via the employment effects of their fuel savings). In an economy with full employment, the primary employment effect of standards is likely to be to shift employment from one sector to another, rather than to increase or decrease employment. For that reason, we focus our partial quantitative analysis on employment in the regulated sector, to examine the

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[163] In the 2014 BLS ERM cited above, the Petroleum and Coal Products Manufacturing sector has a ratio of workers per $1 million of 0.215, lower than all but two of the 181 sectors with non-zero employment per $1 million.

impacts on that sector directly. We discuss the likely direction of other impacts in the regulated sector as well as in other directly related sectors, but we do not quantify those impacts, because they are more difficult to quantify with reasonable accuracy, particularly so far into the future.

For the regulated sector, the partial employment impact due to the substitution effect of increased costs of autos is expected to be positive. The total effect of the standards on motor vehicle employment depends in addition on changes in vehicle sales, which are not quantified; thus, we do not estimate the total effects of the standards in the regulated industry.

Effects in other sectors that are affected by vehicle sales are also ambiguous. Reduced petroleum fuel production implies less employment in the petroleum sectors, although there could be increases in employment related to providing infrastructure for alternative fuels if manufacturers choose to comply with the standard through increased production of vehicles that use those fuels. Finally, consumer spending is expected to affect employment through changes in expenditures in general retail sectors; net fuel savings by consumers are expected to increase demand (and therefore employment) in other sectors. Thus, while the standards are likely to have some effect on employment, this effect is likely to be small enough that it cannot be distinguished from other factors affecting employment, especially macroeconomic conditions. As has been noted, under conditions of full employment, any changes in employment levels in the regulated sector due to this program are mostly expected to be offset by changes in employment in other sectors.

B.3 Other Relevant Factors

B.3.1 Vehicle Safety Effects

In setting emissions standards for mobile source air pollutants, EPA considers factors relevant to public health and welfare, including safety. See, e.g. 74 FR at 49464/3 (Sept. 28, 2009). As part of the Proposed Determination, EPA has assessed the potential of the MY2022-2025 standards to affect vehicle safety. (EPA, of course, also considered the issue of safety in initially promulgating the standards. See 77 FR 62740-768).

In the Draft TAR (Chapter 8), the agencies reviewed the relationships between mass, size, and fatality risk based on the statistical analysis of historical crash data, which included a NHTSA updated analysis performed by using the most recent available crash data. EPA used the results from this updated analysis to calculate the estimated safety impacts of the modeled mass reductions over the lifetimes of new vehicles in response to MY2022-2025 standards.

Consistent with the Draft TAR, Table B.7 presents the safety coefficients assessed in our analysis, expressed as the estimated percent increase in U.S. societal fatality risk per ten billion VMT for each 100-pound reduction in vehicle mass, while holding footprint constant, for each of five classes of vehicles.

Table B.7 Fatality Increase (%) per 100-Pound Mass Reduction While Holding Footprint Constant[164]

MY2003-2010 CY 2005-2011	Fatality Increase (%) Per 100-Pound Mass Reduction While Holding Footprint Constant	
	Point Estimate	95% Confidence Bounds
Cars < 3,197 pounds	1.49	- 0.30 to +3.27
Cars > 3,197 pounds	0.50	- 0.59 to +1.60
CUVs and minivans	-0.99	-2.17 to + 0.19
Truck-based LTVs < 4,947 pounds	-0.10	- 1.08 to +0.88
Truck-based LTVs > 4,947 pounds	-0.72	- 1.45 to +0 .02

EPA believes the results in Table B.7 represent the most up-to-date safety analysis. For that reason, we use those results in the Proposed Determination as the safety coefficients to assess the safety impact in EPA's OMEGA model.

Using the same coefficients as used in the Draft TAR, taken from the 2016 NHTSA study, EPA used the OMEGA core model to estimate the impact of weight reduction on net fatalities per mile driven by the fleet. This is done using the weight reductions applied by OMEGA and applying to those weight reductions to the safety metrics shown in Table B.8. The "Change per 100 lbs" column shows the change in the number of fatalities as a percentage for each 100 pounds of weight removed from vehicles described by the "Safety Class Description" column. The "FMVSS Adjustment" factor is also applied to calculate the impact on fatalities per billion miles of vehicle travel. All of the inputs presented in Table B.8 are consistent with inputs used in the Draft TAR.[165]

Table B.8 Metrics Used in the OMEGA Safety Analysis

Safety Class Description	Change per 100 lbs	Base per billion mile	FMVSS Adjustment
PC below 3197	1.49%	13.59	0.904
PC above 3197	0.51%	11.15	0.904
LT below 4947	-0.10%	14.35	0.904
LT above 4947	-0.72%	16.06	0.904
CUE Minivan	-0.99%	9.00	0.904

Using these metrics, EPA calculated the impact of mass reduction on net vehicle-related fatalities, as shown in Table B.9, which shows the results of EPA's safety analysis over the lifetimes of MY2021 to 2025 vehicles (EPA explains in Section C.1 why MY2021 vehicles are included even though the Proposed Determination is considering the MY2022 to 2025 standards). A positive number would mean that fatalities are projected to increase; a negative number means that fatalities are projected to decrease. As shown, the EPA analysis projects considerable fatality decreases in the reference and control cases. Those decreases should be seen as being relative to the current fleet moving forward in time without mass reductions in response to new standards (i.e., relative to the projected MY2021 through 2025 baseline fleet). The reference case standards reduce fatalities relative to the projected baseline fleet (a fleet that

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[164] Table 8.4, Chapter 8, Draft TAR, EPA-420-D-16-900 (July, 2016).

[165] See Table 8.15 of the Draft TAR, EPA-420-D-16-900 (July 2016).

continues to meet the 2014 standards in place for the year upon which our baseline fleet is generated) due to mass reduction applied to move the fleet from the 2014 standards to the 2021 standards (the reference case standards). In the reference case, those 2021 standards continue indefinitely for subsequent model year vehicles. The control case (i.e., the 2022 through 2025 standards) then results in further mass reduction beyond the reference case level. This further mass reduction is projected to further reduce fatalities relative to both the baseline and reference cases. On net, the EPA analysis shows small net fatality decreases over the lifetimes of MY2021 through 2025 vehicles.

Table B.9 Net Fatality Impacts over the Lifetimes of MY2021-2025 Vehicles

Fuel Price Case	Fatality Impacts in the Reference Case	Fatality Impacts in the Control Case	Net Fatality Impacts
AEO2016 Reference	-1,412	-1,863	-451
AEO2016 High	-1,060	-1,435	-375
AEO2016 Low	-1,670	-2,297	-627

EPA received a few public comments on the mass/safety analysis contained in the Draft TAR Chapter 8. National Resources Defense Council (NRDC) believes strongly that the 2025 standards can be achieved without an increased risk to safety, and that the fleet of future vehicles can be built lighter weight, less polluting and safe. The Alliance of Automobile Manufacturers commented that it found inconsistencies in the results “that require further physical explanations.” Tom Wenzel, of Lawrence Berkeley National Laboratory (LBNL), on behalf of Department of Energy (DOE), recommended that the agencies should use a second set of regression coefficients, such as those used in the “LBNL baseline"[166] to run EPA’s OMEGA model, “because the estimated relationships between mass reduction and societal fatality risk are not consistently statistically different from zero, and are sensitive to the data and variables used in the regression models."

Table B.8 Comparison between NHTSA & LBNL Baseline Model Estimate

	Fatality Increase (%) Per 100-Pound Mass Reduction While Holding Footprint Constant	
MY2003-2010 CY 2005-2011	**NHTSA** **Baseline Point Estimate**	**LBNL** **Baseline Point Estimate**
Cars < 3,197 pounds	1.49	0.52
Cars > 3,197 pounds	0.50	- 0.80
CUVs and minivans	- 0.99	-0.35
Truck-based LTVs < 4,947 pounds	-0.10	-1.01
Truck-based LTVs > 4,947 pounds	-0. 72	-2.27

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[166] Tom Wenzel, Table 5.16, “Assessment of NHTSA’s Report “Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2003-2010 Passenger Cars and LTVs, Preliminary report prepared for the Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy.” LBNL -1005177. (July, 2016).

As indicated at Table B.8, if we were to apply Wenzel's "LBNL baseline" in our OMEGA model, the estimates of potential adverse safety implications would be even less, which might influence a choice to model greater levels of mass reduction in assessing potential compliance pathways. We acknowledge the rationale for Wenzel's recommendation. However, for purposes of the Proposed Determination, we believe it is appropriate to continue using the approach taken in the Draft TAR, since it is more conservative and we want to ensure there are no significant adverse safety implications associated with the 2022-2025 standards.

B.3.2 Alternative Fuel Infrastructure

Although the Draft TAR projected that only a very small fraction of the fleet will need to be PEVs to meet the MY2025 standards, alternative fuel vehicles such as battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) (collectively called plug-in electric vehicles, or PEVs), and fuel cell electric vehicles (FCEVs) are an essential part of any future vehicle fleet intended to meet long term climate and air quality goals, as discussed in Section V. In addition, other alternative fuels such as ethanol (E85) and compressed natural gas (CNG) have the potential to contribute to GHG emission reductions. Chapter 9 of the Draft TAR provided an overview of alternative fuel vehicle infrastructure, including the status, costs, and trends in PEV charging infrastructure and hydrogen infrastructure, and examined the challenges being addressed to scale up the infrastructure as advanced vehicle sales grow in response to market demand and for compliance with the federal standards.

Chapter 9 of the Draft TAR concluded that infrastructure does not present a barrier for alternative fuel vehicles to be used in meeting the 2022-2025 national program GHG and fuel economy standards. We presented information to show that sufficient charging and refueling capacity is likely to exist to support the relatively small numbers of PEVs that we expect manufacturers to choose to produce in order to meet the standards. We also observed that, apart from the regulatory targets, auto manufacturers may decide to expand production of alternative fueled vehicles for other reasons, including market demand.

Although the majority of PEV charging occurs at home and home-based charging is an option for many PEV drivers, national PEV infrastructure in public and work locations is progressing. With over 12,000 public and private stations and over 38,000 connectors, public charging needs are being addressed, additional public charge stations are opening weekly, and strong growth is forecast. With vehicle grid integration, inductive charging, and vehicle to grid bi-direction power flow, tremendous opportunities in PEV infrastructure are on the horizon. These opportunities, coupled with a growing PEV market, will further the commercial infrastructure market and ultimately the availability of PEV infrastructure.

In public comments on the Draft TAR, several stakeholders discussed the conclusions of the Draft TAR about the sufficiency of existing and expected infrastructure development. A number of these comments, generally from the automotive manufacturing industry, focused on the commenters' belief that a greater degree of infrastructure development would be needed because they expect that more of these vehicles will be needed to meet the standards. However, as we discuss in Section C, we continue to conclude that only a few percent of PEVs and FCEVs will be needed to meet the standards based on evaluation of potential least cost compliance pathways. Therefore, we also continue to conclude that current and expected expansion of electric charging and hydrogen fueling infrastructure, as discussed in Chapter 9 of the Draft TAR, will be sufficient to supply that segment of the automotive fleet.

Other comments from the Alliance of Automobile Manufacturers (the Alliance) raised issues that we believe have been adequately addressed in Chapter 9 of the Draft TAR. First, the Draft TAR (on page 9-24) discusses how we accounted for PHEVs, not just BEVs, in discussing vehicle charging points. Next, the Alliance is correct that the Draft TAR does not provide a geospatial assessment of the public charging network. However, while the data analyses presented in the Draft TAR are not region-specific, the aggregate conclusions are still based on a geographically dispersed set of PEVs. Also, regarding concerns that Level 1 charging is not a long-term solution, the Draft TAR's overview of PEV infrastructure also explicitly states that Level 1 charging is a minimum availability for "most" PEVs (page 9-1), and we also discuss the other existing and emerging charging systems. Later discussion in Chapter 9 acknowledges and addresses many of the other concerns mentioned in the Alliance comments. We also note that the Draft TAR did not specifically imply Level 1 charging as the only viable option for multiple unit housing developments, as suggested in the Alliance comments. Regarding the Alliance suggestion that the Draft TAR discussion of charging costs include a more thorough analysis and presentation in order to "fully inform customers," we continue to believe that the Draft TAR provides a reasonable technical assessment of infrastructure issues, which did not include a specific intention of informing EV customers about their charging options.

Regarding hydrogen fueling infrastructure for FCEVs, the Alliance commented that in general, hydrogen infrastructure needs to lead FCEV development. Our expectation is that at a minimum hydrogen infrastructure development should occur in parallel with vehicle introduction, although, as discussed in detail in Chapter 9 of the Draft TAR, recent hydrogen infrastructure development has often occurred ahead of the vehicle deployment. Also, as observed in the Alliance comments, Toyota reported a temporary delay in the release of their FCEV model (Mirai) due to infrastructure availability issues. However, this appears to have been a short-term issue, and more recent data Toyota has released shows continued growth in sales of this model.[167] Overall, as discussed in the Draft TAR, we continue to conclude that hydrogen fueling infrastructure will to be in place to support FCEV deployments.

Finally, Chapter 9 of the Draft TAR also discussed that it is also possible that vehicle manufacturers will continue to market some light-duty vehicles using alternative fuels other than electricity and hydrogen. The Draft TAR specifically discussed the two largest alternative fuel vehicle segments currently, compressed natural gas (CNG) and ethanol (E85). For these vehicles, fueling infrastructure has continued to grow to support vehicle fleet growth. There were no specific comments on the status of infrastructure for these fuels reported in the Draft TAR.

Overall, we continue to conclude that infrastructure will not present a barrier for the small numbers of alternative fuel vehicles that we expect manufacturers to choose to produce as a part of their compliance with the MY2022-2025 GHG standards.

B.3.3 Standards Design Elements

In the design of the MY2012 – 2025 GHG standards, EPA carefully considered the impact the standards can have on vehicle utility and consumer choice such that the automotive companies

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[167] See Toyota's August 2016 sales press release and data: http://www.toyotanewsroom.com/releases/toyota-lexus-august-2016-sales.htm and http://www.toyotanewsroom.com/releases/tms-august-2016-sales-chart.htm.

have the ability to maintain vehicle utility and consumer choice while complying with the standards. EPA decided to use vehicle "footprint" as the attribute to determine the GHG standards for a given automotive manufacturer's fleet (the standard being the production-weighted average of the footprint-based targets for each vehicle produced). The light-duty vehicle GHG standards are curves based on the footprint attribute (Section I shows a graphical depiction of the footprint curves). There are separate passenger car footprint-based standards and light-truck footprint-based standards. Under this approach, the larger the vehicle footprint the less numerically stringent (i.e., higher) the corresponding CO_2 target level. The curves become more stringent year-over-year as the standards are phased-in through MY2025. These footprint based standards were designed to promote GHG emissions improvements in vehicles of all sizes, and are not expected to create incentives for manufacturers to change the size of their vehicles in order to comply with the standards. (The big increase in the number of large SUVs in the fleet from MY2012 to 2015, as shown in the recent Trends report,[168] illustrates this point, since more of these larger-footprint vehicles were produced as the standards increased in stringency, yet this segment also showed the most improvement in GHG reductions over the same time period). Moreover, since the standards are based on the unique, sales-weighted fleet average for each manufacturer, no specific vehicle must meet a given footprint target.

EPA received a variety of comments regarding the footprint approach. Several commenters stressed the importance of the footprint-based standards in ensuring consumer choice and encouraging emissions reductions across vehicles of all sizes. For example, Consumer Federation of America commented that the footprint approach ensures that the standards do not require radical changes in the types or size of vehicles consumers drive, so, the full range of choices will be available to consumers. Consumers Union similarly commented that footprint-based standards encourage automakers to design and sell vehicles that have better fuel economy across vehicle size and class. NACAA commented that the footprint-based approach fully accommodates changes in the car-truck sales mix that can occur due to such factors as economic growth, gasoline prices and other macro-economic trends, meaning that irrespective of consumers' choice of vehicles the rule will result in improvements across the light-duty fleet. The BlueGreen Alliance commented that the foot-print-based structure is key, as it means consumers see fuel savings no matter what kind of vehicle they need and also means that innovation happens across the entire industry. The UAW commented that it is critical to maintain the domestic footprint formula that is currently being used. Motor and Equipment Manufacturers Association (MEMA) also commented supporting the footprint-based National Program because it permits vehicle manufacturers to focus their resources on investing in the best technologies available for their fleet to achieve the levels prescribed by the program.

Several commenters expressed concern regarding the footprint standards, asserting that vehicle footprints are increasing over time. Among the comments, the Center for Biological Diversity asserting that footprints are increasing and that the standards for larger footprint vehicles should be made more stringent. UCS commented that EPA should look very closely at whether manufacturers are unreasonably increasing the footprint of vehicles and consider reassessing the slope of the defined attribute curves to discourage any such behavior. NRDC also recommends that EPA analyze footprint data, especially at time of vehicle redesign when

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[168] Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2016," EPA Office of Transportation and Air Quality, November 2016.

manufacturers are most apt to increase vehicle footprint and should investigate and propose changes to the curves if necessary to preserve the benefits of the program. Georgetown University recommended that the footprint coefficient be adjusted downward to reduce the automakers' incentive to sell larger footprint vehicles relative to other car characteristics.

Related to the comments regarding footprint, EPA received comments supporting a backstop standard. NRDC commented that it is important that EPA adopt a backstop mechanism to make sure the fleet average emissions decrease consistently in future years. Consumers Union recommended for future consideration a minimum efficiency or floor for each footprint size may be necessary to avoid either "footprint creep," (whereby automakers enlarge vehicles in order to water down their compliance targets) or heavy cross-class subsidization (whereby automakers rely on improvements to a limited class of vehicles to avoid improvements to other vehicle classes). UCS recommended that EPA look very closely at whether manufacturers are unreasonably increasing footprint of vehicles and consider reassessing the slope of the defined attribute curves to discourage any such behavior. ACEEE also commented that the footprint curves should be adjusted such that the absolute levels of CO_2 reductions are achieved.

ACEEE commented that pickups are being upsized, and also that manufacturers are pushing the wheels to the corners of some vehicles, resulting in a loss of program benefits. ACEEE suggested that EPA revisit the cut-point for the upper end of the truck footprint curve where the footprint curve flattens out.

EPA also received comment on the current light truck definition. UCS noted that almost all of the new small SUVs that have been introduced have been 4WD which classifies them as light trucks. UCS comments that the large difference (39.8 g/mile on average) in standards between the car and truck curves would provide a motivation for manufacturers to increase the sales of the 4WD model. UCS believes this suggests that manufacturers could be using the 4WD distinction in the definition as a compliance tool and recommends that EPA look at ways to close the "loophole," including developing a single curve for cars and trucks to negate the adverse impacts of any shift between cars and SUVs. NRDC also commented that EPA should investigate this issue.

These commenters suggest various changes to the form of the standards, the footprint curves, or vehicle definitions to address concerns regarding the projected overall less stringent projected 2025 fleetwide CO_2 target level of the program compared to the projections made in the 2012 final rule. (Appendix Section C.1.1 provides the CO_2 fleet targets for all three AEO scenarios for the Proposed Determination). The commenters' recommendations would suggest changing the program to address the issue that the standards are now projected to reach a slightly lower fleetwide CO_2 target level by 2025, due primarily to shifts in consumer preferences toward larger footprint vehicles. In many cases, these suggested changes would have the effect of making the standards more stringent. This Proposed Determination that the MY2022-2025 standards remain appropriate is based on the footprint curves and vehicle definitions currently in the regulations. EPA believes that the program is operating as it was designed and as discussed in Section IV.E of the Proposed Determination document, EPA is proposing that the existing MY2022-2025 standards remain appropriate. EPA recognized in the MY2012-2016 rule that footprints could be larger (or smaller) in the future based in part on consumer demands that are external to the rule.[169] While average footprint has remained relatively flat since the standards were first established,[170] the market shift toward higher truck share in recent years has the same effect of increasing the fleetwide GHG emissions level necessary to meet the GHG standards. This is because, for the same footprint level, the truck curve has a higher GHG emissions target than does the car curve. EPA is not aware of any evidence that the standards structure is motivating the shift from cars to trucks, beyond the market forces such as lower gasoline prices. EPA also notes that the program has only been implemented for a relatively short period (we have final data for four model years, MY2012-2015) and the shifts in consumer preferences may not indicate a long-term trend (truck share, including those vehicles that must meet the truck GHG standards, has ranged from 33 percent to 48 percent since MY2004 and was 43 percent in MY2015). However, EPA understands the concerns of commenters that the program is now projected to deliver a somewhat higher numerical fleetwide CO_2 target than originally estimated.

Regarding the comments on 2WD vs 4WD trucks, EPA has also noted a similar near-term trend. From MY2012-2015, the percentage of SUVs with inertia weight ratings of 4,000 pounds or less that are classified as trucks (primarily because of 4WD) has risen from 46 percent to 58 percent.[171]

Georgetown University commented that the footprint approach is both inefficient and regressive. The commenter believes the footprint approach is inefficient "because it now costs more to reduce national gasoline consumption" and "regressive because the change disproportionately harms lower-income families." The commenter asserts that the footprint standards incentivize sales of larger, less fuel efficient cars. The commenter discusses how manufacturers complied with the flat standards by lowering the price of small cars while raising the price of larger vehicles. EPA discusses comments regarding the progressivity or regressivity of the standards above in the affordability Section B.1.6 of this Appendix. EPA notes, however, that manufacturers offering small vehicles compete in the small vehicle market with other manufacturers where fuel efficiency, along with vehicle price, is one of the primary attributes consumers seek. To the extent manufacturers choose to increase fuel efficiency for these vehicles, those improvements will provide fuel savings for the consumer.

Commenters Richard A. Simmons and Wallace E. Tyner provided comment that the footprint-based standards impose an arbitrarily constant improvement across all classes including many classes whose contribution to fleet-wide fuel consumption is minor. In response, the footprint approach is premised on requiring all vehicle sizes to improve over time, reducing CO_2 emissions across the fleet. EPA notes, however, that manufacturers are allowed to average across their fleet, including transferring credits between the car and light truck categories. The program does not require individual vehicle models to meet a prescribed emissions level; rather the fleet as a whole must comply with the standards. Therefore, manufacturers are able to determine where to most efficiently invest resources to meet the fleet-wide standards and provide vehicles that meet their customer’s needs. At this time, EPA does not believe there is a basis to further subdivide the standards across additional vehicle categories.

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[169] 75 FR 25355, May 7, 2010.

[170] Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2016,” EPA Office of Transportation and Air Quality, November 2016.

[171] Ibid.

B.3.4 Credits, Incentives, and Flexibilities

The National Program was designed with a wide range of optional flexibilities to allow manufacturers to maintain consumer choice, spur technology development, and reduce compliance costs, while achieving significant GHG reductions. Chapter 11 of the Draft TAR provided an overview of these provisions which include averaging, banking, and trading of credits, air conditioning system credits, off-cycle technology credits, and advanced technology vehicle incentives including incentives for large pickups using advanced technologies.

EPA received several comments on various aspects of the credit program. Air conditioning system credits and related comments are discussed in Chapter 2.2.9 of the TSD. EPA also received comments on off-cycle technology credits and advanced technology incentives, as discussed below. EPA believes that the MY2022-2025 standards remain appropriate with the credit and incentive provisions currently in place and EPA is not proposing any changes to these provisions as part of this Proposed Determination. Nevertheless, several of these provisions were developed in the 2012 rulemaking to incentivize very advanced technologies that will likely be needed for long-term GHG reductions beyond the 2025 time frame, such as plug-in hybrid electric vehicles, all electric vehicles, and fuel cell vehicles. EPA requests comment below, in addition to the request for comment on this Proposed Determination, regarding the need for continued incentives for these technologies, including in the MY2022-2025 time frame.

B.3.4.1 Off-cycle Technology Credits

EPA received comments from auto manufacturers and their trade associations and auto suppliers encouraging the agency to broaden the off-cycle credits program (see TSD Chapter 2.2.10 for an overview of the off-cycle credits program and the off-cycle credits generated by auto manufacturers to date). Commenters' recommendations included relaxing or removing credit caps, expanding the credit menu, broadly interpreting the regulatory definitions in determining whether or not a technology qualifies for menu credits, increasing the menu credit values for certain technologies, allowing the use of computer models as the basis of credits, allowing the use of European Union credits and/or methodologies, not requiring other manufacturers to make a credit demonstration once credits are approved for one manufacturer, and streamlining/expediting the credits approval process. The Alliance and Global Automakers comment that these types of changes are necessary since they believe that off-cycle credits are essential for the industry to comply with the GHG standards through MY2025. The Alliance commented that "[t]he industry needs the off-cycle credit program to function effectively to fulfill the significant role that will be needed for generating large quantities of credits from this type of emission reduction." The Alliance further suggested additional credits as incentives for accelerating the phase-in of off-cycle technologies or the phase-out of technologies that have adverse off-cycle impacts. Automakers believe that the above noted changes would spur innovation and that the development of off-cycle technologies should be encouraged.

Automakers also commented that credits should be considered for connected/autonomous vehicle technology. Global Automakers commented that the off-cycle program should account for any real-world GHG emission benefits that can be demonstrated to result from the application of these advanced technologies and be designed to encourage and support the rollout of these additional fuel-saving technologies. The Alliance recommended establishing incentives for the early introduction of safety/congestion mitigation technologies.

EPA also received comments cautioning the agency against expanding the off-cycle credits program without further data to support credit levels. ICCT commented that there is a lack of data on how vehicles are actually operated in the real-world and that real-world benefits only accrue if double-counting is avoided. ICCT suggested that a solution could be for EPA to launch a collaborative data collection program to collect real-world data that could be used to establish standardized credits that would apply to all manufacturers. ACEEE commented that off-cycle credits should be awarded only based on a credible technical demonstration that the technology will provide benefits in the real-world and that the viability of the off-cycle credits program depends on the credibility of the evidence that credits are deserved. ACEEE also commented that off-cycle credits should not be provided for connected or automated technologies until emissions benefits have been demonstrated given the high level of uncertainty surrounding the technologies.

As noted above, EPA is proposing to determine that the existing MY2022-2025 standards remain appropriate, and therefore is not conducting a rulemaking, as it would be required to do if EPA determined that the standards were inappropriate and therefore should change in stringency (in either direction). Therefore, EPA is not proposing to make changes to the off-cycle credits program as part of the Midterm Evaluation, as there is no reason within the scope of the MTE to revisit these provisions. Put another way, EPA is making a proposed determination that would leave the current standards (and associated provisions) unaltered, s taking into account the current regulatory provisions regarding off-cycle credits as part of that proposed determination. The current program will continue to afford manufacturers with the opportunity to generate off-cycle credits, which EPA believes will continue to provide an incentive to develop these technologies and appropriately recognize real world emission reductions. EPA's analysis supports the Proposed Determination that the standards are appropriate with the credits and flexibilities currently in place. See also Appendix Section C.1.1.1 and TSD Section 2.3.4.9 describing how EPA is considering the off-cycle menu credits in assessing the appropriateness of the MY2022-2025 standards. In response to the comments, EPA agrees with ICCT and ACEEE comments that off-cycle credits must continue to be based on data demonstrating the real-world benefits of the off-cycle technology per the regulations that are currently in place. By ensuring that the credits are based on demonstrated real-world benefits, which we believe the current off-cycle regulatory framework does, EPA ensures that emissions reductions associated with the standards are maintained. The existing credits process in place today ensure that credits are legitimate and maintains the integrity of the program.

Though EPA is not proposing changes to the off-cycle credits provisions, with regard to credit caps on the off-cycle menu, EPA nevertheless believes the rationale for the credit caps has not changed. EPA established the 10 g/mile credit cap[172] to address the uncertainty surrounding the data and analysis used as the basis of the menu credits. As noted in the 2012 Final Rule, EPA included the fleet-wide cap because the default credit values were based on limited data, and also because EPA recognized that some uncertainty is introduced when credits are provided based on a general assessment of off-cycle performance as opposed to testing on the individual vehicle models.[173] That uncertainty has not significantly diminished since the 2012 final rule. The expectation that some manufacturers may eventually be limited by the cap, as some commenters

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[172] 40 CFR 86.1869–12(b)(2).
[173] 77 FR 62834, October 15, 2012.

suggest, would not in itself be justification for raising or eliminating the cap. Similarly, the caps on credits associated with thermal controls which some commenters specifically raised, were put in place to address synergistic effects that may come into play with several technologies focused on reducing air conditioning use. These concerns regarding synergistic effects have not changed. More importantly, the rules allow for greater credit amounts if manufacturers can demonstrate that their technology actually provides more off-cycle benefit than the menu value.[174] Therefore EPA believes the cap remains appropriate.

EPA received comments that some menu credit values should be increased. For example, as support for revising upward the credits for stop-start systems, some commenters point to recent information showing that there is more idle time in the real world than EPA estimated in determining the menu credit for stop-start systems. The commenters, however, do not address the other key element of estimating credits for engine stop-start - system effectiveness. Systems vary significantly in hardware, design, and calibration, leading to wide variations in how much of the idle time the engine is actually turned off. EPA has learned that stop-start systems may be less effective in the real world than the agency estimated in its 2012 rulemaking analysis, which would offset the benefits of the higher idle time estimates. The Alliance further commented that vehicles equipped with 48 volt systems should receive additional stop-start credits beyond the current menu credits because the 48 volt systems would allow stop-start to be more effective. However, no data is provided. While the 48 volt systems have the potential to allow for a higher level of stop-start effectiveness, system design and calibration remains an important element in determining an appropriate credit level. The variation in effectiveness supports the current approach of providing a conservative menu credit with an opportunity for manufacturers to generate additional credits if a manufacturer is able to demonstrate a high level of real-world system effectiveness for its system. This type of uncertainty is also an example of why retaining a credit cap is appropriate at this time.

Some suppliers also commented in support of increasing menu credits for individual technologies represented in the menu. Enhanced Protective Glass Automotive Association commented in support of increasing the glass glazing credit stating that overall glazing area of passenger vehicles has continued to increase, particularly the roof area. Denso commented that additional stop-start credits should be provided for vehicles equipped with regenerative braking.

EPA also received comments recommending adding technologies to the menu. Because off-cycle credits beyond those already available are not included in EPA's analysis of the feasibility of the MY2022-2025 standards and are consequently not needed to meet the standards, EPA is not expanding the menu and has not analyzed the European Union technologies or other suggested technologies as part of the Proposed Determination. Commenters did not provide data to assess the performance of any specific technology. Regarding comments on the off-cycle credits process, EPA believes that it is critical for the integrity of the program for the agency to thoroughly evaluate credits and resolve questions regarding real-world benefits prior to moving forward in approving credits. In the early years of the program, there have been unanticipated issues with credit requests that have taken additional time to resolve. For example, there have been occasions where EPA has scrutinized whether a technology meets the definition established in the regulations for a technology to be eligible for the menu credit. While this may slow down

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[174] 40 CFR section 86.1869-12 (b)(3), (c) and (d).

the approval process or result in credits not being approved, it remains paramount to ensure credits are not provided to technologies that do not provide actual off-cycle benefits, and thereby do not meet the regulations. See section 86.1869-12 (a) (off cycle technologies must "have a measureable, demonstrable, and verifiable real-world CO2 reduction that occurs outside the [FTP and HFET].") The longer time frames for EPA review have not caused manufacturers to lose credits where credits are determined by EPA to be warranted under the regulations. EPA also notes that the menu has been effectively used by many manufacturers to generate off-cycle credits. In MY2014, the first year menu credits were available, manufacturers fleet-wide generated about 2.3 g/mile of credits based on the menu. In MY2015, menu-based credits fleet-wide increased to nearly 3 g/mile of credits. In MY2015, eleven manufacturers generated menu-based credits ranging from 0.2 to 6.1 g/mile. (See TSD Chapter 2.2.10). Therefore, these data suggest that the menu is working as intended.

MECA offered comments on the off-cycle credits process, suggesting starting with conservative menu credits based on a limited demonstration on a limited number of vehicles, which could be followed by further data gathering and allowing suppliers to participate in the credits process. In response, while only manufacturers are allowed to submit applications for off-cycle credits, there is nothing in the regulations precluding suppliers from working with manufacturers on test programs to demonstrate off-cycle technologies. Also, manufacturers may apply for a conservative credit level as long as the data demonstrates that the real-world benefit for the technology would be at least as large as the credit being requested. Mercedes Benz applied this type of approach in their application for stop-start credits, basing the requested credits on limited data representing worst-case conditions.[175] Mercedes could request additional credits if they undertook a more rigorous demonstration program that supported those additional credits. While EPA is not making regulatory changes to the off-cycle program, EPA believes there is flexibility within the current structure of the program to allow for such approaches.

ICCT commented that more off-cycle credits should be considered in EPA's assessment of feasibility and costs than were included in the Draft TAR analysis, which only included limited off-cycle credits for stop-start systems and active aerodynamics (see Draft TAR Chapter 12.1.1.3). ICCT believes that the off-cycle technologies represent lower cost options for manufacturers and that including more off-cycle credits in the analysis would lower the costs estimated for the program. EPA agrees with this comment, especially in light of the significant interest in off-cycle credits expressed by the manufacturer, and is including more off-cycle technologies in its analysis where sufficient supporting data was available, as discussed in Appendix Section C.1.1.1.

Several of the comments from the Alliance and Global Automakers were also items raised in a petition the commenters submitted jointly on June 20, 2016.[176] The petition is discussed in Appendix Section B.3.5, below. None of the off-cycle credits issues raised in the comments change EPA's assessment of the appropriateness of the MY2022-2025 standards. However, EPA looks forward to working with the auto industry petitioners and other stakeholders as we fully

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[175] "EPA Decision Document: Mercedes-Benz Off-cycle Credits for MYs 2012-2016," U.S. EPA-420-R-14-025, Office of Transportation and Air Quality, September 2014.

[176] "Petition for Direct Final Rule with Regard to Various Aspects of the Corporate Average Fuel Economy Program and the Greenhouse Gas Program", Auto Alliance and Global Automakers, June 20, 2016.

consider the issues raised in the petition, including those raised on the off-cycle credit program. EPA will respond to the petition in a separate action.

B.3.4.2 Advanced Technology Vehicle Incentives

As discussed in the Draft TAR Chapter 11, the light duty vehicle rules also provide several temporary incentives for advanced technology vehicles. These include temporarily allowing manufacturers not to count upstream emissions associated with electricity for plug-in vehicles (the electric portion of operation is counted as having 0 g/mile CO_2 emissions), providing multipliers through MY2021 for advanced technology vehicles, and providing temporary incentives for large pickup trucks using hybridization or technologies providing equivalent benefits.[177]

EPA received comments regarding incentives for advanced technology vehicles. Auto manufacturers and their trade associations generally commented in support of extending or expanding these provisions. The Alliance and Global Automakers commented that EPA should permanently allow the use of the 0 g/mile factor rather than requiring manufacturers to account for upstream emissions associated with electric operation. Auto manufacturers note that EPA has adopted the Clean Power Plan to address GHG emissions associated with electricity generation since the MY2017-2025 vehicle standards were adopted which addresses upstream emissions. Edison Electric Institute commented that the upstream factor should be updated to reflect declining emissions associated with electricity production.

The Alliance, Global Automakers, and manufacturers commented that the advanced technology multipliers should be extended through MY2025 to help to continue to spur investment in the advanced technologies. Securing America's Future Energy also commented in support of extending multipliers to MY2025. American Petroleum Institute commented that multipliers should be removed from the program because they distort the commercial market by favoring certain technologies over others.

The Alliance further commented that the phase-in of upstream emissions and the loss of the multipliers moves the program from a framework of favorable incentives for electric operation into an unusually disfavored status becoming the only vehicles that would be required to include upstream emissions. FCA commented that the upstream requirement effectively degrades the emissions performance of plug-in vehicles to the level comparable to traditional HEVs. Volkswagen similarly commented that CO_2 benefit of a PHEV would be nearly equated to a standard HEV, but will incur 50 percent higher costs for OEMs, resulting in no customer financial benefit by choosing a PHEV over a HEV.

