



OFFICE OF THE GOVERNOR

March 15, 2017

The Honorable Scott Pruitt
Administrator, U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, D.C. 20460

Dear Administrator Pruitt:

President Trump's decision today to weaken emission standards in cars is an unconscionable gift to polluters. Once again, you've put the interests of big oil ahead of clean air and politics ahead of science.

And these actions have very bad consequences.

In fact, your agency's own analysis shows that over the lifetime of these cars, the 2022-25 vehicle emission standards would:

- Save consumers more than \$1,650 per vehicle.
- Reduce oil consumption by nearly 40 billion gallons of refined gasoline and diesel fuel.
- Decrease greenhouse gas emissions by 540 million metric tons.

I have attached three separate reports produced by scientists, engineers and other experts analyzing the feasibility of the standards in question. All three reports demonstrate that America is on track to meet these standards. The technology is advancing and costs are coming down.

If Washington continues down this road, California will take the necessary actions to preserve current standards and protect the health of our people and the stability of our climate. We can't stand by while cases of lung disease and asthma needlessly increase and families get gouged at the pump.

When Richard Nixon established the Environmental Protection Agency in 1970, he noted that: "The Congress, the Administration and the public all share a profound commitment to the rescue of our natural environment, and the preservation of the Earth as a place both habitable by and hospitable to man."

Now is not the time to turn our back on that commitment.

Sincerely,

A handwritten signature in black ink, reading 'Edmund G. Brown Jr.', with a stylized flourish at the end.

Edmund G. Brown Jr.

January 18, 2017



California's Advanced Clean Cars Midterm Review

*Summary Report for the Technical Analysis
of the Light Duty Vehicle Standards*

California Environmental Protection Agency

 **Air Resources Board**

Executive Summary

In 2012, the California Air Resources Board (ARB or the Board) adopted the Advanced Clean Cars (ACC) program, a comprehensive set of standards for new vehicles in California through model year 2025. The components of the ACC program are the Low-Emission Vehicle III (LEV III) regulations that reduce criteria pollutants and greenhouse (GHG) emissions from light- and medium-duty vehicles for model years 2015 through 2025 and the zero-emission vehicle (ZEV) regulation, which acts as the focused technology-forcing piece of the ACC program by requiring manufacturers to produce increasing numbers of pure ZEVs (that is battery electric and fuel cell electric vehicles) and plug-in hybrid electric vehicles (PHEV) in the 2018 through 2025 model years.

When adopting these standards, the Board directed staff to conduct reviews specific to the California standards: the ZEV regulation, the 1 milligram per mile (mg/mi) particulate matter (PM) emission standard, and a general review of the format of the GHG standards, and to return with staff's review no later than December 2016. This document and its associated appendices reflect the staff assessment in response to the Board. Table ES.1 displays summaries of the Board direction to staff from the adopted Board resolution. Additionally, the Board also committed to participating in a joint-agency review with the United States Environmental Protection Agency (U.S. EPA) and the National Highway Traffic Safety Administration (NHTSA) of the 2022 through 2025 model year GHG vehicle standards.

Table ES.1. Key Board Direction in 2012 Advanced Clean Cars Resolution

<i>Program</i>	<i>Board Resolution Direction</i>
GHG	Participate in a joint-agency midterm evaluation with the U.S. EPA and NHTSA of the federal passenger vehicle GHG standards and corporate average fuel economy (CAFE) standards for the 2022 through 2025 model years
	Monitor consumer purchasing trends and California's fleet mix to evaluate any potential shift in vehicle footprint to larger, higher polluting vehicles and the reclassification of cars as trucks
PM	Re-examine the measurement methods, stringency, and timing of the adopted 2025 model year 1 mg/mi PM emission standard
ZEV	Monitor consumer acceptance of PHEVs and report on expected volumes in the ZEV program
	Analyze in-use data for range extended battery electric vehicles (BEVx) and PHEVs, and propose appropriate modifications as needed

Technology Progress since 2012

A significant part of the review focused on progress in technology since the original analysis and adoption of the standards in 2012. Advancements have already occurred in the vehicle and engine technologies being introduced by vehicle manufacturers to reduce GHG and criteria pollutant emissions including PM. ZEV technology has also seen significant development that, in many cases, is beyond what was envisioned just four years ago.

GHG Emission Control Technology Developments

- Manufacturers have successfully employed a variety of technologies that reduce GHG emissions and increase fuel efficiency many at a faster rate of deployment than was originally projected, notably, large penetration rates of advanced engine and transmissions across the industry in the last five years.
- Currently, manufacturers are over complying with the GHG requirements¹ and are offering various vehicles on the road today that are already able to comply with the GHG standards for later model years. For example, of the more than 1,300 conventional vehicle model configurations available in 2016, 23 truck configurations,² 23 sport utility vehicle (SUV) configurations,³ and 26 passenger car configurations⁴ meet 2020 or later GHG standards with a conventional gasoline powertrain. An additional 78 model variants comprised of hybrid electric vehicles (HEVs), PHEVs, and BEVs also meet the 2020 or later standards.

PM and Criteria Pollutant Emission Control Technology Developments

- In response largely to the ZEV regulation, manufacturers have been marketing passenger cars and SUVs meeting the 2025 LEV III criteria pollutant fleet average requirement of super ultra-low emissions vehicles (SULEV30) for over a decade. Sixteen manufacturers certified 74 vehicle models to the SULEV30 standards in 2016, including mainstream models like the Honda Civic, Chevrolet Impala, Nissan Altima, and Jeep Cherokee. The technology to meet this stringent requirement is well defined and manufacturers have significant lead time to incorporate it across their fleets.
- Testing data confirms that newer gasoline direct injection (GDI) vehicles have significantly lower PM emissions than earlier generation GDI vehicles and are readily capable today of meeting the upcoming 3 mg/mi standard with typical emission rates from 1.2-1.5 mg/mi.
- These significant advances in PM control from GDI engines position manufacturers well to make the final refinements in control towards the 1 mg/mi PM standard.

¹ EPA 2015a. United States Environmental Protection Agency. *Greenhouse Gas Emission Standards for Light-Duty Vehicles: Manufacturer Performance Report for the 2014 Model Year*. EPA-420-R-15-026. December 2015.

<https://nepis.epa.gov/Exe/ZyPDF.cgi/P100O5TH.PDF?Dockey=P100O5TH.PDF>

² Some variants of the F-150 meet the 2024 GHG standards while some variants of the Ram 1500 and the Chevrolet Silverado meet the 2021 GHG standards

³ Such as the Subaru Outback, the Nissan Rogue, and the Honda CR-V. Includes minivans and station wagons classified as trucks.

⁴ Such as the Mazda 6, the Hyundai Sonata, and the Honda Civic

ZEV Technology Developments

- Through August 2016, nearly 230,000 ZEVs and PHEVs have been registered in California, with an additional 62,000 in nine Section 177 states that have adopted California's ZEV regulation. These contribute towards the more than half a million ZEVs and PHEVs in the U.S. and the expected 2 million ZEVs and PHEVs around the world by year's end.
- Battery technology has improved and battery costs (as well as other component costs) have fallen dramatically (largely due to reduced material costs, manufacturing improvements, and higher manufacturing volumes), leading to an increase from 25 PHEV and BEV models offered today to manufacturer announcements of more than 70 unique models to be released over the next 5 model years.
- ZEV electric infrastructure in California and Section 177 ZEV states has grown with substantial investments in the past several years, and accelerated investments are expected as new infrastructure developments emerge. Over 17,000 Level 2 and 2,100 direct current fast charger (DCFC) connectors have been deployed across California and the nine Section 177 ZEV states.
- California's current programs enabled by important legislation (most prominently Assembly Bill 8⁵) are launching the first major FCEV market and hydrogen fueling network in the U.S. Three FCEVs are currently for sale in California while 25 retail hydrogen refueling stations are open in California with an additional 20 stations already in development. Toyota and Honda have also announced partnerships with private companies for financial support of additional stations in California and the Northeast.

This summary report and its 13 appendices encompass ARB's technical analysis for the midterm review of the adopted LEV III GHG and PM emission standards and ZEV requirements. The findings from this analysis support the following recommendations.

Findings and Recommendations:

2022 through 2025 model year GHG emission standards

Continue California participation in the National Program by maintaining the "deemed to comply" provision allowing for compliance with the adopted U.S. EPA GHG standards for 2022 through 2025 model years. The extensive multi-year joint-agency work summarized in the draft 2016 Technical Assessment Report (2016 TAR) showed clearly that the current national 2022 through 2025 model year GHG emission standards can be readily met at the same or lower cost than originally projected when the standards were adopted in 2012, predominantly with advanced gasoline engines and transmissions. The 2016 TAR analysis did not include several other new advanced vehicle technologies being introduced by vehicle manufacturers in the next few years that may provide significant benefits at similar or lower costs. Accordingly, after consideration of public comments received on the 2016 TAR, U.S. EPA released a Proposed Determination for public comment on November 30, 2016 that the national GHG standards currently in place for 2022-2025 model years remain appropriate under

⁵ Assembly Bill No. 8 (Perea, Statutes of 2013, Chapter 401)

the Clean Air Act and do not need to be amended. After considering additional public comments received on the Proposed Determination, U.S. EPA released a Final Determination on January 13, 2017 affirming that the national GHG standards for 2022-2025 model years would remain as adopted.

The updated national vehicle forecast shows that changes in vehicle fleet composition due to increased truck sales are now projected to result in a slightly higher 2025 model year fleet average CO₂ level. Similarly updated analysis for California, however, found that the originally projected California GHG benefits will still be achieved. An analysis specific to the California car/truck fleet mix projects the 2025 model year fleet average to be the same or lower than originally projected. Despite a similar trend as seen nationally in increased truck sales, the updated analysis projects the equivalent CO₂ fleet average in California will be between 153 and 167 grams per mile CO₂ compared to the original 2012 ARB projection of 166 grams CO₂ per mile, largely due to the actual share of passenger cars in the fleet mix being much higher than originally estimated. As such, the deemed-to-comply provision adopted by ARB to allow compliance with national GHG standards that preserved the GHG-reduction benefits of the California-specific GHG standards still puts California on track to achieve the projected GHG reductions from the 2025 model year fleet. Compliance with the current national GHG standards for model years 2022-2025 will result in equivalent or greater GHG benefits (at the same or lower cost to manufacturers) than originally projected for California and accordingly, consistent with the U.S. EPA Final Determination, changes to the stringency of the national or California GHG standards are not necessary or warranted.

These findings on the benefits to California are based on an analysis assuming the existing national GHG standards. If the stringency of the national GHG standards were substantially changed, despite the Final Determination by U.S. EPA based on a comprehensive record demonstrating that the existing standards should be maintained, these findings would likely be different. In that event, California could revisit whether it would have to conduct a new analysis to determine whether compliance with a new National Program would be an appropriate approach under California's LEV III program to address California's unique air quality challenges and its mandates to achieve aggressive GHG reductions to protect public health and the environment.

1 milligram per mile particulate matter emission standard

As previously reported to the Board in 2015, maintain the existing PM emission gravimetric measurement method for the 1 mg/mi standard. In responding to Board direction regarding examination of the tailpipe emission measurement capability at 1 mg/mi PM levels, staff reported to the Board in October 2015 that the gravimetric method for determining PM emissions is appropriate for measuring low PM emission levels and that the method will remain the approved procedure for determination of compliance with ARB's LEV III PM emission standards. This decision was based on extensive emission testing and research of

laboratory methods conducted by ARB and published in the peer-reviewed literature.⁶ The agency's research was conclusive with respect to the applicability of the gravimetric method, but also included several PM measurement alternatives such as counting particles and, while the work showed that none of the alternatives were equivalent to the current gravimetric method of determining PM mass, it revealed some potential benefits of several of the alternatives. Thus, the agency is committed to track further developments to ensure ARB's measurement capabilities remain at the forefront of PM emission metrology and technology.

Maintain the stringency and implementation schedule of the adopted 1 mg/mi PM emission standard applicable in 2025 model year. To respond to the Board's additional direction regarding reassessing stringency and implementation of the 1 mg/mi PM standard, additional emission testing and a review of vehicle PM emission control technology was conducted and is included in this report (Appendices J and K). This work determined that compliance with the 1 mg/mi emission standard by 2025 model year is feasible and that manufacturers are on track to meet this standard. The findings also support that the currently provided lead time is necessary to ensure manufacturers can incorporate broadly the knowledge gained from the in-use operation of newer, 3 mg/mi compliant, GDI systems into normally scheduled engine redesigns to optimize for PM control at little to no added cost. Test data and analysis shows that, although vehicle manufacturers have achieved significant PM emission reductions over the last engine redesign cycle, some are not yet controlling PM emissions well enough to consistently maintain the 1 mg/mi limit across all applicable operating conditions and over all vehicle models. In particular, further improvements are needed for gasoline direct injection (GDI) vehicles to meet a 1 mg/mi standard with a sufficient compliance margin, but manufacturers and suppliers appear to be on track to achieve control within the current lead time provided by the adopted regulation. Thus, earlier implementation than 2025 model year of the 1 mg/mi PM standard is not supported by this analysis as the reduced lead time would jeopardize the ability of manufacturers to ensure robust solutions that can be incorporated into scheduled engine redesigns and would likely lead to reliance on more costly, interim solutions such as gasoline particulate filters (GPF) to comply. On the other hand, the GPF is a viable solution, albeit at a higher cost, available to manufacturers now for meeting the most stringent 1 mg/mi PM limit.

Develop more comprehensive PM emission standards to phase-in with the 1 mg/mi standard in 2025 model year to ensure manufacturers implement robust control strategies that result in low PM emissions in the real world. The most recent set of emission test results suggests that additional regulatory requirements are needed to better ensure that when the 1 mg/mi Federal Test Procedure (FTP) standard is phased-in, it results in robust in-use PM control over a broader spectrum of driving conditions than encountered in the FTP. To this end, ARB plans to develop a more stringent US06 cycle PM emission standard, which would verify PM is well-controlled over more aggressive in-use driving conditions, as well as consider PM emission standards for other test cycles and ambient conditions as necessary to ensure in-use PM emissions are minimized.

⁶ ARB 2015a. California Air Resources Board. "An Update on the Measurement of PM Emissions at LEV III Levels". October 2015. https://www.arb.ca.gov/msprog/levprog/leviii/lev_iii_pm_measurement_feasibility_tsd_20151008.pdf

California's ZEV regulation

Strengthen the ZEV program for 2026 and subsequent model years to continue on the path towards meeting California's 2030 and later climate change and air quality targets. Set new requirements to target credit provisions and regulatory structure adjustments in order to increase certainty on future vehicle volumes, technology improvement, and PHEV qualifications and other factors to maximize GHG and criteria pollutant reductions.

For the first time since the initial adoption of the regulation, the Board adopted increased ZEV credit requirements in 2012. This action, in concert with the development of strong comprehensive complementary policies to support infrastructure deployment and consumer awareness, led to the advancement of ZEV technology and growth in ZEV sales. Since the adoption of the 2018 through 2025 model year standards, manufacturers have been exceeding the annual requirements of the ZEV regulation and expanding the market nationwide by delivering ZEVs and PHEVs in states which have not adopted California's ZEV regulation. Thus, committing now to a strong set of post-2025 requirements reinforces current progress and encourages manufacturers to continue advancements to electrify their fleets.

Modeling to meet the 2030 GHG targets established by SB 32 in the ARB Mobile Source Strategy report, released in May 2016, indicates approximately three million additional ZEVs and PHEVs will be needed in 2026 through 2030. To reach these volumes with any certainty, the new regulation will need modifications that provide a more direct connection to vehicle volumes and require vehicle characteristics that best ensure market success. For such significant revisions to the regulation to be successful, however, it would require greater market acceptance, more technology advancements, and lower technology costs than is known with certainty today. In PHEVs alone, the product offerings and architecture variations are increasing in diversity and it is too early to determine which combinations will be appealing to consumers while providing maximum GHG and criteria pollutant benefits. For BEVs, a step change is occurring with multiple offerings expected with 200+ miles of range at prices closer to mainstream conventional vehicles (even before state and federal incentives), with the first of these being launched within weeks of this report's release. Additionally, substantial changes to the regulatory structure will impact vehicle manufacturer product and compliance planning and necessitate sufficient lead time and stability to implement successfully while minimizing disruption to research, investment, and design cycles. Development of future new ZEV requirements needs to be done in concert with additional GHG (and potentially criteria pollutant) fleet-wide emission reduction requirements as was previously done in the 2012 ACC program. This coordinated approach ensures the regulations of multiple pollutants benefit from the synergistic effects and result in a single integrated policy to help meet California's air quality and GHG goals. To this end, ARB intends to continue to collaborate on a technical basis with its federal partners such as the U.S. Department of Energy (DOE), U.S. EPA, and NHTSA to research, develop, and promote advancement of vehicle technologies including ZEV technologies necessary for California's long term goals.

Maintain the current ZEV stringency for California through 2025 model year including the existing regulatory and credit structure. In 2012, the Board strengthened the ZEV regulation, nearly tripling the credit requirements for pure ZEVs in 2025 model year, and shifting

away from a stair-step approach (where requirements remained the same for three years at a time) to a simpler, linear annual increase in the requirements. Since then, the regulation has been achieving the goal of accelerating development of ZEV technology towards commercialization in California as demonstrated by the clear growth in the ZEV market, the introduction of more capable and longer range vehicles than originally projected, and earlier reduction in battery costs than anticipated. The 2012 Board action has resulted in over 215,000 ZEVs and PHEVs being placed in California over the last five years and an expansion from 25 models offered today to over 70 unique ZEV and PHEV models expected in the next five years. As a result of the vehicle technology advancements evident in the market, new minimum compliance scenarios were developed that project approximately 1.2 million cumulative sales of ZEVs and PHEVs by 2025 in California. While this revised compliance picture reflects a lower volume of vehicles than originally projected in 2012, the resultant improvements in ZEV and PHEV attributes, such as all-electric range and vehicle price, are expected to further broaden the appeal of these vehicles beyond the initial consumers and help achieve necessary future market expansion. Simply put, the market is seeing the introduction of better ZEVs. Outside of California, ZEV markets are expanding in the U.S. as well as globally, indicating that the industry is beginning a significant shift towards greater electrification.

Despite these successes, it is widely recognized that the ZEV and PHEV market is still in the early stages of development. While the market is rapidly changing with nine BEV and PHEV models already discontinued since their introduction, it is also unknown how many of the 70 announced models will succeed in the market. The current market has benefited from multiple purchase incentives that have substantially discounted ZEVs and PHEVs such that their prices are more aligned with those of conventional vehicles. But, between 2018 and 2025, these and other incentives are expected to phase out. While decreased reliance on incentives is essential for building a self-sustaining market, it is unclear what consumer response will be without purchase and other incentives (like high occupancy vehicle (HOV) lane access). Consumer awareness of ZEVs is still low and top motivations like saving money on fuel are less influential as gasoline prices remain low. Given the market uncertainties that still exist in these early years, regulatory stability of the 2018 through 2025 model year standards can help ensure a continued path of increasing, but achievable, ZEV volumes.

Maintain the existing flexibilities, including as amended in 2014, for intermediate volume manufacturers (IVMs). Regarding the ZEV requirements applicable to IVMs, this analysis found that a further reduction in the requirements is not warranted at this time. The Board adopted a number of flexibilities in the original rulemaking in 2012 and in an additional rulemaking in 2014 to help ease the transition of the IVMs into the more stringent requirements starting in model year 2018. While smaller than other manufacturers, to their credit, these manufacturers do have competitive products in the market and generally agree that there is a need to develop and introduce ZEV technologies to remain competitive into the future. All five current IVMs have clear and concrete plans to bring ZEVs to market in the next few years, with relevant announcements for two of the five as recently as November 2016. Additionally, as shown in the revised compliance scenario analysis, there are sufficient credits, both in their own banks and in the market, available for IVMs to help bridge any interim compliance gaps.

Maintain the existing credit structure and use caps for PHEVs through the 2025 model year. PHEVs will continue to play a role in the electrification of transportation for long-term emission reduction targets. The adopted standards are consistent with ARB's long-term modeling scenarios and already recognize PHEVs not only can help consumers and manufacturers transition to pure ZEVs but that they also can continue to be a significant share of the vehicle market. Based on in-use data from PHEVs, emission testing, and analysis of electric use conducted by ARB, PHEVs can generate significant benefits over conventional vehicles but do not generally result in GHG or criteria pollutant emission reductions equal to pure ZEVs. Given this and even more importantly, the technology-forcing goals of the ZEV regulation, the current regulation appropriately awards more credits to the longer range pure ZEV vehicles.

Further, as shown in the updated compliance scenarios, PHEVs are projected to make up more than 60 percent of all ZEVs and PHEVs on the road by 2025 even with the current use caps on PHEV credits. This indicates the current regulatory structure already provides sufficient flexibility as the ZEV market is developing to determine the role PHEVs will ultimately play. The new analysis does not support more flexibility for PHEVs at this time such as allowing manufacturers to comply with ZEV requirements with more PHEVs than currently allowed. And, while strong electric drive capability PHEVs with significant all-electric range and minimal engine starts are very encouraging, the analysis in this report finds that their benefits do not match or exceed those of pure ZEVs and, hence, PHEVs are appropriately credited less than pure ZEVs in the existing regulation. Furthermore, allowing for more credits per PHEV such that fewer total vehicles are needed to comply does not result in additional emission benefits or furtherance of the technology-forcing goals of the ZEV regulation.

Continue efforts by ARB and other stakeholders to accelerate and expand non-regulatory complementary policies that have been identified as successful in building market demand and removing remaining barriers to ZEV adoption. Irrespective of any regulatory action, appropriate complementary policies will need to be in place to support the expansion of the ZEV market as the market share will need, at a minimum, to approximately triple in the next nine years. ARB and other stakeholders will need to accelerate and expand non-regulatory and complementary actions that have been identified as successful to continue to enhance market demand for ZEVs and remove the remaining barriers to ZEV adoption. Examples of such policies include consumer rebates and tax credits, carpool lane access, availability of public charging infrastructure, parking incentives, and others.

ZEV regulation requirement for Section 177 ZEV states

Maintain the adopted flexibilities for the Section 177 ZEV states. Through Section 177 of the Clean Air Act, several states have previously adopted various California vehicle regulations to help achieve their air quality or GHG targets. In particular, nine states have adopted California's ZEV regulation, collectively requiring that 25 percent to 30 percent of all new vehicles sold in the U.S. be subject to ZEV regulation requirements. California and its Section 177 ZEV state partners have embraced a strong collaboration for supporting ZEVs, entering into

a multi-state Memorandum of Understanding (MOU) in 2013 to help facilitate successful market development especially in the areas of non-regulatory complementary policies.

Recognizing the market development in the Section 177 ZEV states was not yet as far along as California's, the Board adopted additional regulatory flexibilities and lead time to create a ramp into the 2018 and subsequent model year requirements for the states. Despite current lower sales in the Section 177 ZEV states, increased product offerings coming for the states, expiration of regulatory flexibilities that may have discouraged past sales efforts in the states, and more comprehensive complementary policies provide sufficient support for manufacturers to meet the increasingly stringent ZEV requirements in the Section 177 ZEV states.

Additionally, credits both created in the Section 177 ZEV states and generated through the travel provision in the California market will help manufacturers who need more time to build a market for their vehicles between 2018 and 2025 model years.

Summary Report: California's Mid-term Review of the Adopted LEV III GHG, PM, and ZEV Standards

Introduction

What is the Advanced Clean Cars program?

In 2012, the California Air Resources Board (ARB) adopted the Advanced Clean Cars (ACC) program, a comprehensive set of standards for new vehicles in California through model year 2025. This historic program, developed in coordination with the United States (U.S.) Environmental Protection Agency (EPA) and National Highway Traffic Safety Administration (NHTSA), combined the control of smog-causing (criteria) pollutants and greenhouse gas (GHG) emissions into a single coordinated set of requirements for model years 2015 through 2025 and assured the development of environmentally superior passenger cars and other vehicles that will continue to deliver the performance, utility, and safety vehicle owners have come to expect all while saving the consumer money through significant fuel savings. The components of the ACC program are the Low-Emission Vehicle III (LEV III) regulations that reduce criteria pollutants and GHG emissions from light- and medium-duty vehicles and the zero-emission vehicle (ZEV) regulation, which requires manufacturers to produce an increasing number of pure ZEVs (meaning battery electric and fuel cell electric vehicles) and plug-in hybrid electric vehicles (PHEV) in the 2018 through 2025 model years. When fully implemented, new vehicles are expected to emit 34 percent fewer GHG emissions and 75 percent fewer smog-forming emissions than today's vehicles.

Vehicles and transportation fuels are the dominant sources of carbon emissions in California. ACC is an integral part of California's ambitious long-term requirements to reduce the State's impact on climate change and improve ambient air quality. The vehicle programs are a critical measure in the State Implementation Plan⁷ (SIP) for achieving national ambient air quality standards in the South Coast and San Joaquin Valley. They are also an integral part in ARB's Scoping Plan to achieve the GHG reduction goals that were established through California legislation and Executive Orders.⁸ This year, GHG reduction targets in Executive Order B-30-15 were codified with the passage of Senate Bill (SB) 32 (Statutes 2016, Chapter 249, Pavley), which expanded the California Global Warming Solutions Act of 2006, by directing ARB to ensure that statewide GHG emissions are reduced to at least 40 percent below the 1990 level by 2030. Also in 2016 California enacted Assembly Bill (AB) 197 (Statutes 2016, Chapter 250, Garcia). AB 197, among other provisions, declares that continuing to reduce GHG emissions is critical for the protection of all areas of the state, but especially for the state's most vulnerable

⁷ ARB 2016a. California Air Resources Board. Proposed 2016 State Strategy for the State Implementation Plan. May 17, 2016. <https://www.arb.ca.gov/planning/sip/2016sip/2016statesip.pdf>

⁸ Executive Orders S-3-05 (Schwarzenegger, 2005) and B-30-15 (Brown, 2015) establish long term GHG emission reductions of the state of 80% and 40% below 1990 levels by 2050 and 2030 (respectively).

communities, as those communities are affected first, and most frequently, by adverse impacts of climate change.

Although significant strides have been made toward improving California's air quality, health-based state and federal ambient air quality standards continue to be exceeded in major regions throughout California. To achieve the 1997 8-hr ozone standard by the attainment date in 2023, oxides of nitrogen (NOx) emissions in the greater Los Angeles region must be reduced by an additional two thirds beyond reductions from all of the control measures in place today. Furthermore, to achieve the more stringent 75 parts per billion (ppb) 2008 8-hr ozone standard by 2031 will require an 80 percent reduction in NOx from 2012 levels. ARB is working with the local air quality management districts to prepare SIPs informed by ARB's Mobile Source Strategy.⁹ The plans for attaining the most recently adopted 70 ppb ozone standard have not begun, but are expected to have to rely heavily on significant and on-going progress towards zero and near-zero mobile source emissions in California. The third generation "LEV III" regulations, adopted as part of the ACC program, build upon the requirements of the earlier LEV regulations and continue to reduce emissions from the light- and medium-duty fleet through the 2025 model year.

What is the midterm review (MTR), and how is California's review different from the joint-agency national midterm evaluation?

The primary differences between state and federal actions are in the scope of the different reviews. While the national midterm evaluation was solely focused on a review of the federal GHG (and associated fuel economy) standards, ARB's MTR is required to review California's PM standard and ZEV regulation in addition to a review of the GHG standards. When adopting the current ACC program standards, the Board committed to participating in a joint-agency review with U.S. EPA and NHTSA of the 2022 through 2025 model year GHG tailpipe standards, first in a letter written the summer before the rulemaking,¹⁰ and later when adopting the ACC standards in its January 2012 Resolution.¹¹ The Board also directed staff to conduct reviews specific to the California standards: the ZEV regulation, the 1 mg/mi particulate matter (PM) emission limit, and a general technical review relative to the format of the adopted GHG standards, the use of vehicle footprint as a key attribute, and reliance on the federal corporate average fuel economy or CAFE car/truck definitions. The Board also directed staff to return with its review no later than December 2016. Resolution 12-11 specified areas for staff to consider for its review as shown in Table 1 below.

⁹ ARB 2016b. California Air Resources Board. ARB Mobile Source Strategy. May 2016.
<https://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf>

¹⁰ Nichols, 2011. Chairman Mary Nichols (California Air Resources Board.) Commitment Letter. July 2011.