The Alliance commented that the advanced technology incentive for large pickups should be less restrictive and the scope expanded beyond large pickups to all light trucks including SUVs in order to provide a meaningful incentive. The Alliance commented that the penetration rate thresholds are too restrictive and likely the reason there is no indication that manufacturers will pursue the incentives. Toyota, VNG, and Westport Fuel Systems also commented in support of extending and expanding the large pickup incentives.

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[177] See 40 CFR 86.1866-12 and 40 CFR 86.1870-12.

Global Automakers recommended that "the agencies consider how to address the difficulties that will be created by expiring and diminishing credits, and assess how the current credit provisions can be revised to better advance the goals of the National Program"

In response to these comments, as noted above, EPA is proposing to reaffirm the MY2022-2025 standards based on the regulatory program as it now stands. Put another way, EPA is proposing to retain the standards taking into account the current regulatory provisions on incentives for advanced technology vehicles (just as it is proposing to find the standards appropriate considering the current regulations regarding off-cycle credits). With regard to comments on extending the 0 g/mile factor for electric operation, for the Proposed Determination, EPA has considered upstream emissions in its analysis and has found that the standards remain feasible and can be met largely with advanced gasoline vehicles (see Appendix Section C.1.1.1 for a discussion of how upstream emissions are treated in EPA's assessment). Therefore, at this time we believe no change is needed to how the program treats upstream emissions. The analyses supporting the Proposed Determination also show that the standards remain appropriate without changes to the incentives multiplier and large pickup provisions. EPA's analysis is based on cost-effective technologies available to meet the standards with no reliance on the multiplier or large pickup incentives and therefore the agency finds no reason within the scope of the MTE to revisit these provisions.

Global Automakers further commented that "credits represent real world GHG reductions and fuel savings, and can be used to encourage early action that benefits both the environment and customers." In response, the advanced technology incentives are not based on real world benefits and in fact reduce the benefits of the program to the extent that the incentives are used by manufacturers.[178] They were included in the program to "encourage early action" by the manufacturers, consistent with the Global Automakers comments. This is a key difference between the incentive provisions for advanced technologies and the air conditioning and off-cycle credits which are based on additional GHG reductions. It is also a key reason why the incentives are temporary while the air conditioning and off-cycle credits are currently allowed indefinitely under the GHG program. However, EPA believes that in the long-term, advanced technology vehicles such as plug-in electric hybrids, all electric vehicles, and fuel cell vehicles will be needed in larger and larger volumes in order for continued reductions in GHG emissions to occur in the post-2025 timeframe. EPA recognizes that the purpose of the temporary 0 gram/mile upstream emissions factor, and the incentive multipliers for MY2017-2021, are to help manufacturers in the near-term with the higher costs of these advanced technologies and the various challenges the technologies face in the market place. EPA requests comment on the appropriateness of considering extending or modifying the temporary incentives for PHEVs, BEVs, and FCEVs to promote these technologies in the near-term in order to incentivize larger volume adoption in the long-term. This request for comment is in addition to the request for comment on EPA's proposed determination of the appropriateness of maintaining the current incentive provisions for MY2022-2025, as the focus of this request for comment is on the transition to post-model year 2025 time frame.

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[178] EPA accounted for the dis-benefits associated with the incentives in the analysis of GHG inventories in the 2012 Final Rule. See 77 FR 62891, October 15, 2012.

B.3.4.3 Other Incentives

EPA received a variety of comments regarding other incentives. The American Council for Ethanol encouraged EPA to restore meaningful credits for flexible fuel vehicles (FFVs) and consider the establishment of a new incentive for internal combustion engines optimized for high-octane, low carbon fuels. Fuel Freedom Foundation similarly suggested that EPA consider a credit for material compatibility with higher ethanol blends to facilitate the introduction of high octane mid-ethanol blends.

Adsorbed Natural Gas Products commented that incentives and credits for natural gas vehicles be maintained beyond 2021 and that they be comparable to those for electric vehicles for MY2022 and later model years. NGV America also commented that EPA should remove the 2 to 1 range requirement for using the utility factor in determining vehicle emissions levels. The Center for Biological Diversity commented that the multiplier incentive for CNG vehicles should be eliminated from the GHG program due to fuel system leakage issues and upstream emissions associated with natural gas extraction.

Volkswagen commented that it "would recommend and support creating a credit system that rewards investments from car manufactures in the development and deployment of renewable energy and fuels as well as infrastructure. The latter could help significantly increase the deployment of alternative powertrain by expediting the development of a larger network of alternative refueling infrastructure. The increase of available and better infrastructure helps to give consumers confidence and leads to better acceptance of PHEVs, BEVs, and FCEVs."

As with the comments above in Appendix Sections B.3.4.1 and B.3.4.2 on off-cycle and advanced technology credits, the comments noted in this Section B.3.4.3 on other credits approaches are beyond the scope of our proposed determination. EPA is proposing that the standards remain appropriate with the credits provisions currently in place.

B.3.5 Program Harmonization

EPA received several comments regarding harmonization of the EPA and NHTSA programs. The Alliance commented that the National Program has not resulted in harmonization across EPA, NHTSA, and CARB programs. The Alliance refers to a June 20, 2016 petition submitted by the Alliance and Association of Global Automakers[179] asking EPA and NHTSA to make several regulatory changes they believe would better harmonize the programs.[180] The Alliance commented that there are inconsistencies in the Draft TAR technical assessments and that the assessments ignored costs associated with California's ZEV mandate. Global Automakers asserted that the MTE must address whether improvements can be made to the regulatory program to reduce the "friction" caused by multiple inconsistent requirements. Global Automakers commented that areas that need greater harmonization include regulatory process,

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[179] "Petition for Direct Final Rule with Regard to Various Aspects of the Corporate Average Fuel Economy Program and the Greenhouse Gas Program," Auto Alliance and Global Automakers, June 20, 2016.

[180] On June 20, 2016, the Alliance and Global Automakers petitioned the agencies to make several regulatory changes they believe would better harmonize respective regulations for GHG emissions and fuel economy. EPA and NHTSA have not yet responded to the manufacturers' June 20, 2016 petition and EPA is not attempting to respond to the petition here, only to respond to comments received on the TAR. Consideration of the petition by EPA and NHTSA and the MTE are two distinct and separate processes. The petition was not specific to MYs 2022-2025 and several of the items in the petition concern harmonization in the earlier years of the program.

modeling methodology, standards and credits programs, and federal and state programs. Note that EPA has not yet responded to those elements of the June 2016 petition. EPA intends to work with the Petitioners and other stakeholders in the future as we carefully consider the requests made in the June 2016 petition.

Global Automakers also raised issues regarding the CARB regulatory process and ZEV program, where they noted that manufacturers may be in compliance with GHG and CAFE standards but out of compliance with ZEV. Issues specific to the California ZEV program are outside the scope of EPA's MTE process defined in EPA's regulations. Global Automakers also recommends, citing the 2015 National Academy of Sciences report recommendations that the agencies move to a single metric, rather than continue with separate GHG and CAFE standards. The commenter believes that such an approach would increase harmonization, especially with regard to the treatment of air conditioning leakage credits. In response, moving to a new metric as the basis for the standards is also beyond the factors EPA is considering in the MTE.[181]

Several other commenters including FCA, Ford, Toyota, National Automobile Dealers Association (NADA), Motor and Equipment Manufacturers Association (MEMA), BorgWarner, Denso, and the UAW also provided comments supporting further harmonization of the programs.

The Alliance and Global Automakers have characterized many of the above items as significant harmonization issues. EPA believes that the auto trade associations' current characterization of "harmonization" goes well beyond the original intent of the National Program in terms of harmonization. In the 2009 Notice of Intent (NOI) preceding the MY2012-2016 rulemaking, EPA and NHTSA provided a clear view of the National Program, stating "Both agencies seek to propose a coordinated program that can achieve important reductions in GHG emissions and improvements in fuel economy…based on technology that will be commercially available and that can be incorporated at a reasonable cost."[182] The 2009 NOI states that the National Program "will reflect a carefully coordinated and harmonized approach to implementing these two statutes and will be in accordance with all substantive and procedural requirements imposed by law" and "Key elements of a harmonized and coordinated National Program the agencies intend to propose are the level and form of the standard, the available compliance mechanisms, and general implementation elements." At the outset, the National Program was predicated on "two separate sets of standards" and that "most companies would also apply some air conditioning improvements to reduce GHG emissions" and that those "would not translate into fuel economy improvements." It was clear that there would be differences, as the 2009 NOI states "Given differences in their respective statutory authorities, however, the agencies anticipate there will be some important differences in the development of their proposals." The NOI anticipated that the CAFE standards would be somewhat lower than the mile per gallon equivalent of the corresponding GHG standards due to some of these items but that the agencies would generally attempt to harmonize its standards "in a way that allows them to achieve their respective statutory and regulatory goals." The NOI further states that the goal of the National Program is to provide "regulatory compatibility that allows manufacturers to

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[181] Among the factors EPA regulations require EPA to consider is the "impact of the greenhouse gas emissions standards on the Corporate Average Fuel Economy standards and a national harmonized program." See 40 CFR 86.1818-12(h)(1)(vii).

[182] 74 FR 24008, May 22, 2009.

build a single national light-duty fleet that would comply with both the GHG and CAFE standards."

EPA believes that the National Program has been implemented consistent with the vision the agencies have communicated from the earliest stages of the program. The National Program was possible because of the close relationship between reducing CO_2 tailpipe emissions and improving fuel economy. The more fuel efficient a vehicle is, the less fuel it burns to travel a given distance; the less fuel it burns, the less CO_2 is emitted in traveling that distance. Therefore, the same sets of technologies that improve fuel efficiency also at the same time reduce CO_2 emissions (note there are some technologies that reduce GHG emissions but do not improve fuel efficiency, for example, reduction of air conditioning refrigerant emissions). In this way, the National Program allows auto manufacturers to use a common set of technologies to simultaneously address both issues of reducing CO_2 emissions and improving fuel efficiency. (See 75 FR 25327, May 7, 2010).

Going back to the first time the agencies established standards for the 2012-2016 model years, EPA and NHTSA were clear that there were some important differences in the statutory authorities (see 75 FR 25330, May 7, 2010; see also 77 FR 62674), and that the stringency of the respective standards was in fact established to account for differences in air conditioning improvements. The agencies have worked to establish a National Program subject to the differences in statutory authorities. The differences in certain aspects of the GHG and CAFE programs existed when the MY2022-2025 were first established and do not lead EPA to find that the GHG standards for MYs 2022-2025 are no longer appropriate.

In the MY2017-2025 rulemaking, the agencies took steps to maintain equivalent stringency and ensure that a single fleet of vehicles may be produced by a manufacturer that meets both the CAFE and GHG standards. Statutory differences between the CAA and EPCA/EISA result in restrictions for credit transfers and trading and domestic and import car fleets under CAFE that don't exist for the GHG standards. Also, under CAFE, manufacturers are not able to generate and use credits based on air conditioning refrigerant leakage reductions. These factors were appropriately considered in establishing MY2022-2025 GHG standards and in EPA's Draft TAR evaluation of those standards.

EPA and NHTSA have also pledged and taken many steps to enhance one-stop compliance procedures and testing provisions with the program. Thus, compliance is based on a single test procedure. Little to no additional data is required to demonstrate compliance with either the CAA GHG standards or the CAFE fuel economy standards. Certification, testing, reporting, and associated compliance activities are essentially identical under both programs. EPA accommodated the EPCA-EISA provisions whereby manufacturers can pay fines in lieu of compliance by adopting the Temporary Lead Time Allowance Alternative Standards, which allows OEMs which had paid fines under CAFE additional lead time to come into compliance with the full complement of the GHG standards. The agencies have adopted the same credit and incentive provisions to the extent authorized by law.

In their comments on the Draft TAR, the Alliance and Global Automakers refer to issues raised in their June 2016 petition that they believe are relevant for the MTE. Several of the issues involve changes sought for the CAFE program rather than EPA's GHG program and therefore are not relevant to whether the GHG standards themselves remain appropriate and also are not within EPA's statutory authority to address. There were three issues raised in the petition that are relevant to the GHG program. These were not direct harmonization issues. One issue, also covered by Alliance and Global Automaker comments, recommended that EPA streamline and expand the off-cycle credits program. ACEEE and ICCT also commented on the manufacturers' petition raising concerns regarding changes proposed by manufacturers in the petition for the off-cycle credits program. They commented that the off-cycle credits are to be awarded only based on a credible technical demonstration that the technologies will provide benefits in the real-world and that the viability of the off-cycle credits depends of the credibility of the evidence that the credits are deserved. Issues raised in comments which also parallel items in the petition regarding off-cycle credits are discussed in Appendix Section B.3.4.1.

The second issue raised in the auto petition for EPA's consideration concerns how credits are managed within the GHG program. The Alliance and Global Automakers would like EPA to allow more flexibility in using credits generated under the various credits programs such as air conditioning or off-cycle credits by allowing them to be carried forward or back independently. Under this approach, a manufacturer would be allowed, for example, to carry their air conditioning credits back to cover a previous deficit while running a deficit in a current model year. The third issue pertains to advanced technology multipliers, which are available only through MY2021 and therefore the issue is not relevant for MYs 2022-2025.

While EPA will be taking a separate action to respond to this petition, none of the issues raised in the petition would change EPA's assessment of the appropriateness of the MY2022-2025 standards. EPA is making a proposed determination that the MY2022-2025 standards are still appropriate, based on the existing regulations, including the credit provisions raised in the auto petition. EPA intends to work with the Petitioners and other stakeholders in the future as we carefully consider the requests made in the June 2016 petition.

Appendix C EPA's Assessment of the MY2022-2025 GHG Standards

This section documents EPA's assessment of the impacts of the MY2022 through 2025 GHG emission standards for light duty vehicles. In Chapter 2 of the TSD, EPA presents the technology costs and effectiveness values used as inputs to our OMEGA analysis. In Section C.1 of this Appendix, EPA presents projected CO_2 targets and achieved levels in meeting the MY2022-2025 standards, along with the associated average costs per vehicle and technology penetrations for a central set of input values as well as for several sensitivity cases. In Section C.2, EPA presents our estimates of emission inventory impacts, including CO_2 and other GHGs and criteria pollutants, and impacts on fuel consumption. In Section C.2.4, we present payback metrics to illustrate how long it takes for fuel savings to "pay back" the higher upfront costs. Lastly, in Section C.3, EPA presents our benefit cost analysis for both a model year lifetime analysis (considering the full lifetimes of MY2021-2025 vehicles) and a calendar year analysis (considering the calendar years 2021 through 2050).

The MY2022-2025 GHG standards will significantly reduce harmful GHG emissions. CO_2 emissions from automobiles are the product of fuel combustion and, consequently, reducing CO_2 emissions will also achieve a significant reduction in projected fuel consumption. EPA's projections of these impacts are also shown in this section. Because of anticipated changes to driving behavior and fuel production, co-pollutant emissions would also be affected by the standards. This analysis quantifies the impacts on GHGs, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and hydrofluorocarbons (HFC-134a); impacts on criteria air pollutants, including carbon monoxide (CO), fine particulate matter ($PM_{2.5}$), sulfur dioxide (SO_2), and the ozone precursors hydrocarbons (VOC) and oxides of nitrogen (NO_X); and impacts on several air toxics, including benzene, 1,3-butadiene, formaldehyde, acetaldehyde, and acrolein.

This section describes the methods used in EPA's analysis. Detailed discussion of the inputs to this analysis are found elsewhere in the Proposed Determination Appendix and in the accompanying Technical Support Document (e.g., baseline fleet development is in Chapter 1 of the TSD; technology costs and effectiveness are in Chapter 2 of the TSD; VMT, rebound effect, and other economic inputs are in Chapter 3 of the TSD). Chapter 1 of the TSD also includes a discussion of how the ZEV program is characterized in our analysis fleet which includes over 400,000 ZEV program vehicles by MY2025.

All OMEGA input and output files for runs presented in this section, and all input and output files supporting the inventories, benefits and costs presented here are in the EPA docket and are available on EPA's website at https://www.epa.gov/regulations-emissions-vehicles-and-engines/optimization-model-reducing-emissions-greenhouse-gases. Based on input from public comments and other updated information, we made certain updates to what we term the "OMEGA Suite" of tools used in generating a full benefit-cost analysis. Those updates, detailed in the TSD Chapter 5, include:

- The baseline fleet was updated from a basis in MY2014 to MY2015
- Future vehicle sales projections were updated based on AEO2016 sales projections.
- The ZEV program sales were updated based on the updates mentioned above.

- All fuel prices used throughout the OMEGA Suite were updated to AEO2016 fuel prices.
- All monetized values (technology costs, maintenance costs, SCC and non-GHG cost/ton values, etc.) have been updated to 2015 dollars for consistency with AEO2016 fuel price estimates.
- The OMEGA ICBT was updated to include payback calculations in the case where loan purchases were used rather than simply cash purchases.

C.1 Projected Compliance Costs, Technology Penetrations and Feasibility

As in the 2012 FRM and the Draft TAR analyses, our evaluation here includes identifying potentially available technologies and assessing their effectiveness, cost, and impacts. The wide number of technologies that are available, and likely to be used in combination, requires a method to account for their combined cost and effectiveness, as well as estimates of their availability to be applied to vehicles. The basic methodologies and modeling tools used in this Proposed Determination are similar in many ways to those EPA has used since first setting light-duty GHG standards for the MY2012-2016 standards, and again for the MY2017-2025 standards in 2012. However, EPA updated these tools as part of the development of the Draft TAR to reflect the latest available information, and we have also updated the modeling tools for this Proposed Determination based on consideration of public comments on the Draft TAR and the latest available information.

As done in establishing the GHG standards for MY2012-2016 and 2017-2025, EPA is using a computerized program called the Optimization Model for reducing Emissions of Greenhouse gases from Automobiles (OMEGA). Broadly, OMEGA starts with a description of the future vehicle fleet, including manufacturer, sales, base CO_2 emissions, vehicle footprint, and an assessment of which GHG emissions-reducing technologies are already employed on the vehicles. For the purpose of this analysis, EPA uses OMEGA to analyze over 200 vehicle platforms which encompass over 2,000 vehicle models to capture the important differences in vehicle and engine design and utility of future vehicle sales of roughly 15-17 million units annually in the 2021-2025 timeframe.[183] EPA then provides the model with a list of technologies applicable to various types of vehicles, along with the technologies' cost and effectiveness and the percentage of vehicle sales that we estimate can be applied to each technology during the redesign period. The model combines this information with economic parameters, such as fuel prices and discount rates, to project how various manufacturers could apply, in a cost-minimizing manner, the available technology in order to meet increasing levels of GHG emissions control. In other words, the OMEGA model optimizes to achieve the greatest level of GHG emissions reduction at the lowest cost technology options while giving

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[183] The MY2015 baseline fleet used in this analysis actually consists of over 2000 vehicle models, but many of those are only minor variations of others (generally a minor footprint--a vehicle's footprint is the product of its track width and wheelbase, usually specified in terms of square feet--variation of 0.1 square feet due to, for example, different wheel and/or tire applications). For simplicity here, we do not focus on those minor variations although our modeling does indeed make use of those variations since a different footprint results in a different target for any given vehicle.

consideration to technology and safety-related penetration caps. The result is a description of which technologies could be added to each vehicle and vehicle platform, along with the resulting costs and achieved CO_2 levels. The model can also be set to account for some types of compliance flexibilities.[184]

EPA has described OMEGA's specific methodologies and algorithms previously in the model documentation. See, e.g., 77 FR 62851-852. The model is publicly available on the EPA website, [185] and it has been peer reviewed. Emission control technology can be applied individually or in groups, often called technology "packages." The OMEGA user specifies the cost and effectiveness of each technology or package for a specific "vehicle type," such as high power-to-weight cars with V6 engines or large trucks with V8 engines. The user can limit the application of a specific technology to a specified percentage of each vehicle's sales (i.e., a "maximum penetration cap"). The effectiveness, cost, and any application limits of each technology package can also vary over time.[186] A list of technologies or packages is provided to OMEGA for each vehicle type, providing the connection to the specific vehicles being modeled. Chapter 5 of the TSD includes more details on the OMEGA model and approaches used in OMEGA, such as the building of technology packages, a detailed description of the technology packages, and the mapping of the fleet into vehicle types.

For each manufacturer, OMEGA applies technology (subject to any appropriate penetration caps, as discussed in the TSD) to vehicles until the sales and VMT-weighted emission average complies with a given standard or until all the available technologies have been applied. OMEGA allows the input of a standard, in this case, the GHG standard is in the form of a linear or constrained logistic function, which sets each vehicle's CO_2 target as a function of a vehicle attribute, such as footprint (vehicle track width times wheelbase). When the linear form of footprint-based standard is used, the "line" can be converted to a flat standard for footprints either above or below specified levels. This is referred to as a piece-wise linear standard, and was used in modeling the footprint-based standards in this analysis.

The OMEGA model is designed to estimate the cost of complying with a standard (or target) in a given future year. While the OMEGA design assumes that a manufacturer's entire fleet of vehicles can be redesigned within one redesign cycle, it is unlikely that a manufacturer will redesign the exact same percentage of its vehicle sales in each and every model year. The base emissions and emission reductions of the vehicles being redesigned will vary. Thus, OMEGA inherently assumes the averaging and banking of credits (such credits differ from off-cycle

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[184] While OMEGA can apply technologies that reduce CO_2 efficiency related emissions and refrigerant leakage emissions associated with air conditioner use, this task is currently handled outside of the OMEGA core model. A/C improvements are highly cost-effective, and would always be added to vehicles by the model, thus they are simply added into the OMEGA results at the projected penetration levels (see and Table C.7) for each manufacturer.

[185] https://www.epa.gov/regulations-emissions-vehicles-and-engines/optimization-model-reducing-emissions-greenhouse-gases.

[186] "Learning," as discussed in Section A of this Appendix, is the process whereby the cost of manufacturing a certain item tends to decrease with increased production volumes. While OMEGA does not explicitly incorporate "learning" into the technology cost estimation procedure, the user can currently simulate learning by inputting lower technology costs in each subsequent redesign cycle.

credits)to enable compliance with standards in the intermediate years of a redesign cycle using the technology projected for the final year of the cycle, assuming that the intermediate standards require gradual improvement each year.[187,188] This assumption has been confirmed by compliance data from the 2012-2015 MY light duty vehicle standards, which reflect robust use of averaging by the manufacturers. EPA's GHG program also allows for unlimited transfer of credits between the car and truck fleets within each manufacturer's fleet, allowing the more cost effective of the car/truck fleets to "assist" the other in compliance.

EPA has typically used a 5-year redesign cycle in OMEGA. As such, in the control case for this analysis, some portion of the fleet is estimated for redesign to the MY2025 standards in MY2021. This in turn results in the achieved CO_2 level in the control case in MY2021 being lower than the target level for that model year. We explain below the process used to generate the control case standards in MY2021 (see Section C.1.1.1.2).

Once technology has been added so that every manufacturer meets the specified targets (or exhausts all of the available technologies), the model produces a variety of output files. The files include information about the specific technology added to each vehicle and the resulting costs and emissions levels. Average costs and emissions per vehicle by manufacturer and industry-wide are also determined for each vehicle fleet (car and truck).

Throughout the discussion of EPA's analysis results we refer to a “reference case” and a “control case.” Since the purpose of this Proposed Determination is to assess issues relevant to the MY2022-2025 standards, the reference case refers to a situation where the future fleet continues to comply with the MY2021 standards indefinitely. Note that EPA’s "baseline fleet" (as described in Chapter 1 of the TSD) is based on the MY2015 fleet with sales projections going forward through the year 2030. That fleet, by definition, complies with the 2015 standards in MY2015 but not necessarily in MY2025.[189] That "baseline fleet" is contrasted by the “reference case fleet” which adds additional technology to bring the “baseline fleet” into compliance with the reference case, or 2021 standards. That “reference case fleet” would then continue meeting the reference case standards (i.e., the MY2021 standards) indefinitely. The "control case" refers to any situation where the future fleet complies with the MY2022 through MY2025 standards, and then with the MY2025 standards indefinitely thereafter. The difference between these two

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[187] Averaging and banking credits pertain to averaging under- and over-compliance with the standards. Averaging is allowed across each of the car and truck fleets, and credits may fully transfer from one fleet to the other. If over-compliance exceeds under-compliance in any given year, those over-compliance credits can be banked for future use within the framework of the program. Trading of credits is allowed between entities, presumably at a cost to the recipient and a financial gain to the provider. Off-cycle credits are real CO_2 reductions that would occur in-use, or the real world, but that are not measured on the 2-cycle test upon which the GHG standards are currently based.

[188] EPA considered modeling credit banking as part of this analysis, but decided that the central analysis would not analyze the program using this approach for two reasons. First, since the MY2025 GHG standards continue indefinitely, rather than expiring in 2025, EPA wants to represent the cost of bringing vehicles into compliance with the standards in MY2025. Second, consistent with the design of the OMEGA model, EPA is not using the OMEGA model to project changes on a year-by-year basis, which could be an important element of explicitly modeling credit banking.

[189] Given the fleet changes projected by the year 2025, that fleet in fact does not comply with the MY2015 standards in MY2025.

cases is the incremental effect of the standards (or "delta"). We use the term “central analysis” control case to specifically refer to the MY2022-2025 standards established in the 2012 FRM and as analyzed using what EPA considers to be the central set of input values (e.g., AEO 2016 reference case fuel prices are considered to be part of the central analysis).[190] The general term "control case" can be used for any control case whether it be the central case or a sensitivity case (e.g., AEO 2016 high or low fuel prices are used in sensitivities). As such, while there are several control cases, one control case is actually considered to be the central control case. Sensitivity analyses are meant to illustrate the potential impact of using different inputs.

C.1.1 Central Analysis Results

The central analysis uses the AEO 2016 reference fuel price case and, thus, the AEO 2016 reference fuel price based fleet. The central analysis consists of a reference case representing a future fleet complying with the MY2021 standards indefinitely, and a control case representing a future fleet complying with the MY2022 to 2025 standards in those respective model years, and then with the MY2025 standard indefinitely. See Chapter 1 of the TSD where we describe the reference and control cases in more detail.

C.1.1.1 CO_2 Targets, Achieved CO_2 & Credits

C.1.1.1.1 Reference Case

Because the fleet has changed slightly between the MY2014 based fleet used in the Draft TAR and the MY2015 based fleet used for this Proposed Determination, we have slightly different CO_2 targets than were presented in the Draft TAR. Table C.1 and Table C.2 show the Reference and Control case targets associated with the 2015 based fleet and achieved CO_2 values based on OMEGA. For example, while the reference case car targets in both MY2021 and MY2025 have remained 177 gCO_2/mi in both this analysis and the Draft TAR, the truck target has moved to 247 gCO_2/mi from roughly 251 in the Draft TAR.

Note that the footprint-based GHG standards (i.e., the standard curves) apply to individual vehicles. Depending on the footprint and model year of that individual vehicle, its target value can be determined by selecting the appropriate point on the standard curve. A fleet of vehicles—whether a car or truck fleet, a given manufacturer’s fleet, or the entire fleet—complying with its individual targets (determined by the standard curves) while giving consideration to the sales, or sales weighting, of each would result in a target value for that given fleet. We present here the fleetwide target values for each manufacturer’s car fleet, the entire car fleet, each manufacturer’s truck fleet, and the entire truck fleet. These fleet target values are the sales-weighted CO_2 emissions of each particular fleet assuming that individual vehicles comply with their respective footprint targets.

The reference case targets are shown in Table C.1 for MY2021 and Table C.2 for MY2025. While both tables represent the same set of reference case foot-print based standards curves, the target and achieved CO_2 levels reflect differences, which are attributed to fleet changes between MYs 2021 and 2025.

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[190] Throughout the discussion presented here in Section C, any reference to "AEO" is meant to refer to "AEO2016."

Also reflected in Table C.2 is accounting for upstream emissions associated with any electric (i.e., energy from being plugged-in to an outlet) energy consumption. Because some manufacturers are expected to surpass the 200,000 sales cut-point for BEVs and PHEVs by MY2025 (that is, the sales cutpoint under the EPA regulations after which a manufacturer must count upstream electricity emissions in its GHG compliance calculations), those manufacturers would have to include in their compliance determinations the upstream CO_2 emissions associated with the electric energy being consumed (as is discussed in more detail in the 2012 FRM).[191] However, rather than applying this upstream consideration to only those manufacturers, and because we wish to be conservative in our estimates, we have chosen to model all MY2025 BEVs and PHEVs as including upstream emissions. Our prior analyses, including the Draft TAR, did not consider upstream emissions in compliance modeling. Importantly, these upstream emissions are included only in the MY2025 fleet, both the reference case and the control case. The impact of this is most easily seen by referring to the Tesla achieved CO_2 values in MY2021 (Table C.1) versus in MY2025 (Table C.2). In MY2021, Tesla's reference case target is shown as 206 gCO_2/mi and its achieved level is shown as 0. Then, in MY2025, Tesla's reference case target is shown again as 206 gCO_2/mi while its achieved level is shown as 111 gCO_2/mi. This value of 111 gCO_2/mi is our estimate of the upstream CO_2 that would be part of Tesla's compliance determination. This also holds true for BEVs and PHEVs projected to be sold by all other manufacturers whether part of the ZEV program reference case or generated by OMEGA in the control case.

Table C.1 Reference Case Targets and Achieved CO_2 in MY2021 in the Central Analysis (gCO_2/mi)

Manufacturer	Car Target	Truck Target	Fleet Target	Car Achieved	Truck Achieved	Fleet Achieved
BMW	179	238	195	185	221	195
FCA	183	245	227	205	236	227
Ford	180	269	234	201	257	234
GM	178	271	227	198	255	227
Honda	171	230	201	185	218	201
Hyundai/Kia	177	226	186	181	210	186
JLR	188	233	225	218	227	225
Mazda	175	223	193	177	218	193
Mercedes	182	237	207	197	220	207
Mitsubishi	161	208	181	177	189	181
Nissan	174	241	202	183	228	202
Subaru	171	212	204	213	202	204
Tesla	206		206	0		0
Toyota	175	248	209	177	245	209
Volkswagen	173	232	192	178	223	192
Volvo	182	226	205	191	218	205
Fleet	177	247	211	186	236	211

Note: Fleet values are sales weighted.

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[191] See Section III.C.2 of the 2012 FRM, 77 FR 62810.

Table C.2 Reference Case Targets and Achieved CO_2 in MY2025 in the Central Analysis (gCO_2/mi)

Manufacturer	Car Target	Truck Target	Fleet Target	Car Achieved	Truck Achieved	Fleet Achieved
BMW	178	237	192	186	217	192
FCA	183	246	227	205	237	227
Ford	180	269	232	199	258	232
GM	179	271	224	198	253	224
Honda	172	231	201	185	219	201
Hyundai/Kia	177	226	185	180	212	185
JLR	188	233	224	221	225	224
Mazda	174	223	193	178	218	193
Mercedes	182	236	204	194	220	204
Mitsubishi	161	208	180	177	186	180
Nissan	174	242	200	182	230	200
Subaru	171	212	203	212	201	203
Tesla	206		206	111		111
Toyota	175	247	207	179	242	207
Volkswagen	173	231	191	173	231	191
Volvo	182	226	204	191	219	204
Fleet	177	247	210	187	236	210

Note: Fleet values are sales weighted.

C.1.1.1.2 Control Case

The central analysis control case represents the fleet meeting the MY2022 through MY2025 standards in their respective model years, and the fleet meeting the MY2025 standards indefinitely thereafter. As we did in the Draft TAR, we continue to estimate a 5-year redesign cycle. This cycle is consistent with our understanding of industry practice (although there are indications that cycles are becoming shorter due to competitive pressures, especially on cars). This is consistent with EPA's approach to modeling in the 2012 rule.[192] We know that industry plans ahead for compliance with future standards and carefully considers their redesign cycles when developing their compliance plans. As done in the Draft TAR, to accommodate a 5-year redesign cycle in the context of MY2022-2025 standards, we have estimated that 20 percent of the MY2021 fleet will be redesigned to meet the MY2025 standards, another 20 percent of the MY2022 fleet will be redesigned to meet the MY2025 standards, and so on through MY2024. As noted above, this effectively results in the MY2021 through MY2024 control case targets and achieved CO_2 levels being below (i.e., better than) the reference case target (i.e., the MY2021 target) since 20 percent of each year's fleet will be redesigned to meet the MY2025 standards. We used this same approach in the Draft TAR. The actual standards and the control case targets used in this analysis are shown graphically in Figure C.1 for cars and Figure C.2 for trucks. Note that use of air conditioning (A/C) credits would move these target curves downward to the levels shown in Figures I.1 and I.2 of the Proposed Determination document; the curves shown here are used in OMEGA with the A/C credits being handled outside of OMEGA.