¹¹ ARB 2012a. California Air Resources Board. Resolution 12-11. Available:
<http://www.arb.ca.gov/regact/2012/zev2012/res12-11.pdf>, Accessed August 24, 2016

Table 1 - 2012 Advanced Clean Cars Resolution Direction

Program	Board Resolution Direction
GHG	Participate in a midterm review with the U.S. EPA and NHTSA of the federal passenger vehicle GHG standards and corporate average fuel economy (CAFE) standards for the 2022 through 2025 model years
	Continue collaboration with U.S. EPA and NHTSA during finalization and review of the federal standards to minimize potential lost GHG benefits from differences in how upstream emissions for electricity and hydrogen fueled vehicles are accounted for in the federal standards as compared to the California regulation
	Monitor consumer purchasing trends and California's fleet mix to evaluate any effect of a potential shift in vehicle footprint to larger and more polluting vehicles and the reclassification of cars as trucks that deviates from the fleet size and category mix projected in the approved amendments
PM	Re-examine the measurement methods, stringency, and timing of the adopted 2025 model year 1 mg/mi PM emission standard
ZEV	Monitor consumer acceptance of PHEVs and report on expected volumes in the ZEV program
	Analyze in-use data for range extended battery electric vehicles (BEVx) and PHEVs, and propose appropriate modifications as needed
	Conduct a study of the potential effects of adding an additional category of vehicles to the ZEV regulation for "BEV XX" vehicles that would be allowed greater use of an internal combustion engine than allowed for vehicles approved as "BEV X" vehicles in this action, where such BEX XX vehicles would only be applied to 25 percent of a manufacturer's pure ZEV requirement

In addition to the above Resolution direction, staff also monitored the evolution of the ZEV market and evaluated the effectiveness of the ZEV regulation as adopted in 2012, both in California and in the other states that have adopted California's ZEV regulation. Staff received additional direction at the July 2016 Board Hearing to examine the ZEV credit banks, the treatment of credits for ZEVs and PHEVs within the regulation, and to explore ways to ensure that the market is growing in the appropriate timeframe to meet the long-term air quality and GHG emission reduction goals expressed in the regulation.¹²

What was the review process of the ACC program?

Extensive Consultation with Stakeholders

Over the past four years, staff has held numerous and extensive consultation sessions and technical discussions with experts representing all of the major automakers and other leading technical stakeholder groups with an interest in the ACC standards on each of the three aspects of ARB's midterm review. These discussions involved consideration of auto manufacturer market plans for technology development and examination of the most recent and relevant evidence concerning trends for technology and costs as noted in the 2016 TAR. In 2015, ARB

¹² ARB 2016c. California Air Resources Board. July 2016 Board Transcript. July 21, 2016
<http://www.arb.ca.gov/board/mt/2016/mt072116.pdf>

participated in systematic joint-agency (along with U.S. EPA and NHTSA) discussions with manufacturers regarding the evaluation of the GHG standards, which fed into the 2016 TAR described below. In 2016, ARB held separate discussions with most manufacturers to consider confidential business approaches for upcoming product and compliance plans for the ZEV and PM reviews.

Extramural Research

Research for generation of new knowledge is a key aspect of the agency analysis in support of this MTR. ARB has sponsored or co-sponsored six extramural research projects to support the mid-term review. Three projects have been completed to date. These projects, along with a short description are listed in Table 2 below.

Table 2 - Advanced Clean Cars Midterm Review Extramural Research Projects

Research Contract Title	Author	Project Status
Technical Analysis of Vehicle Load-Reduction Potential for Advanced Clean Cars ¹³	Gregory Pannone, Control Tec (now Novation Analytics)	Complete
New Car Buyer's Valuation of Zero-Emission Vehicles ¹⁴	Dr. Kenneth Kurani, University of California, Davis	Complete
Very low PM measurements for light-duty vehicles (E-99)	Dr. Heejung Jung, University of California, Riverside	Complete
The dynamics of plug-in electric vehicles in the secondary market and their implications for vehicle demand, durability, and emissions	Dr. Gil Tal, University of California, Davis	On-going
Examining Factors that Influence ZEV Sales in California	Dr. J.R. DeShazo, University of California, Los Angeles	On-going
Advanced Plug-In Electric Vehicle Usage and Charging Behavior	Dr. Tom Turrentine, University of California, Davis	On-going

Research findings from the “Technical Analysis of Vehicle Load-Reduction Potential for Advanced Clean Cars” and “New Car Buyer’s Valuation of Zero-Emission Vehicles” have been presented and published. These seminars are webcast and archived.¹⁵ Completion of the remaining projects is underway and ARB expects to make use of those findings in subsequent technical analyses, including those informing new post-2025 regulatory policies.

Annual Board Informational Updates

Beginning in October 2013, staff provided three annual informational updates on the ACC program to the Board, each emphasizing different aspects of staff’s review.¹⁶ Staff’s 2013 update focused on the general plan for the conduct of the midterm review, as well as various complementary policies and initiatives. The 2014 update related an in-depth examination of

¹³ Pannone 2015. Pannone, G., *Technical Analysis of Vehicle Load-Reduction Potential for Advanced Clean Cars*. Contract 13-313. Control-Tec, LLC. 2015. <http://www.arb.ca.gov/research/apr/past/13-313.pdf>

¹⁴ Kurani 2016. Kurani, K. *New Car Buyers Valuation of Zero Emission Vehicles*. Contract 12-332. University of California, Davis. 2016. <https://www.arb.ca.gov/research/apr/past/12-332.pdf>

¹⁵ Access all archived research seminar webinars: <https://www.arb.ca.gov/research/seminars/seminars.htm>

¹⁶ Staff’s annual updates can be accessed at the following link: <https://www.arb.ca.gov/msprog/acc/acc-mtr.htm>

charging and fueling infrastructure needs, development of charging and fueling infrastructure networks in California, and provided detailed information about other on-going studies and research related to this MTR. In 2015, the first part of the PM review was presented to the Board on the topic of PM emission measurement feasibility and general laboratory practices. Additionally, staff presented information on consumer purchasing attitudes regarding ZEVs and PHEVs.

The Joint-Agency Draft 2016 Technical Assessment Report

The results of an extensive multi-year study are presented in the recently published 2016 *Draft Technical Assessment Report: Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025* (referred to as the 2016 TAR throughout this report).¹⁷ The 2016 TAR represents the culmination of new technology assessments, vehicle emission testing, and modeling work and updated analyses of the feasibility, costs and potential pathways to meeting the adopted national GHG standards for model years 2022 to 2025. In the development of the 2016 TAR, the three agencies drew from multiple sources of information ranging from stakeholders such as vehicle manufacturers and vehicle component suppliers to extensive in-house research at U.S. EPA's National Vehicle and Fuel Emissions Laboratory. ARB staff provided an overview of the information presented in the 2016 TAR at the July Board Hearing.

Advanced Clean Cars Symposium: The Road Ahead

In September, 2016 ARB held a two-day technical ACC Symposium "The Road Ahead" in Diamond Bar, California at the South Coast Air Quality Management District headquarters.¹⁸ Over 100 participants and agency staff attended the symposium over the two days, and more participated via webcast. The first day featured presentations made by representatives from industry and academia on various groundbreaking trends in ZEV technologies, including the latest in battery technology, wireless charging, and ARB's analysis of manufacturer provided plug-in electric vehicles (PEV) in use data and emissions testing of PHEVs. The second day covered engine and vehicle technologies that were not extensively used in the analysis for the 2016 TAR but are expected to be on production vehicles in the near term and could help meet the adopted GHG and PM standards.

California's Final Report – The Midterm Review of the Adopted Standards

This report is a compilation of four years of staff work on each aspect of the midterm review. The thirteen appendices (labeled A through M) attached to this summary document will present the staff analyses:

¹⁷ EPA 2016. U.S. EPA, NHTSA, ARB. July 2016. Draft Technical Assessment Report: Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025. July 2016. <https://nepis.epa.gov/Exe/ZyPDF.cgi/P100OXEO.PDF?Dockkey=P100OXEO.PDF>

¹⁸ Agendas and presentations made at the September 26 and 27 Symposium are found here: <https://www.arb.ca.gov/msprog/acc/acc-symposium.htm>

A. Analysis of Zero Emission Vehicle Regulation Compliance Scenarios

Analysis of ZEV regulation compliance scenarios with updated inputs, ZEV calculator, and credit bank analysis.

B. Consumer Acceptance of Zero Emission Vehicles and Plug-in Hybrid Electric Vehicles

Analysis of California and Section 177 ZEV state ZEV and PHEV market development since the adoption of ACC, as well as a look at the potential for further market growth.

C. Zero Emission Vehicle and Plug-in Hybrid Electric Vehicle Technology Assessment

A review of the current status of ZEVs (both BEV and FCEV) and PHEV technology trends and summary of incremental vehicle costs.

D. Zero Emission Vehicle Infrastructure Status in California and Section 177 ZEV States

A review of the current status, station counts, technology trends, and costs of charging and hydrogen fueling infrastructure in California and Section 177 ZEV states.

E. Zero Emission Vehicle Complementary Policies in California and Section 177 ZEV States

A summary of complementary policies (apart from those covered under Appendix D) that are helping to spur the ZEV market in California and the Section 177 ZEV states.

F. Scenario Planning: Evaluating impact of varying plug-in hybrid electric vehicle (PHEV) assumptions on emissions

Analysis of sensitivities for increased electric vehicle miles traveled (eVMT), increased on-road PHEV numbers, and increased fuel economy on ARB's latest long-term emissions reduction plans presented earlier in 2016 in the Mobile Source Strategy.

G. Plug-in Electric Vehicle In-Use and Charging Data Analysis

Analysis of manufacturer provided driving and charging data from eleven different PEV models.

H. Plug-in Hybrid Electric Vehicle Emissions Testing

Description and summary of testing completed in ARB's Haagen-Smit Laboratory on blended PHEVs to analyze criteria pollutant emissions.

I. Alternative Credits for Zero Emission Vehicles and Plug-in Hybrid Electric Vehicles

In accordance with the Board's 2012 resolution, a summary of various alternative ZEV regulation credit structures based on data from Appendix G.

J. Vehicle PM Emission Control Technology Assessment

Assessment of currently available PM emission control technologies, which could be employed on gasoline vehicles to meet the 1 mg/mi standard.

K. PM Emission Testing Results

Description and summary of results from testing at ARB's Haagen-Smit Laboratory of vehicles with advanced gasoline GHG technologies and their ability to comply with the 1 mg/mi PM standard.

L. Emissions Impact Assessment for the 1 mg/mi standard

Background of the PM emission standard and updated emissions inventory analysis for implementing the 1 mg/mi PM standard earlier than in model year 2025.

M. California GHG technology trends

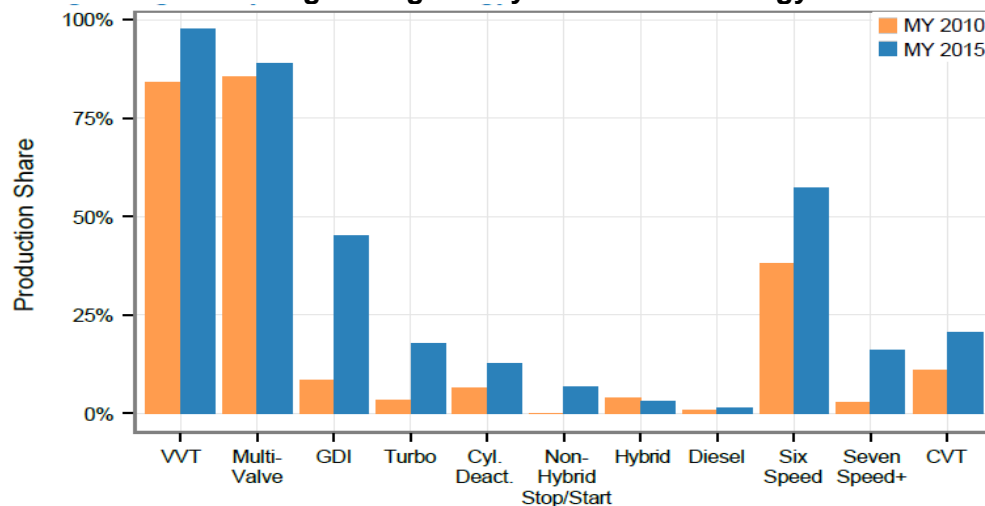
Analysis of trends in the California's light-duty vehicle (LDV) fleet to assess the car/truck split and vehicle footprint effects since the adoption of the ACC regulations.

Greenhouse Gas Emission Standard Review

How have conventional vehicle technologies progressed since the adoption in 2012 of the GHG fleet average standards?

Since adoption of the GHG and fuel economy standards in 2012, manufacturers have employed a variety of technologies that reduce GHG emissions and increase fuel efficiency, many at a faster rate of deployment than was originally projected. According to U.S. EPA's 2015 trends report (Trends Report),¹⁹ large changes in advanced engine and transmission penetration rates have taken place across the industry in the last five years, as shown in Figure 1. As expected, the penetration rate for individual technologies varies between manufacturers.

Figure 1 - Five Year Change in Light-Duty Vehicle Technology Penetration Share



Source: U.S. EPA's *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2015 Trends Report*

¹⁹ EPA 2015b. United States Environmental Protection Agency. *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2015 Trends Report* November 2015. <https://www.epa.gov/fuel-economy/download-co2-and-fuel-economy-trends-report-1975-2015>

What were the main findings of the 2016 TAR?

Independent and parallel analyses were conducted by U.S. EPA and NHTSA, with some input from ARB, thereby resulting in complementary conclusions and identifying multiple possible pathways to comply with the 2022 through 2025 model year GHG and augural fuel economy standards. In support of these analyses, information from multiple sources was used such as new vehicle certifications, full vehicle simulation modeling conducted by the agencies, extensive reviews of the published technical literature and technical conference information, vehicle manufacturer and supplier information and focused discussions, and the 2015 National Academy of Science report “Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles.”²⁰ In general, the analyses confirm that the original estimates of the effectiveness of technologies in terms of efficiency and GHG performance examined in the 2012 Final Rulemaking (FRM) remain appropriate.

Technology Penetration

The agencies found the 2025 model year GHG standards can be met at approximately the same or lower cost, predominantly with advanced gasoline engines and transmissions. Light-weighting, improved aerodynamics, and better tires also provide additional GHG reductions. As shown in Table 3, compliance with the national standards is not expected to prompt automakers to rely on large quantities of ZEVs, PHEVs, or conventional hybrid electric vehicles (HEV). Increased use of such technologies would enable additional GHG emissions reductions but it would also increase projected vehicle costs.

Table 3 - 2025 Model Year Vehicle Technology Fleet Penetrations

2025 Model Year Vehicle Technologies		
	U.S. EPA Analysis	NHTSA Analysis
Turbocharged and Downsized Gasoline Engines	33%	54%
Higher Compression Ratio, Naturally Aspirated Gasoline Engines	44%	<1%
8 speed and other Advanced Transmissions	90%	70%
Mass Reduction	7%	6%
Stop-Start	20%	38%
Mild Hybrid (48 Volt)	18%	14%
Full Hybrid	<3%	14%
Plug-in Hybrid Electric Vehicle*	<2%	<1%
Battery Electric Vehicle*	<3%	<2%

* U.S. EPA’s modeling includes compliance with ZEV regulatory requirements in the reference fleet. Consequently, 3.5% of the fleet is projected to be an electric vehicle or a plug-in hybrid electric vehicle in the 2022 through 2025 model year timeframe due to the adoption of the ZEV regulations in California and Section 177 ZEV states. The NHTSA modeling does not include ZEV regulatory compliance in the reference fleet.

²⁰ NRC 2015. National Research Council. Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles June 18, 2015.

Projected Vehicle Fleet Mix and Associated Emission Benefits

Additional key findings in the 2016 TAR relate to projected benefits and costs. The new analysis relies on updated assumptions of the mix of cars and trucks, which show that nationwide, people are purchasing more trucks and fewer cars than was projected in the 2012 Final Rule of the national program. The future projection of vehicle fleet mix is based on the U.S. Energy Information Administration's 2015 Annual Energy Outlook (AEO) that factors in projected fuel prices with current trends and regulatory requirements. Because trucks are required to meet higher (less stringent) CO₂ standards than cars, the updated projected national fleet average for the 2025 model year is 175 grams per mile versus the original 163 grams per mile projection in the national standard. The corresponding projected fuel economy is 50.8 mpg nationally instead of 54.5 mpg. These updated projections assume that the stringency of the 2022 through 2025 model year GHG standards does not change.

Table 4 - 2025 Model Year Projected National Fleet Mix

MY 2025 Fleet Mix	Original Projection	New Projection
% Car	67%	52%
% Truck	33%	48%
Combined gCO ₂ e/mi	163	175
Combined mpg	54.5	50.8

Incremental Vehicle Costs and Payback Period

Finally, the 2016 TAR and the updated analysis used for the Final Determination project that the average incremental cost per vehicle to comply with the GHG standards in model year 2025 will be about the same or lower than the original projections used in the rulemaking. The payback period, however, has increased relative to the original estimate. This is because current and future fuel prices, as forecast by the 2015 and 2016 AEO, are lower now than what was projected back in 2012 during the original rulemaking. The revised longer estimate for the payback period is still well within the lifetime of the vehicle and operation of the vehicle beyond the payback period will result in additional consumer savings in the form of lower fueling costs.

Table 5 - 2025 Model Year Incremental Vehicle Costs and Payback Period

	Incremental Cost* per Vehicle in MY 2025	Payback Period
2012 Rulemaking	\$ 1,163	3.2 years
2016 TAR:		
U.S. EPA Analysis	\$ 910	5 years
NHTSA Analysis	\$ 1,148	6 years
2016 Final Determination	\$ 875	5 years

* All values adjusted to 2015\$ per the United States Department of Labor Consumer Price Index inflation calculator. For reference, the 2012 rulemaking reported \$1,070 (in 2010\$) and the 2016 TAR reported \$894 and \$1,128 (in 2013\$) for the U.S. EPA and NHTSA analysis, respectively.

What comments were submitted by stakeholders during the federal midterm evaluation?

On July 27, 2016, a “Notice of Availability of Midterm Evaluation Draft Technical Assessment Report for Model Year 2022–2025 Light-Duty Vehicle GHG Emissions and CAFE Standards” was published in the *Federal Register*, opening up a 60-day comment period during which interested parties were requested to submit comments to the agencies for consideration in the proposed determination of the standards. On September 26, 2016, the public comment period for the 2016 TAR closed. Since that time, ARB has worked with the federal agencies to review and address specific comments and generally agrees with the responses in U.S. EPA’s Proposed Determination that was released on November 30, 2016. Public comments for the Proposed Determination were due by December 30, 2016 and were subsequently considered by U.S. EPA before release of a Final Determination on January 13, 2017 that affirmed the existing GHG standards for 2022-2025 model years would remain as adopted. The technical comments are summarized below.

ARB received comments from the Alliance of Automobile Manufacturers, the Global Automakers as well as individual vehicle manufacturers, and component and material suppliers. Comments were also submitted by environmental organizations and fuel advocates.

The manufacturers’ comments are grouped into five categories; 1) numerous flaws in the modeling approaches used by the agencies result in over-estimation of the efficiencies of the technologies evaluated, which in turn leads to under estimation of compliance costs, 2) the agencies failed to adequately address consumer acceptance and employment impacts of the requirements, 3) harmonization of regulatory requirements for the GHG and fuel economy program is needed to assure a coherent and single national program, 4) the GHG and fuel economy credit structures should be streamlined and harmonized, and 5) the 2016 TAR fails to account for the impact on costs from the California ZEV program.

The environmental organizations either supported affirmation of the standards or urged an increase in stringency. They also raised concerns regarding the different modeling approaches used by the agencies. In general, these organizations commented that they felt U.S. EPA’s analysis was more appropriate than NHTSA’s approach, in part because U.S. EPA used more recent engine and transmission data in the modeling and a modeling methodology that kept vehicle performance neutral as technologies were added as well as because it included compliance with ARB’s ZEV regulation in the reference fleet.

The fuel advocates comments can be grouped into four main categories: 1) octane requirements for commercial fuel should be increased to enable the development and use of high efficiency internal combustion engines, with some advocating greater use of ethanol as a fuel additive, 2) flex-fuel credits should be restored, 3) the 2016 TAR fails to consider natural gas as a near-term, cost-effective approach to reducing carbon emissions, particularly for larger trucks. In addition, they argued renewable natural gas offers significant advantages over electrification in achieving life-cycle CO₂ benefits, and 4) the American Petroleum Association commented that credits and multipliers for “Advanced Technology Vehicles” should be

eliminated since they distort the marketplace and ignore the life-cycle emissions of these technologies.

One question of particular interest to California is whether the cost of compliance with the ZEV program should be attributed to the cost of compliance with the GHG regulations. As mentioned in the footnote for Table 3, U.S. EPA's modeling includes compliance with ZEV regulatory requirements in California and the Section 177 ZEV states in the reference fleet, while the NHTSA analysis does not. By including it in the reference fleet, the U.S. EPA analysis neither includes the GHG benefits from ZEVs to lower the fleet average closer to the final standards nor includes the costs from ZEVs required by the California regulation. Inclusion of compliance with the ZEV regulation is consistent with past practice by U.S. EPA and its "Guidelines for Preparing Economic Analyses"²¹ to consider compliance with all other relevant finalized vehicle regulations when assessing the impact of any one program. The ZEV regulation exists independently from the GHG regulations. Consequently, the costs of compliance with the ZEV regulations will not change regardless of the stringency or even the existence of the national GHG regulations. It is, therefore, not appropriate to attribute ZEV regulatory compliance costs to compliance with the national GHG program. California fully accounted for compliance costs in California with the increased ZEV requirements in the economic analysis that supported the 2012 ACC rulemaking. The program also included the costs of compliance for both the LEV III criteria pollutant regulations and the LEV III GHG regulations. Likewise, the states that subsequently adopted the ZEV regulation, as allowed by Section 177 of the Clean Air Act, followed the specific requirements of their individual state to legally adopt such requirements including any relevant economic and cost analysis.

Which other advanced gasoline technologies should ARB consider that were not evaluated in the 2016 TAR?

While the 2016 TAR and updated analysis in the Proposed Determination examined a range of technologies to reduce GHG emissions, some promising technologies under development by the manufacturers were not assessed due to their late stage of development. Among these technologies are variable compression ratio engines and skip-fire cylinder deactivation. These technologies were discussed at the recent ARB "Technology Symposium, Advanced Clean Cars: The Road Ahead," held on September 27-28, 2016. ARB staff is tracking this and other technology for consideration in future clean vehicle policies.

Downsized, turbocharged gasoline direct injection engines play a prominent role in the 2016 TAR due to their significant efficiency gains over conventional non-turbocharged gasoline engines. However, the amount of boost that can be employed in a given engine design is generally limited to prevent pre-ignition under engine high load operation. While this can be mitigated through the use of cooled exhaust gas recirculation and direct injection, the governing factor in limiting boost is the fixed compression ratio inherent in conventional engine designs.

²¹ EPA 2014. National Center for Environmental Economics, Office of Policy, United States Environmental Protection Agency *Guidelines for Preparing Economic Analyses*, December 17, 2010 (updated May 2014). [https://yosemite.epa.gov/ee/epa/eeerm.nsf/vwAN/EE-0568-50.pdf/\\$file/EE-0568-50.pdf](https://yosemite.epa.gov/ee/epa/eeerm.nsf/vwAN/EE-0568-50.pdf/$file/EE-0568-50.pdf)

As a result, a compromise must be made between engine performance at low and high load operating conditions, limiting the efficiency gains offered by turbocharging.

One approach to maximizing efficiency gains from turbocharging is to vary the compression ratio. Nissan Motor Corporation has announced a new production ready 2.0 liter variable compression ratio turbocharged engine (VC-T).²² The VC-T engine can vary its compression ratio between 8:1 (for high power) to 14:1 (for efficiency), depending on engine speed and load demand. In addition, the VC-T runs on the Atkinson cycle at all times providing additional efficiency gains relative to the conventional Otto-cycle operation. The VC-T engine also uses both port fuel injection and direct injection to control emissions during cold-start (particularly PM emissions) and maximize power. Nissan cites a 30 percent efficiency improvement for the 2.0 liter VC-T over a non-turbocharged 3.5 liter V6.

Cylinder deactivation offers efficiency improvements by reducing engine pumping losses during low load operation. Current systems are typically limited to deactivating one half of the engine's cylinders to address noise, vibration, and harshness (NVH) issues and provide up to an 8 percent improvement in engine efficiency. Tula Technology, Inc. has developed a more refined version of cylinder deactivation called Dynamic Skip Fire (DSF),²³ whereby engine cylinders can be deactivated on a continuously variable basis. The decision to fire or skip a cylinder is made before each cylinder event allowing for an immediate response to driver torque demand. The system proactively manages the engine firing sequence, maintaining benchmark NVH characteristics. Other features of the DSF include eliminating catalyst refueling penalties by completely shutting off all cylinders during deceleration, and fast torque control which reduces or eliminates spark retard during transmission shifts. Testing on a 6.2 liter V8 engine has demonstrated a 17 percent reduction in CO₂ emissions.

Variable compression ratio engines and DSF cylinder deactivation are two examples of applications which show how the automobile industry is rapidly improving the efficiency of the internal combustion engine even beyond the technologies evaluated in the 2016 TAR. These recent developments, along with technologies evaluated in the 2016 TAR, are expected to provide automakers with an ever-increasing list of options for improving vehicle efficiency in a cost effective manner, while maintaining consumer appeal and vehicle performance.

Why does ARB think that the 2022 through 2025 model year GHG standards are appropriate?

The analysis in the 2016 TAR and updated in U.S. EPA's Proposed Determination confirmed that the 2022 through 2025 model year GHG standards can be met predominantly with lower

²² Nissan 2016. Fujimoto, Yutaka, Nissan Technical Center N.A., "Introduction of Variable Compression Turbo Engine" (Presented at Technology Symposium, Advanced Clean Cars: The Road Ahead, September 28, 2016). https://www.arb.ca.gov/msprog/consumer_info/advanced_clean_cars/vct_engine_technology_yutaka_fujimoto.pdf

²³ Tula 2016. Younkens, Matthew, Tula Technology, "Tula Technology's Dynamic Skip Fire" (Presented at Technology Symposium, Advanced Clean Cars: The Road Ahead, September 28, 2016). https://www.arb.ca.gov/msprog/consumer_info/advanced_clean_cars/potential_benefits_of_cylinder_deactivation_mattthew_younkens.pdf

cost technology improvements than were originally projected in the 2012 rulemaking. The updated costs and technology mix projections confirm there are more cost-effective technology options than originally thought and result in a slightly lower overall estimated cost to comply. Furthermore, not all GHG reducing technologies that manufacturers are already planning for production were included in the 2016 TAR leaving additional technology paths for manufacturers to use for compliance.

The analysis concludes that minimal usage of ZEV technology will be needed in the national fleet to meet the GHG standards in model year 2025, with less than 5 percent of LDVs taking the form of a BEV or PHEV, as shown in Table 3 above. Given the ZEV market share in California was already at 3 percent in 2015, manufacturers seem adequately positioned to achieve this level of nationwide electrification in another 10 years especially with manufacturer product plans to more than triple the number of ZEV models available in the next five years and with battery costs declining faster and earlier than previously anticipated.

It is also encouraging to note that historically, manufacturers have frequently outpaced projections by the agencies in terms of increasing the capability of a technology to meet the requirements, using additional technologies unforeseen in the original projections, and doing so at lower costs than expected. The automotive market is extremely competitive and manufacturers and suppliers have significant expertise in developing and deploying innovative solutions to meet regulatory standards. The 2016 TAR recognizes this is already happening with technologies like Atkinson cycle engines, 48 Volt mild hybrids, and continuously variable transmissions now projected to have a larger role than what was imagined just four years ago.

Accordingly, this analysis confirms that the current national 2022 through 2025 model year GHG standards can be readily met at the same or lower cost than originally projected and manufacturers will likely continue to make progress towards even more cost-effective solutions.

What is the status of the treatment in the federal program of upstream emissions due to electricity and hydrogen generation for use in vehicles?