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[192] See the 2012 FRM final Joint Technical Support Document, EPA-420-R-12-901, at Section 3.5.1,

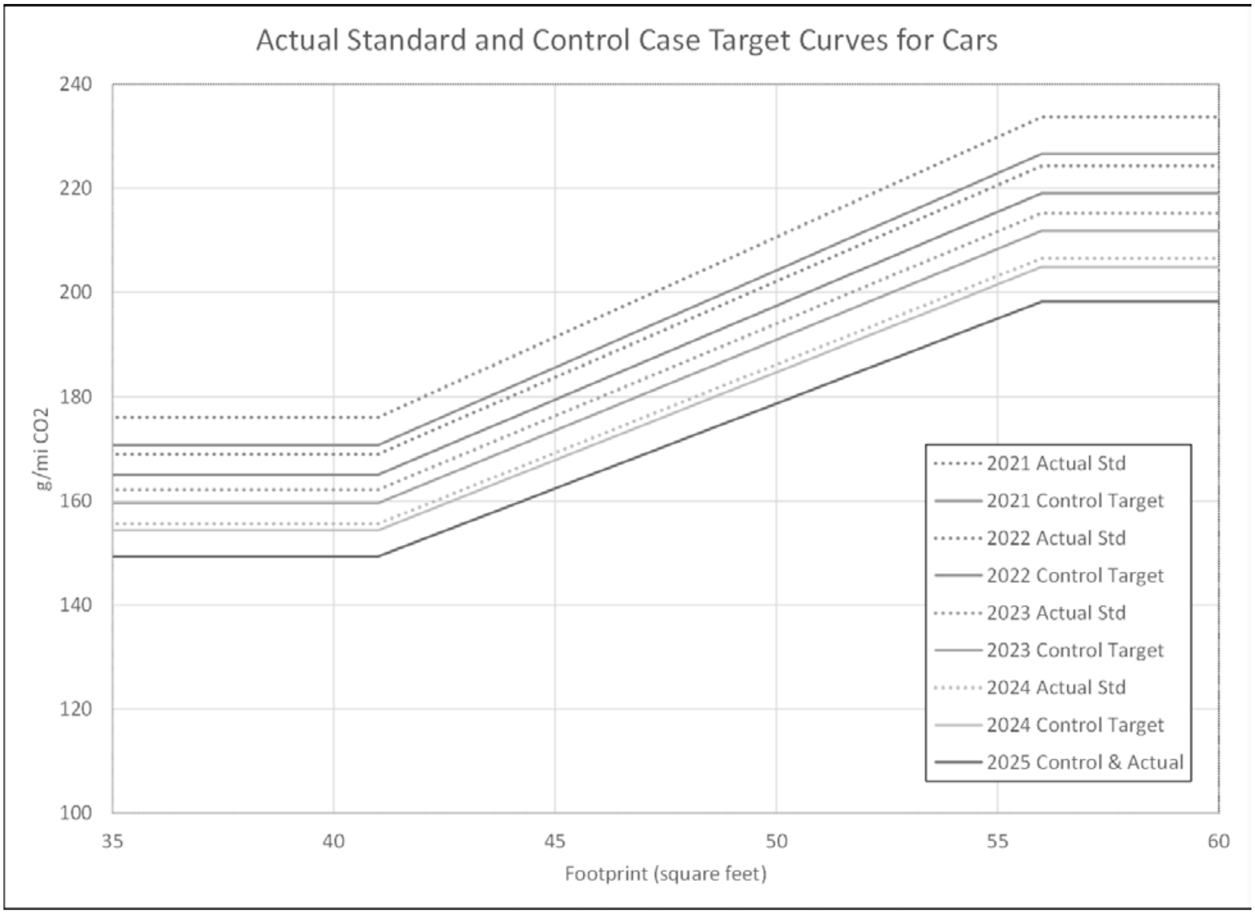

Figure C.1 Actual Standard Curves and the Control Case Target Curves Used for Cars in this Proposed Determination to Reflect a 5-Year Redesign Cycle (Note: the legend reflects the ordering of lines on the chart)

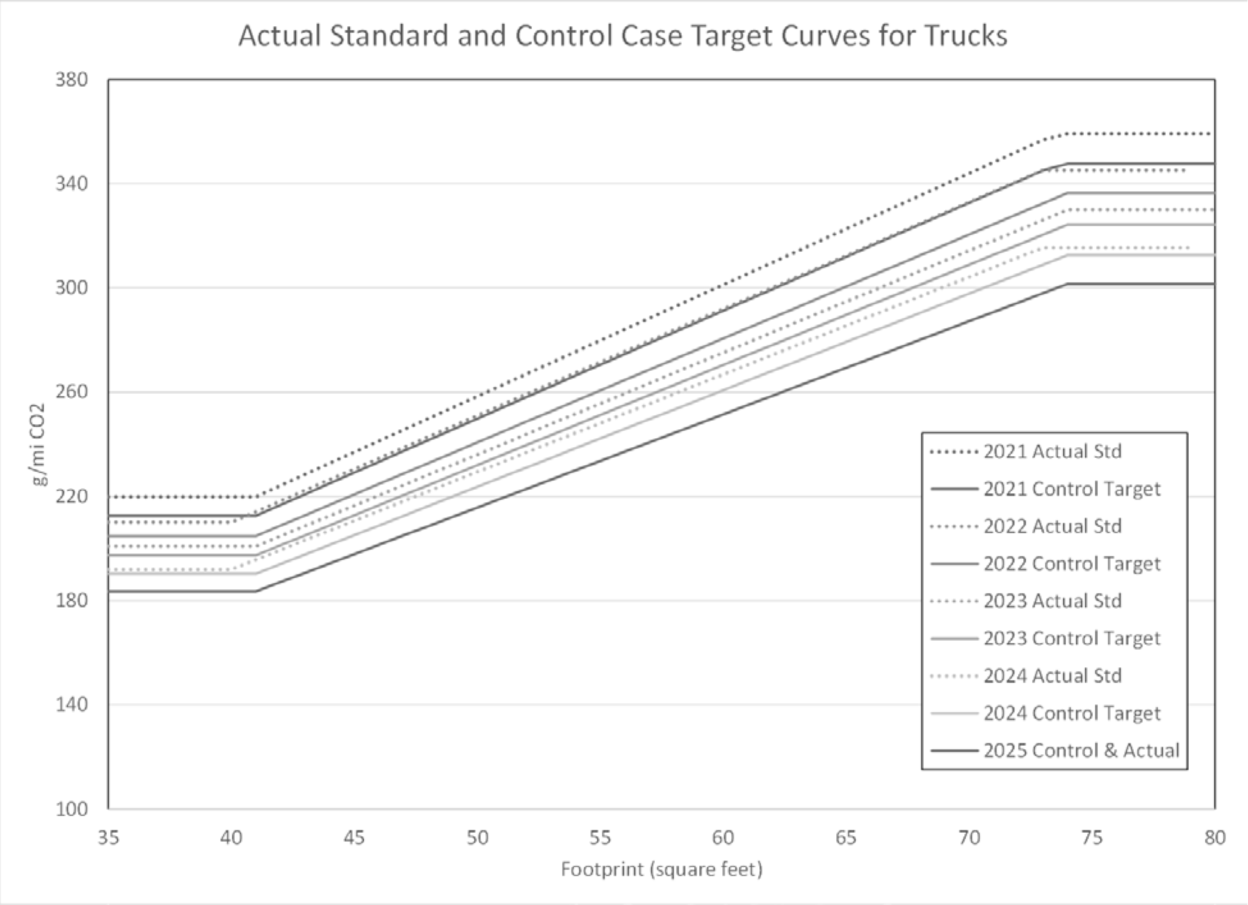

Figure C.2 Actual Standard Curves and the Control Case Target Curves Used for Trucks in this Proposed Determination to Reflect a 5-Year Redesign Cycle (Note: the legend reflects the ordering of lines on the chart)

Shown in these figures are the "actual" or promulgated CO_2 standard curves for the years 2021 through 2024 (dashed lines) and the control case target curves used in this analysis (solid lines). The control case target curves reflect greater stringency (lower CO_2) to reflect the 5-year redesign cycle discussed above. In effect, the target curves represent over-compliance with the actual standard curves in each year leading up to 2025. Just one curve is shown for 2025 since the actual standard and control case target curves are the same by then.

Importantly, the control case "standards" being used here are not new standard curves. Instead, they are an OMEGA modeling artifact used to simulate over-compliance with the actual standards. This over-compliance is being projected by EPA only to accommodate the 5-year redesign cycle stance, reflecting industry practice, consistent with analyses for both of the LDV GHG rules.

Nonetheless, these standard curves, whether actual or the control case curves are being used, are used for determining the OMEGA target values for individual vehicles depending on the MY and their unique footprints. By determining those target values for each vehicle in the fleet and sales-weighting those, a fleet target can be determined for each manufacturer and for the entire fleet. Running that fleet through OMEGA and determining the most cost-effective path toward compliance (while also considering any appropriate technology penetration caps (see Chapter 5.1.3 of the TSD) and other limitations on the application of technology), and considering credits and transfers as allowed under the program, we can estimate the achieved CO_2 level for each manufacturer and for the entire fleet.

We present the CO_2 targets and projected achieved levels in MY2021 in Table C.3 and in MY2025 in Table C.4. Note that the targets and achieved values shown in Table C.3 include over-compliance with the actual standards, as explained above. For the 2012 FRM, EPA predicted an overall fleet average CO_2 performance of 163 g/mi using AEO2011 projections. The Draft TAR predicted an overall fleet average CO_2 performance of 175 g/mi using AEO2015 projections. As shown in Table C.4, the overall fleet performance in MY2025 is predicted to achieve 173 g/mi using AEO2016 projections. This increase in CO_2 emissions relative to the 2012 FRM can be largely attributed to the increased market share of trucks relative to the fleet projected in the 2012 FRM. The slight decrease here relative to the Draft TAR can be attributed to a small increase in car share relative to the projections used in the Draft TAR. Table C.5 shows the car/truck shares in the 2012 FRM, the Draft TAR and this analysis to help illustrate how those shares impact the target values.

Table C.3 Control Case Targets and Achieved CO_2 in MY2021 in the Central Analysis (gCO_2/mi)

Manufacturer	Car Target	Truck Target	Fleet Target	Car Achieved	Truck Achieved	Fleet Achieved
BMW	173	229	188	182	206	188
FCA	177	236	219	200	227	219
Ford	174	260	226	195	248	226
GM	172	261	219	187	249	219
Honda	166	221	194	177	212	194
Hyundai/Kia	171	218	179	176	199	179
JLR	182	225	217	218	218	217
Mazda	169	215	186	173	209	186
Mercedes	176	228	199	195	208	199
Mitsubishi	156	201	175	171	183	175
Nissan	168	232	195	174	225	195
Subaru	166	204	196	196	196	196
Tesla	199		199	0		0
Toyota	169	239	202	171	237	202
Volkswagen	167	224	185	176	208	185
Volvo	176	217	198	186	209	198
Fleet	171	238	204	179	228	204

Note: Fleet values are sales weighted but not VMT weighted; targets include 20% over-compliance to the MY2025 standards.

Table C.4 Control Case Targets and Achieved CO_2 in MY2025 in the Central Analysis (gCO_2/mi)

Manufacturer	Car Target	Truck Target	Fleet Target	Car Achieved	Truck Achieved	Fleet Achieved
BMW	148	194	159	155	176	159
FCA	153	202	187	170	195	187
Ford	150	220	191	161	213	191
GM	149	222	185	162	210	185
Honda	143	189	165	155	177	165
Hyundai/Kia	148	185	154	150	171	154
JLR	157	190	183	192	182	183
Mazda	145	182	159	155	167	159
Mercedes	151	193	168	158	184	168
Mitsubishi	134	170	148	145	154	148
Nissan	144	198	165	150	189	165
Subaru	142	173	166	174	164	166
Tesla	172		172	111		111
Toyota	145	202	170	152	195	171
Volkswagen	144	189	158	146	185	158
Volvo	152	184	168	168	170	168
Fleet	147	202	173	155	193	173

Note: Fleet values are sales weighted but not VMT weighted.

Table C.5 Projections for MY2025: Car/Truck Mix, CO_2 Target Levels, and MPG-equivalent[1]

	2012 Final Rule	Draft TAR	Proposed Determination		
	AEO 2011 Reference	AEO 2015 Reference	AEO 2016 Reference	AEO 2016 Low	AEO 2016 High
Car/truck mix	67/33%	52/48%	53/47%	44/56%	63/37%
CO_2 (g/mi)	163	175	173	178	167
MPG-e[2]	54.5	50.8	51.4	49.9	53.3

Notes:

[1] The CO_2 and MPG-e values shown here are 2-cycle compliance values. Projected real-world values are detailed in Chapter 3 of the TSD; for example, for the Proposed Determination AEO reference fuel price case, real-world CO_2 emissions performance would be 233 g/mi and real-world fuel economy would be about 36 mpg.

[2] Mile per gallon equivalent (MPG-e) is the corresponding fleet average fuel economy value if the entire fleet were to meet the CO2 standard compliance level through tailpipe CO2 improvements that also improve fuel economy. This is provided for illustrative purposes only, as we do not expect the GHG standards to be met only with fuel efficiency technology.

C.1.1.1.3 Off-Cycle, Pickup Incentive and A/C Credits in OMEGA

In achieving the targets as shown in the tables above, manufacturers have available to them off-cycle credits for technologies, such as active aero and stop-start, that achieve real world CO_2 reductions although their impact is not adequately captured on the 2-cycle compliance tests (see 2012 FRM, 77 FR 62726 and 62832-839). There are also incentive credits available for certain advanced technologies, such as strong hybrids on pickup trucks (see 2012 FRM, 77 FR 62738). Lastly, there are A/C credits which EPA assumes that all manufacturers will use in meeting the targets shown above, since they are very cost-effective (see 2012 FRM, 77 FR 62721). Manufacturers have available to them broader options for utilizing off-cycle technologies, including a fuller list of pre-approved off-cycle credits (see 40 CFR 86.1869-12). In the Draft TAR, EPA made the very conservative assumption that only active aero and stop-start technologies would be used by manufacturers toward compliance and, as such, modeled only those off-cycle credits in our OMEGA runs (with the exception of A/C credits which, as with all GHG rules and analyses, are assumed to be used by all manufacturers to the fullest extent). For this Proposed Determination, as we suggested we would do for analyses done after the Draft TAR, see Chapter 12.1.1.1.3, we have added two additional levels of off-cycle credits valued at 1.5 and 3 gCO_2/mi, respectively.[193] These are separate levels of credit and are not additive to one another. These credits are made available in OMEGA during the package building phase and are included on packages already having active aero, improved accessories level 2, lower rolling resistance tires level 2, and advanced transmissions (TRX21 or TRX22). We limited these off-cycle technologies to such packages to ensure that they were being applied, within OMEGA, only where considerable effort had already been made toward compliance (i.e., only packages that had already incorporated considerable levels of efficiency improvements). We describe these off-cycle credits and their assumed costs in Section A of this Appendix and in Chapter 2 of the TSD. The credits shown below are available within the model in both the reference and control cases.

Table C.6 Off-cycle, Pickup Incentive and A/C Credits Available in OMEGA for Achieving the CO_2 Targets (gCO_2/mi)

MY	Vehicle	Active Aero	Stop-Start	Mild HEV Incentive	Strong HEV Incentive	Off-cycle 1 (New in OMEGA)	Off-cycle 2 (New in OMEGA)	A/C Leakage	A/C Efficiency
2021	Car	0.6	2.5	0.0	0.0	1.5	3.0	13.8	5.0
2022	Car	0.6	2.5	0.0	0.0	1.5	3.0	13.8	5.0
2023	Car	0.6	2.5	0.0	0.0	1.5	3.0	13.8	5.0
2024	Car	0.6	2.5	0.0	0.0	1.5	3.0	13.8	5.0
2025	Car	0.6	2.5	0.0	0.0	1.5	3.0	13.8	5.0
2021	Truck, non-pickup	1.0	4.4	0.0	0.0	1.5	3.0	17.2	7.2
2022	Truck, non-pickup	1.0	4.4	0.0	0.0	1.5	3.0	17.2	7.2
2023	Truck, non-pickup	1.0	4.4	0.0	0.0	1.5	3.0	17.2	7.2
2024	Truck, non-pickup	1.0	4.4	0.0	0.0	1.5	3.0	17.2	7.2
2025	Truck, non-pickup	1.0	4.4	0.0	0.0	1.5	3.0	17.2	7.2
2021	Pickup	1.0	4.4	10.0	20.0	1.5	3.0	17.2	7.2
2022	Pickup	1.0	4.4	0.0	20.0	1.5	3.0	17.2	7.2
2023	Pickup	1.0	4.4	0.0	20.0	1.5	3.0	17.2	7.2
2024	Pickup	1.0	4.4	0.0	20.0	1.5	3.0	17.2	7.2
2025	Pickup	1.0	4.4	0.0	20.0	1.5	3.0	17.2	7.2

The magnitude of the credits used within OMEGA, and reflected in the achieved CO_2 values presented in Table C.1 through Table C.4 are shown in the table below. The A/C credits used within OMEGA and reflected in both the targets and the achieved CO_2 values presented in the "Target and Achieved CO_2" tables above are also shown in the tables below.

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[193] See Section A of this Appendix to the Proposed Determination in which we discuss the importance of off-cycle credits and the credit levels that are being reported by manufacturers.

Table C.7 Off-cycle, Pickup Incentive and A/C Credits Used to Achieve the CO_2 Targets in the Central Case Analysis (gCO_2/mi)

	MY2021				MY2025			
Manufacturer	Reference Case Off-cycle Credits	Control Case Off-cycle Credits	Reference & Control Case PU Incentive Credits	Reference & Control Case A/C Credits	Reference Case Off-cycle Credits	Control Case Off-cycle Credits	Reference & Control Case PU Incentive Credits	Reference & Control Case A/C Credits
BMW	3.6	3.6	0.0	20.3	4.5	5.7	0.0	20.1
FCA	2.3	3.4	0.8	22.7	2.4	6.5	0.0	22.7
Ford	0.3	0.7	0.0	22.2	0.3	1.6	0.0	22.1
GM	0.6	0.9	0.0	21.7	0.6	3.4	0.0	21.6
Honda	0.0	0.0	0.0	21.7	0.0	0.8	0.0	21.5
Hyundai/Kia	0.5	0.6	0.0	19.7	0.5	0.9	0.0	19.7
JLR	5.4	5.3	0.0	23.4	6.2	7.3	0.0	23.2
Mazda	0.0	0.1	0.0	20.9	0.0	0.7	0.0	20.9
Mercedes	4.4	4.4	0.0	21.3	4.7	6.4	0.0	21.1
Mitsubishi	0.6	0.7	0.0	21.2	0.7	2.3	0.0	21.0
Nissan	0.4	0.5	0.0	21.1	0.4	1.4	0.0	20.9
Subaru	0.0	0.0	0.0	23.2	0.0	0.9	0.0	23.2
Tesla	0.0	0.0	0.0	18.8	0.0	0.0	0.0	18.8
Toyota	0.3	0.6	0.0	21.4	0.1	1.2	0.0	21.3
Volkswagen	3.0	3.4	0.0	20.6	4.3	6.0	0.0	20.5
Volvo	1.6	2.2	0.0	21.7	1.6	4.7	0.0	21.6
Fleet	1.0	1.3	<0.1	21.6	1.0	2.7	0.0	21.4

Note: For FCA, 0.8 gCO_2/mi of the reference and control case credits in MY2021 are incentive credits from use of mild HEV 48V technology on pickups (PU), that credit is no longer available beyond MY2021; the strong HEV incentive credits, while made available in OMEGA runs, were not used by any manufacturers.

C.1.1.2 Cost per Vehicle

We present the incremental costs of meeting the control case standards in MY2021 and MY2025 relative to the reference case in Table C.8, including for cars, trucks, and the fleet.

As shown in Table C.8, the average per vehicle costs to meet the MY2025 standards in MY2025 (compared to meeting the MY2021 standards in MY2025) is $875. These costs are less than those estimated in the 2012 FRM and are roughly the same as those estimated in the Draft TAR (costs here are less than in the Draft TAR which showed costs as $894 in 2013$ or $920 in 2015$).

We present absolute costs for MY2025 vehicles meeting the 2021 standards (i.e., the reference case) and for MY2025 vehicles meeting the 2025 standards (i.e., the central analysis control case), for cars and trucks in Section C.3.3, Table C.89 and Table C.90**Error! Reference source not found.**. The costs presented there are the costs used as inputs to the Benefit-Cost Analysis discussed in more detail in Sections C.2 and C.3 of this Appendix.

Table C.8 Incremental Per-Vehicle Average Costs to Comply with the Control Case Standards in the Central Analysis (2015$)

	Car		Truck		Fleet	
Manufacturer	2021	2025	2021	2025	2021	2025
BMW	$112	$1,189	$600	$1,651	$242	$1,296
FCA	$209	$1,068	$330	$1,379	$294	$1,284
Ford	$77	$729	$129	$795	$108	$768
GM	$140	$774	$107	$898	$123	$835
Honda	$173	$647	$75	$746	$123	$695
Hyundai/Kia	$87	$674	$166	$829	$100	$699
JLR	$0	$739	$257	$1,573	$210	$1,401
Mazda	$54	$314	$127	$914	$82	$539
Mercedes	$77	$1,403	$436	$1,321	$238	$1,369
Mitsubishi	$174	$918	$181	$885	$177	$905
Nissan	$186	$775	$74	$1,016	$140	$867
Subaru	$149	$526	$66	$671	$84	$640
Tesla	$0	$0	$0	$0	$0	$0
Toyota	$72	$499	$128	$949	$98	$698
Volkswagen	$95	$1,074	$472	$2,218	$218	$1,425
Volvo	$143	$467	$314	$1,345	$232	$910
Fleet	$119	$749	$173	$1,018	$145	$875

C.1.1.3 Technology Penetration

C.1.1.3.1 Reference Case

The tables below present technology penetration rates in the MY2025 reference case (that is, the case where MY2021 standards remain in place in MY2025), in absolute terms, for cars and trucks and for the fleet. First, Table C.9 presents the technology codes and their definitions as used in the following technology penetration tables. For detailed descriptions of each technology, refer to Chapter 2.2 of the TSD. In the interests of space, in this Appendix we do not present the technology penetrations for all technologies considered in this analysis. However, the OMEGA output files include technology penetrations for all technologies considered; those output files are contained in the docket and on EPA's website at https://www.epa.gov/regulations-emissions-vehicles-and-engines/optimization-model-reducing-emissions-greenhouse-gases. Here we present only those technologies that we believe to be most critical to the question of the appropriateness of the MY2022-2025 standards. Therefore, technologies like the accommodation of low friction lubes and lower rolling resistance tires are not presented here (but may be found in the output files as noted above) largely because those technologies are very cost effective and, therefore, have very high penetrations and, while important in achieving the standards, are not the primary drivers behind the feasibility of the standards. The technology penetration rates in Table C.10 through Table C.13 use the AEO 2016 reference fuel price case.

There is a distinction between the technology codes related to weight reduction, "WRtech" and "WRnet," both of which refer to weight reduction technology. The “WRtech” is the specific OMEGA code used to denote the weight reduction technology *applied* to the vehicle. This is the technology used to determine the costs associated with weight reduction. If 10 percent weight reduction technology is applied (i.e., “WRtech” = 10 percent) then the associated costs are those costs for a 10 percent weight reduction. The “WRnet” is the net weight reduction, or the WRtech value less the added weight of any added batteries for electrification (i.e., mild and strong HEVs, BEVs, and PHEVs). The WRnet value determines effectiveness values and also is used in the safety analysis. As shown in the technology penetration tables that follow, there is not much difference between “WRtech” values and “WRnet” values because our modeling projects very little increased electrification of the fleet to meet either the reference or control case standards. Nonetheless, the distinction between these two technologies is important within the modeling and is tracked for that reason. Note also that weight reduction and its application within OMEGA is limited in two ways: (1) by the safety analysis in an effort to ensure no projected net fatality increase as a result of the technology pathway chosen by OMEGA (see Appendix Section B.3.1); and (2), by the technology penetration caps meant to reflect how quickly varying levels of weight reduction could be implemented. Specifically, the safety analysis, as mentioned, is based on the “WRnet” value, while the application of weight reduction in light of the penetration caps is based on the “WRtech” value. We discuss safety and the metrics used on our OMEGA modeling in Section B.3.1 of this Appendix.

Note that the BEV and PHEV technology penetrations include the penetration of ZEV program vehicles as discussed in detail in Chapter 1 of the TSD. Importantly, the ZEV program vehicles were "built" into the fleet with the projection that they would apply 20 percent mass reduction technology (WRtech) and 0 percent net mass reduction (WRnet). The result is that the mass reduction technology penetrations include a 20 percent mass reduction on roughly 2.4 percent of the fleet due to the way we have assessed the ZEV program vehicles.

Lastly, the WR technology penetrations, both “WRtech” and “WRnet,” presented here, reflect percentage reductions from the "Null" vehicle, unlike those presented in the Draft TAR in which presented WR relative to the curb weight of vehicles in the MY2014 baseline. However, since our effectiveness values for WR are relative to the Null vehicle, it is more appropriate for us to present WR levels relative to Null. We have calculated the Null curb weights using the process described in Chapter 2.3.4.6 of the TSD.

Table C.9 Technology Code Definitions used in Technology Penetration Tables

Code	Definition
WRtech	Weight reduction technology applied to "Null"
WRnet	Weight reduction net (includes added weight from batteries on electrified vehicles)
TDS18	Turbocharged and downsized engine - 18 bar BMEP
TDS24	Turbocharged and downsized engine - 24 bar BMEP
TRX11	Transmission level 1 (i.e., 6 speed auto, 6 speed DCT)
TRX21	Transmission level 2 (i.e., TRX11 with a wider gear ratio spread (e.g., 8 gears), current generation CVT)
TRX22	Advanced Transmission level 2 (i.e., TRX21 with efficiency improvements)
Deac	Cylinder deactivation
VVLT	Variable valve lift
VVT	Variable valve timing
Stop-Start	Stop-Start, but without also being hybridized
MHEV48V	Mild hybrid 48 Volt
FullHEV	Strong hybrid
BEV	Full battery electric vehicle
PHEV	Plug-in hybrid electric vehicle
ATK2	Atkinson cycle engine used in naturally aspirated, non-hybrid engines
CEGR	Cooled exhaust gas recirculation
TURBM	ATK2 plus turbocharging (i.e., Miller cycle)
OC1	Off-cycle level 1 (1.5 gCO_2/mi)
OC2	Off-cycle level 2 (3.0 gCO_2/mi)
DSL	Advanced diesel

Note: TRX12, or advanced TRX11 (transmission level 1 with efficiency improvements), is not shown or included in the tables that follow because it is never chosen by OMEGA. All baseline CVTs in the Draft TAR were considered TRX11 while in this Proposed Determination we have considered all baseline CVTs to be TRX21. This change leaves less room for improvement (change from the baseline) for baseline CVT vehicles.

The tables that follow are:

Table C.10 Absolute Technology Penetrations for Cars in the MY2025 Reference Case Central Analysis

Table C.11 Absolute Technology Penetrations for Trucks in the MY2025 Reference Case Central Analysis

Table C.12 Absolute Technology Penetrations for the Fleet in the MY2025 Reference Case Central Analysis

Table C.13 Summary of Absolute Technology Penetrations in the MY2025 Reference Case Central Analysis

Table C.10 Absolute Technology Penetrations for Cars in the MY2025 Reference Case Central Analysis

	WRtech	WRnet	TDS18	TDS24	TRX11	TRX21	TRX22	Deac	VVLT	VVT	Stop-Start	MHEV48V	FullHEV	BEV	PHEV	ATK2	CEGR	TURBM	OC1	OC2	DSL
BMW	9%	8%	49%	11%	2%	60%	26%	30%	60%	90%	57%	32%	0%	2%	8%	17%	27%	0%	44%	17%	1%
FCA	8%	8%	36%	0%	0%	66%	26%	47%	43%	97%	14%	1%	0%	2%	1%	14%	14%	0%	0%	0%	0%
FORD	4%	4%	37%	0%	13%	75%	5%	0%	0%	97%	0%	0%	4%	1%	2%	0%	0%	0%	0%	0%	0%
GM	5%	5%	26%	0%	0%	77%	19%	3%	14%	98%	14%	0%	0%	1%	3%	0%	0%	0%	0%	0%	0%
HONDA	3%	2%	0%	0%	0%	87%	2%	11%	96%	96%	1%	0%	3%	2%	2%	0%	1%	0%	0%	0%	0%
HYUNDAI/KIA	4%	3%	8%	0%	2%	75%	19%	4%	1%	97%	0%	0%	2%	1%	1%	0%	0%	0%	0%	0%	0%
JLR	15%	14%	62%	6%	0%	67%	29%	28%	22%	96%	79%	17%	0%	2%	2%	23%	29%	0%	58%	11%	0%
MAZDA	5%	5%	0%	0%	17%	69%	0%	0%	0%	96%	0%	0%	0%	2%	2%	90%	0%	0%	0%	0%	0%
MERCEDES	11%	10%	57%	8%	0%	66%	28%	28%	54%	93%	82%	9%	0%	3%	3%	21%	29%	0%	55%	0%	1%
MITSUBISHI	4%	3%	8%	0%	0%	67%	17%	5%	0%	97%	0%	0%	0%	1%	1%	2%	2%	0%	0%	0%	0%
NISSAN	6%	5%	11%	0%	0%	74%	18%	0%	9%	95%	0%	0%	0%	4%	2%	0%	0%	0%	0%	0%	0%
SUBARU	2%	1%	18%	0%	0%	72%	1%	0%	0%	96%	0%	0%	0%	2%	2%	0%	83%	0%	0%	0%	0%
TESLA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
TOYOTA	4%	2%	2%	0%	7%	79%	3%	0%	1%	96%	0%	0%	19%	2%	2%	0%	20%	0%	0%	0%	0%
VOLKSWAGEN	10%	9%	53%	5%	0%	63%	27%	27%	57%	84%	81%	6%	0%	2%	2%	23%	37%	0%	50%	1%	12%
VOLVO	10%	10%	96%	0%	0%	72%	24%	0%	7%	96%	69%	0%	0%	2%	2%	0%	0%	0%	0%	0%	0%
All Manufacturers	5%	4%	20%	1%	3%	73%	14%	9%	24%	94%	14%	2%	4%	3%	2%	6%	10%	0%	7%	1%	1%

Table C.11 Absolute Technology Penetrations for Trucks in the MY2025 Reference Case Central Analysis

	WRtech	WRnet	TDS18	TDS24	TRX11	TRX21	TRX22	Deac	VVLT	VVT	Stop-Start	MHEV48V	FullHEV	BEV	PHEV	ATK2	CEGR	TURBM	OC1	OC2	DSL
BMW	15%	14%	26%	7%	0%	63%	30%	55%	33%	88%	43%	50%	0%	7%	0%	39%	31%	3%	28%	42%	5%
FCA	10%	10%	56%	1%	0%	71%	25%	37%	37%	95%	50%	2%	0%	1%	1%	15%	11%	0%	0%	0%	3%
FORD	8%	8%	56%	0%	3%	79%	17%	0%	0%	99%	11%	0%	0%	1%	1%	0%	0%	0%	0%	0%	0%
GM	7%	7%	14%	0%	0%	79%	20%	61%	0%	99%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
HONDA	6%	5%	0%	0%	9%	84%	3%	60%	96%	96%	0%	0%	0%	2%	2%	0%	0%	0%	0%	0%	0%
HYUNDAI/KIA	9%	9%	9%	0%	0%	77%	20%	0%	3%	97%	0%	0%	0%	1%	1%	0%	0%	0%	0%	0%	0%
JLR	15%	13%	37%	11%	0%	64%	29%	44%	44%	93%	45%	48%	0%	5%	2%	23%	29%	2%	19%	52%	0%
MAZDA	6%	5%	0%	0%	13%	77%	6%	0%	0%	96%	0%	0%	0%	2%	2%	71%	0%	0%	0%	0%	0%
MERCEDES	15%	13%	47%	17%	0%	64%	29%	21%	63%	89%	53%	40%	0%	4%	3%	14%	34%	3%	45%	23%	7%
MITSUBISHI	10%	10%	0%	0%	0%	74%	24%	32%	29%	89%	4%	0%	0%	1%	1%	22%	22%	0%	0%	0%	0%
NISSAN	9%	8%	19%	0%	0%	77%	19%	3%	2%	98%	0%	0%	0%	1%	2%	0%	0%	0%	0%	0%	0%
SUBARU	6%	5%	2%	0%	0%	94%	0%	0%	0%	96%	0%	0%	1%	2%	2%	0%	56%	0%	0%	0%	0%
TESLA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
TOYOTA	5%	5%	16%	0%	5%	77%	14%	0%	0%	97%	0%	0%	1%	1%	1%	0%	5%	0%	0%	0%	0%
VOLKSWAGEN	15%	13%	33%	4%	0%	62%	29%	42%	37%	79%	46%	43%	0%	7%	3%	30%	33%	1%	33%	32%	12%
VOLVO	11%	10%	95%	0%	0%	70%	26%	1%	0%	96%	4%	0%	0%	2%	2%	1%	1%	0%	0%	0%	0%
All Manufacturers	8%	7%	28%	1%	2%	77%	17%	26%	21%	96%	14%	4%	0%	1%	1%	6%	9%	0%	3%	3%	1%

Table C.12 Absolute Technology Penetrations for the Fleet in the MY2025 Reference Case Central Analysis

	WRtech	WRnet	TDS18	TDS24	TRX11	TRX21	TRX22	Deac	VVLT	VVT	Stop-Start	MHEV48V	FullHEV	BEV	PHEV	ATK2	CEGR	TURBM	OC1	OC2	DSL
BMW	10%	9%	44%	10%	1%	61%	27%	36%	54%	90%	54%	36%	0%	3%	6%	22%	28%	1%	40%	23%	2%
FCA	10%	9%	50%	1%	0%	70%	26%	40%	39%	96%	39%	1%	0%	1%	1%	15%	12%	0%	0%	0%	2%
FORD	7%	6%	48%	0%	7%	77%	12%	0%	0%	98%	7%	0%	2%	1%	1%	0%	0%	0%	0%	0%	0%
GM	6%	6%	20%	0%	0%	78%	19%	32%	7%	99%	7%	0%	0%	1%	1%	0%	0%	0%	0%	0%	0%
HONDA	4%	3%	0%	0%	4%	85%	2%	35%	96%	96%	0%	0%	2%	2%	2%	0%	1%	0%	0%	0%	0%
HYUNDAI/KIA	5%	4%	8%	0%	1%	75%	19%	3%	1%	97%	0%	0%	1%	1%	1%	0%	0%	0%	0%	0%	0%
JLR	15%	13%	43%	10%	0%	65%	29%	41%	39%	94%	52%	42%	0%	4%	2%	23%	29%	2%	27%	43%	0%
MAZDA	5%	5%	0%	0%	16%	72%	2%	0%	0%	96%	0%	0%	0%	2%	2%	83%	0%	0%	0%	0%	0%
MERCEDES	13%	11%	53%	12%	0%	65%	28%	25%	58%	92%	70%	22%	0%	4%	3%	18%	31%	1%	51%	9%	3%
MITSUBISHI	7%	6%	5%	0%	0%	69%	20%	15%	12%	94%	2%	0%	0%	1%	1%	10%	10%	0%	0%	0%	0%
NISSAN	7%	6%	14%	0%	0%	75%	19%	1%	6%	96%	0%	0%	0%	3%	2%	0%	0%	0%	0%	0%	0%
SUBARU	5%	4%	6%	0%	0%	89%	0%	0%	0%	96%	0%	0%	1%	2%	2%	0%	61%	0%	0%	0%	0%
TESLA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
TOYOTA	4%	3%	8%	0%	6%	78%	8%	0%	0%	97%	0%	0%	11%	2%	2%	0%	13%	0%	0%	0%	0%
VOLKSWAGEN	11%	10%	47%	4%	0%	63%	27%	31%	51%	83%	70%	17%	0%	4%	3%	25%	36%	0%	45%	11%	12%
VOLVO	11%	10%	96%	0%	0%	71%	25%	0%	4%	96%	36%	0%	0%	2%	2%	0%	0%	0%	0%	0%	0%
All Manufacturers	7%	6%	24%	1%	3%	75%	15%	17%	22%	95%	14%	3%	2%	2%	2%	6%	10%	0%	5%	2%	1%

Table C.13 Summary of Absolute Technology Penetrations in the MY2025 Reference Case Central Analysis

	WRtech	WRnet	TDS18	TDS24	TRX11	TRX21	TRX22	Deac	VVLT	VVT	Stop-Start	MHEV48V	FullHEV	BEV	PHEV	ATK2	CEGR	TURBM	OC1	OC2	DSL
Car	5%	4%	20%	1%	3%	73%	14%	9%	24%	94%	14%	2%	4%	3%	2%	6%	10%	0%	7%	1%	1%
Truck	8%	7%	28%	1%	2%	77%	17%	26%	21%	96%	14%	4%	0%	1%	1%	6%	9%	0%	3%	3%	1%
Fleet	7%	6%	24%	1%	3%	75%	15%	17%	22%	95%	14%	3%	2%	2%	2%	6%	10%	0%	5%	2%	1%

Mass reduction technology is applied along a continuum of possible levels, and values shown in the tables above represent the average percentage mass reduction applied (WRtech) and average percentage net mass reduction (WRnet). The values above do not indicate the proportion of the fleet with the technology applied, as is the case with the other technologies shown. Not readily apparent in the tables above is the number, or percentage, of vehicles that receive specific levels of mass reduction. The table below provides more detail on mass reduction technology in our projections by showing the percentage of vehicles that receive the level of mass reduction within the given mass reduction ranges. Note that we account for the additional mass associated with batteries and electrical components of mild and strong HEVs, BEVs and PHEVs, which explains the difference between "WRtech" and "WRnet." "Baseline" represents the amount of mass reduction relative to EPA’s “Null” or “floor” (i.e., in the case of weight reduction, EPA’s “Null” is the 2008 baseline fleet used in the 2012 FRM) present in MY2015 vehicles with MY2025 projected volumes. In the table, we show results both including and excluding the ZEV program vehicles because, as noted above, roughly 2.5 percent of the fleet (the fleet reflecting the ZEV program) was "built" with 20 percent mass reduction technology applied (WRtech) and 0 percent mass reduction on net (WRnet). As shown in the table, the majority of vehicles (~60 percent) in the reference case are applying mass reduction technology resulting in less than 5 percent mass reduction, about 20 percent are applying mass reduction at levels of between 5 and 10 percent, and a small percentage (~18 percent) are applying mass reduction technology resulting in 10 to 15 percent mass reduction. Nearly all vehicles applying 15 to 20 percent mass reduction technology are the ZEV program vehicles, with only an additional 0.5 percent of non-ZEV program vehicles applying that level of mass reduction technology.

Table C.14 Percentage of Vehicles Receiving the Mass Reduction levels within the Indicated Ranges in the MY2025 Reference Case Central Analysis

Fleet	%MR Range	Baseline	WRtech	WRnet
Including ZEV Program Vehicles	<=5%	89.9%	59.2%	62.2%
	6% to <=10%	4.3%	20.4%	20.0%
	11% to <=15%	3.3%	17.4%	17.8%
	16% to <=20%	2.5%	3.0%	0.0%
Excluding ZEV Program Vehicles (as explained above)	<=5%	92.2%	60.8%	61.2%
	6% to <=10%	4.4%	20.9%	20.6%
	11% to <=15%	3.4%	17.8%	18.2%
	16% to <=20%	0.0%	0.5%	0.0%

C.1.1.3.2 Control Case

The technology penetration rates in the MY2025 control case (that is, the case where the MY2025 standards are in effect in MY2025), again in absolute terms, are presented for cars, trucks, and the fleet in the tables below. We also present the technology penetration changes (i.e., the technology added to move from compliance with the reference case standards to the control case standards) for cars, trucks and the fleet in the tables below. All technology penetration rates in Table C.15 to Table C.22 use the AEO 2016 reference fuel price case.

Much like both the 2012 FRM, the 2015 NAS report, and the Draft TAR, the results from the control case show that the MY2025 standards can be met largely through the application of advanced gasoline vehicle technologies, including moderate levels of mild hybridization (i.e., 48 volt systems). For advanced gasoline engines, EPA has projected that the fleet would be 34 percent 18-bar and 24-bar turbo-charged engines and 27 percent Atkinson 2 engines. This similar penetration of two competing engine technologies (i.e., Atkinson 2 and 18-bar/24-bar turbocharged engines) demonstrates that there are multiple cost effective advanced gasoline technologies available to manufacturers. In order to acknowledge that manufacturers may choose to focus on turbo-downsized technology over Atkinson, EPA conducted a sensitivity analysis restricting Atkinson 2 technology application as described in the Sensitivity Analysis Results below. In addition to turbo-charging and Atkinson cycle, EPA has also projected that cylinder deactivation (DEAC), variable valve timing (VVT) and cooled EGR (CEGR) will be prominent engine technologies, with respective penetration rates of 49 percent, 95 percent, and 35 percent. With respect to transmissions, EPA has projected that about 93 percent of the transmissions will be high ratio spread (TRX21+TRX22) and 88 percent of these transmissions will also implement further improvements in transmission efficiency beyond current transmissions (TRX22).

One note regarding Atkinson 2 technology penetration: In their comments on the Draft TAR, AAM stated that they did not believe that the market penetration of Atkinson 2 technology, projected in the Draft TAR of over 40 percent, is likely or feasible. In the Control Case results described above, for the Proposed Determination, the penetration of Atkinson 2 is expected be 27 percent in 2025 MY. This reduction in Atkinson penetration is not in direct response to this AAM comment, but rather the result of updates to EPA's analysis (as described in Appendix A and in the TSD).

Stop-start and Mild HEV technologies, such as 48-volt systems, are anticipated to be applied with increasing frequency. The 48-volt mild hybrids help improve the overall efficiency of conventional powertrains at less expense compared to strong hybridization. Stop-start is projected to penetrate the market in 15 percent of the fleet, and Mild HEVs at 18 percent penetration.

Mass reduction is also expected to be applied at moderate levels across the majority of the fleet. For MY2025 EPA has projected an average mass reduction technology penetration rate for the entire fleet of 9 percent (WRtech) which, when taking into consideration the additional mass of electrification, yields a net mass reduction of 8 percent (WRnet). The highest average amount of mass reduction for an individual manufacturer is projected to be 19 percent for Jaguar-Land Rover and the lowest mass reduction is projected to be 6 percent for both Hyundai/Kia. Note that, as explained above, these mass reduction levels are relative to null and not relative to the baseline case (i.e., the MY2015 case). In the Draft TAR, we presented mass reduction levels relative to the baseline case (MY2014) which was different from the way we presented all of our other technology penetration rates. In this Proposed Determination, we are now presenting all of the absolute technology penetration rates as relative to null. The slightly higher levels of mass reduction presented in this analysis can be explained, at least in part, by the different reference point (null versus baseline level which, in the Draft TAR, was roughly 2 percent across the entire analysis fleet).

We project that some manufacturers will utilize some level of strong electrification as a compliance path. However, EPA has projected a minimal amount of strong electrification technology penetration for the overall fleet. For strong HEVs, battery electric vehicles (BEVs), and plug-in hybrid electric vehicles (PHEVs), EPA has projected fleet technology penetration rates of 2 percent, 3 percent, and 2 percent, respectively. The highest penetration rates for strong HEVs was projected at 11 percent for Toyota. For the highest penetration for any individual manufacturer for BEVs (other than Tesla), Volkswagen has been projected to reach 9 percent, and for PHEVs, BMW is projected to reach 6 percent. EPA notes that our analysis included consideration for compliance with other related regulations, including CARB's ZEV regulation that has also been adopted by nine other states under section 177 of the Federal Clean Air Act. Therefore, some of the BEV and PHEV penetration in the following tables is ZEV program-related (2.5 percent of the combined fleet), some is in EPA's reference fleet projections (1.5 percent of the combined fleet), and some is generated by OMEGA to reach compliance (an additional 0.7 percent of the combined fleet) for a total of 4.7 percent in the central case (using the AEO 2016 reference fuel price case)). See Table C.16 where the final BEV (3 percent) and PHEV (2 percent) penetrations can be added to reach 5 percent; see Table C.22 where the incremental BEV penetration is shown as 1 percent, rounded from 0.5 percent. Note that the reference case tables shown above (see Table C.13) include an additional 0.2 percent BEV penetration that does not show up in the table due to rounding.

The tables that follow for control case technology penetrations are:

Table C.15 Absolute Technology Penetrations for Cars in the MY2025 Control Case Central Analysis

	WRtech	WRnet	TDS18	TDS24	TRX11	TRX21	TRX22	Deac	VVLT	VVT	Stop-Start	MHEV48V	FullHEV	BEV	PHEV	ATK2	CEGR	TURBM	OC1	OC2	DSL
BMW	10%	9%	15%	30%	2%	0%	82%	41%	45%	86%	31%	54%	0%	6%	8%	37%	67%	12%	0%	85%	1%
FCA	11%	10%	9%	22%	0%	0%	94%	66%	31%	97%	59%	9%	0%	2%	1%	56%	65%	0%	84%	13%	0%
FORD	8%	7%	48%	0%	0%	5%	87%	45%	22%	97%	0%	0%	4%	1%	2%	16%	16%	0%	0%	0%	0%
GM	7%	7%	51%	0%	0%	3%	94%	41%	33%	98%	24%	4%	0%	1%	3%	35%	31%	0%	13%	0%	0%
HONDA	4%	3%	0%	0%	0%	3%	88%	13%	94%	96%	1%	0%	3%	2%	2%	1%	3%	0%	0%	0%	0%
HYUNDAI/KIA	4%	4%	12%	0%	2%	0%	93%	83%	12%	97%	1%	1%	2%	1%	1%	63%	62%	0%	0%	0%	0%
JLR	19%	17%	6%	18%	0%	0%	96%	73%	23%	96%	57%	39%	0%	2%	2%	54%	72%	1%	0%	96%	0%
MAZDA	7%	6%	0%	0%	0%	33%	52%	55%	0%	96%	0%	0%	0%	2%	2%	41%	0%	0%	0%	0%	0%
MERCEDES	13%	11%	15%	21%	0%	0%	90%	54%	36%	90%	32%	59%	0%	7%	3%	49%	71%	10%	3%	88%	1%
MITSUBISHI	4%	4%	8%	0%	0%	0%	84%	90%	8%	97%	0%	0%	0%	1%	1%	70%	67%	0%	97%	0%	0%
NISSAN	6%	6%	24%	0%	0%	0%	92%	70%	15%	95%	0%	0%	0%	4%	2%	37%	34%	0%	0%	0%	0%
SUBARU	8%	8%	21%	0%	0%	66%	7%	6%	8%	96%	0%	0%	0%	2%	2%	5%	87%	0%	0%	0%	0%
TESLA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
TOYOTA	5%	3%	17%	0%	0%	44%	50%	27%	3%	96%	0%	0%	19%	2%	2%	0%	20%	0%	0%	0%	0%
VOLKSWAGEN	12%	9%	18%	12%	0%	0%	90%	57%	31%	87%	38%	54%	0%	5%	2%	55%	72%	7%	0%	93%	5%
VOLVO	13%	13%	67%	3%	0%	0%	96%	27%	69%	96%	69%	0%	0%	2%	2%	0%	3%	0%	27%	0%	0%
All Manufacturers	7%	6%	22%	4%	0%	10%	81%	48%	28%	94%	13%	9%	4%	4%	2%	31%	37%	1%	8%	13%	0%

Table C.16 Absolute Technology Penetrations for Trucks in the MY2025 Control Case Central Analysis

	WRtech	WRnet	TDS18	TDS24	TRX11	TRX21	TRX22	Deac	VVLT	VVT	Stop-Start	MHEV48V	FullHEV	BEV	PHEV	ATK2	CEGR	TURBM	OC1	OC2	DSL
BMW	20%	18%	6%	20%	0%	0%	87%	61%	26%	86%	7%	80%	0%	13%	0%	60%	75%	12%	0%	87%	1%
FCA	14%	12%	15%	45%	0%	0%	98%	38%	55%	98%	31%	67%	0%	1%	1%	18%	60%	0%	45%	54%	1%
FORD	11%	11%	77%	0%	0%	0%	99%	22%	19%	99%	29%	1%	0%	1%	1%	7%	6%	0%	0%	0%	0%
GM	8%	6%	27%	0%	0%	0%	99%	72%	15%	99%	27%	67%	0%	1%	0%	10%	8%	0%	19%	0%	0%
HONDA	10%	10%	0%	0%	0%	0%	96%	87%	69%	96%	0%	0%	0%	2%	2%	27%	27%	0%	0%	0%	0%
HYUNDAI/KIA	13%	12%	32%	0%	0%	0%	97%	66%	32%	97%	3%	0%	0%	1%	1%	66%	49%	0%	86%	0%	0%
JLR	19%	16%	18%	34%	0%	0%	91%	39%	53%	91%	14%	77%	0%	7%	2%	39%	72%	29%	0%	91%	0%
MAZDA	10%	10%	26%	0%	0%	0%	96%	53%	12%	96%	0%	0%	0%	2%	2%	71%	53%	0%	0%	0%	0%
MERCEDES	20%	17%	17%	43%	0%	0%	90%	30%	60%	90%	19%	71%	0%	7%	3%	30%	72%	16%	0%	90%	0%
MITSUBISHI	12%	11%	8%	0%	0%	0%	97%	89%	8%	97%	8%	0%	0%	1%	1%	89%	67%	0%	89%	0%	0%
NISSAN	10%	10%	59%	0%	0%	0%	96%	38%	43%	98%	22%	7%	0%	1%	2%	37%	30%	0%	26%	0%	0%
SUBARU	10%	10%	6%	0%	0%	1%	93%	38%	0%	96%	0%	0%	1%	2%	2%	1%	56%	0%	0%	0%	0%
TESLA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
TOYOTA	9%	8%	55%	0%	0%	1%	95%	41%	37%	97%	12%	1%	1%	1%	1%	20%	21%	0%	0%	0%	0%
VOLKSWAGEN	20%	17%	8%	7%	0%	2%	79%	65%	15%	81%	4%	75%	0%	18%	3%	65%	72%	37%	0%	79%	0%
VOLVO	18%	16%	3%	8%	0%	0%	96%	85%	11%	96%	72%	24%	0%	2%	2%	34%	42%	0%	96%	0%	0%
All Manufacturers	11%	10%	33%	9%	0%	0%	96%	49%	34%	97%	19%	29%	0%	2%	1%	22%	33%	2%	16%	16%	0%

Table C.17 Absolute Technology Penetrations for the Fleet in the MY2025 Control Case Central Analysis

	WRtech	WRnet	TDS18	TDS24	TRX11	TRX21	TRX22	Deac	VVLT	VVT	Stop-Start	MHEV48V	FullHEV	BEV	PHEV	ATK2	CEGR	TURBM	OC1	OC2	DSL
BMW	12%	11%	13%	28%	1%	0%	83%	46%	41%	86%	25%	60%	0%	8%	6%	42%	69%	12%	0%	85%	1%
FCA	13%	12%	13%	38%	0%	0%	96%	46%	48%	97%	40%	49%	0%	1%	1%	30%	61%	0%	57%	41%	0%
FORD	10%	9%	65%	0%	0%	2%	94%	31%	20%	98%	17%	0%	2%	1%	1%	11%	10%	0%	0%	0%	0%
GM	8%	7%	39%	0%	0%	1%	97%	57%	24%	99%	25%	35%	0%	1%	1%	23%	20%	0%	16%	0%	0%
HONDA	7%	6%	0%	0%	0%	2%	92%	49%	82%	96%	0%	0%	2%	2%	2%	14%	14%	0%	0%	0%	0%
HYUNDAI/KIA	6%	5%	15%	0%	1%	0%	94%	81%	15%	97%	1%	1%	1%	1%	1%	63%	60%	0%	14%	0%	0%
JLR	19%	16%	16%	31%	0%	0%	92%	46%	47%	92%	23%	69%	0%	6%	2%	42%	72%	23%	0%	92%	0%
MAZDA	8%	7%	10%	0%	0%	21%	69%	54%	4%	96%	0%	0%	0%	2%	2%	52%	20%	0%	0%	0%	0%
MERCEDES	16%	14%	16%	30%	0%	0%	90%	44%	46%	90%	26%	64%	0%	7%	3%	41%	71%	12%	2%	89%	0%
MITSUBISHI	7%	7%	8%	0%	0%	0%	89%	90%	8%	97%	3%	0%	0%	1%	1%	78%	67%	0%	94%	0%	0%
NISSAN	8%	7%	37%	0%	0%	0%	94%	58%	26%	96%	8%	3%	0%	3%	2%	37%	32%	0%	10%	0%	0%
SUBARU	10%	9%	9%	0%	0%	15%	74%	31%	2%	96%	0%	0%	1%	2%	2%	2%	62%	0%	0%	0%	0%
TESLA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%
TOYOTA	7%	5%	33%	0%	0%	25%	70%	33%	18%	97%	5%	0%	11%	2%	2%	9%	20%	0%	0%	0%	0%
VOLKSWAGEN	14%	12%	15%	11%	0%	1%	86%	59%	26%	85%	28%	61%	0%	9%	3%	58%	72%	16%	0%	88%	4%
VOLVO	15%	14%	34%	6%	0%	0%	96%	56%	40%	96%	71%	12%	0%	2%	2%	17%	23%	0%	62%	0%	0%
All Manufacturers	9%	8%	27%	7%	0%	5%	88%	49%	31%	95%	15%	18%	2%	3%	2%	27%	35%	2%	12%	14%	0%

Table C.18 Summary of Absolute Technology Penetrations in the MY2025 Control Case Central Analysis

	WRtech	WRnet	TDS18	TDS24	TRX11	TRX21	TRX22	Deac	VVLT	VVT	Stop-Start	MHEV48V	FullHEV	BEV	PHEV	ATK2	CEGR	TURBM	OC1	OC2	DSL
Car	7%	6%	22%	4%	0%	10%	81%	48%	28%	94%	13%	9%	4%	4%	2%	31%	37%	1%	8%	13%	0%
Truck	11%	10%	33%	9%	0%	0%	96%	49%	34%	97%	19%	29%	0%	2%	1%	22%	33%	2%	16%	16%	0%
Fleet	9%	8%	27%	7%	0%	5%	88%	49%	31%	95%	15%	18%	2%	3%	2%	27%	35%	2%	12%	14%	0%

Table C.19 Incremental Technology Penetrations for Cars in the MY2025 Central Analysis

	WRtech	WRnet	TDS18	TDS24	TRX11	TRX21	TRX22	Deac	VVLT	VVT	Stop-Start	MHEV 48V	FullHEV	BEV	PHEV	ATK2	CEGR	TURBM	OC1	OC2	DSL
BMW	1%	1%	-34%	19%	0%	-60%	57%	11%	-15%	-4%	-26%	22%	0%	4%	0%	21%	40%	12%	-44%	68%	0%
FCA	3%	3%	-27%	22%	0%	-66%	68%	18%	-12%	0%	45%	8%	0%	0%	0%	42%	51%	0%	84%	13%	0%
FORD	3%	3%	11%	0%	-13%	-70%	83%	45%	22%	0%	0%	0%	0%	0%	0%	16%	16%	0%	0%	0%	0%
GM	2%	2%	25%	0%	0%	-74%	75%	38%	20%	0%	10%	3%	0%	0%	0%	35%	30%	0%	13%	0%	0%
HONDA	1%	1%	0%	0%	0%	-83%	86%	2%	-2%	0%	0%	0%	0%	0%	0%	1%	1%	0%	0%	0%	0%
HYUNDAI/KIA	1%	1%	4%	0%	0%	-74%	75%	80%	11%	0%	1%	1%	0%	0%	0%	63%	62%	0%	0%	0%	0%
JLR	3%	3%	-56%	12%	0%	-67%	67%	45%	1%	0%	-22%	22%	0%	0%	0%	31%	43%	1%	-58%	85%	0%
MAZDA	1%	1%	0%	0%	-17%	-35%	52%	55%	0%	0%	0%	0%	0%	0%	0%	-49%	0%	0%	0%	0%	0%
MERCEDES	3%	1%	-42%	13%	0%	-66%	62%	26%	-18%	-4%	-51%	50%	0%	4%	0%	29%	42%	10%	-52%	87%	0%
MITSUBISHI	0%	0%	0%	0%	0%	-67%	67%	85%	8%	0%	0%	0%	0%	0%	0%	68%	66%	0%	97%	0%	0%
NISSAN	1%	1%	13%	0%	0%	-74%	74%	70%	6%	0%	0%	0%	0%	0%	0%	37%	34%	0%	0%	0%	0%
SUBARU	7%	7%	3%	0%	0%	-6%	6%	6%	8%	0%	0%	0%	0%	0%	0%	5%	5%	0%	0%	0%	0%
TESLA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
TOYOTA	1%	1%	15%	0%	-7%	-35%	47%	27%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
VOLKSWAGEN	2%	1%	-34%	8%	0%	-62%	63%	30%	-27%	3%	-43%	48%	0%	3%	0%	32%	35%	7%	-50%	92%	-6%
VOLVO	3%	3%	-30%	3%	0%	-72%	72%	27%	62%	0%	0%	0%	0%	0%	0%	0%	3%	0%	27%	0%	0%
All Manufacturers	2%	2%	2%	3%	-3%	-63%	67%	39%	4%	0%	-1%	7%	0%	0%	0%	25%	27%	1%	1%	12%	0%

Table C.20 Incremental Technology Penetrations for Trucks in the MY2025 Central Analysis

	WRtech	WRnet	TDS18	TDS24	TRX11	TRX21	TRX22	Deac	VVLT	VVT	Stop-Start	MHEV 48V	FullHEV	BEV	PHEV	ATK2	CEGR	TURBM	OC1	OC2	DSL
BMW	5%	4%	-21%	13%	0%	-63%	57%	5%	-7%	-2%	-36%	30%	0%	6%	0%	20%	44%	9%	-28%	45%	-4%
FCA	4%	2%	-41%	44%	0%	-71%	72%	1%	18%	3%	-19%	65%	0%	0%	0%	4%	49%	0%	45%	54%	-3%
FORD	3%	3%	20%	0%	-3%	-79%	82%	22%	19%	0%	18%	1%	0%	0%	0%	7%	6%	0%	0%	0%	0%
GM	1%	0%	13%	0%	0%	-79%	79%	11%	15%	0%	27%	67%	0%	0%	0%	10%	8%	0%	19%	0%	0%
HONDA	5%	5%	0%	0%	-9%	-84%	93%	27%	-27%	0%	0%	0%	0%	0%	0%	27%	27%	0%	0%	0%	0%
HYUNDAI/KIA	3%	3%	23%	0%	0%	-77%	77%	66%	29%	0%	3%	0%	0%	0%	0%	66%	49%	0%	86%	0%	0%
JLR	4%	3%	-19%	23%	0%	-64%	62%	-5%	9%	-2%	-30%	29%	0%	2%	0%	16%	43%	27%	-19%	39%	0%
MAZDA	5%	5%	26%	0%	-13%	-77%	91%	53%	12%	0%	0%	0%	0%	0%	0%	0%	53%	0%	0%	0%	0%
MERCEDES	5%	4%	-31%	26%	0%	-64%	61%	9%	-3%	1%	-34%	31%	0%	3%	0%	16%	39%	14%	-45%	68%	-7%
MITSUBISHI	2%	2%	8%	0%	0%	-74%	74%	58%	-21%	8%	4%	0%	0%	0%	0%	67%	45%	0%	89%	0%	0%
NISSAN	1%	1%	40%	0%	0%	-77%	77%	36%	41%	0%	21%	7%	0%	0%	0%	37%	30%	0%	26%	0%	0%
SUBARU	5%	5%	4%	0%	0%	-93%	93%	38%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%
TESLA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
TOYOTA	3%	3%	39%	0%	-5%	-76%	81%	41%	37%	0%	12%	1%	0%	0%	0%	20%	16%	0%	0%	0%	0%
VOLKSWAGEN	5%	4%	-25%	3%	0%	-61%	50%	24%	-22%	2%	-42%	32%	0%	10%	0%	35%	39%	36%	-33%	47%	-12%
VOLVO	6%	6%	-93%	8%	0%	-70%	70%	84%	11%	0%	68%	24%	0%	0%	0%	33%	42%	0%	96%	0%	0%
All Manufacturers	3%	3%	5%	9%	-2%	-77%	79%	24%	13%	0%	5%	25%	0%	1%	0%	16%	24%	2%	13%	13%	-1%

Table C.21 Incremental Technology Penetrations for the Fleet in the MY2025 Central Analysis

	WRtech	WRnet	TDS18	TDS24	TRX11	TRX21	TRX22	Deac	VVLT	VVT	Stop-Start	MHEV 48V	FullHEV	BEV	PHEV	ATK2	CEGR	TURBM	OC1	OC2	DSL
BMW	2%	1%	-31%	17%	0%	-61%	57%	10%	-13%	-3%	-29%	24%	0%	5%	0%	21%	41%	11%	-40%	62%	-1%
FCA	4%	2%	-37%	37%	0%	-70%	71%	6%	8%	2%	1%	48%	0%	0%	0%	15%	50%	0%	57%	41%	-2%
FORD	3%	3%	16%	0%	-7%	-75%	82%	31%	20%	0%	11%	0%	0%	0%	0%	11%	10%	0%	0%	0%	0%
GM	2%	1%	19%	0%	0%	-77%	77%	25%	17%	0%	18%	35%	0%	0%	0%	23%	19%	0%	16%	0%	0%
HONDA	3%	3%	0%	0%	-4%	-84%	90%	14%	-14%	0%	0%	0%	0%	0%	0%	14%	14%	0%	0%	0%	0%
HYUNDAI/KIA	1%	1%	7%	0%	0%	-75%	75%	78%	14%	0%	1%	1%	0%	0%	0%	63%	60%	0%	14%	0%	0%
JLR	4%	3%	-27%	21%	0%	-65%	63%	5%	7%	-1%	-29%	27%	0%	1%	0%	19%	43%	22%	-27%	49%	0%
MAZDA	3%	3%	10%	0%	-16%	-51%	67%	54%	4%	0%	0%	0%	0%	0%	0%	-30%	20%	0%	0%	0%	0%
MERCEDES	4%	2%	-38%	18%	0%	-65%	62%	19%	-12%	-2%	-44%	42%	0%	3%	0%	23%	41%	11%	-49%	79%	-3%
MITSUBISHI	1%	1%	3%	0%	0%	-69%	69%	74%	-4%	3%	1%	0%	0%	0%	0%	68%	58%	0%	94%	0%	0%
NISSAN	1%	1%	23%	0%	0%	-75%	75%	57%	20%	0%	8%	3%	0%	0%	0%	37%	32%	0%	10%	0%	0%
SUBARU	5%	5%	4%	0%	0%	-74%	74%	31%	2%	0%	0%	0%	0%	0%	0%	2%	1%	0%	0%	0%	0%
TESLA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
TOYOTA	2%	2%	25%	0%	-6%	-53%	62%	33%	18%	0%	5%	0%	0%	0%	0%	9%	7%	0%	0%	0%	0%
VOLKSWAGEN	3%	2%	-31%	6%	0%	-62%	59%	28%	-25%	3%	-43%	43%	0%	5%	0%	33%	36%	16%	-45%	78%	-8%
VOLVO	5%	4%	-61%	6%	0%	-71%	71%	56%	36%	0%	34%	12%	0%	0%	0%	17%	22%	0%	62%	0%	0%
All Manufacturers	2%	2%	3%	6%	-3%	-70%	73%	32%	8%	0%	2%	15%	0%	0.5%	0.0%	21%	25%	2%	7%	13%	-1%

Table C.22 Summary of Incremental Technology Penetrations in the MY2025 Central Analysis

	WRtech	WRnet	TDS18	TDS24	TRX11	TRX21	TRX22	Deac	VVLT	VVT	Stop-Start	MHEV 48V	FullHEV	BEV	PHEV	ATK2	CEGR	TURBM	OC1	OC2	DSL
Car	2%	2%	2%	3%	-3%	-63%	67%	39%	4%	0%	-1%	7%	0%	0%	0%	25%	27%	1%	1%	12%	0%
Truck	3%	3%	5%	9%	-2%	-77%	79%	24%	13%	0%	5%	25%	0%	1%	0%	16%	24%	2%	13%	13%	-1%
Fleet	2%	2%	3%	6%	-3%	-70%	73%	32%	8%	0%	2%	15%	0%	0%	0%	21%	25%	2%	7%	13%	-1%

Not readily apparent in the technology penetration tables above is the number, or percentage, of vehicles that receive specific levels of mass reduction. Table C.23 below provides more detail on mass reduction technology using the same approach as described in the text accompanying Table C.14. As shown in the table, the majority of vehicles (~72 percent) in the control case excluding the ZEV program are applying mass reduction technology (the "WRtech" value) resulting in 10 percent or less mass reduction, and about 19 percent are applying mass reduction technology resulting in 11 to 15 percent mass reduction. Roughly 10 percent on the non-ZEV program vehicles are applying mass reduction technology resulting in 16 to 20 percent mass reduction with all of those being the luxury and luxury-sport vehicle manufacturers such as BMW, Mercedes and Jaguar/Land Rover. Importantly, we again note that our mass reduction levels are now presented relative to null. Of most interest, perhaps, are the mass reduction levels presented in the incremental technology penetration tables--Table C.19 through Table C.22--which show that very little mass reduction is actually being applied within OMEGA to move from the reference case to control case standards. In fact, Table C.22 shows that only 2 percent additional mass reduction technology is being applied within OMEGA to move from the reference to control case standards.

Table C.23 Percentage of Vehicles Receiving the Mass Reduction levels within the Indicated Ranges in the MY2025 Control Case Central Analysis

Fleet	%MR Range	Baseline	WRtech	WRnet
Including ZEV Program Vehicles	<=5%	89.9%	30.6%	34.4%
	6% to <=10%	4.3%	39.2%	40.6%
	11% to <=15%	3.3%	18.5%	18.4%
	16% to <=20%	2.5%	11.7%	6.6%
Excluding ZEV Program Vehicles (as explained above)	<=5%	92.2%	31.4%	32.8%
	6% to <=10%	4.4%	40.2%	41.6%
	11% to <=15%	3.4%	19.0%	18.9%
	16% to <=20%	0.0%	9.5%	6.8%

C.1.2 Sensitivity Analysis Results

C.1.2.1 CO_2 Targets, Achieved CO_2 & Credits

C.1.2.1.1 Reference Case

The different AEO 2016 fuel price cases (shown in Chapter 3 of the TSD) result in unique fleet projections since higher fuel prices are projected to result in fewer truck and more car sales, while lower fuel prices are projected to result in more truck sales and fewer car sales. As a result of these fleet mix differences, the manufacturer-specific footprint based standards would result in different fleet-wide CO_2 target values for each AEO 2016 fuel price case and projected fleet. While we have conducted additional sensitivity runs beyond varying the fuel price projections, only these two fuel price sensitivities (high and low) result in unique CO_2 target values. All other sensitivity runs use the AEO 2016 reference case fuel prices, fleets and resultant targets. Table C.24 shows the reference case targets in MY2025 while Table C.25 shows the reference case achieved levels in MY2025. While the fleet as a whole is projected to exactly achieve its target, these two tables illustrate the general over compliance on trucks (pickups, SUVs, minivans and most cross-over utility vehicles) and under compliance on cars, since OMEGA predicts a slightly more cost-effective path to compliance for trucks compared to cars.

Table C.24 Reference Case CO_2 Targets in MY2025 for Each Sensitivity Case (gCO_2/mi)

	Car			Truck			Combined		
	AEO Low	AEO Ref	AEO High	AEO Low	AEO Ref	AEO High	AEO Low	AEO Ref	AEO High
BMW	178	178	178	237	237	237	196	192	188
FCA	183	183	183	247	246	245	232	227	220
FORD	180	180	180	269	269	267	240	232	222
GM	179	179	178	271	271	270	233	224	213
HONDA	172	172	172	231	231	231	206	201	194
HYUNDAI/KIA	177	177	177	226	226	226	188	185	183
JLR	188	188	188	233	233	233	226	224	220
MAZDA	174	174	174	223	223	223	197	193	188
MERCEDES	182	182	182	236	236	236	209	204	199
MITSUBISHI	161	161	161	208	208	208	184	180	175
NISSAN	174	174	174	242	242	241	206	200	193
SUBARU	171	171	171	212	212	212	205	203	200
TESLA	206	206	206				206	206	206
TOYOTA	175	175	175	247	247	246	213	207	199
VOLKSWAGEN	173	173	173	231	231	231	196	191	186
VOLVO	182	182	182	226	226	226	208	204	200
All Manufacturers	177	177	177	247	247	246	216	210	202

Table C.25 Reference Case CO_2 Achieved in MY2025 for Each Sensitivity Case (gCO_2/mi)

	Car			Truck			Combined		
	AEO Low	AEO Ref	AEO High	AEO Low	AEO Ref	AEO High	AEO Low	AEO Ref	AEO High
BMW	188	186	184	218	217	211	196	192	188
FCA	207	205	201	240	237	235	232	227	220
FORD	208	199	197	258	258	250	240	232	222
GM	203	198	192	256	253	250	233	224	213
HONDA	190	185	184	219	219	213	206	201	194
HYUNDAI/KIA	182	180	180	210	212	209	188	185	183
JLR	221	221	219	228	225	222	226	224	220
MAZDA	178	178	177	218	218	217	197	193	188
MERCEDES	195	194	193	224	220	213	209	204	199
MITSUBISHI	177	177	173	192	186	182	184	180	175
NISSAN	184	182	181	232	230	225	206	200	193
SUBARU	213	212	198	205	201	201	205	203	200
TESLA	111	111	111				111	111	111
TOYOTA	181	179	175	242	242	243	213	207	199
VOLKSWAGEN	172	173	174	232	231	227	196	191	186
VOLVO	192	191	190	220	219	214	208	204	200
All Manufacturers	190	187	184	238	236	232	216	210	202

C.1.2.1.2 Control Case

Table C.26 shows the control case targets in MY2025 while Table C.27 shows the control case achieved levels in MY2025. As in the reference case tables presented above, these two tables illustrate the general over compliance on trucks (pickups, SUVs, minivans and most cross-over utility vehicles) and under compliance on cars. However, a manufacturer's fleet would still comply since manufacturers have the option to transfer credits across the car and truck fleets in a way that achieves the least-cost compliance path.

Table C.26 Control Case CO_2 Targets in MY2025 for Each Sensitivity Case (gCO_2/mi)

	Car			Truck			Combined		
	AEO Low	AEO Ref	AEO High	AEO Low	AEO Ref	AEO High	AEO Low	AEO Ref	AEO High
BMW	148	148	148	194	194	194	162	159	156
FCA	153	153	153	202	202	200	190	187	181
FORD	150	150	150	221	220	219	198	191	183
GM	149	149	148	222	222	221	192	185	176
HONDA	143	143	143	189	189	189	169	165	160
HYUNDAI/KIA	148	148	147	185	185	185	156	154	152
JLR	157	157	157	190	190	190	185	183	181
MAZDA	145	145	145	182	182	182	162	159	156
MERCEDES	151	151	151	193	193	193	172	168	164
MITSUBISHI	134	134	134	170	170	170	151	148	144
NISSAN	144	144	144	198	198	197	170	165	159
SUBARU	143	142	142	173	173	173	168	166	164
TESLA	172	172	172				172	172	172
TOYOTA	146	145	145	202	202	201	176	170	164
VOLKSWAGEN	144	144	144	189	189	189	162	158	154
VOLVO	152	152	152	184	184	184	171	168	165
All Manufacturers	147	147	147	202	202	201	178	173	167

Table C.27 Control Case CO_2 Achieved in MY2025 for Each Sensitivity Case (gCO_2/mi)

	Car			Truck			Combined		
	AEO Low	AEO Ref	AEO High	AEO Low	AEO Ref	AEO High	AEO Low	AEO Ref	AEO High
BMW	154	155	152	182	176	175	162	159	156
FCA	172	170	166	196	195	192	190	187	181
FORD	161	161	160	215	213	210	198	191	183
GM	164	162	159	212	210	205	192	185	176
HONDA	158	155	155	179	177	171	169	165	160
HYUNDAI/KIA	151	150	150	171	171	168	156	154	152
JLR	192	192	178	185	182	183	185	183	181
MAZDA	156	155	152	172	167	167	162	159	156
MERCEDES	160	158	159	186	184	178	172	168	164
MITSUBISHI	147	145	143	156	154	149	151	148	144
NISSAN	151	150	147	189	189	189	170	165	159
SUBARU	178	174	168	166	164	163	168	166	164
TESLA	111	111	111				111	111	111
TOYOTA	152	152	149	196	195	195	176	170	164
VOLKSWAGEN	145	146	146	187	185	184	162	158	154
VOLVO	169	168	168	174	170	164	171	168	165
All Manufacturers	156	155	153	195	193	190	178	173	167

Because we are using updated projections for the future fleet mix, note that none of the combined fleet targets presented in Table C.27 achieve the 163 g/mi CO_2 target (54.5 mpg, if all reductions achieved through fuel economy improvements) projected in the 2012 FRM. This is due to changes in the projections for fleet makeup, mainly-car/truck mix and also footprint characteristics, in the AEO 2016 fleet projections relative to the 2012 FRM projections. (The Draft TAR used AEO 2015 projections which showed similar results).

C.1.2.1.3 Off-Cycle, Pickup Incentive and A/C Credits in OMEGA

Credit availability in each sensitivity case is identical to the central case shown in Table C.6. The magnitude of the credits used within OMEGA, and reflected in the achieved CO_2 values presented in the “Target and Achieved CO_2” tables above are shown in the tables below. The A/C credits used within OMEGA and reflected in both the targets and the achieved CO_2 values presented in the “Target and Achieved CO_2” tables above are also shown in the tables below.

Table C.28 MY2021 Off-cycle, Pickup Incentive and A/C Credits Used to Achieve the CO_2 Targets in the AEO High Fuel Price Case (gCO_2/mi)

Manufacturer	Reference Case Off-cycle Incentive	Reference Case PU Incentive Credits	Reference Case A/C Credits	Control Case Off-cycle Credits	Control Case PU Incentive Credits	Control Case A/C Credits
BMW	3.5	0.0	19.9	3.6	0.0	19.9
FCA	2.6	0.7	22.2	4.0	0.7	22.2
Ford	0.4	0.0	21.6	0.7	0.0	21.6
GM	0.7	0.0	21.1	1.0	<0.1	21.1
Honda	0.0	0.0	21.1	0.2	0.0	21.1
Hyundai/Kia	0.5	0.0	19.5	0.6	0.0	19.5
JLR	5.2	0.0	23.0	5.1	0.0	23.0
Mazda	0.0	0.0	20.5	0.1	0.0	20.5
Mercedes	4.1	0.0	20.8	4.4	0.0	20.8
Mitsubishi	0.6	0.0	20.6	0.7	0.0	20.6
Nissan	0.3	0.0	20.6	0.6	<0.1	20.6
Subaru	0.0	0.0	22.8	0.1	0.0	22.8
Tesla	0.0	0.0	18.8	0.0	0.0	18.8
Toyota	0.3	0.0	20.9	0.6	0.0	20.9
Volkswagen	2.8	0.0	20.2	3.8	0.0	20.2
Volvo	1.7	0.0	21.2	2.2	0.0	21.2
Fleet	1.0	<0.1	21.0	1.3	<0.2	21.0

Note: For FCA, 0.7 gCO_2/mi of the reference and control case credits in MY2021 and, for GM & Nissan, <0.1 gCO2/mi of the control case credits in MY2021 are incentive credits from use of mild HEV 48V technology on pickups (PU), that credit is no longer available beyond MY2021; the strong HEV incentive credits, while made available in OMEGA runs, were not chosen by OMEGA to apply to any manufacturers.