Board direction to staff included continuing to collaborate with U.S. EPA and NHTSA in the development and midterm evaluation of the national standards to minimize the chance for a reduction in GHG benefits from the different regulatory treatment of upstream emissions in the California and Federal programs. At the time of that direction, the California GHG standards included provisions to assign GHG emissions to alternative fuel vehicles like BEVs, PHEVs, and FCEVs to account for any incremental increase in GHG emissions needed to produce the electricity or hydrogen relative to producing gasoline. The federal GHG standards similarly accounted for upstream emissions but a provision was being considered at the time to temporarily waive that requirement and the Board expressed concern that such an action would result in a slight decrease in the cumulative GHG benefits. The final federal standards did ultimately include a temporary exemption from that provision for all BEVs, PHEVs, and FCEVs through the 2021 model year and a more limited exemption through the 2025 model year for a maximum number of vehicles per manufacturer.

Based on the latest projections, a few manufacturers would be expected to exceed the maximum vehicle limits and be required to start accounting for upstream emissions before the 2025 model year. Thus, ARB will continue to work with the federal agencies to track and address this policy issue.

Meanwhile, a number of programs both specific to California and nationwide have evolved that are relevant to the assessment of upstream emissions for electricity generation and hydrogen fuel production. These include California's Low Carbon Fuel Standard (LCFS), which requires a carbon intensity reduction in gasoline and diesel (which can be partly met with alternative fuel credits), and Renewables Portfolio Standard (RPS) which requires a renewable supply for electricity. Both of these rules directionally require reductions in GHG emissions associated with the production of vehicle fuels including electricity and hydrogen. Federally, the Clean Power Plan (CPP) adopted in 2015 could result in substantial reductions in GHG emissions from electricity generation nationwide yet there is significant uncertainty regarding the future of CPP given the current legal challenges. California, however, continues to vigorously defend the CPP and will continue to press U.S. EPA to fulfill its duties to control stationary source GHG emissions. Given these clean fuel programs have progressed beyond what ARB assumed in the 2012 rulemaking, it appears that upstream emissions for PHEVs, BEVs and FCEVs are being addressed.

Have consumer purchasing trends and California's fleet mix shifted in vehicle footprint to larger and higher polluting vehicles or resulted in the reclassification of cars as trucks that would deviate from the projected fleet in staff's original 2012 analysis?

The final question that the Board wished to examine concerning the LEV III GHG regulations was the question of a shift in California's fleet mix to larger vehicles and the reclassification of cars as trucks that deviates from what was projected in the original rule and the impact on the expected benefits of these regulations. As discussed in the 2016 TAR, the current and projected future mix of new vehicle sales has shifted to more trucks and fewer cars than was originally projected in 2012 for the nationwide fleet. However, in terms of the California fleet, as discussed in Appendix M, the trends are similar but the overall result is different because of a larger fraction of car sales in California's market.

With respect to footprint, the California and national fleets are showing a very slight increase in the sales weighted footprint of the combined fleet. However, it is not yet clear if the construct of the GHG standards are the determining factor influencing this trend. In its Trends Report, U.S. EPA looked at the average footprint for new cars and trucks sold nationwide for the 2008 through 2015 model years.²⁴ That analysis, summarized in Table 6 below, shows the average footprint of a new car has increased by 0.8 square feet (approximately 1.8 percent) and the average footprint of a new truck has increased by 1.5 square feet (approximately 2.8 percent) within this time period.

²⁴ EPA 2015b

Table 6 - Average New Car and Truck Footprint for model years 2008 through 2015

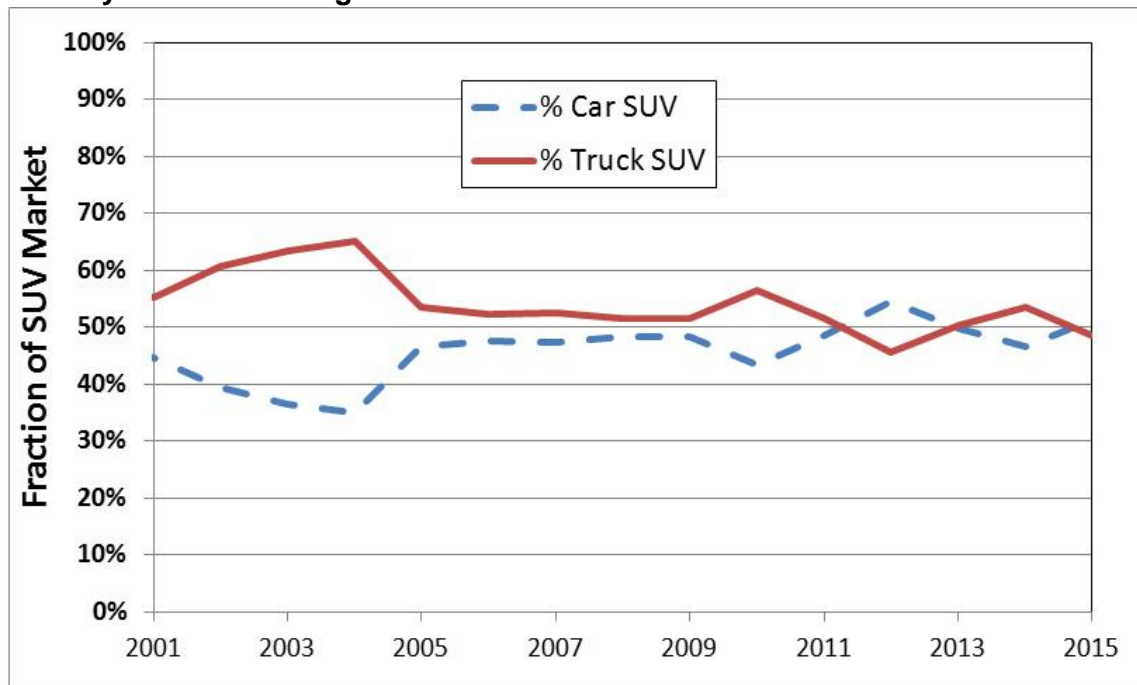
Model Year	Car Footprint (square feet)	Truck Footprint (square feet)
2008	45.3	54.0
2009	45.1	54.0
2010	45.4	53.8
2011	46.0	54.4
2012	45.7	54.5
2013	45.9	54.7
2014	46.1	55.0
2015 (preliminary)	46.1	55.5

Source: U.S. EPA's *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2015 Trends Report*

When combined with the increasing share of the market from truck sales, the slight increase in average footprint does result in an overall increased nationwide car/truck fleet average relative to what was originally projected. The largest influence appears to be a higher share of truck sales that generally have a larger footprint than cars rather than a significant increase in the average footprint within the car or truck segment itself. However, given the substantial lead time necessary to redesign base vehicle platforms including parameters that determine the footprint, it is probably too early to determine the impact of standards adopted only four years ago. Accordingly, the agencies will continue to monitor trends in the national and California-specific fleet and should there be an indication that the footprint based structure of the regulation is resulting in a loss of GHG reductions, ARB can consider options to fill the shortfall in future rulemakings.

On the question of reclassification of cars as trucks, there has been an increase in the share of trucks in new vehicle sales and the 2015 AEO projections noted earlier also predict a larger share of trucks in 2025 than originally projected. However, a shift to more trucks is not necessarily an indication of manufacturers making changes to reclassify vehicles that were formerly considered cars. U.S. EPA looked at national trends associated with the classification of small sport utility vehicles or SUVs (inertia weights of 4,000 pounds or less) as either cars or trucks between model years 2000 and 2015. SUVs of this size are classified as cars if they have 2-wheel drive and as trucks if they have 4-wheel drive and meet other design criteria. Based on the trends shown in Figure 2, it does not appear that a reclassification of small SUVs from cars to trucks is occurring at this time.

Figure 2 - Car-Truck classification of SUVs with inertia weights of 4,000 lbs or less for model years 2000 through 2015



Source: U.S. EPA's *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2015 Trends Report* (EPA 2015b)

Observations to date largely confirm a change in consumer preference from sedans to crossover and small utility vehicles that are not related to a reclassification of an existing model from a car to a truck. For example, Toyota has indicated the RAV4 SUV is poised to displace the Camry sedan as the company's top selling model in the U.S.²⁵ resulting in increased truck sales not because Toyota is reclassifying a vehicle from a car to a truck but because consumers are choosing to buy a different vehicle. However, as noted with respect to vehicle footprint, it has only been four years since the GHG standards were adopted and vehicle redesigns that would be necessary to change a vehicle's classification from car to truck can require significant lead time.

In the California fleet, preliminary data for the 2012 through 2014 model years are generally consistent with the trends observed nationwide although California has a significantly higher share of car sales than the nationwide fleet and the California vehicle footprints are slightly different for both the car and truck fleets. Similar to nationwide, the California car/truck mix is shifting towards higher truck sales but, unlike the national fleet where cars and trucks are expected to be about equal shares by 2025 in the 2015 AEO projections, cars are still expected to remain the larger share of the California fleet in 2025. Staff expects that further changes to car/truck sales mix and average footprint in the California fleet will likely be similar to trends happening nationwide as projected by the more recent 2016 AEO and has developed its

²⁵ Toyota 2015. Toyota Motor Corporation. Bob Carter. Quoted in Bloomberg article December 3, 2015, <http://www.bloomberg.com/news/articles/2015-12-03/toyota-says-rav4-small-suv-will-dethrone-camry-as-its-top-seller>

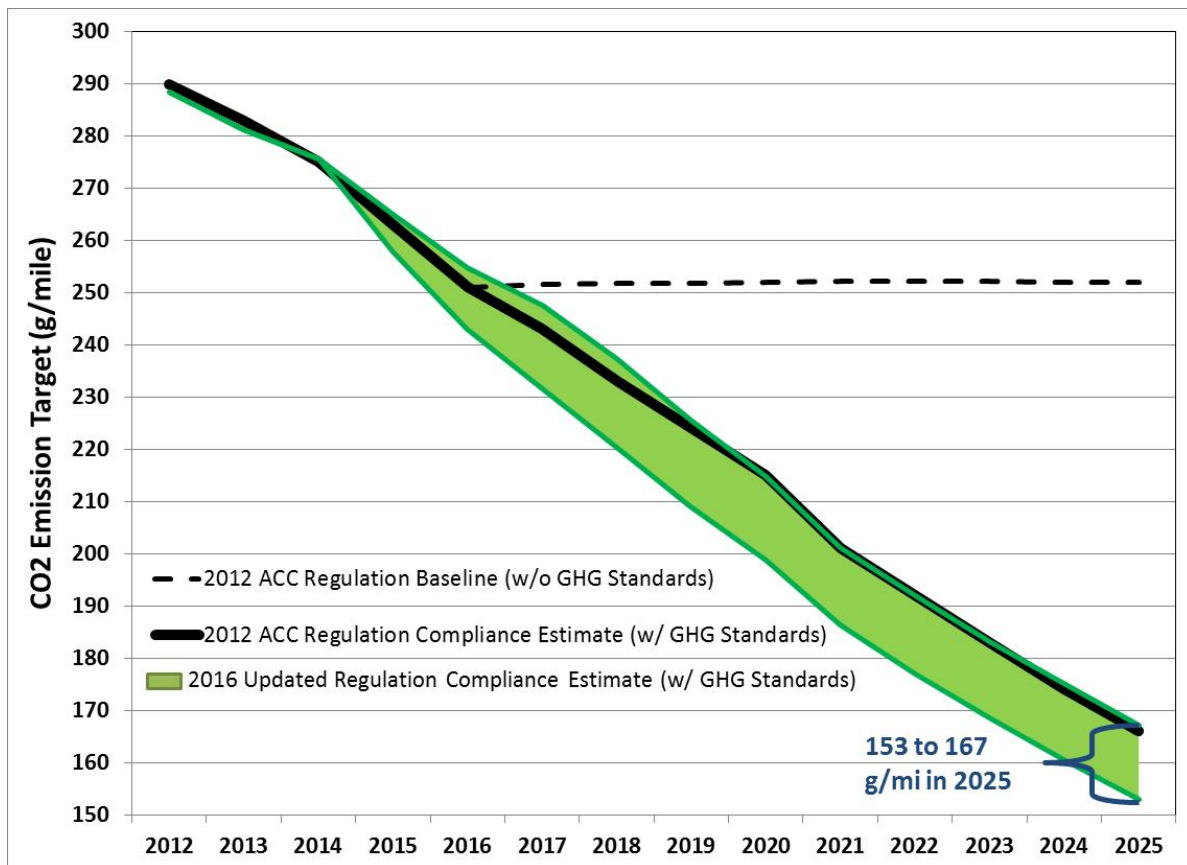
analysis by applying the same growth trends in the nationwide 2016 AEO to the California-specific fleet.²⁶ The reader can refer to Appendix M for further details.

When considered in total, the newer and more accurate information regarding footprint and car/truck share in the California fleet does result in a different projection of GHG benefits than originally projected for ARB's 2012 rulemaking. The original California projection included a conservative assumption that cars represented only 63 percent of the California market and that this fraction would essentially remain unchanged through model year 2025. For footprint, the original assumption was a constant 45.1 and 52.3 square feet for cars and trucks, respectively through 2025 model year. These assumptions resulted in a projected combined new car/truck fleet average of 166 grams per mile (g/mi) CO₂ in the 2025 model year in California. From actual sales data, it is now known that cars represented approximately 73 percent of the California fleet in 2012 and, despite a shift to more trucks since then, the car sales share is still above 69 percent today. It is also known that the actual footprint was about 1 percent higher and the truck footprint was about 5 percent higher than originally estimated.

The higher fraction of car sales results in lower (more stringent) emission targets for those years relative to the original assumptions, but the larger footprints mostly offset those reductions such that the overall emission targets remained essentially the same as the original 2012 projections for the 2012 through 2015 timeframe. Beyond the 2015 timeframe, however, the new projections based on the 2016 AEO generally show increased reductions (more stringent target standards) than originally projected primarily because the car share remains higher than originally thought. Accordingly, the combined new car/truck fleet average in California for 2025 is now projected to be between 153 and 167 g/mi CO₂ when using the AEO scenarios and footprint growth sensitivities analyzed by staff including the AEO reference, high fuel price, and low fuel price scenarios as illustrated in Figure 3 below. Only in the sensitivity case using the AEO reference, coupled with a continued footprint growth, does the combined new car/truck fleet average exceed what was estimated in the 2012 ARB rulemaking (167 vs. the original 166 g/mi CO₂).

²⁶ 2016 TAR utilized data from the 2015 AEO report as the 2016 AEO report wasn't published until Sept 2016

Figure 3 - Updated estimates of combined new car/truck fleet average in CA (gCO₂/mi)



Particulate Matter Emission Standard Review

What are the LEV III particulate matter emission standards?

PM emissions from light- and medium-duty vehicles are regulated as part of the LEV program. Under LEV III, the PM emission standard for passenger cars, light-duty trucks, and medium-duty passenger vehicles was lowered from 10 mg/mi to 3 mg/mi starting with 2017 model year vehicles. The 3 mg/mi PM standard is phased-in incrementally with full implementation by model year 2021. LEV III lowers the PM standard even further to 1 mg/mi starting with 2025 model year vehicles and also phases-in incrementally, with full implementation attained by model year 2028. In the long term, the 1 mg/mi PM standard will be an effective backstop to retain the progress in PM emission reductions achieved by today's gasoline car fleet in California and further reduce the health impacts associated with exposure to PM emissions. It will also help ensure the continued development of low-PM engine technology.

Mitigation of the impact of PM emissions on public health is of paramount concern to ARB. Consequently the Board directed staff to explore the feasibility of implementing this standard earlier than the scheduled 2025 model year implementation. This required a re-evaluation of

both the emission measurement feasibility and the technological feasibility of the 1 mg/mi PM standard based on the best available information available today.

What emission reductions are expected from implementation of the 1 mg/mi PM standard?

The relationship between PM exposure and health effects is well documented in that increased exposure leads to cardiopulmonary disease and several other adverse health outcomes. In general, lower PM standards will help reduce ambient PM_{2.5} emissions levels statewide, in the San Joaquin Valley (SJV), and near busy roadways. The implementation of the adopted 1 mg/mi standard is projected to reduce PM in 2035 by 0.33 tons per day (TPD) statewide and by 0.03 TPD in the San Joaquin Valley.

The black carbon fraction of PM emissions is a recognized short lived climate pollutant with a strong global warming potential (GWP), between 900 and 3200 times more powerful than CO₂, making even small reductions in black carbon directionally beneficial to meeting California's GHG reduction goals. The climate change benefit in 2035 from the black carbon reduction associated with the 1 mg/mi standard is 70,000 and 270,000 metric tons CO₂-equivalent annually for 100-year and 20-year GWP, respectively, which is small but appreciable.

Is the gravimetric PM mass measurement method appropriate for the 1 mg/mi standard?

In October 2015, staff presented a technical review of the feasibility of low PM mass emission measurement to the Board.^{27,28} This review was conducted by ARB researchers, in collaboration with U.S. EPA, industry, and other stakeholders and was based on extensive studies, testing, and laboratory evaluation of PM emissions at 1 mg/mi and below.

As a result of these studies, staff concluded that the existing gravimetric method prescribed for the Federal Test Procedure (FTP) driving cycle and specified in the 40 Code of Federal Regulations, Parts 1065 and 1066 in conjunction with appropriate laboratory practices is sufficient for precise measurement of PM emissions at and below 1 mg/mi. These studies also revealed that, at very low PM emission levels, the correlation of PM mass to various alternative measurement metrics such as solid particle number emissions or black carbon emissions varied for different test cycles and engine technologies resulting in a determination that these methods were not equivalent to the gravimetric method in determining PM mass but still yielded useful information in understanding vehicle PM emissions.

²⁷ ARB 2015b. California Air Resources Board. Staff Presentation. October 22, 2015.

<http://www.arb.ca.gov/board/books/2015/102215/15-8-7pres.pdf>

²⁸ ARB 2015a.

Is technology available today that enables manufacturers to meet a 1 mg/mi PM standard?

While the core necessary technologies exist today, this new assessment suggests that additional refinement prior to vehicle portfolio-wide deployment is needed to ensure a robust solution to meet the standard. Advanced GDI technology, the fuel injection technology preferred by auto manufactures for its GHG benefit, coupled with appropriate in-cylinder improvements such as software or engine hardware modifications can be used to meet the 1 mg/mi PM standard. In-cylinder improvements are primarily aimed at reducing or eliminating fuel impingement on combustion chamber surfaces and other localized rich combustion areas that lead to incomplete combustion and high PM emissions. If cases exist where in-cylinder control is not sufficient or the manufacturer prioritizes other design considerations, aftertreatment devices such as gasoline particulate filters (GPFs) represent a viable alternative to meet the 1 mg/mi emission limit. These compliance options are explained further below.

Manufacturers can use a variety of software improvements to control PM emissions including optimized injection timing, precise fuel metering, and multiple injections per combustion event. These strategies, combined with engine hardware improvements, help to reduce fuel impingement on combustion chamber surfaces, the major contributor to PM emissions. This is particularly critical during cold start operation when the combustion chamber surfaces are cold and PM emissions are at their highest.

Improvements to engine hardware include improvements to the fuel injection system, combustion chamber design, and thermal management. Fuel injection system improvements include injector designs with shaped spray patterns to minimize or eliminate fuel impingement on combustion chamber surfaces, increased fuel system pressures to reduce fuel droplet size and improve atomization, and improved injector tip design to reduce coking, which can lead to increased PM formation as the system ages. Improvements to the combustion chamber and intake port designs include changes to the shape of the piston top to reduce fuel impingement, thermal management of the injector tip and piston top to facilitate rapid evaporation of liquid fuel, and intake port design to increase tumble and reduce wall wetting while improving the air/fuel mixture. Many of these changes require extensive engine hardware re-design.

Manufacturers can also employ aftertreatment changes to reduce PM emissions. Cold-start catalyst light-off strategies to rapidly heat up the catalyst and catalyst design can indirectly reduce PM emissions. Changes to the catalyst layout including the use of a more closely coupled catalyst to the exhaust manifold can reduce catalyst light-off time thereby limiting the duration of a catalyst light-off combustion strategy that temporarily increases engine-out PM emissions. PM emissions can also be directly controlled with a GPF. GPFs are placed in the exhaust to trap PM emitted by the engine regardless of vehicle operational mode. The GPF can be integrated into the existing emission control configuration as a catalyzed substrate that replaces a portion of the three-way catalyst system or as a separate non-catalyzed device that

is added downstream from the existing catalyst(s). GPFs have been reported to have low backpressures such that the adverse effect on GHG emissions is insignificant or minimal.²⁹ While the costs of adding a GPF may be higher than in-cylinder PM control solutions that can be incorporated during a scheduled re-design, they provide manufacturers with a robust alternative strategy for reducing PM emissions.

Are vehicles capable of meeting the 2025 model year 1 mg/mi PM emission standard while complying with the stringent GHG and NMOG+NOx tailpipe standards?

Effective PM emission control balances GHG, hydrocarbon (HC), and NOx emissions against PM reductions. This is particularly critical during cold-start emissions when up to 90 percent of criteria pollutant emissions occur. Some manufacturers have indicated that optimal fuel injection strategies for PM control during cold-start operation can significantly affect HC and NOx emissions. Accordingly, manufacturers must be careful when implementing new control strategies to maintain control of HC, NOx, and GHG emissions.

The test data and analysis presented in this report shows that vehicle manufacturers have achieved significant PM emission reductions over the last redesign cycle and are on track to meet the 1 mg/mi PM emission standard in the required timeframe even as they implement advanced technologies to reduce GHG, HC, and NOx emissions. A key aspect of this assessment is the ability of manufacturers to incorporate necessary in-cylinder 'best-practices' for PM control into scheduled engine updates or redesigns. As noted in Appendix K, recent testing of vehicles using engine technologies representative of likely future low GHG-emitting vehicles has shown considerable reductions in PM emissions in anticipation of the upcoming 3 mg/mi standard with most vehicles already emitting below 1.5 mg/mi. This is substantially lower than earlier generation GDI equipped engines and a direct result of the recent redesigns that most of the tested engines have had in anticipation of upcoming PM emission standards. As noted earlier, the ACC program was designed to ensure that manufacturers fully considered criteria pollutant requirements (including PM emissions) in concert with the increasingly stringent GHG standards as they developed GHG technologies for future vehicles but also factored in engineering and laboratory resource constraints that manufacturers face. These considerations resulted in the longer lead time provided for the phase-in of the 1 mg/mi PM emission standard.

What are the results from ARB's PM test program?

ARB staff procured and tested commercially available vehicles that use low-GHG internal combustion engine technologies that are projected to be commonly used on light-duty vehicles between model years 2022 and 2025. These vehicles are described in Appendix K. Given the

²⁹ Brezny 2016. Dr. Rasto Brezny. MECA. "Particulate Control Experience with GDI and GPFs." (Presented at Technology Symposium, Advanced Clean Cars: The Road Ahead, September 28, 2016). https://www.arb.ca.gov/msprog/consumer_info/advanced_clean_cars/gasoline_direct_injection_particulate_control_experience_with_gasoline%20particulate_filters_for_gasoline_vehicles_rasto_brezny.pdf

scheduled PM standard phase-in, none of the test vehicles were designed to meet the 1 mg/mi standard and none of the GDI equipped vehicles were yet certified to the 3 mg/mi standard (although the results indicate several were likely designed knowing that certification with the 3 mg/mi standard would be required in the next few years). The test program found that, although some vehicles emitted below the 1 mg/mi standard, the majority did not meet the standard with an adequate margin of compliance to account for variability and emission increases that can occur over the full useful life of a vehicle. The low-GHG internal combustion engine technologies that were tested mostly rely on in-cylinder controls that are likely solutions for compliance with the 3 mg/mi PM standard. Among the vehicles ARB tested to evaluate PM emissions include several that meet the stringent LEV II SULEV standards. These results show the potential of vehicles to simultaneously meet the future GHG and low criteria pollutant emission standards including PM standards.

According to staff's analysis presented in Appendix J, there is still opportunity for further improvement of PM control relative to current GDI vehicles. Many of the vehicles ARB tested, presented in Appendix K, emit at levels that would readily comply with the 3 mg/mi PM emission standard with emissions from 1.2 – 1.4 mg/mi on the FTP cycle. This is consistent with manufacturers' assertions that because of variability, uncertainty, and durability requirements for the full vehicle useful life of 150,000 miles, the target emission rate is about half the standard for vehicles certified to the 3 mg/mi PM standard. The data also indicate that controlling PM emissions to meet the 3 mg/mi standard does not necessarily lead to emission rates below 1 mg/mi and, for most vehicles, further work will be necessary to ensure compliance with a 1 mg/mi standard. Given the progress already seen with lower PM levels in anticipation of the 3 mg/mi standard, manufacturers should have sufficient time to incorporate further improvements in fuel system and engine design, controls, and calibration to reduce PM levels below the 1 mg/mi standard.

However, the test results shown in Table 7 below also revealed that some vehicles that exhibit good control of PM emissions on the FTP cycle have notably higher emissions on the US06 cycle, which is representative of high speed and acceleration driving conditions. As indicated by these test results, low FTP PM emissions do not necessarily correspond with low US06 emissions. This is of concern because the FTP and US06 standards are used by ARB to ensure robust in-use emission control over the spectrum of typical real-world driving conditions. Under the LEV III regulations, the FTP PM emission standard drops to 1 mg/mi in 2025, but the US06 standard remains at 6 mg/mi indefinitely. The test program results confirm that the current US06 standard may not ensure a sufficient level of emission control. Further, high emissions during the US06 cycle may relate to higher near-roadway emission levels and subsequent exposures, which can have a disproportionate impact on low income and sensitive populations who may reside, work, or spend significant time near busy roadways.

Table 7 - PM FTP and US06 Test Results

Vehicle	Emission Category	FTP	US06
		Average Mass (mg/mi)	Average Mass (mg/mi)
2012 Lexus IS350	LEV II ULEV	5.6	1.3
2013 Chevy Volt	LEV II SULEV	0.3	0.1
2013 Toyota Prius PHEV	LEV II SULEV	0.1	0.3
2014 Ford Fiesta	LEV II ULEV	1.4	1.4
2014 Mercedes CLA	LEV II ULEV	0.3	0.3
2014 Mini Cooper S	LEV II ULEV	0.4	1.2
2015 Mazda 3	LEV II SULEV	1.5	0.6
2015 Subaru BRZ	LEV II ULEV	1.0	3.1
2016 Honda Accord	LEV III SULEV	0.9	1.7
2016 Hyundai Sonata PHEV	LEV III SULEV30	1.2	2.3
2016 Toyota Prius	LEV III SULEV30	0.1	0.3
2016 Toyota Tacoma	LEV III ULEV70	0.4	2.3
2016 VW Jetta TSI	LEV II ULEV	0.3	1.0

Staff also tested prototype gasoline particulate filters (GPFs) for controlling PM emissions on two newer GDI engines that had gone through a partial redesign cycle, but would not yet readily meet the 3 mg/mile standard. The emission reductions from GPF testing are shown in Table 8. On the FTP, an 88% reduction was observed for both vehicles and brought emissions to a level below 1 mg/mi. The effectiveness of the GPFs on the US06 was somewhat lower, reducing PM emissions by 72% and 54% respectively for the F-150 and Malibu. The results from both vehicles show that GPFs are an effective control technology to meet future 1 mg/mi PM standards, even for particularly challenging engines.

Table 8 – PM GPF Test Results

Vehicle	FTP		US06	
	Average Mass (mg/mi)	GPF Effectiveness (%)	Average Mass (mg/mi)	GPF Effectiveness (%)
2015 FORD F150	5.5		3.9	
2015 FORD F150 W/GPF	0.6	88%	1.1	72%
2016 CHEV MALIBU	7.0		2.1	
2016 CHEV MALIBU W/GPF	0.8	88%	0.9	54%

Should the 1 mg/mi PM emission standard be phased-in earlier based on the new analysis?

As discussed earlier, given manufacturers' progress to date it is reasonable to expect that with a similar effort over the next design cycle(s), all future vehicles will be able to meet the 1 mg/mi FTP standards as projected in the 2012 LEV III ISOR.³⁰ However, accelerating implementation of the 1 mg/mi PM standard would jeopardize the ability of the manufacturers to incorporate the next round of necessary PM refinements across their entire vehicle offerings and within scheduled engine design updates. Less time to engineer and innovate robust solutions would reduce the ability of manufacturers to validate their current round of PM improvements and determine if these improvements are sufficiently durable to ensure low emissions throughout the 150,000 mile useful life of LEV III vehicle standards.

While there are other technologies that are near production ready such as even more advanced injection control systems or GPFs that could be used prior to model year 2025 to meet the 1 mg/mi standard, such technologies would likely result in an increased cost to comply than originally projected and divert testing and development resources from manufacturers that are focused on achieving other required reductions in the same timeframe. Further, these new technologies are still evolving and additional time is needed to ensure they are ready for wide-scale deployment, have sufficient durability, and the implications of their use relative to other emission requirements such as on-board diagnostic systems is understood.

Because of the necessary time to incorporate robust solutions to further reduce PM, implementing the 1 mg/mi PM standards substantially sooner than model year 2025 would likely entail increased costs to manufacturers (through unscheduled redesigns or increased reliance on GPFs) and have limited additional emission benefit. For ambient air quality, the projected incremental PM benefit associated with earlier implementation of the 1 mg/mi standard would be 0.06 TPD statewide and 0.007 TPD in the SJV in 2035. Accordingly, staff is not recommending pursuit of a regulatory action at this time to require earlier implementation of the 1 mg/mi PM emission standard.

What is staff's recommendation with respect to PM standards?

Staff's updated analysis has confirmed that compliance with the 1 mg/mi FTP standard by 2025 is feasible and manufacturers are on track to meet the standard. And, as noted above, staff is not recommending earlier implementation of the 1 mg/mi standard. However, the same research and testing in support of this midterm review has revealed concerns regarding the robustness of PM control under broader in-use driving conditions than the FTP represents.

³⁰ ARB 2012b. California Air Resources Board. *Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider the "LEV III" Amendments to the California Greenhouse Gas and Criteria Pollutant Exhaust and Evaporative Emission Standards and Test Procedures and to the On-Board Diagnostic System Requirements for Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles, and to the Evaporative Emission Requirements for Heavy-Duty Vehicles*. December 7, 2011.
<https://www.arb.ca.gov/regact/2012/leviiiighg2012/levisor.pdf>

Accordingly, staff recommends pursuing a new regulatory update to ensure that, when the 1 mg/mi standard is phased-in, it results in robust PM control over the broad spectrum of driving conditions encountered in-use. Thus, staff recommends that the Board direct staff to: (a) pursue an increase in stringency of the US06 PM standard to ensure a similar level of PM emission control in conjunction with the 1 mg/mi FTP standard; and (b) to investigate adoption of additional standards and procedures applicable to other test cycles and ambient conditions that will ensure more comprehensive control of PM emissions under all operating conditions. These actions will also ensure that any future PM standards achieve meaningful and sustained in-use reductions.

ZEV Review

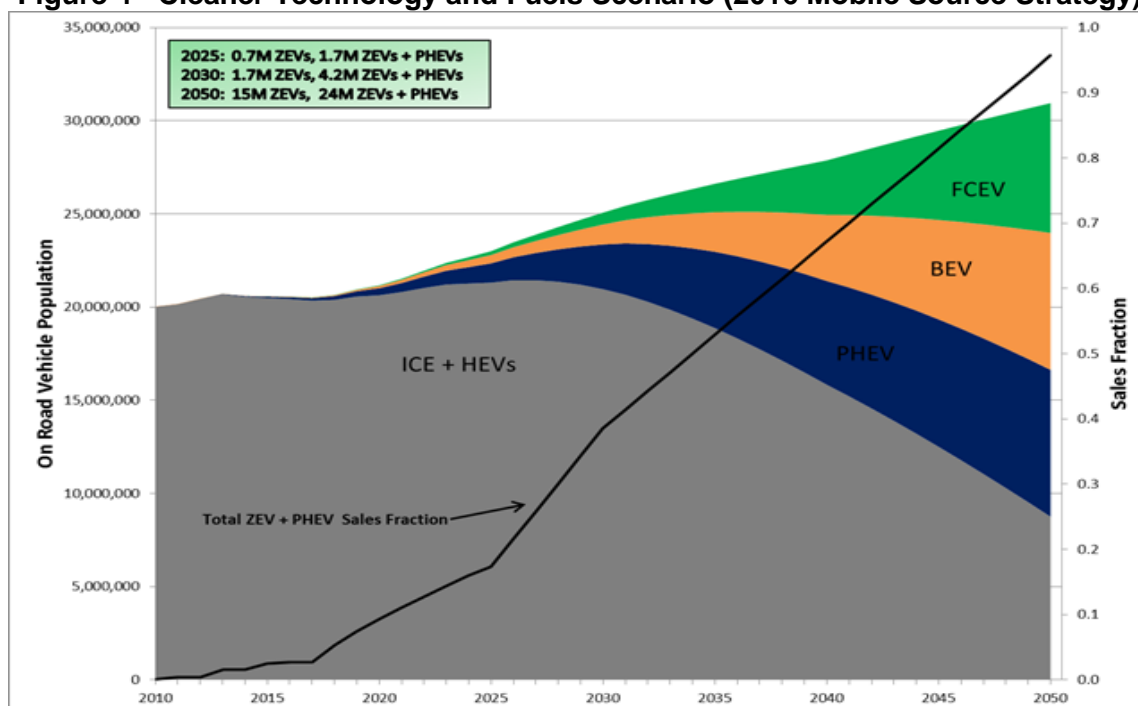
Are ZEVs and PHEVs still necessary for meeting California's long term air quality and GHG goals?

The LDV sector accounts for nearly 30 percent of the state's GHG emissions, making further reductions necessary in order to meet significant 2020, 2030, and 2050 GHG emission reduction targets in the future. In 2009, staff's modeling found "... [pure] ZEVs will need to reach 100 percent of new vehicle sales between 2040 and 2050, with commercial markets for ZEVs launching in the 2015 to 2020 timeframe."³¹ More recently, the ARB Mobile Sources Strategy report, released in May 2016, confirmed the essential role electrification will need to play in the LDV sector to meet California's long term emission reduction goals. The updated VISION scenarios in the Mobile Source Strategy show that PHEVs can remain a permanent fraction of the market, providing more flexibility for manufacturers. However, as shown in Figure 4 the combined sales of pure ZEVs and PHEVs for light-duty vehicles will still need to achieve 100 percent by 2050. A recent American Lung Association analysis confirms the importance of a long-term, full electric transformation to reduce health based and social costs.³² The study estimates health based impacts in 2015 from passenger vehicles in California and the Section 177 ZEV states to be \$24 billion, but that the cost could decline to \$3 billion by 2050 under a scenario where sales of ZEVs and PHEVs reach 100 percent by 2050.

³¹ ARB 2009, California Air Resources Board. November 25, 2009. "2009 White Paper: Summary of Staff's Preliminary Assessment of the Need for Revisions to the Zero-Emission Vehicle Regulation" November 25, 2009. <https://www.arb.ca.gov/msprog/zevprog/2009zevreview/zevwhitepaper.pdf>

³² ALA 2016, American Lung Association. "Clean Air: Health and Climate Benefits of Zero Emission Vehicles" October 2016. <http://www.lung.org/local-content/california/documents/2016zeroemissions.pdf>

Figure 4 - Cleaner Technology and Fuels Scenario (2016 Mobile Source Strategy)



Do PHEVs provide equal or greater environmental benefit than BEVs?

Since 2014, manufacturers have used data from the U.S. Department of Energy (U.S. DOE) EV Project to support a position that PHEVs with substantial electric range could provide greater or equal environmental benefit than BEVs.³³ This assertion along with the Board's direction in 2012 led staff to assess how PHEVs are being used (in comparison to BEVs) and their overall emission impact.

A significant portion of PHEV miles can be attributed to grid powered energy (typically called a vehicle's electric vehicle miles travelled or eVMT). This correlates well with the PHEV's GHG emission benefit. However, eVMT does not provide a complete picture of how "ZEV-like" a PHEV is. One intrinsic benefit of a ZEV is its criteria pollutants emission reduction; zero engine starts mean ZEVs are an ideal solution to reducing criteria pollutant emissions. In this regard, staff analyzed two metrics to evaluate a PHEV's criteria pollutant benefit using data provided by manufacturers: electric only trips (e-trips) and zero-emission vehicle miles traveled (zVMT). e-Trips are trips when the vehicle's engine is not used at all (thus, an avoided engine start), whereas zVMT is the sum of miles from all e-Trips. Table 9, shown below is a summary of staff's analyses; further details can be found in Appendix G.

³³ Honda 2013. Robert Bienenfeld. "Honda's Testimony at the California Air Resources Board's Advanced Clean Car Hearing" October 24, 2013. Available: <http://www.arb.ca.gov/lists/com-attach/21-zev2013-UCJVPFc0VWNVIQN3.pdf>

Table 9 - Summary of eVMT and zVMT

Type of Vehicle	VMT – Annual Miles	eVMT – Annual Miles (% of VMT)	zVMT - Annual Miles (% of VMT)
Toyota Prius (PHEV)	15,283	2,304 (15%)	589 (4%)
Honda Accord (PHEV)	15,221	3,246 (21%)	1,471 (10%)
Ford C-Max Energi (PHEV)	13,920	4,574 (33%)	2,525 (18%)
Ford Fusion Energi (PHEV)	15,076	4,776 (32%)	2,368 (16%)
Chevrolet Volt (PHEV)	12,403	8,924 (72%)	7,313 (59%)
BMW i3 (BEVx)	9,063	8,387 (93%)	N/A
BMW i3 (BEV)	7,916	7,916 (100%)	7,916 (100%)
Ford Focus Electric (BEV)	9,741	9,741 (100%)	9,741 (100%)
Honda Fit (BEV)	9,789	9,789 (100%)	9,789 (100%)
Nissan Leaf (BEV)	10,294	10,294 (100%)	10,294 (100%)
Tesla Model S (BEV)	13,494	13,494 (100%)	13,494 (100%)

Each average presented in Table 9 represents a set of drivers in a given time.³⁴ However, driving data from the same vehicle model can vary widely dependent on when and under what driving conditions the data were collected. As an example, this can be seen when looking at data from the Chevrolet Volt. According to data from U.S. DOE's EV Project, total Volt VMT is ~12,400 miles on average. Approximately 72% of these miles are driven electrically, and are referred to as the vehicle's eVMT fraction. However, according to a 2016 General Motors press release based on a larger data sample of Volt drivers, Volts drive only 60% of their miles on grid-powered energy.³⁵ This difference could be due to the fact that EV Project participants

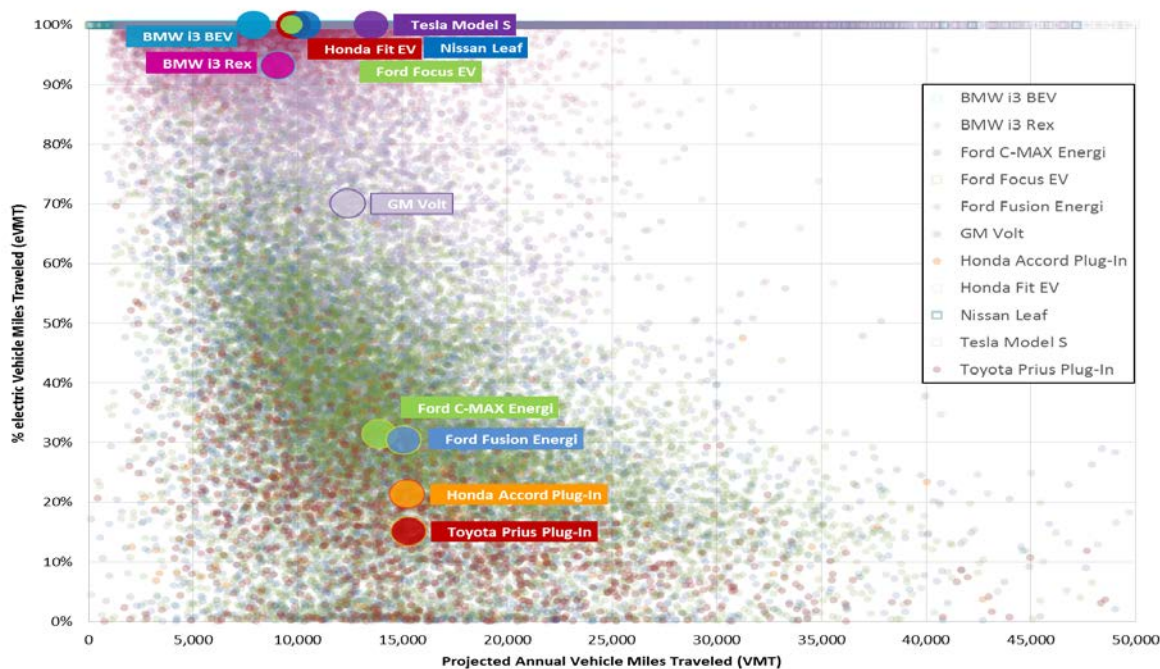
³⁴ Each manufacturer provided data set is fully described in Appendix G, Section II.

³⁵ GM 2016a. General Motors. Press Release. August 1, 2016. <http://www.gm.com/mol/m-2016-aug-080116-volt.html>

were a limited set of very early adopters and were given no-cost Level 2 charging equipment for home installation.³⁶

Table 9 shows average eVMT and zVMT for each PEV analyzed in staff's analysis. Averages, however, do not fully capture the model's potential environmental benefit or impact. These factors (both eVMT and zVMT) are highly driver dependent and based on daily trip distance, daily trip count, and electric charging accessibility and region, just like all VMT for conventional or advanced technology cars. Shown below in Figure 5 and Figure 6, vehicles with similar electric ranges have varied eVMT and zVMT. Even among the BEVs with a 100 to 120 mile urban dynamometer drive schedule (UDDS) electric range, there is significant variance in total VMT, while Tesla's Model S with well over 200 miles of range shows an even wider array of VMT across its single platform.

Figure 5 - eVMT variation across PEVs



³⁶ For a complete description of U.S. DOE of Energy EV Project and staff's full analysis, see Appendix G.

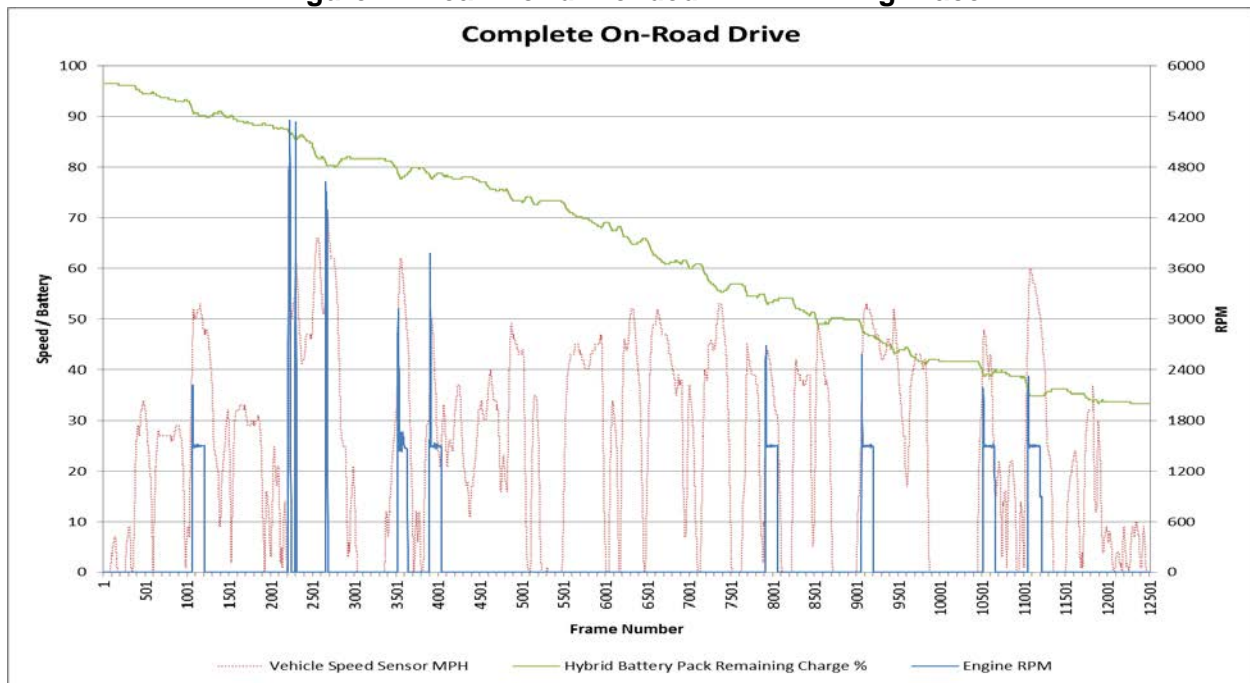
Figure 6 - zVMT variation across PEVs



Looking further into PHEVs criteria pollutant emission impacts, staff evaluated the cold start emissions of three blended PHEVs believed to be representative of currently available PHEVs and the results are presented in Appendix H.

For blended PHEVs, both grid energy and the internal combustion engine (ICE) can be used simultaneously to power the vehicle during charge-depleting (CD) operation. Generally this occurs when the vehicle power demand is higher than what the electric only propulsion system can provide and the vehicle starts the engine to combine the electric and ICE power to meet the vehicle demand. As a result, blended PHEV CD operation introduces a unique driving condition where the initial engine start of a trip occurs at a time where there is an immediate need for the engine to provide significant power and torque to help propel the vehicle. Such starts, referred to here as “high-power” cold-starts, can have different emission characteristics relative to the initial engine start of a conventional vehicle which typically occurs with the vehicle stopped, in park/neutral, and with a very low immediate torque demand. Figure 7 below shows a drive near ARB’s Haagen-Smit Laboratory where a blended PHEV was operated through various roadway conditions to understand the types of conditions that cause these high-power engine starts before the battery has been fully depleted.

Figure 7 - Real-World Blended PHEV Driving Trace



The testing confirms that cold-start emissions can be significantly higher under high-power demand conditions relative to more traditional engine start conditions.³⁷ Staff will conduct further testing and has begun discussions with the vehicle manufacturers to discuss emission control strategies and alternatives that may provide for more robust emission control in these conditions. It is also important to note that all of the vehicles tested are first generation PHEVs and most manufacturers are expected to introduce more capable second generation PHEVs in the near future. To the extent future blended PHEVs have stronger electric propulsion systems and longer electric range, those vehicles should be able to reduce the frequency of trips with an engine start including those with a high-power engine start. As one example, the Prius Prime is Toyota's second generation PHEV and is designed to primarily operate as a non-blended PHEV, thereby potentially eliminating most high-power engine starts. However, as more manufacturers enter the PHEV market and PHEVs are introduced on larger and heavier vehicle platforms, blended PHEVs will likely continue to play a significant role and warrant continued evaluation to ensure in-use start emissions are controlled as robustly as possible.

Based on in-use data from PHEVs, emission testing, and analysis of electric use conducted by ARB, PHEVs can generate significant benefits over conventional vehicles but do not generally result in GHG or criteria pollutant emission reductions equal to pure ZEVs.

Could California meet its long term goals predominantly with PHEVs?

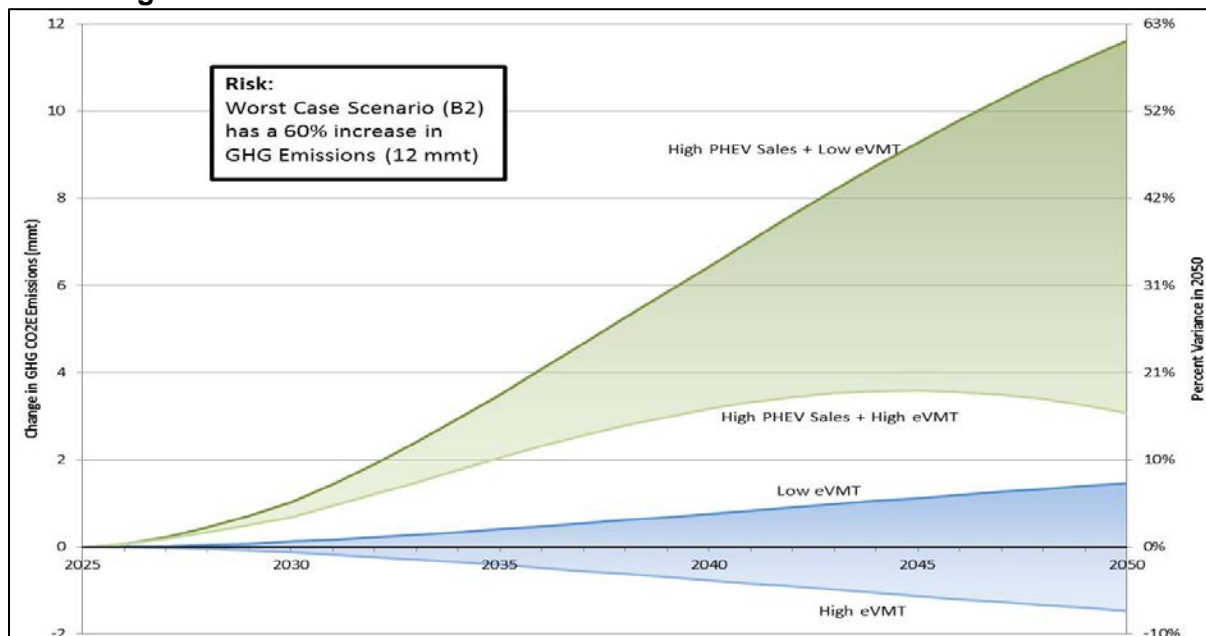
ARB's latest long-term scenario released in the Mobile Source Strategy (called the Cleaner Technologies and Fuels, or CTF, scenario) showed PHEVs could be a significant share of the

³⁷ Appendix H describes staff's in-house PHEV testing.

fleet (see Figure 4 above), and the light-duty vehicle sector would still be on track to meeting its share of emission reductions for the 2030 and 2050 GHG goals. This is due in part to aggressive assumptions in the vehicle sector including PHEVs achieving higher proportions of their miles on electricity, all gasoline vehicles having significant gains in fuel efficiency over time, increases in renewable energy usage, and slower growth in vehicle miles traveled (VMT) from all passenger vehicles. Allowing PHEVs to have a larger role in the future fleet helps to provide additional technology pathways toward meeting California's long term goals. However, as explained in staff's analysis of manufacturer-provided data and in-house testing, emission benefits from PHEVs are not only affected by vehicle range and architecture but are highly driver dependent, leading to significant uncertainty in future projections.

In order to assess the potential impacts of changes in PHEV parameters and higher PHEV sales fractions, staff developed several PHEV-focused VISION scenarios to assess how the presence of PHEVs in the LDV fleet may affect California's ability to meet its statewide GHG and criteria pollutant emission targets in the future. When using the CTF scenario PHEV sales trajectories, higher and lower eVMT growth rates show a modest sensitivity of less than ± 7.5 percent change in projected GHG emissions by 2050. When combined with higher PHEV sales trajectory, however, the projected impact from the eVMT sensitivity ranged from a 16 percent to 60 percent increase in GHG emissions showing a much greater sensitivity to how the PHEVs are used in the fleet. Similar trends are found for criteria pollutants, further explored in Appendix F.

Figure 8 – Well-to-Wheel GHG Emissions of Alternative PHEV Scenarios

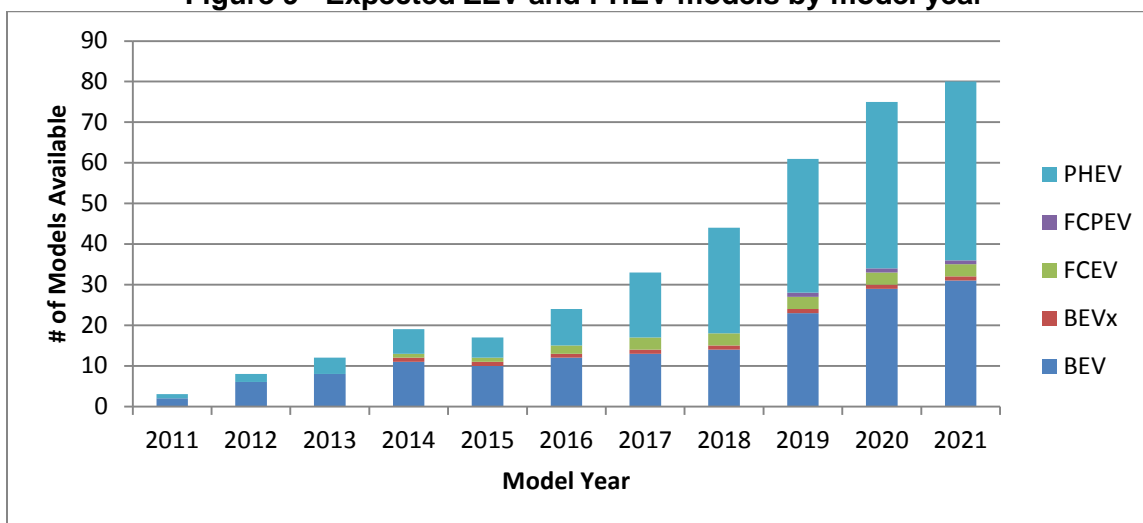


This suggests that, though PHEVs can be a significant share of the future fleet, there are limitations that make it necessary to still pursue substantial BEV and FCEV volumes and that there is additional risk associated with PHEVs dependent on user behavior due to their flexible nature.

How has ZEV technology progressed since 2012?

Technology has progressed faster than staff anticipated during the development of the 2012 rulemaking. Manufacturers are announcing longer range, more capable BEVs and PHEVs on widely diverse platforms, and within segments with high overall sales (i.e., cross-overs, mid-size cars). The most expensive components are also developing quickly and improving in most ways: they are safer, cheaper, and more energy dense resulting in higher energy content battery packs. This has led to the announcement of 80 ZEV and PHEV offerings over the next five model years, shown below.

Figure 9 - Expected ZEV and PHEV models by model year



BEVs and PHEVs

In 2012, BEVs were expected to be primarily small vehicles, with no more than 100 miles test range capability. Given the Tesla Model S, even at the \$66,000 or higher price point, is the highest selling ZEV (or PHEV) in 2016 MY thus far and is a full size sedan with a real-world range of over 200 miles, manufacturers are quickly responding to the demands in the market. Most notably, lower priced longer range BEVs reached dealer lots within weeks of this report's release.³⁸ These range improvements at lower prices come from various improvements, but predominantly from reduced battery costs and improved battery technology. Battery technology development is achieving higher energy density resulting in longer range from the same physical size battery pack.

In addition to improvements in the battery, manufacturers are announcing BEVs that will be equipped with higher powered fast charging³⁹. This will help lessen charge times for the expected longer range BEVs. Additionally, the emerging car and ride sharing market, and

³⁸ GM 2016b. General Motors. Chevy Bolt EV Website. <http://www.chevrolet.com/bolt-ev-electric-vehicle.html>
Accessed October 25, 2016

³⁹ Porsche 2015. Porsche AG, "World premiere for Porsche Mission E," Porsche AG, 14 September 2015. [Online]. Available: <https://newsroom.porsche.com/en/products/iaa-2015-porsche-mission-e-mobility-all-electrically-concept-car-11391.html>

development in connected and autonomous vehicles (CAV), provide a nexus with PEVs in future years as a way to reduce emissions.⁴⁰

FCEVs

Since the 2012 ACC rulemaking, Hyundai introduced the Tucson FCEV, the first mass-produced FCEV made available for retail lease in California. Toyota followed with the purpose built Mirai, which is offered for lease or sale to consumers. Additionally, Honda has released the Clarity for lease.⁴¹ It is expected that two more manufacturers will release purpose built FCEVs over the next three model years.^{42,43} While current costs remain high, projections based on U.S. DOE cost modeling for FCEVs indicate future reductions. At annual production volumes of 100,000 FCEVs (as are expected with further roll out of hydrogen infrastructure throughout California), the fuel cell system could be near \$6,000 for a 100 kW stack and balance of plant similar to those that have been incorporated into the sedans and crossover utility vehicles currently on the market.⁴⁴ This marks the potential for roughly a 50 percent reduction in cost from today, based solely on economies of scale. Further cost reductions are expected due to technology development by the time annual production rates reach 100,000 FCEVs per year.