Table C.29 MY2025 Off-cycle, Pickup Incentive and A/C Credits Used to Achieve the CO_2 Targets in the AEO High Fuel Price Case (gCO_2/mi)

Manufacturer	Reference Case Off-cycle Credits	Reference Case PU Incentive Credits	Reference Case A/C Credits	Control Case Off-cycle Credits	Control Case PU Incentive Credits	Control Case A/C Credits
BMW	3.6	0.0	19.7	5.3	0.0	19.7
FCA	2.3	0.0	22.2	6.2	0.0	22.2
Ford	0.4	0.0	21.5	1.8	0.0	21.5
GM	0.7	0.0	20.9	3.4	0.0	20.9
Honda	0.0	0.0	21.0	1.6	0.0	21.0
Hyundai/Kia	0.5	0.0	19.4	0.9	0.0	19.4
JLR	5.0	0.0	22.9	6.5	0.0	22.9
Mazda	0.0	0.0	20.4	0.7	0.0	20.4
Mercedes	4.0	0.0	20.6	5.8	0.0	20.6
Mitsubishi	0.6	0.0	20.5	3.0	0.0	20.5
Nissan	0.4	0.0	20.4	1.2	0.0	20.4
Subaru	0.0	0.0	22.8	0.9	0.0	22.8
Tesla	0.0	0.0	18.8	0.0	0.0	18.8
Toyota	0.3	0.0	20.7	1.0	0.0	20.7
Volkswagen	3.5	0.0	20.1	5.7	0.0	20.1
Volvo	1.7	0.0	21.1	4.2	0.0	21.1
Fleet	1.0	0.0	20.9	2.6	0.0	20.9

Table C.30 MY2021 Off-cycle, Pickup Incentive and A/C Credits Used to Achieve the CO_2 Targets in the AEO Low Fuel Price Case (gCO_2/mi)

Manufacturer	Reference Case Off-cycle Credits	Reference Case PU Incentive Credits	Reference Case A/C Credits	Control Case Off-cycle Credits	Control Case PU Incentive Credits	Control Case A/C Credits
BMW	3.8	0.0	20.7	3.8	0.0	20.7
FCA	2.1	0.9	23.1	3.6	0.9	23.1
Ford	0.4	0.0	22.6	0.6	0.0	22.6
GM	0.6	0.0	22.2	0.8	0.0	22.2
Honda	0.0	0.0	22.1	0.0	0.0	22.1
Hyundai/Kia	0.4	0.0	20.0	0.6	0.0	20.0
JLR	5.5	0.0	23.6	5.4	0.0	23.6
Mazda	0.0	0.0	21.3	0.1	0.0	21.3
Mercedes	4.6	0.0	21.8	4.7	0.0	21.8
Mitsubishi	0.6	0.0	21.6	0.7	0.0	21.6
Nissan	0.4	0.0	21.6	0.5	<0.1	21.6
Subaru	0.0	0.0	23.5	0.0	0.0	23.5
Tesla	0.0	0.0	18.8	0.0	0.0	18.8
Toyota	0.2	0.0	21.9	0.6	0.0	21.9
Volkswagen	3.2	0.0	21.0	3.4	0.0	21.0
Volvo	1.4	0.0	22.2	1.9	0.0	22.2
Fleet	1.0	<0.1	22.0	1.4	<0.1	22.0

Note: Note: For FCA, 0.9 gCO_2/mi of the reference and control case credits in MY2021 and, for Nissan, <0.1 gCO2/mi of the control case credits in MY2021 are incentive credits from use of mild HEV 48V technology on pickups (PU), that credit is no longer available beyond MY2021; the strong HEV incentive credits, while made available in OMEGA runs, were not chosen by OMEGA to apply to any manufacturers.

Table C.31 MY2025 Off-cycle, Pickup Incentive and A/C Credits Used to Achieve the CO_2 Targets in the AEO Low Fuel Price Case (gCO_2/mi)

Manufacturer	Reference Case Off-cycle Credits	Reference Case PU Incentive Credits	Reference Case A/C Credits	Control Case Off-cycle Credits	Control Case PU Incentive Credits	Control Case A/C Credits
BMW	4.5	0.0	20.5	6.1	0.0	20.5
FCA	2.3	0.0	23.1	6.5	0.0	23.1
Ford	0.4	0.0	22.6	1.4	0.0	22.6
GM	0.6	0.0	22.1	3.2	0.0	22.1
Honda	0.0	0.0	22.0	0.8	0.0	22.0
Hyundai/Kia	0.5	0.0	20.0	1.0	0.0	20.0
JLR	6.4	0.0	23.5	7.5	0.0	23.5
Mazda	0.0	0.0	21.4	0.8	0.0	21.4
Mercedes	4.8	0.0	21.6	6.7	0.0	21.6
Mitsubishi	0.6	0.0	21.5	1.7	0.0	21.5
Nissan	0.4	0.0	21.4	1.5	0.0	21.4
Subaru	0.0	0.0	23.5	0.9	0.0	23.5
Tesla	0.0	0.0	18.8	0.0	0.0	18.8
Toyota	0.1	0.0	21.8	1.1	0.0	21.8
Volkswagen	4.8	0.0	21.0	6.2	0.0	21.0
Volvo	1.4	0.0	22.1	5.0	0.0	22.1
Fleet	1.0	0.0	21.9	2.7	0.0	21.9

C.1.2.1.4 Cost per Vehicle and Technology Penetrations

In Section C.1.1 , we presented our projections for the technology penetrations and cost per vehicle for the MY2025 central analysis control case. We recognize there are many uncertainties involved when making projections to MY2025, including the makeup of the future fleet which will be influenced in part by future gasoline prices, which technologies manufacturers will actually adopt, and how manufacturers will respond to compliance with the standards given the range of credit programs available including credit trading across manufacturers. As a way to inform how changes in such factors would affect our analysis of the MY2025 standards, we have conducted a wide range of sensitivity analyses, including:

- AEO 2016 high fuel price case, which varies both fuel prices and projected fleet characteristics (see Table C.5).
- AEO 2016 low fuel price case, which varies both fuel prices and projected fleet characteristics (see Table C.5).
- “Perfect” credit trading across all manufacturers. This sensitivity should represent the most cost effective case since any manufacturer in need of credits is assumed to acquire them if they exist.

- No Car/Truck transfers across a single manufacturer's fleet, which forces cars to meet the car curve standards and trucks to meet the truck curve standards. This sensitivity illustrates a more restrictive scenario, since the GHG program in fact allows full transfers across a manufacturer's car and truck fleets, and thus highlights the importance of this flexibility provision.

- No additional mass reduction beyond that included in the projected baseline fleet. That is, no mass reduction is allowed to comply with MY2021 (reference case) or MY2025 (control case) standards. Though EPA believes our mass reduction estimates are fully feasible and reasonable, this sensitivity helps allay any potential concerns that further mass reduction is not feasible or that the future standards cannot be met safely due to an over reliance on mass reduction.

- A non-Atkinson engine technology path which sets a penetration cap on Atkinson-2 technology at 10 percent in both the reference and control cases. This sensitivity shows the impacts of manufacturers choosing a path less dependent on that technology.

- A pathway which doesn't allow for transmission efficiency improvements beyond today's levels ("Non-TRX22 path"). To do this, we have set the penetration cap on TRX22 technology at 0 percent in both the reference and control cases. This sensitivity responds to some industry commenter concerns that we are expecting too much improvement to existing transmissions. This sensitivity was not included in the Draft TAR.

- All of the above runs make use of the ICM approach to estimating indirect costs. We have conducted a sensitivity run using the RPE approach to estimating indirect costs.

Table C.32 MY2025 Absolute Technology Penetrations & Incremental Costs for Cars in Each OMEGA Run (2015$)

Tech	AEO Ref (Central Case)	AEO High	AEO Low	Perfect Trading	No C/T Transfers	No additional MR	Non-ATK2 Path	Non-TRX22 Path	RPE
VVT	94%	93%	94%	94%	94%	94%	94%	93%	95%
VVLT	28%	23%	29%	23%	23%	21%	33%	23%	23%
Deac	48%	51%	46%	54%	62%	60%	45%	59%	57%
TRX11	0%	0%	0%	0%	0%	0%	0%	0%	0%
TRX21	10%	4%	14%	4%	4%	4%	5%	90%	14%
TRX22	81%	86%	77%	87%	87%	86%	86%	0%	77%
TDS18	22%	22%	23%	32%	16%	17%	21%	18%	20%
TDS24	4%	4%	4%	0%	9%	8%	10%	9%	4%
ATK2	31%	35%	29%	38%	50%	47%	5%	48%	29%
CEGR	37%	40%	35%	40%	56%	54%	19%	54%	34%
Miller	1%	1%	2%	0%	2%	3%	0%	2%	1%
Stop-Start	13%	17%	9%	8%	22%	15%	20%	34%	14%
Mild HEV	9%	6%	10%	2%	15%	14%	13%	8%	12%
Full HEV	4%	4%	4%	4%	4%	4%	4%	4%	4%
PHEV	2%	2%	2%	2%	2%	2%	2%	2%	2%
BEV	4%	4%	4%	3%	4%	5%	4%	5%	4%
OC1	8%	9%	6%	2%	42%	28%	25%	35%	7%

OC2	13%	13%	13%	0%	21%	17%	15%	17%	13%
WR tech	7%	7%	7%	7%	8%	2%	7%	8%	6%
WR net	6%	6%	6%	6%	7%	1%	6%	7%	5%
$/veh	$749	$774	$748	$714	$873	$718	$732	$933	$845
Delta $/veh	$0	$25	-$1	-$35	$124	-$31	-$17	$184	$96

Table C.33 MY2025 Absolute Technology Penetrations & Incremental Costs for Trucks in Each OMEGA Run (2015$)

Tech	AEO Ref (Central Case)	AEO High	AEO Low	Perfect Trading	No C/T Transfers	No additional MR	Non-ATK2 Path	Non-TRX22 Path	RPE
VVT	97%	96%	97%	97%	97%	96%	97%	96%	97%
VVLT	34%	34%	35%	37%	27%	34%	43%	37%	27%
Deac	49%	51%	45%	45%	40%	43%	41%	40%	52%
TRX11	0%	0%	0%	0%	0%	0%	0%	0%	0%
TRX21	0%	0%	0%	0%	11%	0%	0%	95%	0%
TRX22	96%	95%	96%	97%	85%	95%	96%	0%	96%
TDS18	33%	28%	33%	51%	33%	38%	31%	38%	32%
TDS24	9%	11%	9%	1%	9%	11%	16%	16%	8%
ATK2	22%	23%	21%	29%	13%	34%	4%	28%	25%
CEGR	33%	36%	31%	24%	24%	43%	23%	41%	34%
Miller	2%	2%	2%	0%	2%	8%	0%	4%	3%
Stop-Start	19%	20%	15%	36%	12%	23%	20%	45%	26%
Mild HEV	29%	33%	28%	31%	18%	40%	41%	30%	33%
Full HEV	0%	0%	0%	0%	0%	1%	1%	1%	1%
PHEV	1%	1%	1%	1%	1%	1%	1%	1%	1%
BEV	2%	3%	2%	1%	2%	3%	2%	3%	2%
OC1	16%	21%	14%	24%	16%	18%	16%	24%	10%
OC2	16%	15%	15%	0%	8%	30%	26%	25%	14%
WR tech	11%	12%	11%	10%	10%	3%	12%	13%	11%
WR net	10%	10%	10%	9%	10%	1%	11%	12%	9%
$/veh	$1,018	$1,067	$993	$988	$887	$887	$1,132	$1,321	$1,256
Delta $/veh	$0	$49	-$25	-$30	-$131	-$131	$114	$303	$238

Table C.34 MY2025 Absolute Technology Penetrations & Incremental Costs for the Fleet in Each OMEGA Run (2015$)

Tech	AEO Ref (Central Case)	AEO High	AEO Low	Perfect Trading	No C/T Transfers	No additional MR	Non-ATK2 Path	Non-TRX22 Path	RPE
VVT	95%	94%	96%	96%	95%	95%	95%	94%	96%
VVLT	31%	27%	32%	30%	25%	27%	38%	30%	24%
Deac	49%	51%	46%	50%	51%	52%	43%	50%	55%
TRX11	0%	0%	0%	0%	0%	0%	0%	0%	0%
TRX21	5%	3%	6%	2%	7%	2%	3%	92%	8%
TRX22	88%	90%	88%	92%	86%	90%	91%	0%	86%
TDS18	27%	24%	28%	41%	24%	27%	26%	27%	26%

TDS24	7%	7%	7%	0%	9%	10%	13%	12%	6%
ATK2	27%	31%	24%	34%	33%	41%	5%	38%	27%
CEGR	35%	39%	32%	33%	41%	49%	21%	48%	34%
Miller	2%	1%	2%	0%	2%	5%	0%	3%	2%
Stop-Start	15%	18%	12%	21%	17%	19%	20%	39%	19%
Mild HEV	18%	16%	20%	16%	16%	27%	26%	18%	22%
Full HEV	2%	3%	2%	2%	2%	3%	2%	3%	3%
PHEV	2%	2%	2%	2%	2%	2%	2%	2%	2%
BEV	3%	4%	3%	2%	3%	4%	3%	4%	3%
OC1	12%	13%	11%	13%	30%	24%	21%	30%	8%
OC2	14%	14%	14%	0%	15%	23%	20%	21%	14%
WR tech	9%	9%	9%	8%	9%	2%	10%	10%	8%
WR net	8%	8%	8%	7%	8%	1%	8%	9%	7%
$/veh	$875	$882	$886	$843	$880	$797	$920	$1,115	$1,038
Delta $/veh	$0	$7	$11	-$32	$5	-$78	$45	$240	$163

C.1.2.1.5 Observations on Sensitivity Analyses

EPA notes the following observations on each of the sensitivity analyses shown above.

- Fuel prices have little impact on the cost per vehicle outcomes. This result is driven by the fact that the projected fleet changes depend on the projected fuel price. Compared to the AEO reference fuel price case, the AEO 2016 high fuel price case has a higher proportion of cars, while the low fuel price case has a higher proportion of trucks, as shown in Table C.5.

- Fuel prices have little impact on the technology penetration outcomes.

- Higher fuel prices do not result in substantially different fleet electrification. Full electric and plug-in hybrid electric vehicle penetrations are essentially constant across all sensitivities. This is largely driven by the BEVs and PHEVs projected in the reference fleet as a result of the ZEV program. Only the mild hybrid technology shows notable differences, ranging from 16 percent to 27 percent of the fleet depending on the sensitivity case.

- Using RPEs to account for indirect costs increases $/vehicle, as would be expected, on the order of $163.

- The incremental $/vehicle result is not heavily dependent on mass reduction and, therefore, the mass reduction cost curves. Disallowing any mass reduction beyond that estimated in the baseline fleet actually decreased incremental $/vehicle by $78. While this may seem counter intuitive, most mass reduction is occurring in the reference cases of all of the OMEGA runs (compare Table C.13 to Table C.18 to see that nearly twice as much mass reduction is occurring in the reference case of the central case runs as compared to that in the control case). As a result, the increased costs expected from the "no additional mass reduction" sensitivity case is actually manifested in the reference case costs, making them higher, thereby making the incremental costs to reach the control case standards less than in the central analysis.

- Limiting estimated penetration of the Atkinson-2 engine technology would increase estimated cost per vehicle from $875 to $920, or roughly $45, but this pathway still shows a cost-effective pathway to the MY2025 standards based primarily on advanced engine technology rather than electrification, with increased penetration of 24-bar turbo-downsized engines, advanced transmissions (TRX22), stop-start, and mild hybrids.

- While the case where car/truck transfers are not allowed has little impact on overall $/vehicle, the limitation of transfers impacts car costs more significantly, increasing their costs from $749 to $873 (+$124) while decreasing truck costs from $1,018 to $887 (-$131). This indicates that, in the central analysis, it is more cost effective to reduce truck emissions (as discussed above and in observation 8 below) and transfer over compliance credits to the less cost effective car fleet. Elimination of transfers also drives the car fleet further into the advanced technologies (TRX22, ATK2, stop-start) and more use of off-cycle credits while simultaneously limiting advanced technology penetrations on trucks.

- The perfect trading sensitivity illustrates the potential value of trading across firms, as the overall $/vehicle impact is reduced by $32 ($875 down to $843), with the car $/vehicle decreasing from $749 down to $714 (-$35) and the truck $/vehicle decreasing from $1018 to $988 (-$30).

C.2 Impacts on Emissions (GHG and non-GHG) and Fuel Consumption

C.2.1 Analytical Tools Used

As in the 2012 final rule establishing MY2017-2025 standards, as well as the Draft TAR, EPA used its OMEGA Inventory Costs and Benefits Tool (ICBT) to project the emissions and fuel consumption impacts of this analysis for the Proposed Determination. The projections of the emission inventory and fleetwide fuel consumption are conducted in the OMEGA ICBT[194] which produces a national scale analysis of the impacts (emission inventory and fuel consumption impacts, monetized co-benefits) of the analyzed program. The OMEGA ICBT incorporates the inputs discussed in Section Appendix A of this Appendix (baseline fleet, technology costs and effectiveness) and TSD Chapter 3 (vehicle miles traveled (VMT), rebound, energy security, and other economic inputs).

The remainder of this subsection provides a summary of the analytical inputs, methodology, and the results of the analysis.

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[194] The relevant ICBT elements are a post-processing tool to OMEGA used to incorporate inventory and cost-specific data not needed in OMEGA, but needed for this analysis.

C.2.2 Inputs to the Emissions and Fuel Consumption Analysis

C.2.2.1 Methods

EPA estimated GHG impacts from several sources including: (a) the impact of the standards on tailpipe CO_2 emissions, (b) projected improvements in the efficiency of vehicle air conditioning systems, (c) reductions in direct emissions of the potent greenhouse gas refrigerant HFC-134a from air conditioning systems, (d) “upstream” emission reductions from gasoline extraction, production and distribution processes as a result of reduced gasoline demand associated with standards, and (e) “upstream” emission increases from power plants as electric powertrain vehicles are projected to increase slightly as a result of the MY2022-2025 standards. EPA additionally accounted for the greenhouse gas impacts of additional vehicle miles traveled (VMT) due to the "rebound" effect discussed in the TSD Chapter 3.

EPA’s estimates of non-GHG emission impacts from the MY2022-2025 standards are broken down by the three drivers of these changes: a) “downstream” emission changes, reflecting the estimated effects of VMT rebound (discussed in Chapter 3 of the TSD) and decreased consumption of motor vehicle fuel; b) “upstream” emission reductions due to decreased extraction, production and distribution of motor vehicle gasoline; c) “upstream” emission increases from power plants as electric powertrain vehicles are projected to be slightly more prevalent in future years.[195] For all criteria and air toxic pollutants, the overall impact of the MY2022-2025 standards is small compared to total U.S. inventories across all sectors.

Although electric vehicles have zero tailpipe emissions, EPA assumes that manufacturers will plan for these vehicles in their regulatory compliance strategy for criteria pollutant and air toxics emissions, and will not over-comply with applicable Tier 3 emissions standards for non-GHG air pollutants. Since the Tier 3 emissions standards are fleet-average standards, EPA assumes that if a manufacturer introduces BEVs into its fleet, then it would correspondingly compensate through changes to vehicles elsewhere in its fleet, rather than produce an overall lower fleet-average emissions level. Consequently, consistent with the 2012 FRM and Draft TAR, EPA assumes neither tailpipe pollutant (other than CO_2), evaporative emissions, nor brake and tire wear particulate matter reductions from the introduction of electric vehicles into the fleet.

Two basic elements feed into the OMEGA ICBT calculation of vehicle tailpipe emissions. These elements are vehicle miles traveled (VMT) and emission rates, where the total emissions are the vehicle miles traveled multiplied by the emission rate in grams/mile. This equation is adjusted in calculations for various emissions, but provides the basic form used throughout this analysis. As an example, in an analysis of a single calendar year, the emissions equation is repeatedly applied to determine the contribution of each model year in the calendar year’s particular fleet. Appropriate VMT and emission factors by age are applied to each model year within the calendar year, and the products are then summed (VMT inputs for this analysis are

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[195] Note that the reference case used by EPA includes vehicle sales in response to the ZEV program. As such, increased power plant emissions associated with those reference case ZEV-program vehicle sales are not attributable to the 2022-2025 GHG standards. However, OMEGA projects a very small increase in EV and PHEV sales above those needed for ZEV compliance; the increased power plant emissions due to those additional EV/PHEV vehicles are attributable to the 2022-2025 GHG standards. Note that EPA continues to apply the electricity emissions factors from those used in the 2012 FRM, though it is possible that emissions factors might change in the future due in part to EPA’s Clean Power Plan regulations.

described in more detail in TSD Chapter 3, emission factors by age are derived from the MOVES model and can be found in the docket to this Proposed Determination). Similarly, to determine the emissions of a single model year, appropriate VMT and emission factors by age are applied to each calendar year between when the model year fleet is produced and projected to be scrapped.

Tailpipe sulfur dioxide (SO_2) emissions, which are largely controlled by the sulfur content of the fuel, are an exception to this basic equation. Decreasing the quantity of fuel consumed decreases tailpipe SO_2 emissions proportionally to the decrease in fuel combusted. Therefore, rather than multiplying the SO_2 emission factor by miles traveled, we multiply by gallons consumed. As such, the SO_2 emission factor is expressed in terms of grams/gallon rather than grams/mile.

C.2.2.2 Global Warming Potentials

In general, when we refer to the four inventoried greenhouse gases on an equivalent basis, Global Warming Potentials (GWPs) are used. In simple terms, GWPs provide a common basis with which to combine several gases with different heat trapping abilities into a single inventory. When expressed in CO_2 equivalent (CO_2e) terms, each gas is weighted by its heat trapping ability relative to that of carbon dioxide. The GWPs used are shown in Table C.35.[196]

Table C.35 Global Warming Potentials (GWP) for Inventoried GHGs

GHG	GWP (CO2e)
CO2	1
CH4	25
N2O	298
HFC (R134a)	1430

C.2.2.3 Years Considered

This analysis presents the projected impacts of the standards in calendar years 2025, 2030, 2040 and 2050. We also present the emission impacts over the estimated full lifetime of MYs 2022-2025 vehicles. The program was quantified as the difference in mass emissions between a control case under the final MY2022-2025 standards and a reference case under the MY2021 standards in place in MY2021 and indefinitely thereafter. As such, negative values represent emissions decreases due to the policy and positive values represent emissions increases due to the policy.

C.2.2.4 Fleet Activity

Vehicle sales projections from the MY2015 baseline through MY2030 are discussed in Section A of this Appendix, as well as the TSD Chapter 1. Vehicle survival schedules and VMT by vehicle age were updated since the TAR to be consistent with an updated version of the EPA

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[196] As with the MY2017-2025 Light Duty rule and the Heavy Duty GHG Phase 2 rule, the GWPs used in this Proposed Determination are consistent with 100-year time frame values in the 2007 Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4).

MOVES model (post-MOVES2014a public release). These updates are described in more detail in the TSD Chapter 3.

C.2.2.5 Upstream Emission Factors

C.2.2.5.1 Gasoline Production and Transport Emission Rates

The gasoline production and transport sector is composed of four distinct components: Domestic crude oil production and transport, petroleum production and refining emissions, production of energy for refinery use, and gasoline transport, storage and distribution. For this Proposed Determination, the upstream emission factors associated with on-road combustion emissions remain the same as those used for the Draft TAR analysis.

Table C.36 Gasoline Production Emission Rates

Pollutant	Emission Rate (g/MMbtu of E10 gasoline)
CO	5.472145
NOx	13.87269
PM2.5	2.07292
PM10	6.048208
SOx	8.089376
VOC	47.4966
1,3-Butadiene	0.001442
Acetaldehyde	0.009798
Acrolein	0.000816
Benzene	0.322958
Formaldehyde	0.081647
Naphthalene	0.015177
CH4	95.454
N2O	0.369224
CO2	19145.2

C.2.2.5.2 Electricity Generation Emission Rates

For the 2012 FRM, EPA conducted an Integrated Planning Model (IPM) analysis of the electricity sector in order to gauge the impacts upon the power grid of the additional electric charging projected to be needed to meet the MY2017-2025 standards.[197] Since the 2012 final rule, EPA has adopted a GHG program for electricity generation, known as the Clean Power Plan.[198] These rules are expected to significantly decrease GHG emissions associated with future electricity generation. The 2012 FRM's IPM modeling projected that the average power plant electricity GHG emissions factor in 2030 for vehicle electricity use would be 0.445 grams/watt-hour.[199] The overall vehicle electricity GHG emissions factor was projected to be

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[197] EPA. Regulatory Impact Analysis: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, Chapter 4.6.3., EPA-420-R-12-016, August 2012, Chapter 4.6.3.

[198] EPA issued a final GHG emissions program, known as the Clean Power Plan, addressing fossil fuel-fired electric generating units. 80 FR 64661, October 23, 2015.

[199] 77 FR 62821, October 15, 2012.

0.534 grams/watt-hour when using a multiplicative value of 1.20 to account for feedstock-related GHG emissions upstream of the power plant. For this Proposed Determination, EPA is continuing to apply the FRM IPM results as a representation of the electrical grid in the time period surrounding 2030. The emission factors are shown in Table C.37 below.

The 2030 IPM results were post-processed to develop gram per kWh emission factors for use in the OMEGA model and inventory cost-benefit analysis. For those emissions that IPM does not generate, we relied upon the National Emissions Inventory (NEI) for air toxic emissions and eGrid for N_2O and CH_4. There are also additional emissions attributable to feedstock generation, or the gathering and transport of fuel to the power plant. Emission factors from the version of GREET 1.8c (as modified for the EPA upstream analysis discussed above) were used to generate feedstock emission factors. Retail electricity price projections from the 2030 FRM IPM run were used in our analysis of electricity fuel costs to drivers. More information regarding the integration of GREET emission factors and IPM modeling can be found in the FRM RIA, Chapter 4.6.

Table C.37 Emission Factors Used in Analysis of Electricity Generation

Pollutant	**IPM (g/kWh)**	**Feedstock (g/kWh)**	**Total (g/kWh)**
VOC	8.28E-03	4.69E-02	5.52E-02
CO	2.89E-01	5.01E-02	3.39E-01
NOx	1.13E-01	1.27E-01	2.41E-01
PM2.5	5.81E-03	6.51E-02	7.09E-02
SO2	1.90E-01	4.69E-02	2.37E-01
CO2	4.45E+02	3.55E+01	4.80E+02
N2O	6.76E-03	6.81E-04	7.44E-03
CH4	8.60E-03	3.31E+00	3.32E+00
1,3-butadiene	0.0E+00	0.00E+00	0.00E+00
Acetaldehyde	5.5E-05	9.47E-06	6.40E-05
Acrolein	2.8E-05	3.15E-05	5.95E-05
Benzene	1.3E-04	1.41E-03	1.54E-03
Formaldehyde	3.0E-05	7.51E-06	3.79E-05

C.2.2.6 Reference Case CO_2 g/mi & kWh/mi

As explained above, EPA assumes that the reference case fleet continues to meet the MY2021 standards indefinitely. Importantly, we model the fleet as meeting the reference (or control) case targets rather than the achieved CO_2 values as reported by the OMEGA core model. We do this because we consider OMEGA core model results (the central case as well as the various sensitivity analyses) to be possible, feasible paths toward compliance and not necessarily the actual path that any given manufacturer will choose. For that reason, we choose to model the target values. Compliance flexibilities such as A/C credits and fleet averaging are included in the modeling. The A/C direct credit from reduction in air conditioning refrigerant emissions (i.e., credit for leakage improvement or switching to lower GWP refrigerants) is added here to the 2-cycle target value to arrive at the 2-cycle tailpipe CO_2 value because, while that credit results in real GHG reductions, it does not result in real tailpipe CO_2 reductions (or real on-road fuel economy improvements). The benefits of off-cycle and A/C indirect credits are implicitly included in the values below because they result in real CO_2 reductions. The fleet CO_2 g/mi and kWh/mi emission rates used for inventory modeling are as shown in the tables below. In the CO_2 g/mi tables, the on-road tailpipe CO_2 values are the values used in generating CO_2 inventory impacts in the reference case. The "gap" noted in the tables below is the gap between compliance and real world fuel economy/tailpipe CO_2, discussed further in the TSD Chapter 3. Entries change slightly year-over-year due to fleet changes.

Table C.38 Reference Case Car On-Road CO_2 g/mi Used in OMEGA ICBT Runs under the AEO Reference Fuel Price Case

MY	2-cycle CO_2 Target, g/mi	A/C Direct Credit, g/mi	Adjusted 2-cycle Tailpipe CO_2, g/mi	Adjusted MPG	Gap	On-road MPG	On-road CO_2 Tailpipe, g/mi
2021	177.1	13.8	190.9	46.6	0.77	35.9	236.2
2022	177.1	13.8	190.9	46.6	0.77	35.9	236.2
2023	177.0	13.8	190.8	46.6	0.77	35.9	236.1
2024	177.0	13.8	190.8	46.6	0.77	36.0	236.1
2025	177.0	13.8	190.8	46.6	0.77	35.9	236.2
2026	177.0	13.8	190.8	46.6	0.77	36.0	236.1
2027	176.9	13.8	190.7	46.6	0.77	36.0	236.0
2028	176.9	13.8	190.7	46.6	0.77	36.0	235.9
2029	176.8	13.8	190.6	46.6	0.77	36.0	235.8
2030	176.8	13.8	190.6	46.6	0.77	36.0	235.8

Note: The on-road values reflect adjustments for both the historical 2-cycle-to-5-cycle gap as well as the projected ethanol content in retail gasoline, and corresponding energy content. The on-road CO_2 is calculated by dividing 8488, the estimated CO_2 grams/gallon from combustion of a gallon of retail gasoline, by the on-road MPG.

Table C.39 Reference Case Truck On-Road CO_2 g/mi Used in OMEGA ICBT Run under the AEO Reference Fuel Price Case

MY	2-cycle CO_2 Target, g/mi	A/C Direct Credit, g/mi	Adjusted 2-cycle Tailpipe CO_2, g/mi	Adjusted MPG	Gap	On-road MPG	On-road CO_2 Tailpipe, g/mi
2021	246.7	17.2	263.9	33.7	0.77	26.0	326.5
2022	246.6	17.2	263.8	33.7	0.77	26.0	326.5
2023	246.4	17.2	263.6	33.7	0.77	26.0	326.2
2024	246.4	17.2	263.6	33.7	0.77	26.0	326.1
2025	246.5	17.2	263.7	33.7	0.77	26.0	326.4
2026	246.4	17.2	263.6	33.7	0.77	26.0	326.2
2027	246.7	17.2	263.9	33.7	0.77	26.0	326.6
2028	246.6	17.2	263.8	33.7	0.77	26.0	326.4
2029	246.2	17.2	263.4	33.7	0.77	26.0	325.9
2030	246.1	17.2	263.3	33.7	0.77	26.0	325.9

Note: The on-road values reflect adjustments for both the historical 2-cycle-to-5-cycle gap as well as the projected ethanol content in retail gasoline, and corresponding energy content. The on-road CO_2 is calculated by dividing 8488, the estimated CO_2 grams/gallon from combustion of a gallon of retail gasoline, by the on-road MPG.

Table C.40 Reference Case Car On-Road CO_2 g/mi Used in OMEGA ICBT Runs under the AEO High Fuel Price Case

MY	2-cycle CO_2 Target, g/mi	A/C Direct Credit, g/mi	Adjusted 2-cycle Tailpipe CO_2, g/mi	Adjusted MPG	Gap	On-road MPG	On-road CO_2 Tailpipe, g/mi
2021	176.9	13.8	190.7	46.6	0.77	36.0	235.9
2022	176.9	13.8	190.7	46.6	0.77	36.0	236.0
2023	176.8	13.8	190.6	46.6	0.77	36.0	235.9

2024	176.8	13.8	190.6	46.6	0.77	36.0	235.8
2025	176.8	13.8	190.6	46.6	0.77	36.0	235.9
2026	176.8	13.8	190.6	46.6	0.77	36.0	235.8
2027	176.7	13.8	190.5	46.6	0.77	36.0	235.8
2028	176.7	13.8	190.5	46.7	0.77	36.0	235.7
2029	176.6	13.8	190.4	46.7	0.77	36.0	235.6
2030	176.6	13.8	190.4	46.7	0.77	36.0	235.6

Note: The on-road values reflect adjustments for both the historical 2-cycle-to-5-cycle gap as well as the projected ethanol content in retail gasoline, and corresponding energy content. The on-road CO_2 is calculated by dividing 8488, the estimated CO_2 grams/gallon from combustion of a gallon of retail gasoline, by the on-road MPG.

Table C.41 Reference Case Truck On-Road CO_2 g/mi Used in OMEGA ICBT Runs under the AEO High Fuel Price Case

MY	2-cycle CO_2 Target, g/mi	A/C Direct Credit, g/mi	Adjusted 2-cycle Tailpipe CO_2, g/mi	Adjusted MPG	Gap	On-road MPG	On-road CO_2 Tailpipe, g/mi
2021	245.2	17.2	262.4	33.9	0.77	26.1	324.8
2022	245.4	17.2	262.6	33.8	0.77	26.1	324.9
2023	245.2	17.2	262.4	33.9	0.77	26.1	324.7
2024	245.2	17.2	262.4	33.9	0.77	26.1	324.7
2025	245.3	17.2	262.5	33.8	0.77	26.1	324.9
2026	245.2	17.2	262.4	33.9	0.77	26.1	324.7
2027	245.5	17.2	262.7	33.8	0.77	26.1	325.0
2028	245.3	17.2	262.5	33.9	0.77	26.1	324.8
2029	244.8	17.2	262.0	33.9	0.77	26.2	324.2
2030	244.7	17.2	261.9	33.9	0.77	26.2	324.1

Note: The on-road values reflect adjustments for both the historical 2-cycle-to-5-cycle gap as well as the projected ethanol content in retail gasoline, and corresponding energy content. The on-road CO_2 is calculated by dividing 8488, the estimated CO_2 grams/gallon from combustion of a gallon of retail gasoline, by the on-road MPG.

Table C.42 Reference Case Car On-Road CO_2 g/mi Used in OMEGA ICBT Runs under the AEO Low Fuel Price Case

MY	2-cycle CO_2 Target, g/mi	A/C Direct Credit, g/mi	Adjusted 2-cycle Tailpipe CO_2, g/mi	Adjusted MPG	Gap	On-road MPG	On-road CO_2 Tailpipe, g/mi
2021	177.1	13.8	190.9	46.6	0.77	35.9	236.2
2022	177.1	13.8	190.9	46.5	0.77	35.9	236.3
2023	177.1	13.8	190.9	46.6	0.77	35.9	236.2
2024	177.0	13.8	190.8	46.6	0.77	35.9	236.1
2025	177.1	13.8	190.9	46.6	0.77	35.9	236.2
2026	177.0	13.8	190.8	46.6	0.77	35.9	236.1
2027	177.0	13.8	190.8	46.6	0.77	36.0	236.1
2028	176.9	13.8	190.7	46.6	0.77	36.0	236.0
2029	176.8	13.8	190.6	46.6	0.77	36.0	235.9
2030	176.8	13.8	190.6	46.6	0.77	36.0	235.9

Note: The on-road values reflect adjustments for both the historical 2-cycle-to-5-cycle gap as well as the projected ethanol content in retail gasoline, and corresponding energy content. The on-road CO_2 is calculated by dividing 8488, the estimated CO_2 grams/gallon from combustion of a gallon of retail gasoline, by the on-road MPG.