Electric Motors and Power Electronics

Applicable for all three of the technologies discussed above, manufacturers are looking ahead to improved electric motors and power electronics and reduced costs in attempts to meet the U.S. Drive targets. Manufacturers are bringing motor costs down by decreasing the total amount of rare earth metals used. General Motors, Honda, and BMW have all found ways to decrease rare earth metal usage in current products. In the case of General Motors, with the second generation Volt, rare earth metals were completely removed from one of their motor/generators in the powertrain system while still making the total powertrain more efficient and powerful for the customer.⁴⁵

Manufacturers are also finding ways to better package power electronics to reduce part counts and complexity, and increase power density. On board chargers are increasing in total power capability and efficiency. Wide bandgap materials, like silicon carbide are currently being tested and developed by companies like Toyota with their hybrid Camry test fleet. Those materials will

⁴⁰ Gardner 2016. Greg Gardner. USA Today. "Lyft will be first to get breakthrough Chevrolet Bolt EV." September 28, 2016. <http://www.usatoday.com/story/money/cars/2016/09/28/lyft-first-get-breakthrough-chevrolet-bolt-ev/91238266/>

⁴¹ Honda 2016. American Honda Motor Corporation. Clarity Fuel Cell Website. <http://automobiles.honda.com/clarity> Accessed December 27, 2016

⁴² Daimler, 2016. Daimler Global Media. "Under the microscope: Mercedes-Benz GLC F-Cell: The fuel cell gets a plug," <http://media.daimler.com/marsMediaSite/en/instance/ko/Under-the-microscope-Mercedes-Benz-GLC-F-CELL-The-fuel-cell-.xhtml?oid=11111320> Accessed September 26, 2016.

⁴³ Reuters 2016. Reuters.com "Hyundai Motor to launch new fuel cell car in early 2016: exec" May 18, 2016. <http://www.reuters.com/article/us-hyundai-motor-fuel-cell-idUSKCN0Y90VI> Accessed January 11, 2017

⁴⁴ EPA 2016

⁴⁵ Brooke 2014. L. Brooke, SAE International. "GM unveils more efficient 2016 Volt powertrain," 29 October 2014. <http://articles.sae.org/13666/> Accessed October 4, 2016

enable even smaller, more efficient, and more power dense electronics on vehicles with lower cooling loads that will enable lower costs and longer ranges.⁴⁶

Incremental Costs

Battery costs have come down from what was assumed in the 2010 TAR and 2012 rulemaking. Comparing the 2010 TAR with the 2016 TAR assumptions, battery costs have been reduced between 20-35% depending on the application and size of battery pack, which can be seen comparing the 2011 BEV100 to the 2016 BEV75 in Table 10 below. However, staff is now expecting to see longer range BEVs on the road in future model years. This means that, compared to the 2012 ARB rulemaking which assumed a 100 mile electric range BEV (BEV100), incremental costs are slightly higher than would have been expected for high volume, fully learned out costs in MY2025 due to the expected increase in on board energy storage requirements (BEV200). Table 10 below compares the previous (2011) cost estimates to the updated 2016 TAR cost estimates.

Table 10 - Incremental Costs (2025 ZEV compared to 2016 ICE vehicle, 2013\$)

2013 \$	2011 ISOR (ACC Rulemaking)			2016 TAR (EPA, NHTSA, ARB) **			
	BEV100	PHEV40	FCEV	BEV75***	% Diff	BEV200	PHEV40
Subcompact	\$ 11,804	\$ 11,182	\$ 8,189	\$ 7,505	36.4%	\$ 12,001	\$ 9,260
MdC / SmMPV	\$ 12,591	\$ 12,037	\$ 10,174	\$ 8,183	35.0%	\$ 13,422	\$ 10,554
Large Car	\$ 14,566	\$ 15,685	\$ 14,613	\$ 11,355	22.0%	\$ 16,746	\$ 13,991

* ISOR Table 5.4 adjusted to 2013\$ with 1.09 CPI factor⁴⁷

** EPA OMEGA EV based on "label" range, ARB is UDDS. "Diff" = EPA BEV75 to ARB BEV100
Label vs. Test adjustment: 0.70

*** 15% weight reduction package

How has the overall ZEV and PHEV market developed in California and the Section 177 ZEV states since 2012?

Beginning in 2010, there was only one regulated manufacturer with a single product on the market: the Chevrolet Volt.⁴⁸ Since that time, the market has grown to a total of 25 models offered by 14 manufacturers. With the exception of the GM "TBD" FCEV and the Mitsubishi Outlander PHEV⁴⁹, every model shown in the 2011 ZEV ISOR (released in preparation for the ACC rulemaking) has been released in the U.S. market. Seven additional models were released that were not anticipated prior to the 2012 ACC rulemaking.

⁴⁶ GreenCar, 2015. Green Car Congress, "Toyota beginning on-road testing of new SiC power semiconductor technology; hybrid Camry and fuel cell bus", 29 January 2015. <http://www.greencarcongress.com/2015/01/20150129-toyotasic.html> [Accessed October 17, 2016].)

⁴⁷ ARB 2011. California Air Resources Board. Initial Statement of Reasons: 2012 Proposed Amendments To The California Zero-Emission Vehicle Program Regulations. <http://www.arb.ca.gov/regact/2012/zev2012/zevisor.pdf>

⁴⁸ The Tesla Roadster was available in very limited quantities. In 2010, Tesla was not regulated under the ZEV regulation.

⁴⁹ The Mitsubishi Outlander is currently available outside of the U.S. but expected to launch in the U.S. in 2017.

California accounts for approximately 48 percent of cumulative ZEV and PHEV sales in the U.S. from 2011 to June 2016, with approximately 50 percent of total U.S. BEV sales and 47 percent of total U.S. PHEV sales. While the absolute number of ZEV and PHEV sales grew by approximately 5.2 percent from 2014 to 2015, the overall market share has remained at approximately 3 percent of statewide LDV sales for 2015 and the first half of 2016.

The Section 177 ZEV States have accounted for approximately 10 percent of cumulative ZEV and PHEV sales in the U.S. from 2011 to June 2016, 11 percent of cumulative U.S. ZEV sales and 18 percent of cumulative PHEV sales. Sales of ZEVs and PHEVs in the Section 177 ZEV states grew rapidly in the first three years, but remained flat at approximately 0.5 percent of total LDV vehicle sales from calendar year 2013 through 2015. During that same time period, ZEV sales increased slightly to 0.2 percent of Section 177 ZEV state LDV sales. By contrast, PHEV sales, which started around 0.3 percent in 2013, fell to around 0.2 percent of Section 177 ZEV state LDV sales in 2015. Despite these past trends, sales of ZEVs and PHEVs are up to 0.6 percent in the Section 177 ZEV states for the first half of 2016, the highest level ever.⁵⁰

ZEV infrastructure in California and Section 177 ZEV states has grown with substantial investments in the past several years, and accelerated investments are expected as new infrastructure efforts emerge. Over 17,000 Level 2 and 2,100 direct current fast charger (DCFC) connectors have been deployed across California and the nine Section 177 ZEV states.⁵¹ Section 177 ZEV state infrastructure has outpaced vehicle deployment, with a higher connector per vehicle ratio than that found in California (refer to Appendix D for details). PEV infrastructure will continue to proliferate due to coordinated efforts through the ZEV Multi-State Task Force in the Section 177 ZEV states, and through California's Public Utility Commission (CPUC) implementation of Senate Bill (SB) 350 (Statutes 2015, 44258.5 section, De Leon author). California's current programs (most prominently legislation such as Assembly Bill 8, Statutes 2011, Section 41081, Perea author)) are enabling growth of the first major FCEV and hydrogen fueling markets in the U.S. Major policy and technical hurdles have been overcome in recent decades thanks to the coordinated efforts of State and industry partners. This substantial progress addresses issues of launching a new technology market. At the same time, stakeholders are also keenly aware of, and are addressing, new challenges in order to move FCEVs and hydrogen fueling into the mass-market.

Where does California and Section 177 ZEV states fit into a growing global ZEV market?

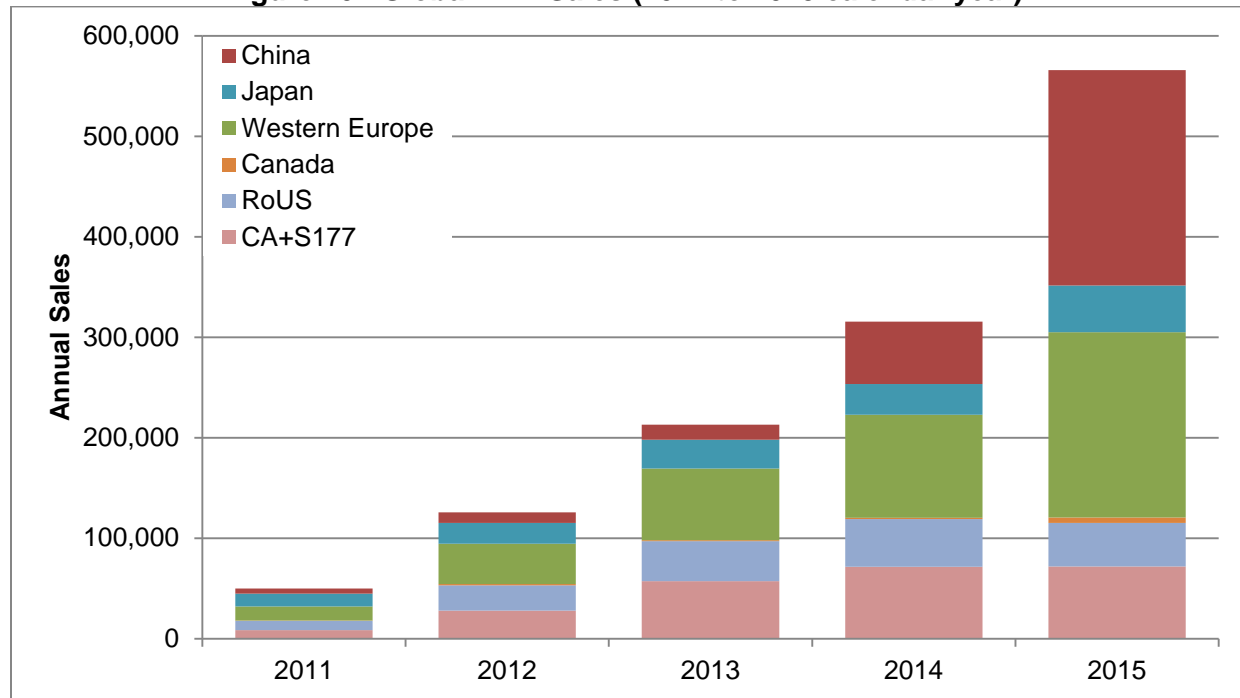
The global PEV market has increased steadily since 2011, reaching over 500,000 annual units in 2015, with many nations proposing increased regulatory pressure to reduce carbon emissions from vehicles. It is expected that the total global PEV market will surpass a cumulative 2 million

⁵⁰ These sales data were calculated using "Dashboard Data", fully described in Appendix B, Section VII

⁵¹ AFDC 2017. U.S. DOE Alternative Fuels Data Center, data as of 01/10/ 2017
<http://www.afdc.energy.gov/fuels/electricity.html>

vehicles by the end of this year (2016).⁵² However, as shown in Figure 10 this growth recently has been concentrated in regions outside of the U.S., though cost reductions from economies of scales occur regardless of location. In 2015, China had the highest PEV sales followed closely by Western Europe; California with the Section 177 ZEV states most recently ranks as the third largest PEV market, surpassing the volumes in Japan and Canada combined.

Figure 10 - Global PEV Sales (2011 to 2015 calendar year)⁵³



Why have sales in the U.S. stagnated in recent model years?

Fleet transformation to PHEVs and pure ZEVs requires not only auto manufacturers to develop and produce such vehicles, but also consumers to demand and ultimately purchase these products. Demand will be dependent on consumer awareness of the vehicles being offered as well as their characteristics – most notably vehicle price, available incentives, driving range, and infrastructure available for recharging/refueling – and how consumers value these attributes. In order for a consumer to purchase or lease a ZEV, they must first be aware that these vehicles are available in the market today. However, the results of independent studies all reveal a low level of ZEV awareness and confusion in California and the rest of the U.S. among the different ZEV technologies. In a 2016 UC Davis survey of new car buyers, over 34 percent of respondents across the U.S. could not name a single BEV available in the market.⁵⁴ Similarly,

⁵² Carrington 2016. Damian Carrington. The Guardian Web Article. “Electric cars set to pass 2m landmark globally by end of 2016” <https://www.theguardian.com/environment/2016/oct/13/electric-car-sales-set-to-pass-2m-landmark-globally-by-end-of-2016>

⁵³ ANL 2016. Argonne National Laboratory. DOE Fact of the Week. March 28, 2016.

<http://energy.gov/eere/vehicles/fact-918-march-28-2016-global-plug-light-vehicle-sales-increased-about-80-2015>

⁵⁴ Kurani 2016.

fewer than half of those polled in 2015 for an NREL study could name a PEV.⁵⁵ Looking at other factors, according to Californians surveyed, PHEV and BEV<200 consumers (BEVs with less than 200 mile range) seem dissatisfied with the electric range of their vehicle. The most common changes PHEV and BEV<200 owners would make to their vehicles is to increase the electric range for a higher price (48 percent and 57 percent) and to give up performance (power/acceleration) for higher electric range (25 percent and 33 percent).⁵⁶

Additional factors, such as dealership availability and readiness or product diversity may also influence the rate at which market shares may grow. Although consumer choices for PHEVs and ZEVs are steadily increasing, they are still far outnumbered by a wide array of conventional technologies that may offer additional appealing characteristics such as lower prices, greater vehicle range, increased cargo and/or passenger capacity, and more attractive vehicle styling. Even for existing BEV drivers of all battery sizes, vehicle range ranked as their top concern during the shopping process, followed by vehicle price or availability of public charging infrastructure. While incentives and other policies may help consumers to overcome some of these concerns, others require further technological advances to satisfy customer requirements within acceptable price points.

However, eliminating barriers is not sufficient for growing a market as consumers also need to be persuaded to select a PHEV or ZEV. Among PEV drivers in California, Connecticut, and Massachusetts, saving money on fuel was the most common primary motivation for all PHEV and BEVx drivers as well as for BEV<200 drivers in California.⁵⁷ These results are consistent with sentiments from non-PEV drivers in a 2015 UC Davis survey of new car buyers that fuel savings, as well as other factors, would be one of their motivations for purchasing a PHEV or ZEV. Therefore, current relatively low gasoline prices create a challenging landscape, especially if utilities are not offering supportive discounts for vehicle charging or consumers are not aware of or opting into these reduced electricity rates. As a result, some consumers may actually spend more money today to operate their PEVs than they would an HEV or ICE.

Finally, an illustrative analysis of dealer inventories of PEVs and comparable vehicles shows there to be disproportionately more PEVs available on dealer lots in California than in Section 177 ZEV states. Whether these inventories reflect sales rates in those areas or automakers producing limited quantities of first generation products cannot be distinguished by evaluating this data.⁵⁸ Regardless, limited dealer inventories will reduce consumers' exposure to these vehicles and may contribute at least partially to the lower sales rates in the Section 177 ZEV States.

⁵⁵ NREL 2016. National Renewable Energy Laboratory. Consumer Views on Plug-in Electric Vehicles – National Benchmark Report. January 2016. <http://www.nrel.gov/docs/fy16osti/65279.pdf>

⁵⁶ See Appendix B, Section VII for description of California's CVRP Ownership Survey 2015 results.

⁵⁷ See Appendix B, Section VII for description of California's CVRP Consumer Survey 2015, Massachusetts 2016 MOR-EV Rebate Survey, and Connecticut's 2016 CHEAPR Rebate survey results

⁵⁸ See Appendix B, Section II for staff's analysis of dealer availability, based on data collected from Edmonds.com

Does staff believe sales will improve in the future?

Historically, there has been no single factor that is solely correlated to increased PEV sales. Rather, continued activity and progress from all parties – government at all levels, industry, and advocacy organizations – on a range of measures will each play a role in supporting, cultivating and expanding consumer interest to enable further market growth of ZEVs and PHEVs.

PEV owners are satisfied with their vehicle as over 92 percent of respondents in California would probably or definitely recommend their specific PEV model. Virtually all of the BEV200+ consumers (99.9 percent) would probably or definitely recommend their vehicle, as would 96 percent of PHEV and 93 percent of short range BEV consumers. As vehicle technology has matured, PHEV and BEV consumers become more likely to definitely recommend their specific PEV model. For example, the percentage of Nissan Leaf owners that would definitely recommend their vehicle jumped from 44 percent for those who purchased in 2012 to 66 percent for those who purchased in 2014.⁵⁶

Already over 10 percent of recent PEV buyers (or lessees) are repeat buyers. Given the large proportion of leases, many consumers will be returning to the market within two to three years and among all current PEV drivers, more than 90 percent would replace their current PEV with a ZEV or PHEV. These existing, satisfied PEV consumers also serve an important function in educating other consumers in the market. According to survey results of recent California rebate recipients⁵⁹, another PEV driver is one of the most influential information sources for new buyers to choose a PHEV or BEV. So the greater the number of drivers coupled with other outreach initiatives, the faster consumer awareness will grow about these vehicles. When asked to design their next vehicle, 25-40 percent of new car buyers (almost exclusively conventional vehicle drivers) chose a PHEV, BEV, or FCEV.⁶⁰ Although these results do not represent a market forecast, they do serve as a measure of market potential that could be realized with the necessary complementary actions to eliminate barriers. Notably, there is no clear evidence that future market growth would only come from previous hybrid electric vehicle (HEV) buyers. From 2015-2016, about 80 percent of the PEVs in California are being sold to consumers with no prior PEV ownership, and among this group only 8 percent are either replacing an HEV or have an HEV as another vehicle in their household.⁵⁹

Consumers cite a variety of factors that prevent their selection of a ZEV or PHEV, that are expected to diminish with time. The majority of all new vehicles sold in the United States start at a base price of less than \$25,000, though with additional option packages the average retail selling price of all vehicles in 2015 was \$33,000.⁶¹ However, about half of the ZEVs and PHEVs sold in 2016 start at a base price over \$35,000 before factoring in federal and state purchase incentives, while additional subsidies from auto manufacturers may reduce the price further still. Manufacturing developments and global economies of scale will facilitate cost reductions, while

⁵⁹ See Appendix B, Section VII for description of California's CVRP Consumer survey data.

⁶⁰ Kurani 2016.

⁶¹ NADA 2016. National Automobile Dealers Association. Alternative Powertrains: Analysis of Recent Market Trends & Value Retention. April 2016. http://img03.en25.com/Web/NADAUCG/%7B49f71c70-31ef-4af9-870b-aeac4c6245bd%7D_201604_Alternative_Powertrains.pdf

continued government incentives can also help to offset the remaining incremental costs. Limited driving range, particularly of BEVs, as well as related infrastructure for charging or hydrogen refueling are also barriers to consumer adoption.^{59,60} As more auto manufacturers introduce additional options, though, in different vehicle segments with increasingly greater electrification, consumers will be more likely to have an option that meets their needs, and within their budgets. Governments at multiple levels as well as some auto manufacturers are also working to deploy more PEV and FCEV fueling infrastructure to support these vehicles.⁶² Concerns about long charging times are also anticipated to be resolved as auto manufacturers and suppliers have already announced advancements on charging speeds and energy storage that will soon be incorporated into product designs.⁶³

What challenges lie ahead for ZEV market growth to continue?

While the market potential exists for increasing market shares of ZEVs and PHEVs, converting consumer interest into actual sales will still have challenges. The current market has benefited from a host of incentives which are set to expire eventually. These incentives have been effective in offsetting some of the incremental costs, and cost parity between ICEs and ZEVs or PHEVs for a self-sustaining market is not anticipated before 2025. The phase out of the largest of these incentives, the federal tax credit, will be staggered with the tax credit for FCEVs expiring on December 31, 2016 and the tax credit for PEVs phasing out for each manufacturer when it reaches 200,000 vehicles nationwide. Based on historic U.S. sales rates, at least four manufacturers would reach this threshold prior to 2025. Leading manufacturers General Motors and Nissan would reach first in 2022 followed by Ford and Tesla, though increasing sales of existing vehicles and introduction of new products would likely accelerate this timeline.⁶⁴ In California, sufficient funding for the state purchase rebate remains an annual uncertainty and recent modifications by the legislature to limit which consumers and vehicles qualify for a rebate may affect market growth. Incentive programs in Section 177 ZEV States have also faced funding shortages at times, and required increased funding.⁶⁵ Additionally, high-occupancy vehicle (HOV) lane access by single-occupancy ZEVs and PHEVs has been an effective incentive in many states; however, in California, current state law sunsets this access in 2019.

The high proportion of leased PEVs and FCEVs has accelerated the development of a secondary PEV market. Although analysis of used vehicle transactions and auction data shows limited net migration of PEVs between states, used vehicle prices of early model PEVs tended to be lower than HEVs but higher than ICEs.⁶⁶ Among the small number of low or moderate income participants in California's Enhanced Fleet Modernization Program purchasing PEVs, PHEVs and HEVs prices were similar, but an average of \$7,000 more than the BEVs that were

⁶² See Appendix D for staff's infrastructure assessment.

⁶³ See Appendix C for staff's technology assessment.

⁶⁴ Calculated from historical sales trends discussed in Appendix B, Section III.A.2.c.

⁶⁵ MassEEA 2016. Massachusetts Department of Energy and Environmental Affairs. Press Release. "Baker-Polito Administration Increases Funding for Electric Vehicle Rebate Program by \$2 Million" January 15, 2016 <http://www.mass.gov/eea/pr-2016/increased-funding-for-electric-vehicle-rebate-program.html>

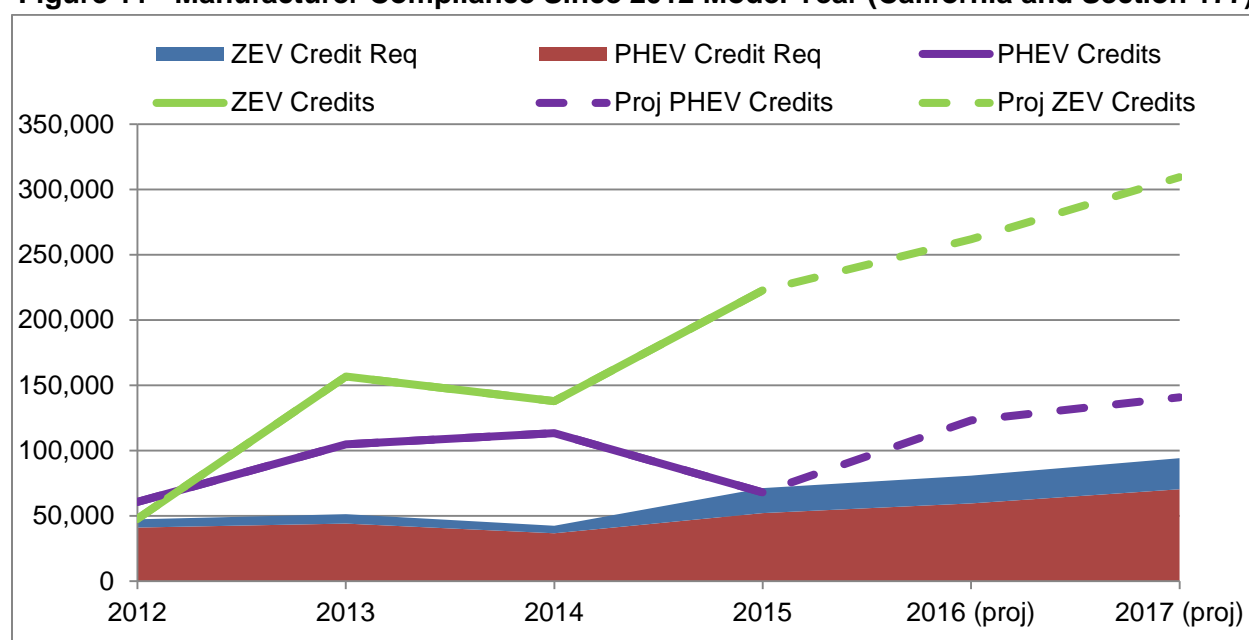
⁶⁶ Based on analysis of Manheim Auction data. See Appendix B, Section VII for a complete description of Manheim Auction data.

purchased. For the broader market, though, lower PEV prices seem to be correlated to selling at faster rates, suggesting that used vehicle sellers are still developing optimal pricing strategies.⁶⁷

How have manufacturers complied with the ZEV regulation since the ACC 2012 rulemaking?

Since the 2012 ACC rulemaking, manufacturers have been over-complying with the ZEV regulation requirements as illustrated in Figure 11 by producing more ZEVs and PHEVs than needed. Likely, this is in preparation for the higher requirements set by the Board for 2018 and subsequent model years. However, this production of vehicles, and subsequent banking of credits has created some controversy, not unlike past reviews of the ZEV regulation. This topic will be discussed further in the following sections.

Figure 11 - Manufacturer Compliance Since 2012 Model Year (California and Section 177)



How have regulatory compliance scenarios changed as a result of the midterm review of the adopted standards?

The latest analysis has taken into consideration technology advancements, manufacturer compliance trends, ZEV regulation credit banks, and future product announcements and resulted in updated minimum regulation compliance scenarios. Compliance scenarios are intended to explain the potential effect various flexibilities and developing technology has on the overall number of vehicles expected from the regulation. These scenarios are “minimum

⁶⁷ Lee 2016. iSeeCars.com, Thomas Lee. Fastest-Selling Used Cars. July 18, 2016. <http://blog.iseecars.com/2016/07/18/fastest-selling-used-cars/>

compliance scenarios”, which emphasizes the main goal of the ZEV regulation: to set a floor to ensure pure ZEV technology is being produced to help the technology reach commercialization. The question that these scenarios answer is how much could be expected (at a minimum) from the ZEV regulation in any given model year. These scenarios are not a market forecast of what actual total sales may be or will likely be in any given model year, but rather are regulatory compliance projections using the best available information at the time of this review.

Each new compliance scenario results in fewer vehicles than the expected compliance scenario prepared for the 2012 Board Hearing and a summary of staff’s analysis can be found in Appendix A. Lower vehicle numbers are due mostly to longer electric range BEVs and PHEVs in every scenario, meaning each vehicle is earning more credit (in some cases twice as much) than originally projected. As pure ZEVs generally earn more credits per car than PHEVs, this change in assumptions directionally resulted in higher ZEV penetration, lower PHEV penetration, and lower overall ZEV and PHEV combined volumes in the new scenarios.

In the new minimum compliance scenarios, the analysis takes into consideration historical credits, a change from past compliance scenarios. To address the issue of credits more directly, credits exist in manufacturers’ credit banks due to vehicles being produced. Historically, the majority of manufacturers have carried a two to three year compliance margin from one year to the next. This factor is reflected in the updated compliance scenarios. A "credit balance" assumption was developed for each compliance scenario based on the number of credits manufacturers would leave in their banks relative to what would be needed for 2026 and subsequent model year compliance. Previously earned ZEV credits in excess of this assumed balance would be spread out evenly across the 2018 to 2025 model years to reduce the manufacturer’s obligation for those years. The other assumptions made for each compliance scenario followed general themes related to the pace of technology development and market uptake. Below is a summary of each compliance scenario staff developed for this assessment.

Table 11 - Staff ZEV Regulatory Compliance Scenario Themes

Scenario	Theme
Mid-Range ZEV-Technology Case	Continued advancement in ZEV technology leads to balance of new sales of improved capability ZEVs and moderate use of banked ZEV and GHG credits
Slow ZEV-Technology Case	Delayed advancement in ZEV technology leads to higher dependence on banked ZEV and GHG credits to support sales of only slightly improved ZEVs
High ZEV-Technology Case	Aggressive advancement in ZEV technology leads to larger increase in new sales of highly capable ZEVs as dominant mechanism for compliance

Results from the mid-range scenario for California and Section 177 ZEV states are shown in Figure 12 and Figure 13 below for the 2018 through 2025 model years only.

Figure 12 - Sales from mid-range scenario for ZEV regulatory compliance (California)

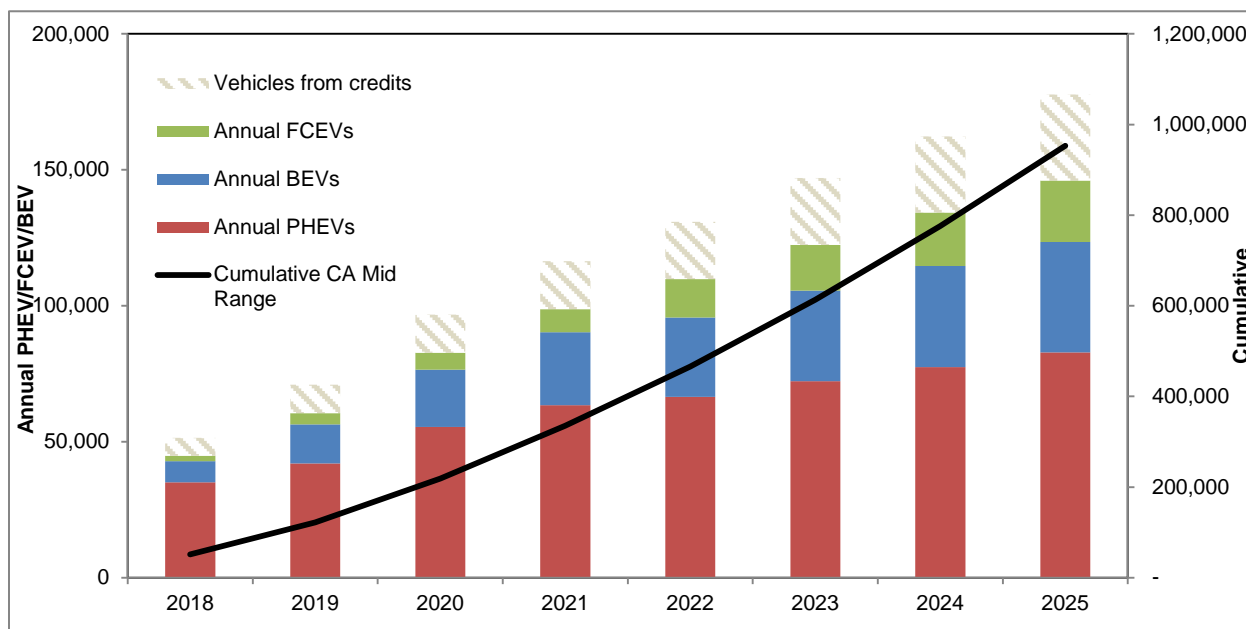
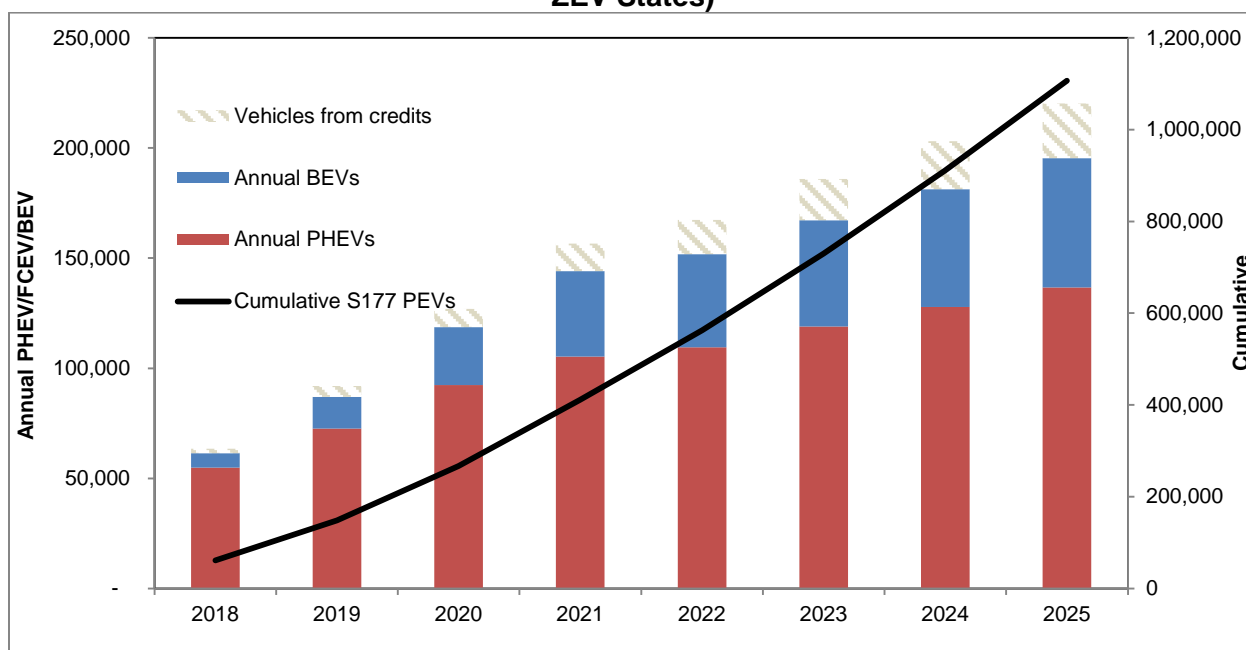


Figure 13 - Sales from mid-range scenario for ZEV regulatory compliance (Section 177 ZEV States)



Through 2015 model year, 182,000 ZEVs and PHEVs have been registered in California, according to Department of Motor Vehicles' registration data. Extrapolating for 2016 and 2017 model years, approximately 165,000 additional ZEVs and PHEVs are expected for the following two model years. Taking these pre-2018 vehicle numbers and adding them to staff's mid-range

regulatory compliance scenario, nearly 1.2 million cumulative ZEVs and PHEVs can be expected by the 2025 model year.

How will historical ZEV credit banks effect future compliance with the ZEV regulation?

As an industry, manufacturers have been over complying with the ZEV regulation since the early years of the program. There are some manufacturers that have complied early and generated ZEV credits and some have bought credits to meet the requirements. In the early years, the Board awarded a large number of credits to jumpstart a very early technology market. To help manufacturers meet the requirements in the Section 177 ZEV states, the Board adopted the travel provision. These early credits provide insurance to the manufacturers for future requirements.

Starting in 2018 model year, the requirements have a steep ramp in the ZEV credit requirements. Also, during the 2012 rulemaking, staff addressed other concerns regarding credits by simplifying the overall credit structure. For example, the travel provision will no longer be applicable for BEVs, and credits generated per vehicle have been reduced.

Manufacturer credit banks will continue into the future, and in some cases, those banks will be representative of technology and market success. However, what is also certain is that there will be some market failures. Over the past four model years, products have already been released in the market, pulled back, revamped, and re-released due to market response to the technology.⁶⁸ It could be argued, though, that credit banks provide space for manufacturers to innovate, and overall the market will benefit from improved products. As ARB re-evaluates the requirements for 2026 model year and beyond, the agency will consider credit structure revisions including taking into account the status of the credit banks at that time and regulatory provisions such as PHEV and BEV qualification criteria, credits per vehicle, credit lifetime, and credit usage limitations.

Is electric vehicle miles traveled (eVMT) or zero-emission vehicle miles traveled (zVMT) an appropriate credit metric for the ZEV regulation?

For 2018 and subsequent model years, PHEVs are credited on a linear scale (between 0.4 and 1.3 credits) based on the certified electric range on the urban dynamometer drive schedule (UDDS). One alternative factor suggested for consideration is electric vehicle miles traveled or eVMT. This is the portion of total vehicle miles that are attributed to electric power instead of gasoline, and therefore correlates with the GHG benefit of such a vehicle.

According to the analysis presented here, eVMT data is highly variable and dependent more on user behavior (driving, charging) than the vehicle itself (its inherent range or motor size).⁶⁹

⁶⁸ Edelstein 2015. Stephen Edelstein. Green Car Reports. "Toyota Prius Plug-in Production to end in June; New One Coming Next Year" May 5, 2015. http://www.greencarreports.com/news/1098145_toyota-prius-plug-in-production-to-end-in-june-new-one-coming-next-year

⁶⁹ See Appendix G for more information on staff's analysis of manufacturer provided data from PEVs.

Though manufacturers have presented average eVMT numbers, data provided by the manufacturers to ARB show increasing overall VMT with unchanging eVMT each year for some models. According to early data received from General Motors⁷⁰ during the EV Project, 72 percent of the Volt miles qualify as eVMT. However, according to more recent General Motors data sources,⁷¹ the eVMT percentage for the Volt is actually closer to 60 percent. At this time, there is significant uncertainty as to how this percentage will increase or decrease with increasing infrastructure,⁷² increased electric range for 2016 and subsequent Chevy Volts, fluctuating electricity and gasoline prices, or an expanding consumer base including customers who may not be as highly motivated to plug in as the earliest adopters.

Further, eVMT only has a strong correlation to a vehicle's GHG emission benefit, but not to its criteria pollutant emission benefits. In the case of the Volt, according to manufacturer provided data, only 59 percent of a Volt's miles would qualify as zero-emission VMT (zVMT), meaning the percent of total miles from trips without any engine operation (and the associated criteria pollutant emissions such as HCs and NOx). PHEVs with longer ranges and higher motor output power (Chevy Volt) do provide greater criteria pollutant benefits than blended-type PHEVs (Ford Fusion PHEV, Toyota Prius Plug-In). However, as illustrated in Figure 14, all PHEVs have lower zVMT than eVMT suggesting the criteria pollutant benefits relative to a BEV are not as great as the GHG benefits.

According to the analysis in Appendix I, it is not clear how changing to an eVMT (or zVMT) metric would better help California and the Section 177 ZEV states to meet long term criteria pollutant and GHG emission reduction goals than the current credit system. The current UDDS based system for 2018 and subsequent model years lines up well with an eVMT based system, especially when compared to a ~100 mile UDDS certified BEV.⁷³ And when compared to a zVMT based system, many PHEVs are likely currently over credited. The following Figure 14 shows a comparison of vehicles based on these various metrics.

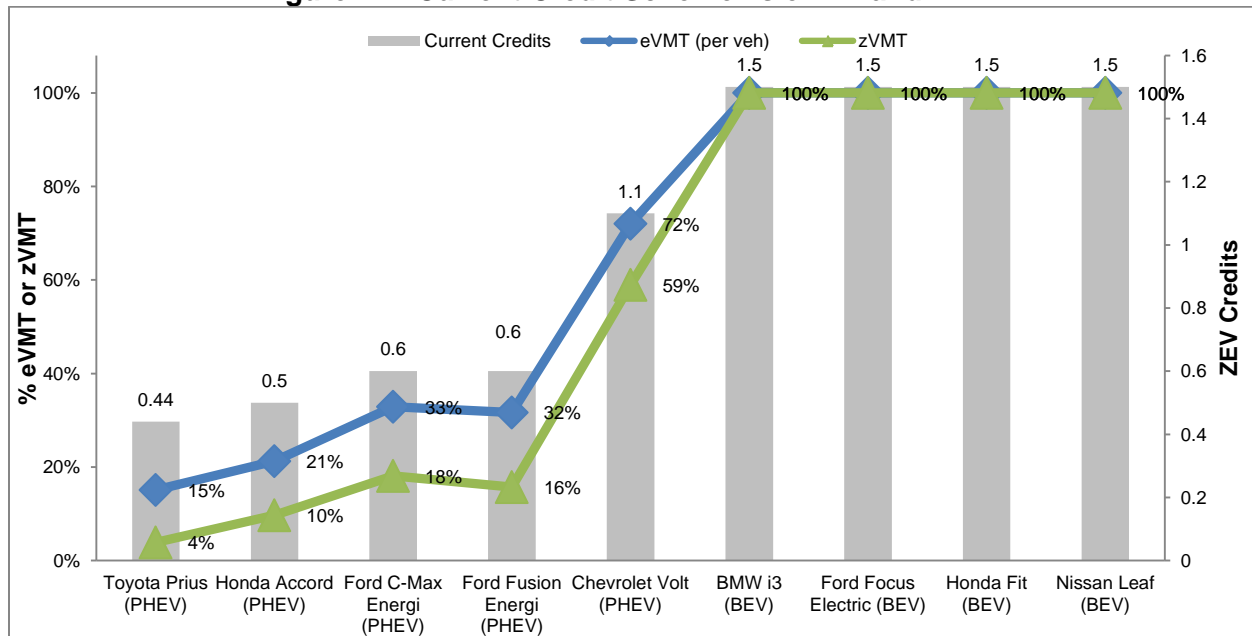
⁷⁰ Data received from GM was from Volts in the EV Project. See Appendix G for more information.

⁷¹ Data based on in-use Volts from the most recent model years.

⁷² See Appendix D for more information on electric vehicle infrastructure roll out.

⁷³ See Appendix I for staff's full analysis on alternative credit structures.

Figure 14 - Current Credit Scheme vs eVMT and zVMT



Range determined over the UDDS cycle does credit what matters to the consumer: the vehicle's electric range. In a 2015 survey of BEV and PHEV drivers, among those responding that they would likely replace their current vehicle with a PHEV, current PHEV drivers indicated an average desired all-electric range of 40-50 miles for their next PHEV while almost all current BEV drivers indicated a desired range of around 80 miles for their future PHEV.⁵⁶ Other ARB and U.S. EPA GHG and criteria pollutant standards reward PHEVs for their environmental benefits while the technology-forcing ZEV regulation credits PHEVs based on an attribute that advances technology and supports consumer acceptance and market expansion: all-electric range.

Should manufacturers be allowed to comply with more PHEVs for the 2018 through 2025 model years than already allowed in the regulation?

No. It is often asserted that PHEVs can appeal to a broader population and serve as a transition to pure ZEV technology and, therefore, should be allowed to play a larger role in compliance with annual ZEV requirements. And as noted earlier, the updated VISION scenarios in the Mobile Source Strategy indicated approximately one-third of the total ZEVs could be PHEVs on a path to meeting 2050 targets. However, while the share of PHEVs can undoubtedly be larger than that, the sensitivity analyses presented in Appendix F demonstrate conclusively that there are both GHG and criteria pollutant consequences from a much higher share of PHEVs along with increased risk given the uncertainty in how consumers will use these vehicles. As shown in the new minimum compliance scenarios, PHEVs are projected to make up more than 60 percent of all ZEVs on the road by 2025 even with the current caps on PHEV credits. Further, banking and trading provisions already exist that would allow manufacturers with excess PHEV generated credits to bank them for future use or perhaps trade with other manufacturers that have not fully utilized their PHEV credit allowances. Combined, this provides sufficient flexibility in the current regulatory structure as the ZEV market is developing

to determine the role PHEVs will ultimately play. Therefore, this new analysis does not support the need for more flexibility for PHEVs at this time such as allowing manufacturers to comply with more PHEVs than currently allowed.

What is the likelihood that the ZEV requirements adopted in 2012 can be met in the Section 177 ZEV states?

Sales of ZEVs and PHEVs in the Section 177 ZEV states lag behind California's market. Many stakeholders point to regulatory flexibilities, such as the travel provision and the existence of banked credits, as part of the cause in holding back sales in the Section 177 ZEV states. These could be factors resulting in lower sales; however, not all states are performing the same. Oregon has a strong ZEV market, just behind California at 2 percent of LDV sales. The market potential for ZEVs and PHEVs in the Section 177 ZEV states exists,⁷⁴ and is slowly increasing through a combination of government support, increased awareness, and expanded product offerings. Much of the support for complementary policies in the Section 177 ZEV states has developed within the past 3 years, after the adoption of the Multi-State ZEV Action Plan.^{75,76}

Recognizing the market development in the Section 177 ZEV states was not yet as far along as California's, the Board adopted additional regulatory flexibilities and lead time to create a ramp into the 2018 and subsequent model year requirements for the states. These flexibilities include reduced credit obligations in the Section 177 ZEV states, spread out over 6 model years,⁷⁷ and the ability to focus regionally on deliveries of PHEVs and ZEVs, rather than state by state.⁷⁸ Additionally, credits both created in the Section 177 ZEV states and generated through the travel provision will help manufacturers who need more time to build a market for their vehicles between 2018 and 2025 model years.⁷⁹

Do intermediate volume manufacturers need different treatment in the ZEV regulation?

In 2012, the Board adopted policies that required intermediate volume manufacturers (IVM) to begin electrifying their fleet starting in 2018. These policies redefined many of the mid-sized manufacturers (Daimler, BMW, Hyundai, Kia, and Volkswagen) as large volume manufacturers (LVM), and allowed the remaining IVMs (Subaru, Volvo, JLR, Mitsubishi, Mazda, and Tesla) to meet their 2018 through 2025 model year requirements exclusively with PHEVs. The Board adopted additional flexibilities in 2014 for the remaining IVMs, ensuring these manufacturers would remain defined as IVMs through 2025 model year, and granted more time to comply with

⁷⁴ Kurani 2016.

⁷⁵ Action Plan 2014. Multi-State ZEV Action Plan. May 2014. <http://www.zevstates.us/about-us/>, click on "Multi-state ZEV Action Plan" link

⁷⁶ MOU 2013. Memorandum of Understanding. October 24, 2013, Can be accessed and downloaded <http://www.zevstates.us/about-us/>, click on "Memorandum of Understanding" link

⁷⁷ CCR Section 1962.1(d)(5)(E)3. and 1962.2(d)(5)(E)1.

⁷⁸ CCR Section 1962.1(d)(5)(E)3.a and b., and 1962.2(d)(5)(E)1.a.i. and ii.

⁷⁹ See Appendix A for staff's analysis of ZEV regulation compliance scenarios

their ZEV requirements. In Resolution 15-07, the Board directed staff to continue to evaluate the issue of regulatory stringency during its midterm review process.⁸⁰

Consultations were held with all but one IVM (Mazda) during the mid-term review process.⁸¹ Manufacturers confirmed various plans to full compliance with the regulation as adopted, and are pursuing both PHEV and ZEV models, some recognizing it will be almost impossible to meet their obligations exclusively with PHEVs. Many of the flexibilities adopted in prior rulemakings adequately met many of the IVMs' concerns. The following table lists the various flexibilities already available to IVMs for the 2018 through 2025 model year ZEV requirements.

Table 12 - IVM ZEV regulatory flexibilities

Applicable Model Years	IVM Flexibility
2018 and 2019	Allowed to meet full requirements with converted partial zero-emission vehicle (PZEV) and advanced technology PZEV (AT PZEV) credits
2018 and 2019	Additional "revenue test" to be able to qualify as IVM instead of LVM
2018 and subsequent model years	Can meet full requirement with PHEV credits
2018 and subsequent model years	Are allowed 3 model years to make up a credit deficit, and deficit can be fulfilled with PHEV credits
2018 through 2022 model years	Allowed to participate in "pooling" in Section 177 ZEV states
2018 and subsequent model years	If average sales grow above 20,000, are allowed 5 years to transition to LVM requirements

These flexibilities adopted by the Board addressed many concerns raised by the IVMs. More importantly, these manufacturers do have competitive products in the market and generally agree that they will need to develop and introduce ZEV technologies to ensure they remain competitive into the future. All five current IVMs have clear and concrete plans to bring ZEVs to market in the next few years, with relevant announcements for Mazda and Subaru made as recently as November 2016.⁸² Additionally, as shown in the new compliance scenarios, there are sufficient credits, both in their own banks and in the market, available for IVMs to help bridge any interim compliance gaps.

⁸⁰ ARB 2014. California Air Resources Board. Resolution 15-07. May 21, 2015
<https://www.arb.ca.gov/regact/2014/zev2014/res15-7.pdf>

⁸¹ Mazda declined to meet with ARB staff regarding the review of the ZEV regulation.

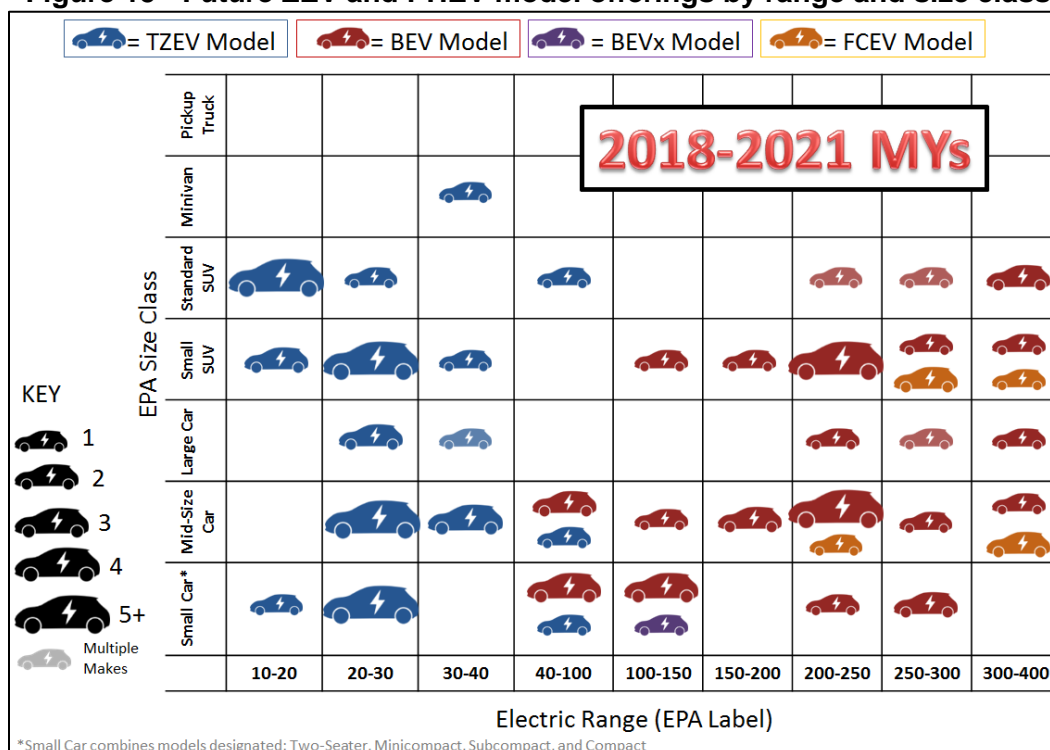
⁸² Greimel 2016. Hans Greimel. Automotive News, "Japan's holdouts begin to embrace EVs". November 27, 2016
<http://www.autonews.com/article/20161127/OEM/311289914/japans-holdouts-begin-to-embrace-evs>

Are the ZEV requirements in California, as adopted in 2012, appropriate for continuing to help develop the ZEV market?

Yes. The analysis reported here found that maintaining the adopted requirements for California through 2025 model year including the existing regulatory and credit structure is appropriate. In 2012, the Board successfully strengthened the ZEV regulation, nearly tripling the requirements for the 2018 through 2025 model years, and shifting away from stair-step requirements (where requirements remained the same for three years at a time) to annual increases in the requirements. Since then, the regulation has been achieving the goal of accelerating development of ZEV technology towards commercialization in California as demonstrated by the growth in the ZEV market, the introduction of more capable and longer range vehicles than originally projected, and earlier reduction in battery costs than anticipated. The 2012 Board action has resulted in over 215,000 ZEVs and PHEVs being placed in California over the last five model years. The transformation of the light-duty fleet has begun. Not only are manufacturers over-complying with the ZEV regulation in preparation for higher 2018 and subsequent model year requirements, manufacturers are delivering ZEVs and PHEVs in states which have not adopted California's ZEV regulation, indicating that the industry is starting to shift towards greater electrification. Manufacturers are competing with each other for PEV consumers by continually refining the products they offer to suit consumer preferences. When asked, consumers have stated a desire for more electric range and more electric drive capability. Manufacturers have responded with more range and, instead of continuing to make vehicles with limited range and capability that barely meet ZEV regulation requirements, will be offering over 70 unique models over the next five model years, in almost every segment (vehicle size class) as illustrated in Figure 15.⁸³

⁸³ See Appendix C for staff's analysis on future expected model offerings.

Figure 15 - Future ZEV and PHEV model offerings by range and size class



As a result of these vehicle technology advancements, the updated minimum compliance scenarios project approximately 1.2 million cumulative sales of ZEVs and PHEVs by 2025 in California. While this number might reflect a lower volume of vehicles needed for compliance than originally projected in 2012, the resultant improvements in ZEV and PHEV attributes, such as all-electric range and vehicle price, will be better vehicles expected to further broaden the appeal of these vehicles beyond the initial consumers and help achieve necessary future market expansion.

Despite the noted successes to date, the ZEV and PHEV market is in the early stages of development. The market is rapidly changing with nine BEV and PHEV models already discontinued since their introduction and it is also unknown how many of the 70 unique models will succeed in the market. The current market has benefited from multiple purchase incentives that have substantially discounted ZEVs and PHEVs such that their prices are more aligned with those of conventional vehicles. But, between 2018 and 2025, these and other incentives are expected to phase out. While decreased reliance on incentives is essential for building a self-sustaining market, it is unclear what consumer response will be without purchase and other incentives (like high occupancy vehicle (HOV) lane access). Consumer awareness of ZEVs is still low and top motivations like saving money on fuel are less influential as gasoline prices remain low. Given the market uncertainties that still exist in these early years, regulatory stability of the 2018 through 2025 model year standards can help ensure a continued path of increasing, but achievable, ZEV volumes.

Based on the midterm review, what ZEV regulatory changes does the new analysis suggest?

For the first time since the initial adoption of the ZEV regulation, the Board adopted increased ZEV credit requirements in 2012. This action, in concert with the development of strong comprehensive complementary policies to support infrastructure deployment and consumer awareness, led to the advancement of ZEV technology and growth in ZEV sales. Building on these strong trends, the new analysis supports a strengthening of the ZEV program for 2026 and subsequent model years to continue on the path towards meeting California's 2030 and later climate change and air quality targets. A rulemaking initiated by 2018 would target credit provisions, the current regulatory structure, and other changes to increase certainty on future vehicle volumes and reconsider PHEV qualifications⁸⁴ and credits to ensure maximum GHG and criteria pollutant reductions are achieved. Development of future ZEV requirements would also need to be coordinated with new GHG (and potentially criteria pollutant⁸⁵) fleet-wide emission reduction requirements as was previously done in the 2012 ACC program where all three elements were simultaneously addressed. This comprehensive approach ensures the regulations are complementary and coordinated for the synergistic effects into a new vehicle policy to help meet California's air quality and GHG goals. To this end, ARB intends to continue to collaborate on a technical basis with its federal partners like the U.S. DOE to promote the advancement of ZEV technologies needed for ARB's long term goals and the U.S EPA and NHTSA to evaluate evolving conventional and electrified vehicle technologies to build on the existing GHG standards and pursue continued reductions in the national GHG standards for 2026 and subsequent model years.

Modeling to meet the 2030 GHG targets established by SB 32 in the ARB Mobile Sources Strategy report, released in May 2016, indicates approximately three million additional ZEVs and PHEVs will be needed in 2026 through 2030. To reach these volumes with any certainty, the new regulation will need modifications that provide a more direct connection to vehicle volumes and require vehicle characteristics that best ensure market success. For such significant revisions to the regulation to be successful, however, it would require greater market acceptance, more technology advancements, and lower technology costs than is known with certainty today. In PHEVs alone, the product offerings and architecture variations are increasing in diversity and it is too early to determine which combinations will be appealing to consumers while providing maximum GHG and criteria pollutant benefits. For BEVs, a step change is occurring with multiple offerings expected with 200+ miles of range at prices closer to mainstream conventional vehicles (even before state and federal incentives), with the first of these being launched within weeks of this report's release. Additionally, substantial changes to the regulatory structure will impact vehicle manufacturer product and compliance planning and

⁸⁴ For example, California Senate Bill 859 recently revised the PHEV eligibility criteria for consumer rebates (CVRP) to a minimum of 20 miles of electric range rather than the 10 mile minimum range in ARB ZEV regulations necessary to qualify for ZEV credits.

⁸⁵ Stronger LEV criteria pollutant fleet emission standards will also be considered as the state implements SIP strategies for the 2031 ambient air quality requirements, in addition to later attainment dates for the new ozone standards.

necessitate sufficient lead time and stability to implement successfully while minimizing disruption to research, investment, and design cycles.