Table C.43 Reference Case Truck On-Road CO_2 g/mi Used in OMEGA ICBT Runs under the AEO Low Fuel Price Case

MY	2-cycle CO_2 Target, g/mi	A/C Direct Credit, g/mi	Adjusted 2-cycle Tailpipe CO_2, g/mi	Adjusted MPG	Gap	On-road MPG	On-road CO_2 Tailpipe, g/mi
2021	247.0	17.2	264.2	33.6	0.77	26.0	326.9
2022	247.0	17.2	264.2	33.6	0.77	26.0	326.9
2023	246.7	17.2	263.9	33.7	0.77	26.0	326.6
2024	246.7	17.2	263.9	33.7	0.77	26.0	326.6
2025	246.9	17.2	264.1	33.6	0.77	26.0	326.9
2026	246.9	17.2	264.1	33.7	0.77	26.0	326.8
2027	247.1	17.2	264.3	33.6	0.77	26.0	327.1
2028	247.0	17.2	264.2	33.6	0.77	26.0	327.0
2029	246.7	17.2	263.9	33.7	0.77	26.0	326.5
2030	246.6	17.2	263.8	33.7	0.77	26.0	326.5

Note: The on-road values reflect adjustments for both the historical 2-cycle-to-5-cycle gap as well as the projected ethanol content in retail gasoline, and corresponding energy content. The on-road CO_2 is calculated by dividing 8488, the estimated CO_2 grams/gallon from combustion of a gallon of retail gasoline, by the on-road MPG.

The reference case electricity consumption rates, including both electricity consumption by ZEV program vehicles and consumption by the very small fraction of BEV and PHEV vehicles projected by OMEGA toward compliance with the reference case standards are shown in the table below. EPA accounts for all electricity consumed by the vehicle. For calculations of GHG emissions from electricity generation, the total energy consumed from the battery is divided by 0.9 to account for charging losses. This factor is included in the values presented in the table below. Within the OMEGA ICBT, a transmission loss divisor of 0.93 is applied to account for losses during transmission, the result being electricity demand at the electric plant. Both values were discussed in the 2012 FRM and the Draft TAR (Chapter 12.2.2.6); the approach in this analysis is unchanged.[200] The estimate of charging losses is based upon engineering judgment and manufacturer CBI. The estimate of transmission losses is consistent, although not identical to the 8 percent estimate used in GREET, as well as the 6 percent estimate in eGrid 2010.[201,202] The upstream emission factor discussed above in Section C.2.2.5 is applied to total electricity production, rather than simply power consumed at the wheel.[203] It is assumed that electrically powered vehicles drive the same drive schedule as the rest of the fleet.[204] Note that the values shown in the table already include a 0.8 on-road "gap" since the gap was considered in determining battery sizing and consumption.[205] The values shown in the kWh/mi table are the values used to generate upstream emission inventory impacts in the applicable reference case.

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[200] See EPA's final RIA in support of the 2012 FRM (EPA-420-R-12-016) at page 4-131.

[201] Argonne National Laboratory's The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model, Version 1.8c.0, available at http://www.transportation.anl.gov/modeling_simulation/GREET/). EPA Docket EPA-HQ-OAR-2009-0472. (Docket No. EPA-HQ-OAR-2010-0799-1105).

[202] EPA eGrid 2010, http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html (Docket No. (EPA-HQ-OAR-2010-0799-0832).

[203] By contrast, consumer electricity costs would not include the power lost during transmission. While consumers indirectly pay for this lost power through higher rates, this power does not appear on their electric meter.

[204] The validity of this assumption will depend on the use of electric vehicles by their purchasers.

[205] See Chapter 2 of the TSD for details on EPA's battery sizing methodology.

Table C.44 Reference Case Car & Truck On-Road kWh/mi Consumption used in the Indicated OMEGA ICBT Runs

	AEO Ref		AEO High		AEO Low	
MY	Car	Truck	Car	Truck	Car	Truck
2021	0.0097	0.0041	0.0098	0.0042	0.0097	0.0041
2022	0.0105	0.0046	0.0106	0.0048	0.0106	0.0045
2023	0.0113	0.0051	0.0115	0.0055	0.0114	0.0049
2024	0.0121	0.0056	0.0124	0.0062	0.0123	0.0053
2025	0.0129	0.0060	0.0133	0.0069	0.0131	0.0057
2026	0.0129	0.0060	0.0133	0.0069	0.0131	0.0057
2027	0.0129	0.0060	0.0133	0.0069	0.0131	0.0057
2028	0.0129	0.0060	0.0133	0.0069	0.0131	0.0057
2029	0.0129	0.0060	0.0133	0.0069	0.0131	0.0057
2030	0.0129	0.0060	0.0133	0.0069	0.0131	0.0057

Note that the values shown in Table C.44 reflect updates from those shown in the Draft TAR. For example, the MY2021 values in the AEO reference fuel price case are 0.0097 and 0.0041 kWh/mi here and were 0.0126 and 0.00137 in the Draft TAR (see Draft TAR Table 12.65). In other words, the car value is lower and the truck value is higher compared to the Draft TAR. This is an artifact of the updated vehicle type determination approach taken in this analysis (see Chapter 2.3.1.4 of the TSD). With this updated approach, we have made available within the model for electrification to the PHEV and full BEV level many more trucks than in the past where we had limited such technology to only those vehicle types not considered to be “towing” vehicle types. In other words, the model now makes available these high levels of electrification for vehicles such as minivans, SUVs and cross-over utility vehicles which, in the past, typically were not mapped into vehicle types allowed for electrification. In this analysis, we limit these levels of electrification only on pickup truck vehicle types. As a result, many ZEV program vehicles have been created within the model in predominantly truck—not pickup, but simply truck (e.g., minivan, SUV)—vehicle types. Given that the total number of BEVs and PHEVs is similar between the Draft TAR and this analysis, and that more BEVs and PHEVs are now projected to be trucks and fewer are cars, we get the differences in the results shown in Table C.44 versus those shown in Draft TAR Table 12.65. Thus we are now estimating slightly higher electricity consumption of the fleet, largely attributed to the higher VMT traveled by trucks than cars. This leads to slightly higher electricity consumption calculated by the OMEGA ICBT in the reference case of this analysis relative to the Draft TAR.

For this analysis, EPA has considered the ZEV program in California and section 177 states in the reference case for this analysis. That analysis fleet is described in detail in the TSD Chapter 1. Our central analysis also includes in the compliance determinations for all manufacturers by MY2025 the upstream emissions attributed to BEVs and the electricity portion of PHEV operation (note that EPA always includes upstream emissions in our GHG emission inventory estimates--the inclusion of upstream emissions for compliance versus inventory are separate issues). Given the ZEV program sales, it appears that some manufacturers are likely to exceed the sales levels beyond which net upstream emissions would have to be considered in their compliance determination.[206] Although other manufacturers appear unlikely to exceed that limit,

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[206] 40 CFR 86.1866-12(a).

to be conservative, as noted previously, we include upstream emissions for all BEV/PHEV and for all manufacturers by MY2025 in both the reference and control cases.

C.2.2.7 Control Case CO_2 g/mi & kWh/mi

As just noted above, we model the fleet as meeting the compliance targets rather than the achieved CO_2 values as reported by the OMEGA core model. The off-cycle credits are implicitly included in the values below, as are all A/C credits, because their use is assumed in meeting the “2-cycle CO_2 Target” values shown. The A/C direct credit is added here to the 2-cycle target value to arrive at the adjusted 2-cycle tailpipe CO_2 value because, while that credit results in real GHG reductions, it does not result in real tailpipe CO_2 reductions (or real on-road fuel economy improvements). The fleet CO_2 g/mi and kWh/mi emission rates used for inventory modeling are as shown in the tables below. In the CO_2 g/mi tables, the on-road tailpipe CO_2 value is the value used in generating CO_2 inventory impacts in the control case. The “Gap” noted in the tables below is the gap between compliance and real world fuel economy/tailpipe CO_2, discussed in Chapter 3 of the TSD. The gap, as shown, is applied to adjusted MPG values.

Table C.45 Control Case Car On-Road CO_2 g/mi Used in OMEGA ICBT Runs under the AEO Reference Fuel Price Case

MY	2-cycle CO_2 Target, g/mi	A/C Direct Credit, g/mi	Adjusted 2-cycle Tailpipe CO_2, g/mi	Adjusted MPG	Gap	On-road MPG	On-road CO_2 Tailpipe, g/mi
2021	171.1	17.2	184.9	48.1	0.77	37.1	229
2022	164.8	17.2	178.6	49.8	0.77	38.4	221
2023	158.7	17.2	172.5	51.5	0.77	39.8	213
2024	152.8	17.2	166.6	53.3	0.77	41.2	206
2025	147.3	17.2	161.1	55.2	0.77	42.6	199
2026	147.3	17.2	161.1	55.2	0.77	42.6	199
2027	147.2	17.2	161.0	55.2	0.77	42.6	199
2028	147.2	17.2	161.0	55.2	0.77	42.6	199
2029	147.1	17.2	160.9	55.2	0.77	42.6	199
2030	147.1	17.2	160.9	55.2	0.77	42.6	199

Note: The on-road values reflect adjustments for both the historical 2-cycle-to-5-cycle gap as well as the projected ethanol content in retail gasoline, and corresponding energy content. The on-road CO_2 is calculated by dividing 8488, the estimated CO_2 grams/gallon from combustion of a gallon of retail gasoline, by the on-road MPG; off-cycle credits are not shown in the table since they are assumed to have been used in meeting the 2-cycle CO_2 Targets.

Table C.46 Control Case Truck On-Road CO_2 g/mi Used in OMEGA ICBT Runs under the AEO Reference Fuel Price Case

MY	2-cycle CO_2 Target, g/mi	A/C Direct Credit, g/mi	Adjusted 2-cycle Tailpipe CO_2, g/mi	Adjusted MPG	Gap	On-road MPG	On-road CO_2 Tailpipe, g/mi
2021	237.7	17.2	254.9	34.9	0.77	26.9	315
2022	228.1	17.2	245.3	36.2	0.77	28.0	304
2023	218.8	17.2	236.0	37.7	0.77	29.1	292
2024	210.0	17.2	227.2	39.1	0.77	30.2	281
2025	201.8	17.2	219.0	40.6	0.77	31.3	271
2026	201.8	17.2	219.0	40.6	0.77	31.3	271
2027	202.0	17.2	219.2	40.6	0.77	31.3	271
2028	201.9	17.2	219.1	40.6	0.77	31.3	271

2029	201.5	17.2	218.7	40.6	0.77	31.4	271
2030	201.5	17.2	218.7	40.6	0.77	31.4	271

Note: The on-road values reflect adjustments for both the historical 2-cycle-to-5-cycle gap as well as the projected ethanol content in retail gasoline, and corresponding energy content. The on-road CO_2 is calculated by dividing 8488, the estimated CO_2 grams/gallon from combustion of a gallon of retail gasoline, by the on-road MPG; off-cycle credits are not shown in the table since they are assumed to have been used in meeting the 2-cycle CO_2 Targets and because they provide real-world CO_2 reductions so do not need to be backed out as do the A/C leakage, or A/C direct credit, values.

Table C.47 Control Case Car On-Road CO_2 g/mi Used in OMEGA ICBT Runs under the AEO High Fuel Price Case

MY	2-cycle CO_2 Target, g/mi	A/C Direct Credit, g/mi	Adjusted 2-cycle Tailpipe CO_2, g/mi	Adjusted MPG	Gap	On-road MPG	On-road CO_2 Tailpipe, g/mi
2021	170.9	13.8	184.7	48.1	0.77	37.1	229
2022	164.6	13.8	178.4	49.8	0.77	38.4	221
2023	158.5	13.8	172.3	51.6	0.77	39.8	213
2024	152.7	13.8	166.5	53.4	0.77	41.2	206
2025	147.2	13.8	161.0	55.2	0.77	42.6	199
2026	147.1	13.8	160.9	55.2	0.77	42.6	199
2027	147.1	13.8	160.9	55.2	0.77	42.6	199
2028	147.0	13.8	160.8	55.3	0.77	42.7	199
2029	146.9	13.8	160.7	55.3	0.77	42.7	199
2030	146.9	13.8	160.7	55.3	0.77	42.7	199

Note: The on-road values reflect adjustments for both the historical 2-cycle-to-5-cycle gap as well as the projected ethanol content in retail gasoline, and corresponding energy content. The on-road CO_2 is calculated by dividing 8488, the estimated CO_2 grams/gallon from combustion of a gallon of retail gasoline, by the on-road MPG; off-cycle credits are not shown in the table since they are assumed to have been used in meeting the 2-cycle CO_2 Targets.

Table C.48 Control Case Truck On-Road CO_2 g/mi Used in OMEGA ICBT Runs under the AEO High Fuel Price Case

MY	2-cycle CO_2 Target, g/mi	A/C Direct Credit, g/mi	Adjusted 2-cycle Tailpipe CO_2, g/mi	Adjusted MPG	Gap	On-road MPG	On-road CO_2 Tailpipe, g/mi
2021	236.3	17.2	253.5	35.1	0.77	27.1	314
2022	226.9	17.2	244.1	36.4	0.77	28.1	302
2023	217.7	17.2	234.9	37.8	0.77	29.2	291
2024	209.0	17.2	226.2	39.3	0.77	30.3	280
2025	200.8	17.2	218.0	40.8	0.77	31.5	270
2026	200.7	17.2	217.9	40.8	0.77	31.5	270
2027	200.9	17.2	218.1	40.7	0.77	31.4	270
2028	200.8	17.2	218.0	40.8	0.77	31.5	270
2029	200.4	17.2	217.6	40.8	0.77	31.5	269
2030	200.3	17.2	217.5	40.9	0.77	31.5	269

Note: The on-road values reflect adjustments for both the historical 2-cycle-to-5-cycle gap as well as the projected ethanol content in retail gasoline, and corresponding energy content. The on-road CO_2 is calculated by dividing 8488, the estimated CO_2 grams/gallon from combustion of a gallon of retail gasoline, by the on-road MPG; off-cycle credits are not shown in the table since they are assumed to have been used in meeting the 2-cycle CO_2 Targets and because they provide real-world CO_2 reductions so do not need to be backed out as do the A/C leakage, or A/C direct credit, values.

Table C.49 Control Case Car On-Road CO_2 g/mi Used in OMEGA ICBT Runs under the AEO Low Fuel Price Case

MY	2-cycle CO_2 Target, g/mi	A/C Direct Credit, g/mi	Adjusted 2-cycle Tailpipe CO_2, g/mi	Adjusted MPG	Gap	On-road MPG	On-road CO_2 Tailpipe, g/mi
2021	171.2	13.8	185.0	48.0	0.77	37.1	229
2022	164.9	13.8	178.7	49.7	0.77	38.4	221
2023	158.7	13.8	172.5	51.5	0.77	39.8	214
2024	152.9	13.8	166.7	53.3	0.77	41.1	206
2025	147.4	13.8	161.2	55.1	0.77	42.6	199
2026	147.3	13.8	161.1	55.2	0.77	42.6	199
2027	147.3	13.8	161.1	55.2	0.77	42.6	199
2028	147.2	13.8	161.0	55.2	0.77	42.6	199
2029	147.2	13.8	161.0	55.2	0.77	42.6	199
2030	147.2	13.8	161.0	55.2	0.77	42.6	199

Note: The on-road values reflect adjustments for both the historical 2-cycle-to-5-cycle gap as well as the projected ethanol content in retail gasoline, and corresponding energy content. The on-road CO_2 is calculated by dividing 8488, the estimated CO_2 grams/gallon from combustion of a gallon of retail gasoline, by the on-road MPG; off-cycle credits are not shown in the table since they are assumed to have been used in meeting the 2-cycle CO_2 Targets.

Table C.50 Control Case Truck On-Road CO_2 g/mi Used in OMEGA ICBT Runs under the AEO Low Fuel Price Case

MY	2-cycle CO_2 Target, g/mi	A/C Direct Credit, g/mi	Adjusted 2-cycle Tailpipe CO_2, g/mi	Adjusted MPG	Gap	On-road MPG	On-road CO_2 Tailpipe, g/mi
2021	238.0	17.2	255.2	34.8	0.77	26.9	316
2022	228.4	17.2	245.6	36.2	0.77	27.9	304
2023	219.1	17.2	236.3	37.6	0.77	29.0	292
2024	210.3	17.2	227.5	39.1	0.77	30.1	282
2025	202.2	17.2	219.4	40.5	0.77	31.3	271
2026	202.1	17.2	219.3	40.5	0.77	31.3	271
2027	202.3	17.2	219.5	40.5	0.77	31.2	272
2028	202.3	17.2	219.5	40.5	0.77	31.3	272
2029	201.9	17.2	219.1	40.6	0.77	31.3	271
2030	201.9	17.2	219.1	40.6	0.77	31.3	271

Note: The on-road values reflect adjustments for both the historical 2-cycle-to-5-cycle gap as well as the projected ethanol content in retail gasoline, and corresponding energy content. The on-road CO_2 is calculated by dividing 8488, the estimated CO_2 grams/gallon from combustion of a gallon of retail gasoline, by the on-road MPG; off-cycle credits are not shown in the table since they are assumed to have been used in meeting the 2-cycle CO_2 Targets and because they provide real-world CO_2 reductions so do not need to be backed out as do the A/C leakage, or A/C direct credit, values.

The table below shows the control case electricity consumption rates, including both electricity consumption by ZEV program vehicles and projected BEV and PHEV vehicles generated by OMEGA toward compliance with the control case standards. These consumption levels include charging losses (a 90 percent divisor) and a 93 percent transmission loss divisor (not included in the values below) applied by the OMEGA ICBT. Note that the values shown in the table already include a 0.8 on-road “gap” since the gap was considered in determining battery sizing and consumption.

The control case kWh/mi inputs to the OMEGA ICBT are shown in the table below. Because fuel prices slightly impact the projected penetration of BEV and PHEV vehicles, unique kWh/mi inputs are presented for each fuel price scenario. The values shown in the kWh/mi table are the values used to generate upstream emission inventory impacts in the applicable control case.

Table C.51 Control Case Car & Truck On-Road kWh/mi Consumption used in the Indicated OMEGA ICBT Runs

	AEO Ref		AEO High		AEO Low	
MY	Car	Truck	Car	Truck	Car	Truck
2021	0.00993	0.00495	0.01013	0.00493	0.00987	0.00477
2022	0.01102	0.00574	0.01161	0.00620	0.01092	0.00547
2023	0.01212	0.00652	0.01309	0.00747	0.01197	0.00616
2024	0.01321	0.00731	0.01457	0.00873	0.01302	0.00685
2025	0.01430	0.00809	0.01605	0.01000	0.01407	0.00754
2026	0.01430	0.00809	0.01605	0.01000	0.01407	0.00754
2027	0.01430	0.00809	0.01605	0.01000	0.01407	0.00754
2028	0.01430	0.00809	0.01605	0.01000	0.01407	0.00754
2029	0.01430	0.00809	0.01605	0.01000	0.01407	0.00754
2030	0.01430	0.00809	0.01605	0.01000	0.01407	0.00754

As discussed above in the context of Table C.44, the values shown in Table C.51 are different than shown in the Draft TAR (see Draft TAR Table 12.68). The reasons discussed in the context of Table IV-42 for the reference case are the same as the reasons here in the control case. With the updated vehicle type approach used in this analysis, we have made available for electrification to the PHEV and full BEV level many more trucks than in the past. In other words, we make available these high levels of electrification for vehicles such as minivans, SUVs and cross-over utility vehicles which, in the past, typically were not mapped into vehicle types allowed for electrification. In this analysis, we limit these levels of electrification only on pickup truck vehicle types. As a result, many ZEV program vehicles have been created within the model in predominantly truck—not pickup, but simply truck (e.g., minivan, SUV)—vehicle types. Given that the total number of BEVs and PHEVs is similar between the Draft TAR and this analysis, and that more BEVs and PHEVs are now trucks and fewer are cars, we get the differences in the results shown in Table C.51 versus those shown in Draft TAR Table 12.68. This impacts the estimated electricity consumption of the fleet, most easily understood by the higher VMT traveled by trucks than cars. This leads to slightly higher increases in electricity consumption calculated by the OMEGA ICBT in this analysis relative to the Draft TAR since a fair number of the “OMEGA-created” BEVs and PHEVs are traveling truck VMT.

It is important to emphasize that these CO_2 and kWh emission rate projections are based on EPA's current projections of a wide range of inputs, including the mix of cars and trucks, as well as the mix of vehicle footprint values in varying years. It is of course possible that the actual CO_2 emissions values, as well as the actual use of incentives and credits, will be either higher or lower than these projections.

C.2.2.8 Criteria Pollutant and Select Toxic Pollutant Emission Rates

For the analysis of criteria emissions in this Proposed Determination, EPA estimates the increases in emissions of each criteria air pollutant from additional vehicle use by multiplying the increase in total miles driven by cars and light trucks of each model year and age by their estimated emission rates per vehicle-mile of each pollutant. These emission rates differ between cars and light trucks, between gasoline and diesel vehicles, and by age. With the exception of SO_2, EPA calculated the increase in emissions of these criteria pollutants from added car and light truck use by multiplying the estimated increases in vehicle use during each year over their expected lifetimes by per-mile emission rates appropriate to each vehicle type, fuel used, model year, and age as of that future year.

EPA estimated the relevant emission rates using the most recent version of the Motor Vehicle Emission Simulator (post-MOVES2014a, with updates that include the AEO2016 vehicle population, mileage, and scrappage rates, discussed in more detail in TSD Chapter 3). The MOVES model assumes that the per-mile rates at which these pollutants are emitted are determined by EPA regulations and the effectiveness of after-treatment of engine exhaust emissions, and are thus unaffected by changes in car and light truck GHG standards. As a consequence, the downstream impacts of required increases in fuel economy on emissions of these pollutants from car and light truck use are determined entirely by the increases in driving that result from the fuel economy rebound effect.

Emission factors in the MOVES database are expressed in the form of grams per vehicle-hour of operation. To convert these emission factors to grams per mile, MOVES was run for the year 2050, and was programmed to report aggregate emissions from vehicle start, running, brake and tire wear and crankcase exhaust operations. EPA ran MOVES for every calendar year from 2015 to the year 2050 in order to generate emission factors for each age of each model year. Separate estimates were developed for each vehicle type, as well as for a winter and a summer month in order to reflect the effects of temporal variation in temperature and other relevant variables on emissions. All calendar years were run using national averages calculated from the aggregation of the county level default estimates (national aggregation).

The MOVES emissions estimates were then summed to the model year level and divided by total distance traveled by vehicles of that model year in order to produce per-mile emission factors for each pollutant. The resulting emission rates represent average values across the nation, and incorporate variation in temperature and other operating conditions affecting emissions over an entire calendar year. These national average rates also reflect county-specific differences in fuel composition, as well as in the presence and type of vehicle inspection and maintenance programs. Average emission rates were assumed not to increase after 30 years of age.

Emission rates for the criteria pollutant SO_2 were calculated by using EPA-estimated average fuel sulfur content, together with the simplifying assumption that the entire sulfur content of fuel is emitted in the form of SO_2. These calculations assumed that national average gasoline and diesel sulfur levels would remain at current levels, because there are no current regulations that will change those levels, and we have no expectation that the market will cause such changes on its own.

C.2.3 Outputs of the Emissions and Fuel Consumption Analysis

In this section, EPA presents the emissions inventory impacts, fuel, and electricity consumption results. Section C.2.3.1 shows impacts in a given calendar year resulting from the control case analysis. These results are not cumulative, and are presented to show the continued impacts of the analysis beyond the control case years. Section C.2.3.2 shows impacts for a given model year cohort of vehicles, as well as cumulative sums of impacts due to vehicle model years included in the control case (over the whole vehicle lifetime, as discussed in the TSD Chapter 3). Tables presenting emissions inventory impacts are generally shown as reductions, such that emission decreases would be shown as a positive number. Tables presenting fuel and energy consumption are shown as absolute impact, such that fuel or energy consumption decreases would be show as a negative number. See specific table notes for more clarification. Discussion of the inputs to this analysis can be found in Section C.2.2, above.

C.2.3.1 Calendar Year Results

Table C.52 Annual Emissions Reductions of the MY2022-2025 Standards on GHGs in Select Calendar Years (MMT CO2e)

Calendar Year ->	2025	2030	2040	2050
Net GHG	40.6	102	185	234
Net CO2	39.7	99.5	181	228
Net other GHG	0.89	2.23	4.07	5.12
Downstream GHG	32.4	81.3	148	186
CO2 (excluding A/C)	32.6	81.6	149	187
A/C – indirect CO2	-0.13	-0.32	-0.59	-0.75
A/C – direct HFCs	0.00	0.00	0.00	0.00
CH4 (rebound effect)	0.00	0.00	-0.01	-0.01
N2O (rebound effect)	-0.02	-0.05	-0.09	-0.12
Fuel Production and Distribution GHG	9.08	22.78	41.46	52.24
Fuel Production and Distribution CO2	8.04	20.15	36.68	46.22
Fuel Production and Distribution CH4	1.00	2.51	4.57	5.76
Fuel Production and Distribution N2O	0.05	0.12	0.21	0.27
Electricity Upstream GHG	-0.95	-2.28	-4.10	-5.14
Electricity Upstream CO2	-0.81	-1.94	-3.48	-4.37
Electricity Upstream CH4	-0.14	-0.33	-0.60	-0.76
Electricity Upstream N2O	0.00	-0.01	-0.02	-0.02

Note: These values are expressed as emission reductions, such that positive values imply an emissions decrease, and negative values imply an emissions increase.

Table C.53 Annual Emission Reductions of the MY2022-2025 Standards on GHGs (MMT CO2e)

Calendar Year	CO2	HFC	CH4	N2O	**Total**
2021	2.6	0.0	0.1	0.0	**2.6**
2022	7.9	0.0	0.2	0.0	**8.1**
2023	16.0	0.0	0.3	0.0	**16.4**
2024	26.6	0.0	0.6	0.0	**27.2**
2025	39.7	0.0	0.9	0.0	**40.6**
2026	52.4	0.0	1.1	0.0	**53.6**
2027	64.9	0.0	1.4	0.0	**66.3**
2028	77.0	0.0	1.7	0.0	**78.7**
2029	88.5	0.0	1.9	0.1	**90.5**
2030	99.5	0.0	2.2	0.1	**102**
2031	110	0.0	2.4	0.1	**113**
2032	120	0.0	2.6	0.1	**123**
2033	130	0.0	2.8	0.1	**133**
2034	139	0.0	3.0	0.1	**142**
2035	147	0.0	3.2	0.1	**151**
2036	155	0.0	3.4	0.1	**159**
2037	163	0.0	3.6	0.1	**166**
2038	169	0.0	3.7	0.1	**173**
2039	175	0.0	3.8	0.1	**179**
2040	181	0.0	4.0	0.1	**185**
2041	187	0.0	4.1	0.1	**191**
2042	192	0.0	4.2	0.1	**196**
2043	197	0.0	4.3	0.1	**201**
2044	201	0.0	4.4	0.1	**206**
2045	206	0.0	4.5	0.1	**211**
2046	211	0.0	4.6	0.1	**215**
2047	215	0.0	4.7	0.1	**220**
2048	220	0.0	4.8	0.1	**224**
2049	224	0.0	4.9	0.1	**229**
2050	228	0.0	5.0	0.1	**234**
Sum	**4045**	**0.0**	**88.4**	**2.4**	**4136**

Note: These values are expressed as emission reductions, such that positive values imply an emissions decrease, and negative values imply an emissions increase.

Table C.54 Annual Emission Reductions of the MY2022-2025 Standards on Criteria Pollutants in Select Years

		CY2030		CY2040	
	Pollutant	Impacts (short tons)	% of U.S. Inventory[207]	Impacts (short tons)	% of U.S. Inventory
Total	VOC	53,575	0.09	96,948	0.16
	CO	-29,612	-0.04	-67,192	-0.08
	NOx	13,625	0.09	24,238	0.16
	PM2.5	2,012	0.03	3,630	0.06
	SOx	8,317	0.13	15,163	0.23
Downstream (Rebound)	VOC	-1,284	0.00	-2,907	0.00
	CO	-34,454	-0.04	-76,040	-0.09
	NOx	-1,399	-0.01	-3,132	-0.02
	PM2.5	-77.7	0.00	-181	0.00
	SOx	-16.3	0.00	-29.4	0.00
Fuel production & distribution	VOC	55,104	0.09	100,296	0.17
	CO	6,349	0.01	11,555	0.01
	NOx	16,095	0.10	29,294	0.19
	PM2.5	2,405	0.04	4,377	0.07
	SOx	9,385	0.14	17,082	0.26
Electricity	VOC	-245	0.00	-441	0.00
	CO	-1,506	0.00	-2,707	0.00
	NOx	-1,071	-0.01	-1,924	-0.01
	PM2.5	-315	-0.01	-566	-0.01
	SOx	-1,051	-0.02	-1,890	-0.03

Note: These values are expressed as emission reductions, such that positive values imply an emissions decrease, and negative values imply an emissions increase.

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[207] The total U.S. inventory for selected pollutants (in short tons) was derived from the EPA National Emissions Inventory (NEI) 2011 (https://www.epa.gov/air-emissions-inventories/national-emissions-inventory).

Table C.55 Annual Emission Reductions of the MY2022-2025 Standards on Select Toxic Pollutants in Select Years

		CY2030		CY2040	
	Pollutant	Impacts (short tons)	% of U.S. Inventory	Impacts (short tons)	% of U.S. Inventory
Total	1,3- Butadiene	-7.65	-0.013	-17.5	-0.029
	Acetaldehyde	-20.7	-0.002	-53.5	-0.006
	Acrolein	-0.93	-0.002	-2.43	-0.005
	Benzene	315	0.111	551	0.194
	Formaldehyde	87.0	0.006	155	0.011
Downstream (Rebound)	1,3- Butadiene	-9.32	-0.015	-20.5	-0.034
	Acetaldehyde	-31.8	-0.004	-73.7	-0.009
	Acrolein	-1.62	-0.003	-3.68	-0.007
	Benzene	-53.0	-0.019	-119	-0.042
	Formaldehyde	-7.60	-0.001	-17.6	-0.001
Fuel production & distribution	1,3- Butadiene	1.67	0.003	3.05	0.005
	Acetaldehyde	11.4	0.001	20.7	0.002
	Acrolein	0.95	0.002	1.73	0.003
	Benzene	375	0.132	682	0.241
	Formaldehyde	94.8	0.007	173	0.013
Electricity	1,3- Butadiene	0.00	0.000	0.00	0.000
	Acetaldehyde	-0.28	0.000	-0.51	0.000
	Acrolein	-0.26	-0.001	-0.47	-0.001
	Benzene	-6.8	-0.002	-12.3	-0.004
	Formaldehyde	-0.17	0.000	-0.30	0.000

Note: These values are expressed as emission reductions, such that positive values imply an emissions decrease, and negative values imply an emissions increase.

The fuel consumption analysis relied on the same set of fleet and activity inputs as the emission analysis. EPA modeled the entire fleet as using petroleum gasoline (consistent with OMEGA model results showing a lack of projected diesel penetration in the central analysis), and used a conversion factor of 8887 grams of CO_2 per gallon of petroleum gasoline in order to determine the quantity of fuel savings. The term petroleum gasoline is used here to mean fuel with 115,000 BTU/gallon. This is different than retail fuel, which is typically blended with ethanol and has a lower energy content as discussed earlier in Section C.2.2 .

Table C.56 Annual Impacts of the MY2022-2025 Standards on Petroleum Fuel (E0) and Electricity Consumption

Calendar Year	Petroleum Gasoline (billion gallons)	Petroleum Gasoline (billion barrels)	Electricity (billion kWh)
2021	-0.24	-0.01	0.16
2022	-0.73	-0.02	0.40
2023	-1.5	-0.04	0.7
2024	-2.5	-0.06	1.2
2025	-3.7	-0.09	1.7
2026	-4.8	-0.11	2.2
2027	-6.0	-0.14	2.7
2028	-7.1	-0.17	3.1
2029	-8.1	-0.19	3.6
2030	-9.2	-0.22	4.0
2031	-10.1	-0.24	4.4
2032	-11.1	-0.26	4.8
2033	-11.9	-0.28	5.2
2034	-12.8	-0.30	5.6
2035	-13.5	-0.32	5.9
2036	-14.3	-0.34	6.2
2037	-14.9	-0.36	6.5
2038	-15.6	-0.37	6.8
2039	-16.1	-0.38	7.0
2040	-16.7	-0.40	7.2
2041	-17.2	-0.41	7.5
2042	-17.6	-0.42	7.7
2043	-18.1	-0.43	7.9
2044	-18.5	-0.44	8.0
2045	-18.9	-0.45	8.2
2046	-19.4	-0.46	8.4
2047	-19.8	-0.47	8.6
2048	-20.2	-0.48	8.7
2049	-20.6	-0.49	8.9
2050	-21.0	-0.50	9.1
Sum	**-372**	**-8.85**	**163**

Note: These values are expressed as absolute inventory changes, such that negative values imply a decrease in consumption, and positive values imply an increase in consumption.

C.2.3.2 Model Year Lifetime Results

Table C.57 MY Lifetime Emission Reductions of the MY2022-2025 Standards on GHGs (MMT CO2e)

Model Year	Downstream (including A/C)	Fuel Production & Distribution	Electricity	Total
2021	26.6	8.5	-1.2	**33.9**
2022	55.2	17.6	-1.8	**71.0**
2023	84.0	26.7	-2.5	**108**
2024	112	35.5	-3.2	**144**
2025	139	44.3	-3.9	**180**
Sum	**417**	**133**	**-12.6**	**537**

Note: These values are expressed as emission reductions, such that positive values imply an emissions decrease, and negative values imply an emissions increase.

Table C.58 MY Lifetime Emission Reductions of the MY2022-2025 Standards on Select Criteria Pollutants (Short tons)

Model Year	VOC	CO	NOx	PM2.5	SO2
2021	17,692	-19,226	3,897	612	2,622
2022	36,863	-36,795	8,555	1,354	5,720
2023	56,227	-51,552	13,415	2,093	8,813
2024	74,880	-62,894	18,251	2,798	11,764
2025	93,782	-71,553	23,288	3,504	14,724
Sum	**279,444**	**-242,018**	**67,406**	**10,362**	**43,644**

Note: These values are expressed as emission reductions, such that positive values imply an emissions decrease, and negative values imply an emissions increase.

Table C.59 MY Lifetime Emission Reductions of the MY2022-2025 Standards on Select Toxic Pollutants (Short tons)

Model Year	Benzene	1,3 Butadiene	Formaldehyde	Acetaldehyde	Acrolein
2021	91.1	-4.72	22.8	-14.1	-0.77
2022	195	-9.24	48.4	-27.7	-1.41
2023	303	-13.2	75.4	-39.0	-1.95
2024	410	-16.5	102	-48.2	-2.36
2025	522	-19.1	131	-55.5	-2.66
Sum	**1,520**	**-62.8**	**380**	**-184**	**-9.16**

Note: These values are expressed as emission reductions, such that positive values imply an emissions decrease, and negative values imply an emissions increase.

Table C.60 MY Lifetime Impacts of the MY2022-2025 Standards on Retail Blended Fuel and Electricity Consumption

Model Year	Retail Gasoline (billion gallons)	Retail Gasoline (billion barrels)	Electricity (billion kWh)
2021	-3.22	-0.08	1.91
2022	-6.69	-0.16	2.97
2023	-10.2	-0.24	4.11
2024	-13.5	-0.32	5.26
2025	-16.9	-0.40	6.5
Sum	**-50.5**	**-1.20**	**20.7**

Note: These values are expressed as absolute inventory changes, such that negative values imply a decrease in consumption, and positive values imply an increase in consumption.