Since the adoption of the 2018 through 2025 model year standards, manufacturers have been exceeding the annual requirements of the ZEV regulation and expanding the market nationwide by delivering ZEVs and PHEVs in states which have not adopted California's ZEV regulation. Thus, committing now to a strong set of post-2025 requirements reinforces current progress and encourages manufacturers to further advances to electrify their fleets. Stronger post-2025 requirements will inherently influence the last model years before 2025 as manufacturers take actions to stay ahead of the requirements with some compliance margin. In the interim, ARB and interagency efforts should be made to help accelerate infrastructure deployment, increase consumer awareness, improve dealer knowledge, and preserve incentives. Staff will also continue to assess the development of the ZEV and PHEV market, battery and fuel cell technology, PEV and hydrogen infrastructure, the nexus with autonomous and car sharing transportation developments, the proliferation of complementary policies, and the overall environmental and economic impact of this emerging market.

What are some alternative regulatory and non-regulatory changes that the Board could consider prior to 2026 model year?

The analysis of the midterm review fully support the conclusion to focus on substantial new regulatory action for model year 2026 and beyond to increase certainty on future vehicle volumes while maintaining the existing requirements through 2025. As noted earlier, manufacturers are currently producing more vehicles than the regulation requires and, at least in part, it is because of the more stringent requirements starting in 2018 model year. In 2018, changes to the credit structure cause most vehicles to earn fewer credits per car as well as the overall requirement to increase in stringency every year from 2018 to 2025. Likewise, if the changes for 2026 result in increased stringency through structure and/or credit changes as intended, it is logical to assume that manufacturers would be similarly motivated to over-comply, or perhaps 'early-comply', in the years leading up to 2026 model year and result in increased vehicle volumes before 2026.

However, at the July 2016 hearing, the Board requested additional analysis by staff to address concerns around ZEV credits and increasing the number of ZEVs on the road prior to 2026 model year. The alternatives staff has considered include: a) increasing the ZEV requirement percentages for the final year of the current program (2025 model year); b) creating a credit usage restriction that may, for example, require a fraction of any model year's compliance be from vehicles produced in that model year or by that manufacturer; c) increasing the cap on PHEV credits allowed, but requiring additional PHEVs to have increased electric range and electric drive capability; and d) increasing the ZEV requirements for the 2023-2025 model years with a focus on requiring additional pure ZEVs. Given the need to provide sufficient lead time following any formal rulemaking approval, the additional vehicles resulting from these alternatives could be minimal relative to production levels in anticipation of future requirements for 2026 model year and beyond. Furthermore, the flexibility provided by credits, even with

restrictions, would not necessarily require manufacturers to alter product plans to comply with increased requirements.

Non-regulatory actions will be just as critical as the ZEV regulation requirements in bolstering demand for ZEVs. Studies such as recent International Council on Clean Transportation (ICCT) research⁸⁶ highlight historical correlations between existing ZEV sales and current regional market support actions (e.g., infrastructure, consumer campaigns, etc.). However, such relationships will continue to be dynamic and staff intends to evaluate changing market conditions to inform future decisions which may include contracts for external research to support this analysis.

Staff intends to continue to evaluate the market, including the effectiveness of complementary policies, over the next few years to help inform future regulatory proposals and to better quantify what is needed to support further development of the ZEV and PHEV market. The Low Carbon Transportation and Fuels Investments and Air Quality Improvement Program (AQIP) Funding Plan for fiscal year 2016 -2017 discussed potential indicators for assessing a self-sustaining market in accordance with SB 1275. These indicators include: new ZEV and PHEV sales, battery and fuel cell technology advancements and costs, infrastructure development, product diversity, the used market for ZEV and PHEVs, consumer awareness, avoided health impacts, and consumer willingness to pay.⁸⁷ Evaluation of these and other indicators, such as consumer purchase motivations, vehicle attributes, energy prices, and cumulative installed battery capacity, will help to assess the overall health and potential of the ZEV and PHEV markets in California and Section 177 ZEV States going forward.

Summary

The electrification of the light-duty fleet has begun. The ACC regulations, as adopted in 2012, continue to push manufacturers to produce more efficient and cleaner vehicles than ever before, and will continue to do so for years to come. Consistent with the draft 2016 TAR and Final Determination, updated analysis confirmed that the technology is available to readily meet, if not exceed, the current 2022 through 2025 model year national GHG emission standards at the same or lower cost than originally projected when the standards were adopted in 2012, predominantly with advanced gasoline engines and transmissions. Building on the staff's 2015 report to the Board on the feasibility of measurement at low PM emission levels, additional emission testing and a review of vehicle PM emission control technology was conducted by staff and determined that compliance with the 1 mg/mi emission standard by 2025 model year is feasible and that manufacturers are on track to meet this standard.

⁸⁶ ICCT 2016, International Council on Clean Transportation. "Sustaining Electric Vehicle Market Growth in U.S. Cities," October 2016. <http://www.theicct.org/leading-us-city-electric-vehicle-2016>

⁸⁷ ARB 2016d. California Air Resources Board. Proposed Fiscal year 2016-17 Funding Plan for Low Carbon Transportation and Fuels Investments and the Air Quality Improvement Program. May 20, 2016 https://www.arb.ca.gov/msprog/aqip/fundplan/proposed_fy16-17_fundingplan_full.pdf

The ZEV regulation, significantly revised in 2012, continues to play a critical role in transitioning the vehicle fleet to achieve California's long term air quality and GHG goals and has resulted in hundreds of thousands of ZEVs and PHEVs being placed in California over the last five years. Not only are manufacturers over-complying with the ZEV regulation in preparation for higher 2018 and subsequent model year requirements, manufacturers are delivering ZEVs and PHEVs in states which have not adopted California's ZEV regulation.

As described in the Executive Summary above, and expanded upon throughout this report, the following recommendations have been prepared by staff for the Board's consideration in the California Midterm Review.

2022 through 2025 model year GHG emission standards

- Continued participation in the National Program by maintaining the "deemed to comply" provision allowing for compliance with the adopted U.S. EPA GHG standards for 2022 through 2025 model years.

1 milligram per mile particulate matter emission standard

- As previously reported to the Board in 2015, maintain the existing PM measurement method for the 1 mg/mi standard.
- Maintain the stringency and implementation schedule of the adopted 1 mg/mi PM standard scheduled to begin in 2025 model year.
- Initiate regulatory action to develop and adopt additional PM standards to phase-in with the 1 mg/mi standard in 2025 model year to ensure manufacturers implement robust control strategies that result in low PM emissions in the real world.

California's ZEV regulation

- Strengthen the ZEV program for 2026 and subsequent model years to continue on the path towards meeting California's 2030 and later climate change and air quality targets.
- Maintain the adopted requirements for California through 2025 model year including the existing regulatory and credit structure.
- Maintain the existing ZEV requirements and flexibilities, including as amended in 2014, for IVMs.
- Maintain the existing ZEV regulation credit structure and caps for PHEVs through the 2025 model year.
- Maintain the ZEV regulation and flexibilities for the Section 177 ZEV states.
- Continue efforts by ARB and other stakeholders to accelerate and expand non-regulatory complementary policies that have been identified as successful in building market demand and removing remaining barriers to ZEV adoption.

Given the conclusion of the federal midterm evaluation process with the decision by U.S. EPA to maintain the adopted GHG standards in the Final Determination, ARB will remain engaged with U.S. EPA and NHTSA in support of continued participation in the National Program. Additionally, the agency will continue rigorous efforts to promote complementary policies that support the expanding ZEV market. Simultaneously, ARB will begin new multi-year technical

and market analysis to inform an expected rulemaking for the 2026 model year and beyond. In these efforts, ARB intends to build on its history of technical collaboration with federal agencies including U.S. DOE, U.S. EPA, and NHTSA in furthering the development and deployment of advanced vehicle technologies necessary for California's GHG and clean air targets. ARB also recognizes the value of a continued national program for GHG standards and plans to continue to coordinate with EPA and NHTSA in the development of future standards.

LIST OF ACRONYMS AND ABBREVIATIONS

AEO:	Annual Energy Outlook
ARB:	California Air Resources Board
BEV:	Battery electric vehicle
CAFE:	Corporate Average Fuel Economy
CAV:	Connected and autonomous vehicles
CCR:	California Code of Regulations
CD:	Charge-depleting
CO ₂ :	Carbon dioxide
DSF:	Dynamic Skip Fire
EGR:	Exhaust gas recirculation
EIA:	Energy Information Administration
eVMT:	Electric vehicle miles traveled
FCEV:	Fuel cell electric vehicle
FTP:	Federal Test Procedure
GDI:	Gasoline direct injection
GHG:	Greenhouse gas
g/mi:	Grams per mile
GPF:	Gasoline particulate filter
HC:	Hydrocarbons
ISOR:	Initial Statement of Reasons
IVM:	Intermediate volume manufacturer
LDV:	Light-duty vehicle
LEV:	Low-emission vehicle
mg/mi:	Milligrams per mile
mpg:	Miles per gallon
MTR:	Midterm review
MY:	Model year
NHTSA:	National Highway Traffic Safety Administration
NMOG:	Non-methane organic gas
NO _x :	Oxides of nitrogen
NVH:	Noise, vibration, and harshness
PEV:	Plug-in electric vehicle
PFI:	Port Fuel Injection
PHEV:	Plug-in hybrid electric vehicle
PM:	Particulate matter
ppb:	Parts per billion
Section 177	
ZEV states:	States that adopt and enforce California's ZEV regulations under Clean Air Act (CAA) Section 177
SJV:	San Joaquin Valley
SULEV:	Super-ultra-low-emission vehicle
SUV:	Sport utility vehicle
TAR:	Technical Assessment Report
TPD:	Tons per day

TZEV:	Transitional zero-emission vehicle
UDDS:	Urban dynamometer drive schedule
ULEV:	Ultra-low-emission vehicle
US06:	A high-speed, high-acceleration, test procedure designed to measure off-cycle emissions
U.S. DOE:	United States Department of Energy
U.S. EPA:	United States Environmental Protection Agency
VC-T:	Variable compression ratio turbocharged engine
VMT:	Vehicle miles traveled
ZEV:	Zero-emission vehicle
zVMT:	Zero-emission vehicle miles traveled

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THE ADMINISTRATOR OF THE ENVIRONMENTAL PROTECTION AGENCY

WASHINGTON, D C 20460

JAN 12 2017

Dear Stakeholders:

I have determined that the model year (MY) 2022-2025 light-duty vehicle greenhouse gas (GHG) standards adopted in the 2012 final rule establishing the MY2017-2025 standards (77 FR 62624, October 15, 2012) are appropriate under section 202 (a)(1) of the Clean Air Act. This adjudicatory Final Determination concludes the Midterm Evaluation of standards required under 40 CFR 86.1818-12(h) of the Environmental Protection Agency (EPA) regulations.

This Final Determination follows the November 2016 release of the EPA's Proposed Determination and the July 2016 release of a Draft Technical Assessment Report (TAR), issued jointly by the EPA, the National Highway Traffic Safety Administration (NHTSA), and the California Air Resources Board (CARB). Opportunities for public comment were provided for both the Draft TAR and the Proposed Determination. In the Draft TAR, the agencies examined a wide range of issues relevant to GHG emissions standards for MY2022-2025, and shared with the public their initial technical analyses of those issues. The Draft TAR was required by the EPA's regulations as the first step in the Midterm Evaluation process. In developing the Proposed Determination, the EPA considered public comments on the Draft TAR and updated its analyses where appropriate in response to comments and to reflect the latest available data. The EPA has likewise considered public input on the Proposed Determination in developing this Final Determination.

As described in more detail in the enclosed rationale, I have determined that the standards adopted in 2012 by the EPA remain feasible, practical and appropriate under section 202(a) and do not need to be revised, after considering the factors laid out in the 2012 rule. I strongly believe that issuing this Final Determination at this time, in light of the robust technical record that supports it, is in the best interests of the auto industry, the One National Program to which the EPA, NHTSA and CARB committed in 2012, and public health and welfare. The success of the industry to date in achieving seven years of record sales while producing a large variety of vehicles that meet or exceed the standards reflects the fact that the development and deployment of advanced technology conventional gasoline engines has happened consistent with a robust vehicle market, more rapidly than we predicted, and at costs that are comparable or slightly lower than we predicted. I have considered carefully all the information submitted to the EPA from all stakeholders on the Proposed Determination, as well as on the Draft TAR, and I am confident that the standards as they currently exist can be met at a reasonable cost.


I note that in response to the EPA's solicitation of comment on the topic, several commenters spoke to the need for additional incentives or flexibilities in the out years of the program including incentives that could continue to help promote the market for very advanced technologies, such as electric vehicles. My determination, based on the record before me, is that the 2022-2025 standards currently in effect are feasible (evaluated against the criteria established in the 2012 rule) and appropriate under section 202, and do not need to be revised. This conclusion, however, neither precludes nor prejudices the possibility of a future rulemaking to provide additional incentives for very clean technologies or flexibilities that

could assist manufacturers with longer term planning without compromising the effectiveness of the current program. The EPA is always open to further dialogue with the manufacturers, NHTSA, CARB and other stakeholders to explore and consider the suggestions made to date and any other ideas that could enhance firms' incentives to move forward with and to help promote the market for very advanced technologies, such as electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), and fuel cell vehicles (FCEVs).

Materials related to the Final Determination and Midterm Evaluation are available in docket EPA-HQ-OAR-2015-0827 and at <https://www.epa.gov/regulations-emissions-vehicles-and-engines/midterm-evaluation-light-duty-vehicle-ghg-emissions>.

We thank you for your interest in this issue.

Sincerely,



Gina McCarthy

Enclosure

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

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

U.S. Environmental Protection Agency

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Executive Summary

The 2012 rulemaking establishing the National Program for federal greenhouse gas (GHG) emissions and corporate average fuel economy (CAFE) standards for model years (MY)2017-2025 light-duty vehicles included a regulatory requirement for the Environmental Protection Agency (EPA) to conduct a Midterm Evaluation (MTE) of the GHG standards established for model years (MY)2022-2025.¹ In this final order, the Administrator is making a final adjudicatory determination (hereafter "determination") that, based on her evaluation of extensive 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, the MY2022-2025 standards remain appropriate under section 202 (a) (1) of the Clean Air Act. This action leaves those standards entirely as they now exist, unaltered. The regulatory status quo is unchanged. This final order constitutes a final agency action. See 76 FR 48763 (Aug. 9, 2011).

This Final Determination follows the November 2016 Proposed Determination issued by the EPA Administrator and the July 2016 release of a Draft Technical Assessment Report (TAR), issued jointly by the EPA, the National Highway Traffic Safety Administration (NHTSA), and the California Air Resources Board (CARB). Opportunities for public comment were provided for both the Draft TAR and the Proposed Determination. In the Draft TAR, the agencies examined a wide range of issues relevant to GHG emissions standards for MY2022-2025, and shared with the public their initial technical analyses of those issues. The Draft TAR was required by EPA's regulations as the first step in the Midterm Evaluation process. In developing the Proposed Determination, the Administrator considered public comments on the Draft TAR and EPA updated its analyses where appropriate in response to comments and to reflect the latest available data. The Administrator has likewise considered public input on the Proposed Determination in developing this Final Determination.

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 before the Administrator, given the latest available data and information. EPA's regulations establish April 1, 2018, as the latest date for such a determination, but otherwise do not constrain the Administrator's discretion to select an earlier determination date. The Administrator is choosing to make the Final Determination now, recognizing that long-term regulatory certainty and stability are important for the automotive industry and will contribute to the continued success of the program, which in turn will reduce emissions, improve fuel economy, deliver significant fuel savings to consumers, and benefit public health and welfare.

EPA received more than 100,000 public comments on the Proposed Determination, with comments from about 60 organizations and the rest from individuals. These public comments have informed the Administrator's Final Determination, and EPA has responded to those comments in the accompanying Response to Comments (RTC) document. This record²

¹ 40 CFR 86.1818-12(h).

² This record, the basis for the Administrator's determination, is contained in EPA Docket ID No. EPA-HQ-OAR-2015-0827.

represents the most current information available, as informed by public comment, and provides the basis for the Administrator's Final Determination, as called for in the 2012 rule.

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.³

This Final Determination is the Administrator's final decision 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 now 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."⁴

The EPA has now concluded all the required steps in the MTE process and the record upon which the Administrator is making this Final Determination reflects all the elements specified in the regulations. As discussed above, EPA issued (jointly with NHTSA and CARB) the July 2016 Draft Technical Assessment Report (TAR) and sought public comment on it. EPA updated

³ 40 CFR 86.1818-12(h)(1).

⁴ 40 CFR 86.1818-12(h)(2).

its Draft TAR assessment in response to public comments as part of the November 2016 Proposed Determination. EPA also sought public comment on the Proposed Determination that the GHG standards for MY2022-2025 remain appropriate under section 202 (a)(1) of the Act. If those comments had included information that led the Administrator to the determination that the standards are inappropriate, EPA would then have had to initiate a rulemaking seeking to amend those standards, as specified in the MTE regulation.⁵ However, no factual evidence came to light in the public comments or otherwise that leads the Administrator to a different conclusion than the one set forth in the Proposed Determination. The Administrator is thus making this Final Determination that the standards remain appropriate, and that no further action under the Midterm Evaluation is necessary. Thus the standards remain unchanged and the regulatory status quo is unaltered. See also 76 FR 48763 (Aug. 9, 2011) (“[t]he MY2022-2025 GHG standards will remain in effect unless and until EPA changes them by rulemaking”).

EPA’s updated analyses presented in the Proposed Determination built upon and were directly responsive to public comments on the Draft TAR. The Administrator has fully considered public comments submitted in response to the Proposed Determination, and EPA has responded to comments in the accompanying Response to Comments (RTC) document. The Administrator believes that there has been no information presented in the public comments on the Proposed Determination that materially changes the Agency’s analysis documented in the Proposed Determination. Therefore, the Administrator considers the analyses presented in the Proposed Determination⁶ as the final EPA analyses upon which her Final Determination is based.

The Administrator notes that, in response to EPA’s solicitation of comment on the topic, several commenters spoke to the need for additional incentives or flexibilities in the out years of the program including incentives that could continue to help promote the market for very advanced technologies, such as electric vehicles. She notes that her determination, based on the record before her, is that the MY2022-2025 standards currently in effect are feasible (evaluated against the criteria established in the 2012 rule) and appropriate under section 202, and do not need to be revised. This conclusion, however, neither precludes nor prejudices the possibility of a future rulemaking to provide additional incentives for very clean technologies or flexibilities that could assist manufacturers with longer term planning without compromising the effectiveness of the current program. The EPA is always open to further dialogue with the manufacturers, NHTSA, CARB and other stakeholders to explore and consider the suggestions made to date and any other ideas that could enhance firms’ incentives to move forward with and to help promote the market for very advanced technologies, such as electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), and fuel cell vehicles (FCEVs).

The basis for the Administrator’s assessment supporting her decision that the MY2022-2025 standards are appropriate is summarized below.

The Standards Are Feasible at Reasonable Cost, Without Need for Extensive Electrification. As part of 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

⁵ 40 CFR 86.1818-12(h) (final sentence).

⁶ Proposed Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation, EPA-420-R-16-020, and accompanying Technical Support Document, EPA-420-R-16-021, November 2016.

MY2022-2025 standards. This analysis demonstrates that compliance can be achieved through a number of different technology pathways reflecting predominantly the application of technologies already in commercial production. The EPA also considered further developments in technologies where there is reliable evidence that those technologies could be feasibly deployed by 2025. The standards are in fact devised so as not to force manufacturers into a single compliance path, and the analysis showing multiple compliance pathways indicates that the standards provide each manufacturer with the flexibility to apply technologies in the way it views best to meet the needs of its customers. Moreover, 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 EPA's assessment. We have already seen this type of innovative development since the MY2017-2025 GHG standards were originally promulgated in 2012, including expanded use of continuously variable transmissions and introduction of higher expansion ratio, naturally aspirated gasoline engines (Atkinson). Updated information also shows that some of the technologies we did anticipate in 2012 are costing less, and are more effective, than we anticipated at that time.

EPA further projects 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, and, as noted, that there are multiple available compliance pathways based on the predominant use of these technologies. This analysis is consistent with both agencies' findings in the 2012 final rulemaking (FRM). Table ES-1 shows fleet-wide penetration rates for a subset of the technologies EPA projects could be used to comply with the MY2025 standards. The analyses further indicate that very low levels of strong hybrids and electric vehicles (both plug-in hybrid electric vehicles (PHEV) and electric vehicles (EV)) will be needed to meet the standards. EPA analyzed a central case low-cost pathway as well as multiple sensitivity cases, all of which show that compliance can be achieved through a number of different technology pathways without extensive use of strong hybrid or electric vehicles. These sensitivity cases include various fuel price scenarios, cost markups, and technology penetrations (e.g., lower Atkinson penetration, lower mass reduction, alternative transmissions). See Table ES-1, presenting the sensitivity cases as a range of technology penetrations and per-vehicle costs. These costs are lower than those projected in the 2012 rule; at that time, the EPA projected that average per-vehicle costs, although reasonable, would be about \$1,100.⁷

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

	Final Determination	
	Primary Analysis	Range of Sensitivities Analyzed
Turbocharged and downsized gasoline engines (%)	34%	31 - 41%
Higher expansion ratio, naturally aspirated gasoline engines (%)	27%	5 - 41%
8 speed and other advanced transmissions ² (%)	93%	92 - 94%
Mass reduction (%)	9%	2 - 10%

⁷ 77 FR 62853, October 15, 2012; Draft Technical Assessment Report, Table 12.44.

Off-cycle technology ³	26%	13 - 51%
Stop-start (%)	15%	12 - 39%
Mild Hybrid (%)	18%	16 - 27%
Strong Hybrid (%)	2%	2 - 3%
Plug-in hybrid electric vehicle ⁴ (%)	2%	2%
Electric vehicle ⁴ (%)	3%	2 - 4%
Per vehicle cost (2015\$)	\$875	\$800 - \$1,115

Notes:

¹ Percentages shown are absolute rather than incremental. Values based on AEO 2016 reference case.

² Including continuously variable transmissions (CVT).

³ In addition to modeling the off-cycle credits of stop-start and active aerodynamics, EPA also assessed additional off-cycle technologies as unique technologies that can be applied to a vehicle and that reduce CO₂ emissions by either 1.5 g/mi or 3 g/mi. See Proposed Determination Appendix C.1.1.1.3,

⁴ Electric vehicle penetrations include the California Zero Emission Vehicle (ZEV) program.

The Standards Will Achieve Significant CO₂ and Oil Reductions. Based on various assumptions, including the U.S. Department of Energy's Annual Energy Outlook (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 (CO₂) target of 173 grams/mile (g/mi) in MY2025 (Table ES-2). The projected fleet average CO₂ target represents a 2-cycle GHG emissions compliance level equivalent to 51.4 mpg-e (if all reductions were achieved exclusively through fuel economy improvements).⁸ EPA projects that this GHG compliance level of 51.4 mpg-e could be met by automakers with average real world/label fuel economy of about 36 mpg. Given that the MY2016 real world fleet average fuel economy is about 26 mpg, this means that the fleet must improve real world fuel economy by about 10 mpg over the 9-year period from 2016 to 2025, or about one mpg per year.⁹

As a sensitivity, Table ES-2 also includes 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. 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. Thus, as shown in Table ES-2, different 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 CO₂ targets and MPG-e levels projected for MY2025. These estimated CO₂ 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.

In our analysis for this Final Determination, we are applying the same footprint-based curves to the updated fleet projections for MY2025. It is important to keep in mind that the updated

⁸ The projected MY2025 target of 173 g/mi represents an approximate 50 percent decrease in GHG emissions relative to the fuel economy standards that were in place in 2010. It is clear from current GHG manufacturer performance 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.

⁹ U.S. EPA, Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2016," November 2016, www.epa.gov/fuel-economy/trends-report.

MY2025 fleet wide projections reflected in this Final Determination are still projections-- 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. Put another way, each manufacturer will not know what its individual standard is until MY2025, since that individual standard is determined by the type and number of vehicles the manufacturer chooses to produce.

Table ES-2 Projections for MY2025: Car/Truck Mix, CO₂ Target Levels, and MPG-equivalent¹

	2012 Final Rule	Final Determination		
	AEO 2011 Reference	AEO 2016 Reference	AEO 2016 Low	AEO 2016 High
Fuel Price in 2025 (\$/gallon) ²	\$3.87	\$2.97	\$1.97	\$4.94
Car/truck mix	67/33%	53/47%	44/56%	63/37%
CO ₂ (g/mi)	163	173	178	167
MPG-e ³	54.5	51.4	49.9	53.3

Notes:

¹ The CO₂ and MPG-e values shown here are 2-cycle compliance values. Projected real-world values are detailed in the Proposed Determination TSD Chapter 3; for example, AEO reference fuel price case, real-world CO₂ emissions performance would be 233 g/mi and real-world fuel economy would be about 36 mpg.

² AEO 2011 fuel price is 2010\$ (equivalent to \$4.21 in 2015\$); AEO 2016 fuel prices are 2015\$.

³ 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.

EPA estimates that over the vehicle lifetimes the MY2022-2025 standards will reduce GHG emissions by 540 million metric tons and reduce oil consumption by 1.2 billion barrels, as shown in Table ES-3.

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

	Final Determination ¹
GHG reduction (million metric tons, MMT CO ₂ e)	540
Oil reduction (billion barrels)	1.2

Note:

¹ Values based on AEO 2016 reference case.

The Standards Will Provide Significant Benefits to Consumers and to the Public. The net benefits of the MY2022-2025 standards are nearly \$100 billion (at 3 percent discount rate). Table ES-4 presents the societal monetized benefits associated with meeting the MY2022-2025 standards. The EPA also evaluated the benefit-costs of additional scenarios (AEO 2016 high and low fuel price scenarios). See Proposed Determination 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 (excluding fuel savings) and the fuel savings, each independently, exceed the costs. That is, 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 \$)

	Final Determination ²	
	3 Percent Discount Rate	7 Percent Discount Rate
Vehicle Program	-\$33	-\$24
Maintenance	-\$3	-\$2
Fuel	\$92	\$52
Benefits ¹	\$42	\$32
Net Benefits	\$98	\$59

Notes:

¹All values are discounted back to 2016. See the Proposed Determination Appendix C for details on discounting social cost of GHG and non-GHG benefits, and for a discussion that the costs and benefits reflect some early compliance with the MY2025 standard in MY2021.

² Values 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. The average loan period is 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 fifth year of ownership. Consumers would realize net savings of \$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 2016 (see Proposed Determination Appendix C), approximately \$2 per gallon in 2025, the lifetime fuel savings significantly outweigh the increased lifetime costs.

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

	Final Determination ¹
Payback period – 5-year loan purchase ² (years)	<1
Payback period – Cash purchase (years)	5
Net Lifetime Consumer Savings (\$, discounted at 3%)	\$1,650

Notes:

¹ Values based on AEO 2016 reference case and 2015\$

² Using an interest rate of 4.25 percent.

The Auto Industry is Thriving and Meeting the Standards More Quickly than Required. While the Final Determination focuses on the MY2022-2025 standards, we note that the auto industry, on average, has out-performed the first four years of the light-duty GHG standards (MY2012-2015). This has occurred concurrently with a period during which the industry successfully rebounded after a period of economic distress. The recently released GHG Manufacturer

Performance Report for the 2015 Model Year shows that the National Program is working even at low fuel prices and automakers are over-complying with the standards, notwithstanding that the MY2015 standard was the most stringent to date, and that the increase in stringency from the previous model year was also the most pronounced to date.¹⁰ Further, concurrently with outperforming the GHG standards, sales have increased for seven straight years, for the first time in 100 years, to an all-time record high in 2016, reflecting positive consumer response to vehicles meeting the standards.

The Administrator's Final Determination is that the MY2022-2025 standards remain appropriate. In light of the pace of progress in reducing GHG emissions since the MY2022-2025 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), the Administrator concludes that the record does not support a conclusion that the MY2022-2025 standards should be revised to make them less stringent. The Administrator did consider whether it would be appropriate to propose to amend the standards to increase their stringency. In her view, the current record, including the current state of technology and the pace of technology development and implementation, could support a proposal, and potentially an ultimate decision, to adopt more stringent standards for MY2022-2025. However, she also recognizes that regulatory certainty and consequent stability is important, and that it is important not to disrupt the industry's long-term planning. Long lead time is needed to accommodate significant redesigns. The Administrator also believes a decision to maintain the current standards provides support to a timely NHTSA rulemaking to adopt MY2022-2025 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,¹¹ and thus to a harmonized national program. The Administrator consequently has concluded that it is appropriate to provide the full measure of lead time for the MY2022-2025 standards, rather than adopting (or, more precisely, proposing to adopt) new, more stringent standards with a shorter lead time.