C.2.3.3 AEO Fuel Price Sensitivity - Calendar and Model Year Summaries

In this section, EPA presents the central case emissions impact analysis results using AEO 2016 reference fuel price cases (shown in Section C.2.2) with two additional analyses based on the low and high fuel price cases found in the Annual Energy Outlook 2016 report (see TSD Chapter 3 for more discussion regarding these fuel price cases). These additional analyses provide a good bracket around the uncertainty in fuel price projections and shows the magnitude of the effect of differing fuel price projections on emission impacts. Similar to Sections C.2.3.1 and C.2.3.2, Section C.2.3.3 shows non-cumulative calendar year results for all three fuel price, and follows with model year lifetime and cumulative sum results for all three fuel price cases.

Table C.61 Annual Emission Reductions of the MY2022-2025 Standards and AEO Fuel Price Cases on Total GHGs (MMT CO2e)

Calendar Year	AEO Low Fuel Price Case	**Central Case AEO Reference Fuel Price Case**	AEO High Fuel Price Case
2022	8.97	**8.11**	7.30
2025	44.7	**40.6**	36.3
2030	114	**102**	87
2040	211	**185**	155
2050	268	**234**	193

Note: These values are expressed as emission reductions, such that positive values imply an emissions decrease, and negative values imply an emissions increase.

Table C.62 Annual Impacts of the MY2022-2025 Standards on Fuel Consumption

Calendar Year	AEO Low Fuel Price Case		**Central Case - AEO Reference Fuel Price Case**		AEO High Price Case	
	Petroleum Gasoline (E0) (Billon Gallons)	Electricity (Billion kWh)	**Petroleum Gasoline (E0) (Billion Gallons)**	**Electricity (Billion kWh)**	Petroleum Gasoline (E0) (Billon Gallons)	Electricity (Billion kWh)
2022	-0.81	0.37	**-0.73**	**0.40**	-0.66	0.45
2025	-4.01	1.55	**-3.65**	**1.68**	-3.31	2.34
2030	-10.2	3.77	**-9.15**	**4.03**	-7.98	5.79
2040	-18.9	6.89	**-16.7**	**7.25**	-14.1	10.4
2050	-24.0	8.73	**-21.0**	**9.10**	-17.6	12.9

Note: These values are expressed as absolute inventory changes, such that negative values imply a decrease in consumption, and positive values imply an increase in consumption.

Table C.63 MY Lifetime Emission Reductions of the MY2022-2025 Standards and AEO Fuel Price Cases on Total GHGs (MMT CO2e)

Model Year	AEO Low Fuel Price Case	**Central Case AEO Reference Fuel Price Case**	AEO High Fuel Price Case
2021	37.5	**33.9**	30.3
2022	78.8	**71.0**	63.9
2023	120	**108**	99
2024	158	**144**	129
2025	199	**180**	157
Sum	593	**537**	479

Note: The values shown in the table above are expressed as emission reductions, such that negative values imply an emissions increase while positive values imply an emissions decrease.

Table C.64 MY Lifetime Impacts of the MY2022-2025 Standards and AEO Fuel Price Cases on Retail Fuel Consumption

Calendar Year	AEO Low Fuel Price Case		**Central Case AEO Reference Fuel Price Case**		AEO High Fuel Price Case	
	Retail Gasoline (billion gallons)	Electricity (billion kWh)	**Retail Gasoline (billion gallons)**	**Electricity (billion kWh)**	Retail Gasoline (billion gallons)	Electricity (billion kWh)
2021	-3.54	1.76	**-3.22**	**1.91**	-2.88	1.74
2022	-7.39	2.76	**-6.69**	**2.97**	-6.07	3.68
2023	-11.2	3.81	**-10.2**	**4.11**	-9.38	5.80
2024	-14.8	4.85	**-13.5**	**5.26**	-12.3	7.78
2025	-18.6	6.00	**-16.9**	**6.48**	-14.9	9.70
Sum	-55.5	19.2	**-50.5**	**20.7**	-45.6	28.7

Note: These values are expressed as absolute inventory changes, such that negative values imply a decrease in consumption, and positive values imply an increase in consumption.

C.2.4 Consumer Benefits: Payback Period and Lifetime Fuel Savings

In this section, EPA looks at the cost of owning a new vehicle meeting the MY2025 standards and the payback period – the point at which consumer savings from reduced gasoline expenditures exceed the upfront costs of the vehicle. For example, relative to the reference case (i.e., the MY2021 standards), a new MY2025 vehicle is estimated to cost roughly $875 more due to the addition of new GHG reducing/fuel economy improving technology (see Table C.34). This new technology will result in lower fuel consumption and, therefore, savings in fuel expenditures. An important question is how many months or years would pass before the fuel savings exceed the cumulative costs.

The tables below present EPA's estimates of net costs associated with owning a new MY2025 vehicle in each of the AEO fuel price cases. For purposes of this analysis, we are using a "sales weighted average vehicle" which means the combined car/truck fleet, weighted by sales on the cost side and usage on the fuel savings side, to arrive at a single weighted vehicle analysis. The table uses results from the OMEGA Inventory, Costs and Benefits Tool analysis discussed in Section C.2. Included in the analysis are maintenance costs (see Chapter 2 of the TSD), sales taxes and insurance costs (see Chapter 3 of the TSD). This analysis does not include other impacts such as reduced refueling events, or other societal impacts, such as the potential rebound miles driven or the value of driving those rebound miles, or noise, congestion and crashes, since the focus is meant to be on those factors consumers likely think about most while in the showroom considering a new car purchase, and on those factors that result in more or fewer dollars in their pockets. As noted, to estimate the cumulative vehicle costs, we have included not only the sales tax on the new car purchase but also the increased insurance premiums that would result from the more valuable vehicle (see Chapter 3 of the TSD). The payback periods were calculated using both 3 percent and 7 percent discount rates.

As shown in these tables, payback occurs in the 5th year of ownership using both a 3 and a 7 percent discount rate. Note that, in the first table, the delta cost per vehicle is shown as $863 when the cost per vehicle presented earlier was $875 (see Table C.8). The $863 value is $875 discounted at 3 percent to the mid-year point of the first year of ownership.

Note that, in the tables that follow, the "Delta Purchase Costs per Vehicle" column shows the summation of the delta costs per vehicle, the increased taxes and increased insurance costs. The values shown in each table can be summed across those individual columns. However, the "Cumulative Delta Operating Costs per Vehicle" column is a cumulative summation of current and prior year costs, it is not a simple summation of costs across columns. For example, in Table C.65, row 2 shows a value of $483 which is the cumulative summation of $693 (year 1 operating costs) plus $15 (year 2 purchase costs) plus $6 (year 2 maintenance costs) minus $232 (year 2 fuel savings) with the result being $483 in cumulative increased costs).

Table C.65 Payback Period for the Sales Weighted Average MY2025 Vehicle Relative to the Reference Case Standards, AEO Reference Fuel Price Case, Cash Purchase (3% discounting, 2015$)

Year of Ownership	Delta Cost per Vehicle	Delta Taxes per Vehicle	Delta Insurance per Vehicle	Delta Purchase Costs per Vehicle	Delta Maintenance Costs per Vehicle	Delta Fuel Costs per Vehicle	Cumulative Delta Operating Costs per Vehicle
1st	$863	$47	$16	$926	$6	-$238	$693
2nd	$0	$0	$15	$15	$6	-$232	$483
3rd	$0	$0	$14	$14	$5	-$223	$279
4th	$0	$0	$13	$13	$5	-$213	$85
5th	$0	$0	$12	$12	$5	-$202	**-$100**
6th	$0	$0	$11	$11	$5	-$189	-$274
7th	$0	$0	$10	$10	$4	-$178	-$437
8th	$0	$0	$9	$9	$4	-$166	-$589

Note: Insurance costs include depreciation effects and all cost metrics shown include vehicle survival rate factors.

Table C.66 Payback Period for the Sales Weighted Average MY2025 Vehicle Relative to the Reference Case Standards, AEO Reference Fuel Price Case, Cash Purchase (7% discounting, 2015$)

Year of Ownership	Delta Cost per Vehicle	Delta Taxes per Vehicle	Delta Insurance per Vehicle	Delta Purchase Costs per Vehicle	Delta Maintenance Costs per Vehicle	Delta Fuel Costs per Vehicle	Cumulative Delta Operating Costs per Vehicle
1st	$846	$46	$16	$908	$6	-$234	$680
2nd	$0	$0	$15	$15	$5	-$219	$481
3rd	$0	$0	$13	$13	$5	-$203	$296
4th	$0	$0	$12	$12	$5	-$186	$126
5th	$0	$0	$10	$10	$4	-$170	-$30
6th	$0	$0	$9	$9	$4	-$153	-$170
7th	$0	$0	$8	$8	$3	-$139	-$298
8th	$0	$0	$7	$7	$3	-$125	-$412

Note: Insurance costs include depreciation effects and all cost metrics shown include vehicle survival rate factors.

Although not included in the Draft TAR, for this Proposed Determination we have also calculated the payback periods for loan purchases, using a range of 48, 60 and 72-month loan periods. As described in Chapter 3 of the TSD, we have used loan rates of 4.25 percent for each of these loan periods. Included in these estimates is the vehicle "survival" rate[208] on the purchase costs. The paybacks for each loan period at both 3 percent and 7 percent discounting are shown in Table C.67 through Table C.72 . Note that, for the 5 and 6-year loan cases, the payback occurs in the first year. Note that the columns showing delta costs per vehicle, taxes and insurance show the same information as the cash purchase tables above. Those metrics have not changed. However, the "Delta Purchase Costs per Vehicle" column now shows the majority of the purchase costs (the "Delta Cost per Vehicle") spread out over a 4-year (48-month period) as the vehicle costs and taxes are paid back via loan rather than cash. The cumulative delta operating costs are now much lower than in the cash purchase case, although they remain positive until the 5th year when payback is achieved.

Table C.67 Payback Period for the Sales Weighted Average MY2025 Vehicle Relative to the Reference Case Standards, AEO Reference Fuel Price Case, 4-Year (48 Month) Loan Purchase (3% discounting, 2015$)

Year of Owner ship	Delta Cost per Vehicle	Delta Taxes per Vehicle	Delta Insurance per Vehicle	Delta Purchase Costs per Vehicle	Delta Maintenance Costs per Vehicle	Delta Fuel Costs per Vehicle	Cumulative Delta Operating Costs per Vehicle
1st	$863	$47	$16	$262	$6	-$238	$30
2nd	$0	$0	$15	$253	$6	-$232	$56
3rd	$0	$0	$14	$243	$5	-$223	$82
4th	$0	$0	$13	$233	$5	-$213	$107
5th	$0	$0	$12	$12	$5	-$202	**-$78**
6th	$0	$0	$11	$11	$5	-$189	-$252
7th	$0	$0	$10	$10	$4	-$178	-$415
8th	$0	$0	$9	$9	$4	-$166	-$567

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[208] Vehicle survival rate reflects the number of vehicles expected to remain in service during each future calendar year after they are produced and sold. See the TSD Chapter 3 for details on the methodology.

Note: Insurance costs include depreciation effects and all cost metrics shown include vehicle survival rate factors. Taxes are rolled into the loan purchase costs.

Table C.68 Payback Period for the Sales Weighted Average MY2025 Vehicle Relative to the Reference Case Standards, AEO Reference Fuel Price Case, 4-Year (48 Month) Loan Purchase (7% discounting, 2015$)

Year of Ownership	Delta Cost per Vehicle	Delta Taxes per Vehicle	Delta Insurance per Vehicle	Delta Purchase Costs per Vehicle	Delta Maintenance Costs per Vehicle	Delta Fuel Costs per Vehicle	Cumulative Delta Operating Costs per Vehicle
1st	$846	$46	$16	$257	$6	-$234	$29
2nd	$0	$0	$15	$239	$5	-$219	$54
3rd	$0	$0	$13	$221	$5	-$203	$77
4th	$0	$0	$12	$204	$5	-$186	$99
5th	$0	$0	$10	$10	$4	-$170	-$57
6th	$0	$0	$9	$9	$4	-$153	-$197
7th	$0	$0	$8	$8	$3	-$139	-$324
8th	$0	$0	$7	$7	$3	-$125	-$439

Note: Insurance costs include depreciation effects and all cost metrics shown include vehicle survival rate factors. Taxes are rolled into the loan purchase costs.

In Table C.69 (5-year loan, 3 percent discounting) and Table C.70 (5-year loan, 7 percent discounting), the vehicle costs and taxes are now paid back over a 5-year period ("Delta Purchase Costs per Vehicle" column) and the payback periods are immediate because fuel savings outweigh the increased costs of owning the vehicle.

Table C.69 Payback Period for the Sales Weighted Average MY2025 Vehicle Relative to the Reference Case Standards, AEO Reference Fuel Price Case, 5-Year (60 Month) Loan Purchase (3% discounting, 2015$)

Year of Ownership	Delta Cost per Vehicle	Delta Taxes per Vehicle	Delta Insurance per Vehicle	Delta Purchase Costs per Vehicle	Delta Maintenance Costs per Vehicle	Delta Fuel Costs per Vehicle	Cumulative Delta Operating Costs per Vehicle
1st	$863	$47	$16	$217	$6	-$238	**-$16**
2nd	$0	$0	$15	$209	$6	-$232	-$32
3rd	$0	$0	$14	$201	$5	-$223	-$49
4th	$0	$0	$13	$193	$5	-$213	-$64
5th	$0	$0	$12	$184	$5	-$202	-$78
6th	$0	$0	$11	$11	$5	-$189	-$251
7th	$0	$0	$10	$10	$4	-$178	-$414
8th	$0	$0	$9	$9	$4	-$166	-$567

Note: Insurance costs include depreciation effects and all cost metrics shown include vehicle survival rate factors. Taxes are rolled into the loan purchase costs.

Table C.70 Payback Period for the Sales Weighted Average MY2025 Vehicle Relative to the Reference Case Standards, AEO Reference Fuel Price Case, 5-Year (60 Month) Loan Purchase (7% discounting, 2015$)

Year of Ownership	Delta Cost per Vehicle	Delta Taxes per Vehicle	Delta Insurance per Vehicle	Delta Purchase Costs per Vehicle	Delta Maintenance Costs per Vehicle	Delta Fuel Costs per Vehicle	Cumulative Delta Operating Costs per Vehicle
1st	$863	$47	$16	$187	$6	-$238	-$46

2nd	$0	$0	$15	$180	$6	-$232	-$91
3rd	$0	$0	$14	$173	$5	-$223	-$136
4th	$0	$0	$13	$166	$5	-$213	-$178
5th	$0	$0	$12	$158	$5	-$202	-$217
6th	$0	$0	$11	$150	$5	-$189	-$252
7th	$0	$0	$10	$10	$4	-$178	-$415
8th	$0	$0	$9	$9	$4	-$166	-$567

Note: Insurance costs include depreciation effects and all cost metrics shown include vehicle survival rate factors. Taxes are rolled into the loan purchase costs.

Table C.71 (6-year loan, 3 percent discounting) and Table C.72 (6-year loan, 7 percent discounting) show the payback metrics for a 6-year loan and, as with the 5-year loan case, the payback periods are immediate.

Table C.71 Payback Period for the Sales Weighted Average MY2025 Vehicle Relative to the Reference Case Standards, AEO Reference Fuel Price Case, 6-Year (72 Month) Loan Purchase (3% discounting, 2015$)

Year of Ownership	Delta Cost per Vehicle	Delta Taxes per Vehicle	Delta Insurance per Vehicle	Delta Purchase Costs per Vehicle	Delta Maintenance Costs per Vehicle	Delta Fuel Costs per Vehicle	Cumulative Delta Operating Costs per Vehicle
1st	$846	$46	$16	$183	$6	-$234	**-$45**
2nd	$0	$0	$15	$170	$5	-$219	-$88
3rd	$0	$0	$13	$158	$5	-$203	-$128
4th	$0	$0	$12	$145	$5	-$186	-$165
5th	$0	$0	$10	$133	$4	-$170	-$198
6th	$0	$0	$9	$122	$4	-$153	-$226
7th	$0	$0	$8	$8	$3	-$139	-$354
8th	$0	$0	$7	$7	$3	-$125	-$468

Note: Insurance costs include depreciation effects and all cost metrics shown include vehicle survival rate factors. Taxes are rolled into the loan purchase costs.

Table C.72 Payback Period for the Sales Weighted Average MY2025 Vehicle Relative to the Reference Case Standards, AEO Reference Fuel Price Case, 6-Year (72 Month) Loan Purchase (7% discounting, 2015$)

Year of Ownership	Delta Cost per Vehicle	Delta Taxes per Vehicle	Delta Insurance per Vehicle	Delta Purchase Costs per Vehicle	Delta Maintenance Costs per Vehicle	Delta Fuel Costs per Vehicle	Cumulative Delta Operating Costs per Vehicle
1st	$862	$47	$16	$187	$6	-$232	-$39
2nd	$0	$0	$15	$173	$5	-$217	-$78
3rd	$0	$0	$13	$160	$5	-$201	-$114
4th	$0	$0	$12	$148	$5	-$185	-$146
5th	$0	$0	$10	$135	$4	-$169	-$175
6th	$0	$0	$9	$124	$4	-$152	-$200
7th	$0	$0	$8	$8	$3	-$138	-$326
8th	$0	$0	$7	$7	$3	-$124	-$440

Note: Insurance costs include depreciation effects and all cost metrics shown include vehicle survival rate factors. Taxes are rolled into the loan purchase costs.

Table C.73 through Table C.76 present the payback periods for cash purchases under the AEO High and Low fuel price cases using 3 and 7 percent discounting. As expected, the high fuel price case leads to shorter payback periods (e.g., payback in the 3rd year under both the 3 and 7 percent discount rate cases) while the low fuel price case leads to longer payback periods.

Table C.73 Payback Period for the Sales Weighted Average MY2025 Vehicle Relative to the Reference Case Standards, AEO High Fuel Price Case, Cash Purchase (3% discounting, 2015$)

Year of Ownership	Delta Cost per Vehicle	Delta Taxes per Vehicle	Delta Insurance per Vehicle	Delta Purchase Costs per Vehicle	Delta Maintenance Costs per Vehicle	Delta Fuel Costs per Vehicle	Cumulative Delta Operating Costs per Vehicle
1st	$869	$47	$16	$932	$5	-$373	$564
2nd	$0	$0	$16	$16	$5	-$360	$225
3rd	$0	$0	$14	$14	$5	-$348	-$104
4th	$0	$0	$13	$13	$5	-$329	-$415
5th	$0	$0	$12	$12	$4	-$309	-$708
6th	$0	$0	$11	$11	$4	-$290	-$982
7th	$0	$0	$10	$10	$4	-$275	-$1,243
8th	$0	$0	$9	$9	$4	-$251	-$1,481

Note: Insurance costs include depreciation effects and all cost metrics shown include vehicle survival rate factors.

Table C.74 Payback Period for the Sales Weighted Average MY2025 Vehicle Relative to the Reference Case Standards, AEO High Fuel Price Case, Cash Purchase (7% discounting, 2015$)

Year of Ownership	Delta Cost per Vehicle	Delta Taxes per Vehicle	Delta Insurance per Vehicle	Delta Purchase Costs per Vehicle	Delta Maintenance Costs per Vehicle	Delta Fuel Costs per Vehicle	Cumulative Delta Operating Costs per Vehicle
1st	$852	$47	$16	$915	$5	-$366	$553
2nd	$0	$0	$15	$15	$5	-$340	$233
3rd	$0	$0	$13	$13	$4	-$316	-$66
4th	$0	$0	$12	$12	$4	-$288	-$338
5th	$0	$0	$10	$10	$4	-$261	-$585
6th	$0	$0	$9	$9	$3	-$235	-$807
7th	$0	$0	$8	$8	$3	-$215	-$1,011
8th	$0	$0	$7	$7	$3	-$189	-$1,190

Note: Insurance costs include depreciation effects and all cost metrics shown include vehicle survival rate factors.

Table C.75 Payback Period for the Sales Weighted Average MY2025 Vehicle Relative to the Reference Case Standards, AEO Low Fuel Price Case, Cash Purchase (3% discounting, 2015$)

Year of Ownership	Delta Cost per Vehicle	Delta Taxes per Vehicle	Delta Insurance per Vehicle	Delta Purchase Costs per Vehicle	Delta Maintenance Costs per Vehicle	Delta Fuel Costs per Vehicle	Cumulative Delta Operating Costs per Vehicle
1st	$873	$48	$16	$936	$7	-$165	$778
2nd	$0	$0	$16	$16	$6	-$158	$642
3rd	$0	$0	$14	$14	$6	-$151	$512
4th	$0	$0	$13	$13	$6	-$143	$388
5th	$0	$0	$12	$12	$5	-$135	$270
6th	$0	$0	$11	$11	$5	-$126	$161
7th	$0	$0	$10	$10	$5	-$118	$58
8th	$0	$0	$9	$9	$5	-$110	-$39

Note: Insurance costs include depreciation effects and all cost metrics shown include vehicle survival rate factors.

Table C.76 Payback Period for the Sales Weighted Average MY2025 Vehicle Relative to the Reference Case Standards, AEO Low Fuel Price Case, Cash Purchase (7% discounting, 2015$)

Year of Ownership	Delta Cost per Vehicle	Delta Taxes per Vehicle	Delta Insurance per Vehicle	Delta Purchase Costs per Vehicle	Delta Maintenance Costs per Vehicle	Delta Fuel Costs per Vehicle	Cumulative Delta Operating Costs per Vehicle
1st	$856	$47	$16	$919	$6	-$162	$763
2nd	$0	$0	$15	$15	$6	-$149	$635
3rd	$0	$0	$13	$13	$5	-$137	$516
4th	$0	$0	$12	$12	$5	-$125	$408
5th	$0	$0	$10	$10	$5	-$114	$309
6th	$0	$0	$9	$9	$4	-$102	$220
7th	$0	$0	$8	$8	$4	-$92	$140
8th	$0	$0	$7	$7	$3	-$83	$67
9th	$0	$0	$6	$6	$3	-$74	$3
10th	$0	$0	$5	$5	$3	-$65	-$54

Note: Insurance costs include depreciation effects and all cost metrics shown include vehicle survival rate factors.

The table below shows the lifetime fuel savings and the lifetime net savings (fuel less increased costs) associated with the standards using each of the three AEO fuel price cases and at both the 3 percent and 7 percent discount rates. Note that the lifetime net savings values shown in the table include added costs associated with maintenance, insurance and taxes, and the fuel savings resulting from less fuel usage. These analyses compare the lifetime fuel savings and net savings (after considering vehicle costs) associated with a vehicle meeting the MY2025 standards under the various control cases to a vehicle meeting the MY2021 standards in MY2025 (the reference case).

Table C.77 Lifetime Fuel Savings and Net Savings for the Sales-Weighted Average MY2025 Vehicle Purchased with Cash under Each of the AEO Fuel Price Cases (2015$)

Case	3 Percent Discount Rate		7 Percent Discount Rate	
	Lifetime Fuel Savings	Lifetime Net Savings	Lifetime Fuel Savings	Lifetime Net Savings
AEO High Fuel Prices	$4,209	$3,054	$3,223	$2,145
AEO Reference Fuel Prices	**$2,804**	**$1,648**	$2,128	$1,051
AEO Low Fuel Prices	$1,899	$723	$1,439	$345

C.3 Summary of Benefits and Costs of the MY2022-2025 Standards

In Section C.3.2, EPA presents results of its model year analysis, which looks at the lifetimes of MY2021-2025 vehicles. In Section C.3.3, EPA presents results of its calendar year analysis, which looks at annual impacts through the year 2050. The inventory inputs used to generate the monetized benefits presented here are discussed in Section C.2. The monetary inputs used to generate the monetized benefits and costs presented here are discussed in Chapter 3 of the TSD, where we present $/ton, $/gallon and $/mile premiums, as applicable, that are applied to the inventory inputs to generate the benefit cost analysis results. In Section C.3.1 below, we present the $/vehicle inputs to the OMEGA Inventory, Cost and Benefits analysis.

C.3.1 Cost/Vehicle Inputs to the OMEGA Inventory, Cost and Benefit Analysis

The vehicle costs used as inputs to the OMEGA Inventory, Cost and Benefit Tool (ICBT) are shown in **Error! Reference source not found.** Table C.78 and Table C.79 are based on interpolations between the costs of the reference or control case standards in MY2021 and the reference or control case standards in MY2025 (both based on actual OMEGA output), using the reference or control case CO_2 targets for each fleet (car and truck) for each individual OEM.

Table C.78 Reference Case Absolute Cost per Vehicle Used as Inputs to the OMEGA Inventory, Cost and Benefit Tool (2015$)

	AEO Low Fuel Price Case		AEO Reference Fuel Price Case		AEO High Fuel Price Case	
MY	Car	Truck	Car	Truck	Car	Truck
2021	$717	$899	$750	$936	$793	$983
2022	$709	$883	$743	$919	$786	$967
2023	$695	$861	$731	$895	$772	$943
2024	$677	$837	$715	$869	$756	$918
2025	$681	$833	$721	$865	$762	$913
2026	$681	$833	$721	$864	$762	$913
2027	$681	$834	$721	$865	$761	$913
2028	$681	$833	$720	$865	$761	$913
2029	$680	$832	$720	$864	$761	$911
2030	$680	$832	$720	$863	$761	$911

Table C.79 Control Case Absolute Cost per Vehicle Used as Inputs to the OMEGA Inventory, Cost and Benefit Tool (2015$)

	AEO Low Fuel Price Case		AEO Reference Fuel Price Case		AEO High Fuel Price Case	
MY	Car	Truck	Car	Truck	Car	Truck
2021	$827	$1,075	$868	$1,108	$919	$1,167
2022	$978	$1,264	$1,020	$1,303	$1,074	$1,371
2023	$1,124	$1,446	$1,164	$1,491	$1,223	$1,569
2024	$1,266	$1,625	$1,306	$1,676	$1,369	$1,764
2025	$1,430	$1,826	$1,470	$1,883	$1,536	$1,980
2026	$1,429	$1,826	$1,469	$1,882	$1,536	$1,979
2027	$1,429	$1,827	$1,469	$1,884	$1,535	$1,981
2028	$1,428	$1,827	$1,468	$1,883	$1,535	$1,979
2029	$1,428	$1,824	$1,468	$1,881	$1,534	$1,976
2030	$1,428	$1,824	$1,468	$1,880	$1,534	$1,975

C.3.2 Model Year Analysis

In our model year analysis, we look at the impacts over the lifetimes of MY2021-2025 vehicles. All values are discounted at 3 percent and 7 percent discount rates with the exception of the social costs of greenhouse gases that are discounted at the discount rate used in their generation. All values are discounted back to CY 2016.

C.3.2.1 Central Analysis: AEO 2016 Reference Fuel Price Case

In the central analysis, we use AEO 2016 reference fuel prices and fleet projections, and, as noted, we include our estimate of BEV and PHEV sales required by the ZEV program in the reference and control case fleets. Importantly, Table C.80, which uses a 3 percent discount rate, shows that technology and maintenance costs are estimated at roughly $36 billion ($32.6+2.9) and benefits excluding fuel savings are estimated at roughly $42 billion (includes energy security; crashes, noise, congestion; travel; refueling; mid-point of non-GHG; and the 3 percent average SC-GHG value). In other words, even without fuel savings, benefits outweigh costs. Further, the fuel savings alone, nearly $92 billion, is more than double the costs. Similarly, Table C.81, which uses a 7 percent discount rate, shows that technology and maintenance costs are estimated at roughly $26 billion ($23.9+1.7) and benefits excluding fuel savings are estimated at roughly $32 billion (includes energy security; crashes, noise, congestion; travel; refueling; mid-point of non-GHG; and, the 3 percent average SC-GHG value). In other words, even without fuel savings, benefits outweigh costs. Again, the fuel savings alone, more than $52 billion, far exceeds the costs.

Table C.80 MY Lifetime Costs & Benefits Using AEO Reference Fuel Prices (3 Percent Discount Rate, Billions of 2015$)[a,b,c]

	2021	2022	2023	2024	2025	Sum
Vehicle Program	-$2.0	-$4.3	-$6.7	-$8.8	-$10.9	-$32.6
Maintenance	-$0.4	-$0.5	-$0.6	-$0.7	-$0.8	-$2.9
Pre-tax Fuel	$6.0	$12.4	$18.6	$24.4	$30.1	$91.6
Energy Security	$0.3	$0.6	$0.9	$1.2	$1.5	$4.6
Crashes, Noise, Congestion	-$0.6	-$1.2	-$1.8	-$2.4	-$2.9	-$8.9
Travel Value	$0.7	$1.4	$2.1	$2.7	$3.2	$10.1
Refueling	$0.5	$1.0	$1.5	$2.0	$2.5	$7.6
Non-GHG	$0.3 - $0.8	$0.7 - $1.7	$1.1 - $2.5	$1.5 - $3.3	$1.8 - $4.1	$5.5 - $12.4
GHG						
SC-GHG 5% Avg	$0.3	$0.6	$1.0	$1.3	$1.5	$4.7
SC-GHG 3% Avg	$1.3	$2.6	$4.0	$5.3	$6.5	$19.7
SC-GHG 2.5% Avg	$2.0	$4.1	$6.2	$8.2	$10.1	$30.6
SC-GHG 3% 95th	$3.8	$8.0	$12.0	$15.8	$19.6	$59.3
Net Benefits						
SC-GHG 5% Avg	$5.5	$11.2	$16.9	$22.1	$27.3	$83.1
SC-GHG 3% Avg	$6.4	$13.3	$19.9	$26.1	$32.3	$98.0
SC-GHG 2.5% Avg	$7.1	$14.7	$22.1	$29.1	$35.9	$108.9
SC-GHG 3% 95th	$9.0	$18.6	$28.0	$36.7	$45.4	$137.7

Notes:

[a] The non-GHG benefits presented in this table are based on PM2.5-related benefit per ton values (see Chapter 3 of the TSD for more information); the range of benefits are derived from two premature mortality estimates - the American Cancer Society cohort study (Krewski et al., 2009) and the Harvard Six-Cities study (Lepeule et al., 2012). The range of benefits also assumes either a 3 percent or 7 percent discount rate in the valuation of PM-related premature mortality to account for a twenty-year segmented cessation lag. Benefit-per-ton values were estimated for the years 2020, 2025 and 2030. We hold values constant for intervening years (e.g., the 2020 values are assumed to apply to years 2021-2024; 2025 values for years 2026-2029; and 2030 values for years 2031 and beyond). See Chapter 3 of the TSD for the benefit per ton values used in this analysis.

[b] GHG benefit estimates include reductions in CO2, CH4, and N2O but do not include HFC reductions. Note that net present value of reduced GHG emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SC-CO2, SC-CH4, and SC-N2O, each discounted at rates of 5,

3, 2.5 percent) is used to calculate net present value of SC-CO2, SC-CH4, and SC-N2O, respectively, for internal consistency. Refer to the Chapter 3 of the TSD for more detail.

[c] Chapter 3 of the TSD notes that SC-GHGs increase over time. Corresponding to the years in this table (2021-2025), the SC-CO2 estimates range as follows: for Average SC-CO2 at 5%: $14-$16; for Average SC-CO2 at 3%: $47-$52; for Average SC-CO2 at 2.5%: $71-$77; and for 95th percentile SC-CO2 at 3%: $140-$160. For the years 2021-2025, the SC-CH4 estimates range as follows: for Average SC-CH4 at 5%: $640-$730; for Average SC-CH4 at 3%: $1,400-$1,600; for Average SC-CH4 at 2.5%: $1,900-$2,000; and for 95th percentile SC-CH4 at 3%: $3,700-$4,200. For the years 2021-2025, the SC-N2O estimates range as follows: for Average SC-N2O at 5%: $5,500-$6,200; for Average SC-N2O at 3%: $17,000-$19,000; for Average SC-N2O at 2.5%: $25,000-$27,000; and for 95th percentile SC-N2O at 3%: $45,000-$50,000. TSD Chapter 3 also presents these SC-GHG estimates.

Table C.81 MY Lifetime Costs & Benefits Using AEO Reference Fuel Prices (7 Percent Discount Rate, Billions of 2015$)[a,b,c]

	2021	2022	2023	2024	2025	Sum
Vehicle Program	-$1.6	-$3.4	-$5.0	-$6.4	-$7.6	-$23.9
Maintenance	-$0.2	-$0.3	-$0.3	-$0.4	-$0.4	-$1.7
Pre-tax Fuel	$3.8	$7.5	$10.9	$13.7	$16.3	$52.2
Energy Security	$0.2	$0.4	$0.5	$0.7	$0.8	$2.6
Crashes, Noise, Congestion	-$0.4	-$0.8	-$1.1	-$1.4	-$1.6	-$5.2
Travel Value	$0.4	$0.9	$1.2	$1.5	$1.7	$5.8
Refueling	$0.3	$0.6	$0.9	$1.1	$1.3	$4.3
Non-GHG	$0.2 - $0.4	$0.4 - $0.9	$0.6 - $1.3	$0.8 - $1.7	$0.9 - $2.0	$2.9 - $6.5
GHG						
SC-GHG 5% Avg	$0.3	$0.6	$1.0	$1.3	$1.5	$4.7
SC-GHG 3% Avg	$1.3	$2.6	$4.0	$5.3	$6.5	$19.7
SC-GHG 2.5% Avg	$2.0	$4.1	$6.2	$8.2	$10.1	$30.6
SC-GHG 3% 95th	$3.8	$8.0	$12.0	$15.8	$19.6	$59.3
Net Benefits						
SC-GHG 5% Avg	$3.2	$6.2	$9.0	$11.5	$13.7	$43.6
SC-GHG 3% Avg	$4.1	$8.2	$12.1	$15.5	$18.6	$58.5
SC-GHG 2.5% Avg	$4.8	$9.7	$14.3	$18.4	$22.2	$69.4
SC-GHG 3% 95th	$6.7	$13.6	$20.1	$26.0	$31.7	$98.1

Notes:

[a] The non-GHG benefits presented in this table are based on PM2.5-related benefit per ton values (see Chapter 3 of the TSD); the range of benefits are derived from two premature mortality estimates - the American Cancer Society cohort study (Krewski et al., 2009) and the Harvard Six-Cities study (Lepeule et al., 2012). The range of benefits also assumes either a 3 percent or 7 percent discount rate in the valuation of PM-related premature mortality to account for a twenty-year segmented cessation lag. Benefit-per-ton values were estimated for the years 2020, 2025 and 2030. We hold values constant for intervening years (e.g., the 2020 values are assumed to apply to years 2021-2024; 2025 values for years 2026-2029; and 2030 values for years 2031 and beyond). See Chapter 3 of the TSD for the benefit per ton values used in this analysis.

[b] GHG benefit estimates include reductions in CO2, CH4, and N2O but do not include HFC reductions. Note that net present value of reduced GHG emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SC-CO2, SC-CH4, and SC-N2O, each discounted at rates of 5, 3, 2.5 percent) is used to calculate net present value of SC-CO2, SC-CH4, and SC-N2O, respectively, for internal consistency. Refer to Chapter 3 of the TSD for more detail.

[c] Chapter 3 of the TSD notes that SC-GHGs increase over time. Corresponding to the years in this table (2021-2025), the SC-CO2 estimates range as follows: for Average SC-CO2 at 5%: $14-$16; for Average SC-CO2 at 3%: $47-$52; for Average SC-CO2 at 2.5%: $71-$77; and for 95th percentile SC-CO2 at 3%: $140-$160. For the years 2021-2025, the SC-CH4 estimates range as follows: for Average SC-CH4 at 5%: $640-$730; for Average SC-CH4 at 3%: $1,400-$1,600; for Average SC-CH4 at 2.5%: $1,900-$2,000; and for 95th percentile SC-CH4 at 3%: $3,700-$4,200. For the years 2021-2025, the SC-N2O estimates range as follows: for Average SC-N2O at 5%: $5,500-$6,200; for Average

SC-N2O at 3%: $17,000-$19,000; for Average SC-N2O at 2.5%: $25,000-$27,000; and for 95th percentile SC-N2O at 3%: $45,000-$50,000. TSD Chapter 3 also presents these SC-GHG estimates.

C.3.2.2 AEO 2016 High Fuel Price Case

In the AEO high fuel price analysis, we use AEO 2016 high fuel prices and fleet projections, and we include our estimate of BEV and PHEV sales required by the ZEV program in the reference and control case fleets. Note that in this analysis of AEO high and low fuel price sensitivities, we have corrected an error in the Draft TAR, in which we inadvertently applied AEO reference fuel prices in calculating monetized fuel savings to both the AEO high and low fuel price cases. Importantly, Table C.82, which uses a 3 percent discount rate, shows that technology and maintenance costs are estimated at roughly $34 billion ($31.6+2.4) and benefits excluding fuel savings are estimated at roughly $42 billion (includes energy security; crashes, noise, congestion; travel; refueling; mid-point of non-GHG; and, the 3 percent average SC-GHG value). In other words, even without fuel savings, estimated monetized benefits outweigh costs. Similarly, Table C.83, which uses a 7 percent discount rate, shows that technology and maintenance costs are estimated at roughly $25 billion ($23.1+1.4) and benefits excluding fuel savings are estimated at roughly $31 billion (includes energy security; crashes, noise, congestion; travel; refueling; mid-point of non-GHG; and, the 3 percent average SC-GHG value). In other words, even without fuel savings, benefits outweigh costs.

Table C.82 MY Lifetime Costs & Benefits Using AEO High Fuel Prices (3 Percent Discount Rate, Billions of 2015$)[a,b,c]

	2021	2022	2023	2024	2025	Sum
Vehicle Program	-$1.9	-$4.2	-$6.6	-$8.5	-$10.3	-$31.6
Maintenance	-$0.3	-$0.4	-$0.5	-$0.6	-$0.7	-$2.4
Pre-tax Fuel	$9.1	$19.0	$28.9	$37.2	$44.5	$138.7
Energy Security	$0.3	$0.6	$0.9	$1.1	$1.3	$4.1
Crashes, Noise, Congestion	-$0.6	-$1.2	-$1.8	-$2.2	-$2.6	-$8.4
Travel Value	$1.0	$2.1	$3.1	$3.9	$4.6	$14.6
Refueling	$0.5	$0.9	$1.4	$1.8	$2.2	$6.8
Non-GHG	$0.3 - $0.7	$0.6 - $1.4	$1.0 - $2.2	$1.2 - $2.8	$1.5 - $3.3	$4.6 - $10.3
GHG						
SC-GHG 5% Avg	$0.3	$0.6	$0.9	$1.1	$1.3	$4.2
SC-GHG 3% Avg	$1.1	$2.4	$3.6	$4.7	$5.7	$17.6
SC-GHG 2.5% Avg	$1.8	$3.7	$5.6	$7.3	$8.8	$27.3
SC-GHG 3% 95th	$3.4	$7.2	$11.0	$14.2	$17.1	$52.9
Net Benefits						
SC-GHG 5% Avg	$8.9	$18.4	$27.9	$35.8	$42.7	$133.6
SC-GHG 3% Avg	$9.7	$20.2	$30.6	$39.4	$47.0	$147.0
SC-GHG 2.5% Avg	$10.3	$21.5	$32.6	$42.0	$50.2	$156.7
SC-GHG 3% 95th	$12.0	$25.0	$38.0	$48.9	$58.5	$182.3

Notes:

[a] The non-GHG benefits presented in this table are based on PM2.5-related benefit per ton values (see Chapter 3 of the TSD); the range of benefits are derived from two premature mortality estimates - the American Cancer Society cohort study (Krewski et al., 2009) and the Harvard Six-Cities study (Lepeule et al., 2012). The range of benefits also assumes either a 3 percent or 7 percent discount rate in the valuation of PM-related premature mortality to account for a twenty-year segmented cessation lag. Benefit-per-ton values were estimated for the years 2016, 2020, 2025 and 2030. We hold values constant for intervening years (e.g., the 2016 values are assumed to apply to years 2017-2019;

2020 values for years 2021-2024; 2025 values for years 2026-2029; and 2030 values for years 2031 and beyond). See Chapter 3 of the TSD for the benefit per ton values used in this analysis.

[b] GHG benefit estimates include reductions in CO2, CH4, and N2O but do not include HFC reductions. Note that net present value of reduced GHG emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SC-CO2, SC-CH4, and SC-N2O, each discounted at rates of 5, 3, 2.5 percent) is used to calculate net present value of SC-CO2, SC-CH4, and SC-N2O, respectively, for internal consistency. Refer to Chapter 3 of the TSD for more detail.

[c] Chapter 3 of the TSD notes that SC-GHGs increase over time. Corresponding to the years in this table (2021-2025), the SC-CO2 estimates range as follows: for Average SC-CO2 at 5%: $14-$16; for Average SC-CO2 at 3%: $47-$52; for Average SC-CO2 at 2.5%: $71-$77; and for 95th percentile SC-CO2 at 3%: $140-$160. For the years 2021-2025, the SC-CH4 estimates range as follows: for Average SC-CH4 at 5%: $640-$730; for Average SC-CH4 at 3%: $1,400-$1,600; for Average SC-CH4 at 2.5%: $1,900-$2,000; and for 95th percentile SC-CH4 at 3%: $3,700-$4,200. For the years 2021-2025, the SC-N2O estimates range as follows: for Average SC-N2O at 5%: $5,500-$6,200; for Average SC-N2O at 3%: $17,000-$19,000; for Average SC-N2O at 2.5%: $25,000-$27,000; and for 95th percentile SC-N2O at 3%: $45,000-$50,000. TSD Chapter 3 also presents these SC-GHG estimates.

Table C.83 MY Lifetime Costs & Benefits Using AEO High Fuel Prices (7 Percent Discount Rate, Billions of 2015$)[a,b,c]

	2021	2022	2023	2024	2025	Sum
Vehicle Program	-$1.6	-$3.3	-$4.9	-$6.2	-$7.2	-$23.1
Maintenance	-$0.2	-$0.3	-$0.3	-$0.3	-$0.4	-$1.4
Pre-tax Fuel	$5.8	$11.6	$17.0	$21.2	$24.3	$80.0
Energy Security	$0.2	$0.3	$0.5	$0.6	$0.7	$2.4
Crashes, Noise, Congestion	-$0.4	-$0.7	-$1.1	-$1.3	-$1.5	-$4.9
Travel Value	$0.6	$1.3	$1.8	$2.2	$2.5	$8.4
Refueling	$0.3	$0.6	$0.8	$1.0	$1.2	$3.9
Non-GHG	$0.2 - $0.4	$0.4 - $0.8	$0.5 - $1.1	$0.6 - $1.4	$0.7 - $1.6	$2.4 - $5.4
GHG						
SC-GHG 5% Avg	$0.3	$0.6	$0.9	$1.1	$1.3	$4.2
SC-GHG 3% Avg	$1.1	$2.4	$3.6	$4.7	$5.7	$17.6
SC-GHG 2.5% Avg	$1.8	$3.7	$5.6	$7.3	$8.8	$27.3
SC-GHG 3% 95th	$3.4	$7.2	$11.0	$14.2	$17.1	$52.9
Net Benefits						
SC-GHG 5% Avg	$5.3	$10.7	$15.6	$19.4	$22.3	$73.3
SC-GHG 3% Avg	$6.2	$12.5	$18.4	$23.0	$26.6	$86.7
SC-GHG 2.5% Avg	$6.8	$13.8	$20.4	$25.6	$29.8	$96.4
SC-GHG 3% 95th	$8.5	$17.3	$25.7	$32.5	$38.1	$122.1

Notes:

[a] The non-GHG benefits presented in this table are based on PM2.5-related benefit per ton values (see Chapter 3 of the TSD); the range of benefits are derived from two premature mortality estimates - the American Cancer Society cohort study (Krewski et al., 2009) and the Harvard Six-Cities study (Lepeule et al., 2012). The range of benefits also assumes either a 3 percent or 7 percent discount rate in the valuation of PM-related premature mortality to account for a twenty-year segmented cessation lag. Benefit-per-ton values were estimated for the years 2016, 2020, 2025 and 2030. We hold values constant for intervening years (e.g., the 2016 values are assumed to apply to years 2017-2019; 2020 values for years 2021-2024; 2025 values for years 2026-2029; and 2030 values for years 2031 and beyond). See Chapter 3 of the TSD for the benefit per ton values used in this analysis.

[b] GHG benefit estimates include reductions in CO2, CH4, and N2O but do not include HFC reductions. Note that net present value of reduced GHG emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SC-CO2, SC-CH4, and SC-N2O, each discounted at rates of 5, 3, 2.5 percent) is used to calculate net present value of SC-CO2, SC-CH4, and SC-N2O, respectively, for internal consistency. Refer to Chapter 3 of the TSD for more detail.

[c] Chapter 3 of the TSD notes that SC-GHGs increase over time. Corresponding to the years in this table (2021-2025), the SC-CO2 estimates range as follows: for Average SC-CO2 at 5%: $14-$16; for Average SC-CO2 at 3%: $47-$52; for Average SC-CO2 at 2.5%: $71-$77; and for 95th percentile SC-CO2 at 3%: $140-$160. For the years 2021-2025, the SC-CH4 estimates range as follows: for Average SC-CH4 at 5%: $640-$730; for Average SC-CH4 at 3%: $1,400-$1,600; for Average SC-CH4 at 2.5%: $1,900-$2,000; and for 95th percentile SC-CH4 at 3%: $3,700-$4,200. For the years 2021-2025, the SC-N2O estimates range as follows: for Average SC-N2O at 5%: $5,500-$6,200; for Average SC-N2O at 3%: $17,000-$19,000; for Average SC-N2O at 2.5%: $25,000-$27,000; and for 95th percentile SC-N2O at 3%: $45,000-$50,000. TSD Chapter 3 also presents these SC-GHG estimates.

C.3.2.3 AEO 2016 Low Fuel Price Case

In the AEO low fuel price analysis, we use AEO 2016 low fuel prices and fleet projections, and we include our estimate of BEV and PHEV sales required by the ZEV program in the reference and control case fleets. Note that in this analysis of AEO high and low fuel price sensitivities, we have corrected an error in the Draft TAR, in which we inadvertently applied AEO reference fuel prices in calculating monetized fuel savings to both the AEO high and low fuel price cases. Importantly, Table C.84, which uses a 3 percent discount rate, shows that technology and maintenance costs are estimated at roughly $38 billion ($34.7+3.1) and benefits excluding fuel savings are estimated at roughly $43 billion (includes energy security; crashes, noise, congestion; travel; refueling; mid-point of non-GHG; and, the 3 percent average SC-GHG value). In other words, even without fuel savings, benefits outweigh costs. Similarly, Table C.85 , which uses a 7 percent discount rate, shows that technology and maintenance costs are estimated at roughly $27 billion ($25.4+1.8) and benefits excluding fuel savings are estimated at roughly $33 billion (includes energy security; crashes, noise, congestion; travel; refueling; mid-point of non-GHG; and, the 3 percent average SC-GHG value). In other words, even without fuel savings, benefits outweigh costs.

Table C.84 MY Lifetime Costs & Benefits Using AEO Low Fuel Prices (3 Percent Discount Rate, Billions of 2015$)[a,b,c]

	2021	2022	2023	2024	2025	Sum
Vehicle Program	-$2.1	-$4.7	-$7.1	-$9.3	-$11.5	-$34.7
Maintenance	-$0.4	-$0.5	-$0.6	-$0.8	-$0.9	-$3.1
Pre-tax Fuel	$4.1	$8.4	$12.5	$16.3	$20.1	$61.3
Energy Security	$0.3	$0.7	$1.0	$1.3	$1.7	$5.0
Crashes, Noise, Congestion	-$0.7	-$1.3	-$1.9	-$2.5	-$3.0	-$9.4
Travel Value	$0.5	$1.0	$1.5	$1.9	$2.3	$7.2
Refueling	$0.6	$1.1	$1.7	$2.2	$2.7	$8.3
Non-GHG	$0.4 - $0.9	$0.8 - $1.9	$1.3 - $2.8	$1.7 - $3.7	$2.1 - $4.6	$6.2 - $14.0
GHG						
SC-GHG 5% Avg	$0.3	$0.7	$1.1	$1.4	$1.7	$5.2
SC-GHG 3% Avg	$1.4	$2.9	$4.4	$5.8	$7.2	$21.7
SC-GHG 2.5% Avg	$2.2	$4.6	$6.8	$9.0	$11.2	$33.7
SC-GHG 3% 95th	$4.3	$8.8	$13.3	$17.4	$21.7	$65.5
Net Benefits						
SC-GHG 5% Avg	$3.3	$6.8	$10.1	$13.2	$16.4	$49.9
SC-GHG 3% Avg	$4.4	$9.0	$13.5	$17.6	$21.9	$66.4
SC-GHG 2.5% Avg	$5.2	$10.6	$15.9	$20.8	$25.9	$78.4
SC-GHG 3% 95th	$7.2	$14.9	$22.4	$29.3	$36.4	$110.2

Notes:

[a] The non-GHG benefits presented in this table are based on PM2.5-related benefit per ton values (see Chapter 3 of the TSD); the range of benefits are derived from two premature mortality estimates - the American Cancer Society cohort study (Krewski et al., 2009) and the Harvard Six-Cities study (Lepeule et al., 2012). The range of benefits also assumes either a 3 percent or 7 percent discount rate in the valuation of PM-related premature mortality to account for a twenty-year segmented cessation lag. Benefit-per-ton values were estimated for the years 2016, 2020, 2025 and 2030. We hold values constant for intervening years (e.g., the 2016 values are assumed to apply to years 2017-2019; 2020 values for years 2021-2024; 2025 values for years 2026-2029; and 2030 values for years 2031 and beyond). See Chapter 3 of the TSD for the benefit per ton values used in this analysis.

[b] GHG benefit estimates include reductions in CO2, CH4, and N2O but do not include HFC reductions. Note that net present value of reduced GHG emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SC-CO2, SC-CH4, and SC-N2O, each discounted at rates of 5, 3, 2.5 percent) is used to calculate net present value of SC-CO2, SC-CH4, and SC-N2O, respectively, for internal consistency. Refer TSD Chapter 3 for more detail.

[c] Chapter 3 of the TSD notes that SC-GHGs increase over time. Corresponding to the years in this table (2021-2025), the SC-CO2 estimates range as follows: for Average SC-CO2 at 5%: $14-$16; for Average SC-CO2 at 3%: $47-$52; for Average SC-CO2 at 2.5%: $71-$77; and for 95th percentile SC-CO2 at 3%: $140-$160. For the years 2021-2025, the SC-CH4 estimates range as follows: for Average SC-CH4 at 5%: $640-$730; for Average SC-CH4 at 3%: $1,400-$1,600; for Average SC-CH4 at 2.5%: $1,900-$2,000; and for 95th percentile SC-CH4 at 3%: $3,700-$4,200. For the years 2021-2025, the SC-N2O estimates range as follows: for Average SC-N2O at 5%: $5,500-$6,200; for Average SC-N2O at 3%: $17,000-$19,000; for Average SC-N2O at 2.5%: $25,000-$27,000; and for 95th percentile SC-N2O at 3%: $45,000-$50,000. TSD Chapter 3 also presents these SC-GHG estimates.

Table C.85 MY Lifetime Costs & Benefits Using AEO Low Fuel Prices (7 Percent Discount Rate, Billions of 2015$)[a,b,c]

	2021	2022	2023	2024	2025	Sum
Vehicle Program	-$1.7	-$3.6	-$5.3	-$6.7	-$8.0	-$25.4
Maintenance	-$0.2	-$0.3	-$0.4	-$0.4	-$0.5	-$1.8
Pre-tax Fuel	$2.6	$5.1	$7.3	$9.1	$10.9	$34.9
Energy Security	$0.2	$0.4	$0.6	$0.8	$0.9	$2.9
Crashes, Noise, Congestion	-$0.4	-$0.8	-$1.2	-$1.4	-$1.7	-$5.5
Travel Value	$0.3	$0.6	$0.9	$1.1	$1.2	$4.1
Refueling	$0.4	$0.7	$1.0	$1.2	$1.5	$4.8
Non-GHG	$0.2 - $0.5	$0.5 - $1.0	$0.7 - $1.5	$0.9 - $1.9	$1.0 - $2.3	$3.2 - $7.3
GHG						
SC-GHG 5% Avg	$0.3	$0.7	$1.1	$1.4	$1.7	$5.2
SC-GHG 3% Avg	$1.4	$2.9	$4.4	$5.8	$7.2	$21.7
SC-GHG 2.5% Avg	$2.2	$4.6	$6.8	$9.0	$11.2	$33.7
SC-GHG 3% 95th	$4.3	$8.8	$13.3	$17.4	$21.7	$65.5
Net Benefits						
SC-GHG 5% Avg	$1.8	$3.5	$5.0	$6.4	$7.7	$24.4
SC-GHG 3% Avg	$2.9	$5.7	$8.4	$10.8	$13.1	$40.9
SC-GHG 2.5% Avg	$3.6	$7.3	$10.8	$14.0	$17.1	$52.9
SC-GHG 3% 95th	$5.7	$11.6	$17.3	$22.4	$27.6	$84.6

Notes:

[a] The non-GHG benefits presented in this table are based on PM2.5-related benefit per ton values (see Chapter 3 of the TSD); the range of benefits are derived from two premature mortality estimates - the American Cancer Society cohort study (Krewski et al., 2009) and the Harvard Six-Cities study (Lepeule et al., 2012). The range of benefits also assumes either a 3 percent or 7 percent discount rate in the valuation of PM-related premature mortality to account for a twenty-year segmented cessation lag. Benefit-per-ton values were estimated for the years 2016, 2020, 2025 and 2030. We hold values constant for intervening years (e.g., the 2016 values are assumed to apply to years 2017-2019; 2020 values for years 2021-2024; 2025 values for years 2026-2029; and 2030 values for years 2031 and beyond). See Chapter 3 of the TSD for the benefit per ton values used in this analysis.

[b] GHG benefit estimates include reductions in CO2, CH4, and N2O but do not include HFC reductions. Note that net present value of reduced GHG emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SC-CO2, SC-CH4, and SC-N2O, each discounted at rates of 5, 3, 2.5 percent) is used to calculate net present value of SC-CO2, SC-CH4, and SC-N2O, respectively, for internal consistency. Refer to TSD Chapter 3 for more detail.

[c] Chapter 3 of the TSD notes that SC-GHGs increase over time. Corresponding to the years in this table (2021-2025), the SC-CO2 estimates range as follows: for Average SC-CO2 at 5%: $14-$16; for Average SC-CO2 at 3%: $47-$52; for Average SC-CO2 at 2.5%: $71-$77; and for 95th percentile SC-CO2 at 3%: $140-$160. For the years 2021-2025, the SC-CH4 estimates range as follows: for Average SC-CH4 at 5%: $640-$730; for Average SC-CH4 at 3%: $1,400-$1,600; for Average SC-CH4 at 2.5%: $1,900-$2,000; and for 95th percentile SC-CH4 at 3%: $3,700-$4,200. For the years 2021-2025, the SC-N2O estimates range as follows: for Average SC-N2O at 5%: $5,500-$6,200; for Average SC-N2O at 3%: $17,000-$19,000; for Average SC-N2O at 2.5%: $25,000-$27,000; and for 95th percentile SC-N2O at 3%: $45,000-$50,000. TSD Chapter 3 also presents these SC-GHG estimates.

C.3.2.4 Summary of Model Year (MY) Lifetime Benefit-Cost Analysis Results

Table C.86 summarizes EPA's model year lifetime BCA results. The differences in all categories when comparing across fuel price cases are the result of the different fleet makeups across fuel prices, different ZEV program sales projections across fuel prices cases, and the different fuel prices themselves and their impact on fuel savings. The benefits values include: energy security; crashes, noise, congestion; travel; refueling; mid-point of non-GHG; and, the 3 percent average SC-GHG value.

Table C.86 MY Lifetime Costs & Benefits in Each AEO Fuel Price Case (Billions of 2015$)

	3 Percent Discount Rate			7 Percent Discount Rate		
	AEO Low	AEO Ref	AEO High	AEO Low	AEO Ref	AEO High
Vehicle Program	-$34.7	-$32.6	-$31.6	-$25.4	-$23.9	-$23.1
Maintenance	-$3.1	-$2.9	-$2.4	-$1.8	-$1.7	-$1.4
Fuel	$61.3	$91.6	$138.7	$34.9	$52.2	$80.0
Benefits	$42.9	$41.9	$42.2	$33.2	$31.9	$31.3
Net Benefits	$66.4	$98.0	$147.0	$40.9	$58.5	$86.7

Note: Benefits and Net Benefits values presented here use the mid-point value of the non-GHG range for the applicable discount rate and the central SC-GHG values (average SC-CO2, average SC-CH4, and average SC-N2O, each at 3 percent) discounted at 3 percent in all cases.

Importantly, Table C.86 shows that, in all cases, the monetized net benefits are greater than the fuel savings. In other words, even excluding fuel savings, the benefits of the standards outweigh the costs.

C.3.3 Calendar Year Analysis

In our calendar year (CY) analysis, we look at the impacts year-over-year through the year 2050. All annual values are presented without discounting and the stream of values for the years 2021 through 2050 are then discounted back to the year 2016 at both 3 and 7 percent discount rates, with the exception that all social costs of greenhouse gases are discounted at the discount rate used in their generation.

C.3.3.1 Central Analysis: AEO 2016 Reference Fuel Price Case

In the central analysis, we use AEO 2016 reference fuel prices and fleet projections, and we include our estimate of BEV and PHEV sales required by the ZEV program in the reference case fleet.

Table C.87 Annual Costs & Benefits Using AEO Reference Fuel Prices (Billions of 2015$) [a,b,c]

	2025	2030	2040	2050	NPV, 3%	NPV, 7%
Vehicle Program	-$14.4	-$14.6	-$16.4	-$18.4	-$241.3	-$119.3
Maintenance	-$0.3	-$0.8	-$1.3	-$1.7	-$15.0	-$6.6
Pre-tax Fuel	$9.8	$26.9	$60.0	$75.6	$617.9	$261.2
Energy Security	$0.5	$1.4	$2.9	$3.7	$30.5	$12.9
Crashes, Noise, Congestion	-$1.1	-$2.7	-$4.9	-$6.1	-$53.9	-$23.3
Travel Value	$1.1	$2.9	$6.3	$7.9	$65.5	$27.8
Refueling	$0.8	$2.2	$4.5	$6.4	$49.7	$21.1
Non-GHG	$0.6 - $1.5	$1.6 - $4.0	$2.9 - $7.2	$3.6 - $9.0	$35.1 - $78.5	$13.6 - $30.4
GHG						
SC-GHG 5% Avg	$0.7	$1.9	$4.5	$7.0	$30.0	$30.0
SC-GHG 3% Avg	$2.1	$5.8	$12.7	$18.4	$136.0	$136.0
SC-GHG 2.5% Avg	$3.1	$8.4	$17.7	$25.2	$215.0	$215.0
SC-GHG 3% 95th	$6.3	$17.5	$38.5	$56.3	$414.1	$414.1
Net Benefits						
SC-GHG 5% Avg	-$1.8	$20.0	$60.5	$80.5	$540.2	$225.9
SC-GHG 3% Avg	-$0.4	$23.9	$68.7	$91.9	$646.1	$331.8
SC-GHG 2.5% Avg	$0.6	$26.5	$73.7	$98.8	$725.2	$410.9
SC-GHG 3% 95th	$3.9	$35.6	$94.5	$129.8	$924.2	$609.9

Notes:

[a] The non-GHG benefits presented in this table are based on PM2.5-related benefit per ton values (see Chapter 3 of the TSD); the range of benefits are derived from two premature mortality estimates - the American Cancer Society cohort study (Krewski et al., 2009) and the Harvard Six-Cities study (Lepeule et al., 2012). The range of benefits also assumes either a 3 percent or 7 percent discount rate in the valuation of PM-related premature mortality to account for a twenty-year segmented cessation lag. Benefit-per-ton values were estimated for the years 2016, 2020, 2025 and 2030. We hold values constant for intervening years (e.g., the 2016 values are assumed to apply to years 2017-2019; 2020 values for years 2021-2024; 2025 values for years 2026-2029; and 2030 values for years 2031 and beyond). See Chapter 3 of the TSD for the benefit per ton values used in this analysis.

[b] GHG benefit estimates include reductions in CO2, CH4, and N2O but do not include HFC reductions. Note that net present value of reduced GHG emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SC-CO2, SC-CH4, and SC-N2O, each discounted at rates of 5, 3, 2.5 percent) is used to calculate net present value of SC-CO2, SC-CH4, and SC-N2O, respectively, for internal consistency. Refer to TSD Chapter 3 for more detail.

[c] Chapter 3 of the TSD notes that SC-GHGs increase over time. Corresponding to the years in this table (2021-2025), the SC-CO2 estimates range as follows: for Average SC-CO2 at 5%: $14-$16; for Average SC-CO2 at 3%: $47-$52; for Average SC-CO2 at 2.5%: $71-$77; and for 95th percentile SC-CO2 at 3%: $140-$160. For the years 2021-2025, the SC-CH4 estimates range as follows: for Average SC-CH4 at 5%: $640-$730; for Average SC-CH4 at 3%: $1,400-$1,600; for Average SC-CH4 at 2.5%: $1,900-$2,000; and for 95th percentile SC-CH4 at 3%: $3,700-$4,200. For the years 2021-2025, the SC-N2O estimates range as follows: for Average SC-N2O at 5%: $5,500-$6,200; for Average SC-N2O at 3%: $17,000-$19,000; for Average SC-N2O at 2.5%: $25,000-$27,000; and for 95th percentile SC-N2O at 3%: $45,000-$50,000. TSD Chapter 3 also presents these SC-GHG estimates.

C.3.3.2 AEO 2016 High Fuel Price Case

In the AEO high fuel price analysis, we use AEO 2016 high fuel prices and fleet projections, and we include our estimate of BEV and PHEV sales required by the ZEV program in the reference case fleet.

Table C.88 Annual Costs & Benefits Using AEO High Fuel Prices (Billions of 2015$) [a,b,c]

	2025	2030	2040	2050	NPV, 3%	NPV, 7%
Vehicle Program	-$13.6	-$13.1	-$14.7	-$16.5	-$218.9	-$108.9
Maintenance	-$0.3	-$0.6	-$1.1	-$1.3	-$12.2	-$5.4
Pre-tax Fuel	$15.6	$39.8	$77.2	$96.4	$835.6	$359.7
Energy Security	$0.4	$1.2	$2.5	$3.1	$26.0	$11.1
Crashes, Noise, Congestion	-$1.0	-$2.4	-$4.3	-$5.3	-$47.8	-$20.8
Travel Value	$1.7	$4.1	$7.9	$9.8	$85.5	$36.9
Refueling	$0.8	$2.0	$3.9	$5.4	$42.5	$18.1
Non-GHG	$0.5 - $1.2	$1.3 - $3.1	$2.2 - $5.5	$2.8 - $6.8	$27.2 - $60.9	$10.6 - $23.7
GHG						
SC-GHG 5% Avg	$0.6	$1.6	$3.7	$5.8	$25.3	$25.3
SC-GHG 3% Avg	$1.9	$5.0	$10.6	$15.2	$114.3	$114.3
SC-GHG 2.5% Avg	$2.8	$7.2	$14.8	$20.9	$180.7	$180.7
SC-GHG 3% 95th	$5.7	$15.1	$32.1	$46.5	$348.1	$348.1
Net Benefits						
SC-GHG 5% Avg	$5.0	$34.7	$78.9	$102.0	$780.0	$333.2
SC-GHG 3% Avg	$6.3	$38.1	$85.7	$111.4	$869.1	$422.2
SC-GHG 2.5% Avg	$7.2	$40.3	$89.9	$117.0	$935.5	$488.6
SC-GHG 3% 95th	$10.1	$48.1	$107.3	$142.7	$1,102.9	$656.0

Notes:

[a] The non-GHG benefits presented in this table are based on PM2.5-related benefit per ton values (see Chapter 3 of the TSD); the range of benefits are derived from two premature mortality estimates - the American Cancer Society cohort study (Krewski et al., 2009) and the Harvard Six-Cities study (Lepeule et al., 2012). The range of benefits also assumes either a 3 percent or 7 percent discount rate in the valuation of PM-related premature mortality to account for a twenty-year segmented cessation lag. Benefit-per-ton values were estimated for the years 2016, 2020, 2025 and 2030. We hold values constant for intervening years (e.g., the 2016 values are assumed to apply to years 2017-2019; 2020 values for years 2021-2024; 2025 values for years 2026-2029; and 2030 values for years 2031 and beyond). See Chapter 3 of the TSD for the benefit per ton values used in this analysis.

[b] GHG benefit estimates include reductions in CO2, CH4, and N2O but do not include HFC reductions. Note that net present value of reduced GHG emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SC-CO2, SC-CH4, and SC-N2O, each discounted at rates of 5, 3, 2.5 percent) is used to calculate net present value of SC-CO2, SC-CH4, and SC-N2O, respectively, for internal consistency. Refer to TSD Chapter 3 for more detail.

[c] Chapter 3 of the TSD notes that SC-GHGs increase over time. Corresponding to the years in this table (2021-2025), the SC-CO2 estimates range as follows: for Average SC-CO2 at 5%: $14-$16; for Average SC-CO2 at 3%: $47-$52; for Average SC-CO2 at 2.5%: $71-$77; and for 95th percentile SC-CO2 at 3%: $140-$160. For the years 2021-2025, the SC-CH4 estimates range as follows: for Average SC-CH4 at 5%: $640-$730; for Average SC-CH4 at 3%: $1,400-$1,600; for Average SC-CH4 at 2.5%: $1,900-$2,000; and for 95th percentile SC-CH4 at 3%: $3,700-$4,200. For the years 2021-2025, the SC-N2O estimates range as follows: for Average SC-N2O at 5%: $5,500-$6,200; for Average SC-N2O at 3%: $17,000-$19,000; for Average SC-N2O at 2.5%: $25,000-$27,000; and for 95th percentile SC-N2O at 3%: $45,000-$50,000. TSD Chapter 3 also presents these SC-GHG estimates.

C.3.3.3 AEO 2016 Low Fuel Price Case

In the AEO low fuel price analysis, we use AEO 2016 low fuel prices and fleet projections, and we include our estimate of BEV and PHEV sales required by the ZEV program in the reference case fleet.

Table C.89 Annual Costs & Benefits Using AEO Low Fuel Prices (Billions of 2015$) [a,b,c]

	2025	2030	2040	2050	NPV, 3%	NPV, 7%
Vehicle Program	-$15.3	-$16.1	-$18.1	-$20.3	-$264.4	-$130.2
Maintenance	-$0.4	-$0.9	-$1.6	-$2.0	-$17.7	-$7.7
Pre-tax Fuel	$6.7	$17.9	$43.1	$54.8	$434.5	$182.1
Energy Security	$0.5	$1.5	$3.3	$4.2	$34.5	$14.6
Crashes, Noise, Congestion	-$1.1	-$2.9	-$5.3	-$6.8	-$58.6	-$25.3
Travel Value	$0.8	$2.1	$4.7	$6.0	$48.5	$20.5
Refueling	$0.9	$2.5	$5.2	$7.3	$56.3	$23.8
Non-GHG	$0.7 - $1.6	$1.8 - $4.5	$3.4 - $8.3	$4.2 - $10.6	$40.6 - $90.9	$15.7 - $35.1
GHG						
SC-GHG 5% Avg	$0.7	$2.1	$5.1	$8.1	$34.1	$34.1
SC-GHG 3% Avg	$2.3	$6.5	$14.4	$21.1	$154.6	$154.6
SC-GHG 2.5% Avg	$3.4	$9.4	$20.2	$29.0	$244.5	$244.5
SC-GHG 3% 95th	$7.0	$19.7	$43.9	$64.7	$470.9	$470.9
Net Benefits						
SC-GHG 5% Avg	-$6.0	$9.3	$42.2	$58.5	$333.0	$137.3
SC-GHG 3% Avg	-$4.4	$13.7	$51.5	$71.6	$453.5	$257.8
SC-GHG 2.5% Avg	-$3.3	$16.7	$57.2	$79.5	$543.4	$347.7
SC-GHG 3% 95th	$0.3	$26.9	$81.0	$115.1	$769.7	$574.1

Notes:

[a] The non-GHG benefits presented in this table are based on PM2.5-related benefit per ton values (see Chapter 3 of the TSD); the range of benefits are derived from two premature mortality estimates - the American Cancer Society cohort study (Krewski et al., 2009) and the Harvard Six-Cities study (Lepeule et al., 2012). The range of benefits also assumes either a 3 percent or 7 percent discount rate in the valuation of PM-related premature mortality to account for a twenty-year segmented cessation lag. Benefit-per-ton values were estimated for the years 2016, 2020, 2025 and 2030. We hold values constant for intervening years (e.g., the 2016 values are assumed to apply to years 2017-2019; 2020 values for years 2021-2024; 2025 values for years 2026-2029; and 2030 values for years 2031 and beyond). See Chapter 3 of the TSD for the benefit per ton values used in this analysis.

[b] GHG benefit estimates include reductions in CO2, CH4, and N2O but do not include HFC reductions. Note that net present value of reduced GHG emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SC-CO2, SC-CH4, and SC-N2O, each discounted at rates of 5, 3, 2.5 percent) is used to calculate net present value of SC-CO2, SC-CH4, and SC-N2O, respectively, for internal consistency. Refer to TSD Chapter 3 for more detail.

[c] Chapter 3 of the TSD notes that SC-GHGs increase over time. Corresponding to the years in this table (2021-2025), the SC-CO2 estimates range as follows: for Average SC-CO2 at 5%: $14-$16; for Average SC-CO2 at 3%: $47-$52; for Average SC-CO2 at 2.5%: $71-$77; and for 95th percentile SC-CO2 at 3%: $140-$160. For the years 2021-2025, the SC-CH4 estimates range as follows: for Average SC-CH4 at 5%: $640-$730; for Average SC-CH4 at 3%: $1,400-$1,600; for Average SC-CH4 at 2.5%: $1,900-$2,000; and for 95th percentile SC-CH4 at 3%: $3,700-$4,200. For the years 2021-2025, the SC-N2O estimates range as follows: for Average SC-N2O at 5%: $5,500-$6,200; for Average SC-N2O at 3%: $17,000-$19,000; for Average SC-N2O at 2.5%: $25,000-$27,000; and for 95th percentile SC-N2O at 3%: $45,000-$50,000. TSD Chapter 3 also presents these SC-GHG estimates.

C.3.3.4 Summary of Calendar Year (CY) Benefit-Cost Analysis Results

In our CY analysis, we look at the impacts of the MY2022-2025 standards year-over-year through the year 2050. All annual values are discounted back to the year 2016 at both 3 and 7 percent discount rates with the exception that all social costs of greenhouse gases are discounted at the discount rate used in their generation. The table below summarizes the net present values presented in the calendar year analysis tables above using the 3 percent average SCC value.

Table C.90 CY Net Present Value Costs & Benefits in Each AEO Fuel Price Case (Billions of 2015$)

	3 Percent Discount Rate			7 Percent Discount Rate		
	AEO Low	AEO Ref	AEO High	AEO Low	AEO Ref	AEO High
Vehicle Program	-$264.4	-$241.3	-$218.9	-$130.2	-$119.3	-$108.9
Maintenance	-$17.7	-$15.0	-$12.2	-$7.7	-$6.6	-$5.4
Fuel	$434.5	$617.9	$835.6	$182.1	$261.2	$359.7
Benefits	$301.1	$284.6	$264.6	$213.6	$196.5	$176.8
Net Benefits	$453.5	$646.1	$869.1	$257.8	$331.8	$422.2

Note: Benefits and Net Benefits values presented here use the mid-point value of the non-GHG range for the applicable discount rate and the central SC-GHG values (average SC-CO2, average SC-CH4, and average SC-N2O, each at 3 percent) discounted at 3 percent in all cases.

As noted above in our MY analysis summary, in all cases, the net benefits are greater than the fuel savings. In other words, even excluding fuel savings, the benefits of the standards outweigh the costs.