¹⁰ “Greenhouse Gas Emission Standards for Light-duty Vehicles, Manufacturer Performance Report for the 2015 Model Year, November 2016, EPA-420-R-16-014.<https://www.epa.gov/regulations-emissions-vehicles-and-engines/ghg-emission-standards-light-duty-vehicles-manufacturer>.”

¹¹ 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).

I. Introduction

A. Background on 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. Light-duty vehicles, which include passenger cars, sport utility vehicles, crossover utility vehicles, minivans, and pickup trucks, make up about 60 percent of all U.S. transportation-related GHG emissions and fuel consumption.¹² The agencies finalized the first set of National Program standards covering model years (MYs) 2012-2016 in May 2010¹³ and the second set of standards, covering MY2017-2025, in October 2012.¹⁴ The National Program is one of the most significant federal actions ever taken to reduce domestic GHG emissions and improve automotive fuel economy, establishing standards that increase in stringency year-over-year from MY2012 through MY2025 and projected to reach a level that nearly doubles fuel economy and halves GHG emissions compared to MY2010.

Through the coordination of the National Program with the California Air Resources Board's 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.¹⁵ In addition, the Canadian government has adopted standards aligned with the U.S. EPA GHG standards through MY2025, further facilitating manufacturers' ability to produce vehicles satisfying harmonized standards.¹⁶ 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 reduce carbon dioxide (CO₂) emissions by 6 billion metric tons and reduce oil consumption by 12 billion barrels over the lifetime of MY2012-2025 vehicles. The 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 rule establishing GHG standards for MY2017-2025 light-duty vehicles included a requirement for the agency to conduct a Midterm Evaluation (MTE) of the MYs 2022-2025 GHG standards. Through the MTE, EPA must determine whether the GHG standards for MY2022-2025,

¹² Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014, EPA Publication number EPA 430-R-16-002, April 15, 2016. Overall transportation sources account for 26 percent of total U.S. GHG emissions.

¹³ 75 FR 25324, May 7, 2010.

¹⁴ 77 FR 62624, October 15, 2012.

¹⁵ 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.

¹⁶ EPA has coordinated with Environment and Climate Change Canada (ECCC) and Transport Canada throughout the Midterm Evaluation, including collaborating on a number of technology research projects. See Draft Technical Assessment Report Chapter 2.2.3, p. 2-8.

established in 2012, are still appropriate, within the meaning of section 202(a)(1) of the Clean Air Act, in light of the record before the Administrator, given the latest available data and information. See 40 CFR 86.1818-12(h). The MTE regulations provide that if the Administrator were to make a 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 the EPA would initiate a rulemaking to amend the standards to make them either more or less stringent. See 40 CFR 86.1818-12(h) (final sentence). This regulatory provision to conduct a rulemaking is limited only to the situation where the Administrator makes a determination that the standards are not appropriate and should be changed, to be either more or less stringent, and not to the situation where the Administrator, as in the case of this Final Determination, determines that the standards are appropriate and should not be changed. See 77 FR 62784 (Oct. 15, 2012) (stating that if EPA concludes the standards are appropriate it will “announce that final decision and the basis for EPA’s decision” and if the EPA decides the standards are not appropriate, it will “initiate a rulemaking to adopt standards that are appropriate under section 202(a)”).

In the 2012 rulemaking, the EPA stated its intention that the MTE would entail "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). Indeed, the analyses supporting this MTE have been as robust and comprehensive as that in the original setting of the MY2017-2025 standards, *Id.*, although the nature of the decision-making the EPA has undertaken based on those analyses is very different, as established by design of the MTE regulations. In the 2012 rule, the EPA was faced with establishing the MY2017-2025 standards, while in this Final Determination the EPA has evaluated those standards in light of developments to date in order to determine if the existing standards are appropriate. *Id.* In gathering data and information throughout the MTE process, the EPA has drawn from a wide range of sources, including vehicle certification data, research projects and vehicle testing programs initiated by the agencies, input from stakeholders, and information from technical conferences, published literature, studies published by various organizations, and the many public comments.

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.¹⁷ For the EPA, the Draft TAR was the first formal step in the MTE process as required under EPA’s regulations.¹⁸ 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 EPA received over 200,000 public comments on the Draft TAR, including about 90 comments from organizations and the rest from individuals. 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,

¹⁷ 81 FR 49217, July 27, 2016.

¹⁸ See 40 CFR 86.1818-12(h)(2)(i).

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 EPA considered in updating its analyses in support of the Administrator's Proposed Determination. The EPA also considered the few additional comments received after the close of the comment period on the Draft TAR.¹⁹

On November 30, 2016, EPA Administrator issued a proposed adjudicatory determination²⁰ proposing to find that the MY2022-2025 standards remain appropriate under the Clean Air Act. Because the Administrator was 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, the Proposed Determination did not include a Notice of Proposed Rulemaking. See section 86.1818-12(h). In this Final Determination, the Administrator has once again considered public comments -- those received on the Proposed Determination. The EPA received more than 100,000 comments on the Proposed Determination, with about 60 comments from organizations and the rest from individuals. The EPA responds to the public comments in the accompanying Response to Comments (RTC) document.

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;

¹⁹ After the close of the comment period on the Draft TAR, EPA received and docketed additional comments from Volkswagen, the Electric Drive Transportation Association, and the Alliance of Automobile Manufacturers (a non-technical comment), all of which the EPA considered in the Proposed Determination.

²⁰ As noted in the Proposed Determination, and discussed more fully in the Response to Comments, the determination is not a rulemaking. None of EPA's rules, the Administrative Procedures Act, or the Clean Air Act require that the determination be made by rulemaking. EPA is properly exercising its discretion to proceed by adjudication. The final determination evaluates the technical record and concludes that the current standards are appropriate. As with past mid-course evaluations of Title II rules, where the EPA evaluates standards and decides not to change them, it need not undertake, and is not undertaking, a rulemaking. For example, in the final rule for heavy-duty engine standards (66 FR 5063, January 18, 2001), EPA announced regular biennial reviews of the status of the key emission control technology. EPA subsequently issued those reviews in 2002 and 2004, without going through rulemaking. See EPA Report 420-R-02-016; EPA Report 420-R-04-004. Or for instance, in the final rule for the Nonroad Tier 3 standards (63 FR 56983, Oct 23, 1998), EPA committed to reviewing the feasibility of the standards by 2001 and to adjust them by rulemaking if necessary. In 2001, without engaging in rulemaking, the EPA published a report, see EPA Report 420-R-01-052, accepted comments, and concluded publicly that the standards remained technologically feasible. (Memorandum: "Comments On Nonroad Diesel Emissions Standards: Staff Technical Paper," from Chet France to Margo Oge, June 4, 2002).

- 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.²¹

The preamble to the 2012 final rule further listed ten relevant factors that the agencies will consider at a minimum during the MTE. The EPA in fact addressed all of these issues in the Draft TAR, and considered them further in the Proposed Determination and in this Final Determination.²²

- 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;
- 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.²³

In the 2012 final rule, the agencies projected that the MY2025 standards would be met largely through advances in conventional vehicle technologies, including advances in gasoline engines (such as downsized/turbocharged engines) and transmissions, vehicle weight reduction, improvements in aerodynamics, more efficient 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 EPA estimated that some increased electrification of the fleet would occur through the expanded use of stop/start and mild hybrid technologies, but projected that the MY2025 standards could be met with only about five percent of the fleet being strong hybrid electric vehicles (HEVs) and only about two percent of the fleet to be electric vehicles (EV) or plug-in hybrid electric vehicles (PHEVs).²⁴ All of these technologies were available at the time of the

²¹ 40 CFR 86.1818-12(h).

²² 76 FR 48673 (Aug. 9, 2011) and 77 FR 62784, October 15, 2012.

²³ Among the other factors deemed relevant and addressed in the Draft TAR and Proposed Determination, EPA's analysis examined the potential impact of the California Zero Emission Vehicle (ZEV) program, which California has revised since the 2012 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.

²⁴ 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.

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.

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.²⁵ 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 evaluation in the 2012 rule, including non-hybrid Atkinson cycle gasoline engines and 48-volt mild hybrid systems. Other technologies are being utilized at greater rates than the agencies projected, such as continuously variable transmissions (CVTs). These additional technologies have resulted in projected compliance pathways which differ slightly from those in the 2012 final rule with respect to some of the specific technologies expected to be applied to meet the future standards. However, the conclusions of the 2012 Final Rule, the July 2016 Draft TAR, the November 2016 Proposed Determination, and this Final Determination are very similar: that advanced gasoline vehicles will be the predominant technologies that manufacturers can use 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.²⁶ As discussed below, the standards are also projected to be achievable through multiple feasible technology pathways at reasonable cost -- less than projected in the 2012 rulemaking -- and with significant direct benefit to consumers in the form of net savings due to purchasing less fuel.

The Administrator notes that, in response to EPA's solicitation of comment on the topic, several commenters spoke to the need for additional incentives or flexibilities in the out years of the program including incentives that could continue to help promote the market for very advanced technologies, such as electric vehicles. She notes that her determination, based on the record before her, is that the MY2022-2025 standards currently in effect are feasible (evaluated against the criteria established in the 2012 rule) and appropriate under section 202, and do not need to be revised. This conclusion, however, neither precludes nor prejudices the possibility of a future rulemaking to provide additional incentives for very clean technologies or flexibilities that could assist manufacturers with longer term planning without compromising the effectiveness of the current program. The EPA is always open to further dialog with the manufacturers, NHTSA, CARB and other stakeholders to explore and consider the suggestions made to date and any other ideas that could enhance firms' incentives to move forward with and

²⁵ "Greenhouse Gas Emission Standards for Light-duty Vehicles, Manufacturer Performance Report for the 2015 Model Year, November 2016, EPA-420-R-16-014.

²⁶ "Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles," National Research Council of the National Academies, June 2015, Finding 2.1 (p. 2-83).

to help promote the market for very advanced technologies, such as electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), and fuel cell vehicles (FCEVs).

B. Background on the Light-duty Vehicle GHG Standards

The GHG emissions standards are attribute-based standards, based on vehicle footprint.²⁷ In other words, the standards are based on a vehicle's size: larger vehicles have numerically higher GHG emissions targets and smaller vehicles have numerically lower GHG emissions targets. Manufacturers are not compelled to build vehicles of any particular size or type, and each manufacturer has a unique fleetwide standard for each of its car and truck fleets that reflects the light-duty vehicles it chooses to produce in a given model year. Each automaker's standard automatically adjusts each year based on the vehicles (sizes and volumes) it produces. With fleetwide averaging, a manufacturer can produce some models that exceed their target, and some that are below their target. This approach also helps preserve 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. In addition, manufacturers have available many other flexibility provisions, including banking and trading of credits across model years and trading credits across manufacturers.

The footprint curves for the MY2012-2025 GHG standards, illustrating the year-over-year stringency increases, are shown below in Figure I.1 and Figure I.2.²⁸

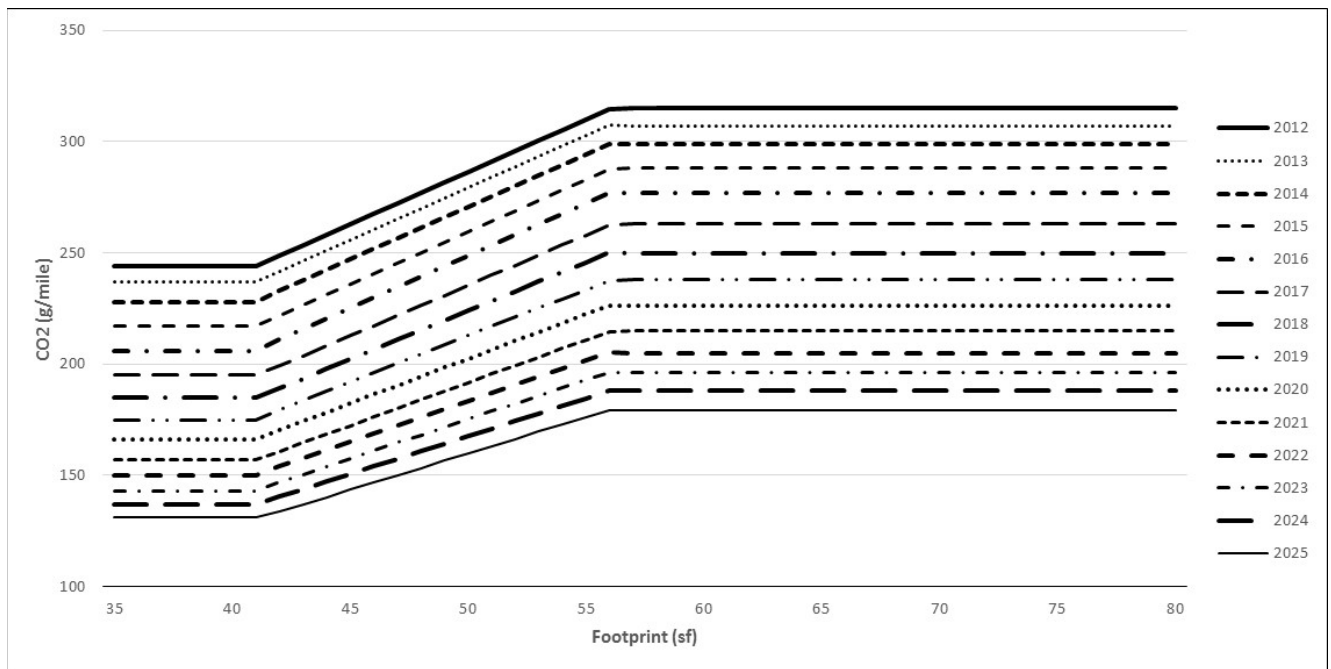


Figure I.1 CO₂ (g/mile) Passenger Car Standards Curves

²⁷ 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.

²⁸ See 40 CFR 86.1818-12(c).

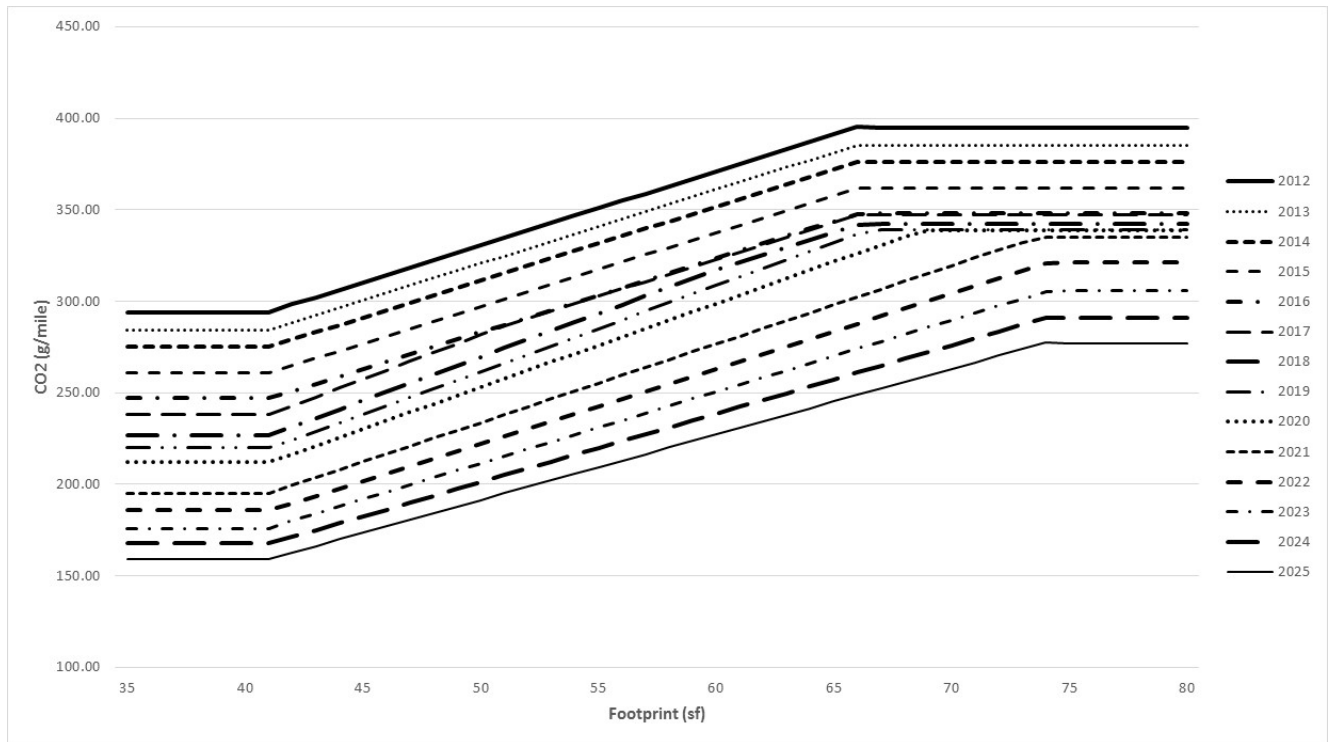


Figure I.2 CO₂ (g/mile) Light Truck Standards Curves

C. Climate Change Science

In the Proposed Determination, the EPA presented an overview of climate change science as laid out in the climate change assessments from the National Academies, the U.S. Global Change Research Program, and the Intergovernmental Panel on Climate Change. The EPA summarized the impacts to human health, to ecosystems, and to physical systems in the United States and around the world, from heat waves to sea level rise to disruptions of food security. Impacts to vulnerable populations such as children, older Americans, persons with disabilities, those with low incomes, indigenous peoples, and persons with preexisting or chronic conditions were also highlighted. The most recent assessments have confirmed and further expanded the science that supported the 2009 Endangerment and Cause or Contribute Findings for Greenhouse Gases Under section 202(a) of the Clean Air Act; Final Rule (74 FR 66496, December 15, 2009), as discussed in the more recent 2016 Finding That Greenhouse Gas Emissions from Aircraft Cause or Contribute to Air Pollution That May Reasonably Be Anticipated to Endanger Public Health and Welfare (81 FR 54422, August 15, 2016). Furthermore, the climate system continues to change: in 2015, CO₂ concentrations grew by more than 2 parts per million, reaching an annual average of 401 ppm, sea level continued to rise at 3.3 mm/year since the satellite record started in 1993, Arctic sea ice continues to decline, and glaciers continue to melt.²⁹ 2016 was the

²⁹ Blunden, J. and D. S. Arndt, Eds., 2016: State of the Climate in 2015. Bull. Amer. Meteor. Soc., 97 (8), S1–S275, DOI:10.1175/2016BAMSSStateoftheClimate.

warmest year in the global average surface temperature record going back to 1880, the third year in a row of record temperatures.

II. The Administrator’s Assessment of Factors Relevant to the Appropriateness of the MY2022-2025 Standards

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 before the Administrator.³⁰ In this final order, the Administrator is making a final determination that the GHG standards currently in place for MYs 2022-2025 remain appropriate under the Clean Air Act. The consequence of this determination is that the standards remain unchanged, there is no alteration in the rules, and the regulatory status quo continues. The Administrator has fully considered public comments submitted on the Proposed Determination, and the EPA has responded to comments in the accompanying Response to Comments (RTC) document. The Administrator believes that there has been no information presented in the public comments on the Proposed Determination that materially changes the Agency’s analysis documented in the Proposed Determination.³¹ Therefore, the Administrator considers the analyses presented in the Proposed Determination as the final the EPA analyses upon which this Final Determination is based.

The EPA regulations³² 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:

- (i) The availability and effectiveness of technology, and the appropriate lead time for introduction of technology;
- (ii) The cost on the producers or purchasers of new motor vehicles or new motor vehicle engines;
- (iii) The feasibility and practicability of the standards;
- (iv) The impact of the standards on reduction of emissions, oil conservation, energy security, and fuel savings by consumers;
- (v) The impact of the standards on the automobile industry;
- (vi) The impacts of the standards on automobile safety;
- (vii) The impact of the greenhouse gas emission standards on the Corporate Average Fuel Economy standards and a national harmonized program; and
- (viii) The impact of the standards on other relevant factors.³³

³⁰ See 40 CFR 86.1818-12(h).

³¹ Proposed Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation, EPA-420-R-16-020, and accompanying Technical Support Document, EPA-420-R-16-021, November 2016. In adopting the midterm evaluation provisions, EPA indicated that it “expect[ed] to place primary reliance on peer-reviewed studies” and on “NAS reports” in making midterm evaluation determinations. 77 FR 62787. EPA has in fact done so. See Draft TAR Section 2.2.1 and 2.2.3.

³² See 40 CFR 86.1818-12(h)(1)(i) through (viii).

³³ 40 CFR 86.1818-12(h)(1).

Below we discuss each of these factors in light of the analyses upon which this Final Determination is based.

(i) The availability and effectiveness of technology, and the appropriate lead time for introduction of technology; (ii) the cost on the producers or purchasers of new motor vehicles or new motor vehicle engines; (iii) the feasibility and practicability of the standards

Several of the factors relate to the technology assessment -- technology availability and effectiveness, lead time for introducing technologies, and the costs, feasibility and practicability of the standards. On the basis of EPA's extensive technical analyses contained in the Proposed Determination, and after consideration of the additional comments received by the agency, the Administrator finds that there will be multiple technologies available at reasonable cost to allow the industry to meet the MY2022-2025 standards, with the majority in commercial production today, and others under active development with reliable evidence of feasibility and availability in the market by 2025. See Proposed Determination Sections II and IV.A, and TSD Chapter 2. As in the 2012 FRM, The Administrator further finds that the MY2025 standards can be achieved with very low levels of strong hybrid or plug-in electrified vehicles. The EPA's extensive review of the literature, including but not limited to the 2015 NAS study, makes it clear that advanced gasoline vehicle technologies will continue to improve between now and 2025. In addition, the significant technology advances that have already occurred in just the four years since the 2012 final rule are a strong indication that technology will continue to advance, with clear potential for additional innovation over the next eight years.

The EPA projects a range of potential compliance pathways for each manufacturer and the industry as a whole to meet the MY2022-2025 standards (see Proposed Determination Table IV.5 and Appendix C which show a "central case" and eight sensitivity cases). This analysis indicates 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. The 2015 National Academy of Sciences study on fuel economy technologies similarly 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. It is 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 expect that ongoing innovation will result in further improvements to existing technologies and the emergence of others.

As we note throughout this document, the EPA carefully considered and responded in detail to all of the significant public comments as part of the record for the Proposed Determination. Some industry commenters have expressed the view that the EPA did not in fact consider their technical comments. As described in the Proposed Determination and Chapter 2 of the TSD, a number of changes the EPA made to its analysis between the Draft TAR and the Proposed Determination were in response to those technical comments highlighted by the Alliance of Automobile Manufacturers and Global Automakers. These included updating the baseline fleet to a MY2015 basis, better accounting for certain technologies in that baseline fleet, improving

the vehicle classification structure to improve the resolution of cost-effectiveness estimates applied in the OMEGA model, updating effectiveness estimates for certain advanced transmission technologies, conducting additional sensitivity analyses (including those where certain advanced technologies are artificially constrained), and adding quality assurance checks of technology effectiveness into the ALPHA and Lumped Parameter Model. See Proposed Determination Appendix A at A-1 and A-2. EPA consulted with NHTSA and CARB as part of the process of developing the Proposed Determination. The Final Determination is based on an administrative record at the very least as robust as that for the 2012 FRM, including extensive state-of-the-art research projects conducted by EPA and consultants to both agencies, data and input from stakeholders, multiple rounds of public comment, information from technical conferences, published literature, and studies published by various organizations. EPA put primary emphasis on the many peer-reviewed studies, as well as on the National Academy of Sciences 2015 report on fuel economy technologies.

Auto industry commenters believe that EPA's analysis generally overestimates the effect of advanced gasoline technologies, that these technologies will not be sufficient to meet the standards, and that higher levels of electrified vehicles will be needed to meet the MY2022-2025 standards. The EPA has carefully considered these comments and our assessment is that the commenters are not considering the possibility of applying the full range of road load reduction and non-electrified powertrain technologies broadly across high volume models, and in the combinations, that the EPA assessed in the Proposed Determination and Draft TAR. In some cases, the auto industry comments, including the Alliance of Automobile Manufacturers (Alliance), are based on the premise that the only possible technologies available in MY2025 will be represented by technology already contained in the fleet today (more specifically, that contained in the Draft TAR's MY2014 baseline fleet), and that those technologies will not improve in efficiency. The EPA disagrees with this assertion; several recently released engines have already demonstrated efficiencies that exceed those in the MY2014 fleet.³⁴ These actual engines illustrate that improvement has continued beyond the assumed basis of the comments, and it is highly unlikely that even these recent developments represent the limit of achievable efficiencies in the future. EPA's assessment is consistent with the MY2015 NAS report, in which the committee wrote that in the context of increasingly stringent fuel economy and GHG emissions standards, "gasoline-fueled spark ignition (SI) engine will continue to be the dominant powertrain configuration even through 2030 (pg S-1)."³⁵ 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 commenters do not even allow for the recombination of existing technologies, and thus severely and unduly limit potential effectiveness increases obtainable by MY2025. The EPA notes that events have already disproven this assumption; as one specific example, Ford introduced a 10-speed automatic transmission on the MY2017 F150 paired with a turbocharged downsized engine, which represents a technology combination that was not previously available and was therefore not considered (and would be deemed impossible) by the Alliance comments. NGO commenters, on

³⁴ These engines include the 1.5L Honda turbo, Volkswagen's EA888-3B Miller cycle, and Hyundai-Kia's 2.0L Atkinson cycle engine.

³⁵ The 2015 NAS report also included an example technology pathway which illustrated how the application of conventional, non-electrified technologies would enable the example midsize car to meet its MY2025 footprint target (pp 8-18, 8-19).

the other hand, believe that EPA's analysis is robust and that, if anything, EPA's assessment of technologies is overly conservative as we did not consider additional technologies expected to be in the market in the MY2022-2025 timeframe.

The EPA also has carefully considered comments and issues related to powertrain improvements, including advanced engine technologies and improvements to transmission technologies. See 76 FR 48763 and 77 FR 62784. A key technology the EPA assessed in the Draft TAR and Proposed Determination to be available at reasonable cost is the Atkinson Cycle engine in non-hybrid applications. The Atkinson Cycle architecture has already been demonstrated in production domestically (Mazda, Toyota, Hyundai-Kia), enhanced with cooled exhaust gas recirculation (Mazda), and in Europe further enhanced with cylinder deactivation (Volkswagen). These production examples are consistent with EPA engine modeling and initial hardware testing that shows synergies between the use of cooled exhaust gas recirculation and cylinder deactivation with Atkinson Cycle engines. See TSD Chapter 2.3.4.1.4. In addition, and as explained in TSD Chapter 2.3.4.1.8.3 and further below, the EPA conducted sensitivity analyses constraining penetration of Atkinson-cycle engines and found that there are other cost-effective compliance paths available which rely chiefly on engine technology alternatives, rather than on electrification. We did not receive information in the comments on the Proposed Determination that provided a basis for reaching a different conclusion. Among these alternative technology paths are increased penetration of gasoline direct injected, turbo-downsized engines (a chief technology in the agencies' 2012 FRM assessment). The EPA has carefully considered and addressed the comments questioning the effectiveness values the EPA estimated for this technology; the EPA continues to believe these estimates are well grounded. The EPA explained in detail why the engine configuration used in its effectiveness estimates is representative, why the friction reduction assumptions are sound based on the use of coatings and other materials and technologies throughout the engine's moving components, and why the production engines cited as alternatives in the comments are not representative of feasible effectiveness values in 2025 given that they lack various technologies that improve efficiency (including variable valve lift, external cooled exhaust gas recirculation, sequential turbocharging, and higher peak cylinder pressure capability). See TSD Chapter 2.3.4.1.9.1.

The EPA is projecting average per vehicle costs of \$875 across the fleet (see Table ES-1 and Proposed Determination Table IV.5).³⁶ These costs are lower than those projected in the 2012 rule, which the EPA estimated at about \$1,100 (see Table 12.44 of the Draft TAR). The EPA found in the 2012 rule that these (higher) costs were reasonable, even without considering the payback in the form of less fuel used, which more than offsets these costs. See 77 FR 62663-62665, 62880 and 62922. Consequently, the EPA regards these lower estimated per-vehicle costs to be reasonable. Furthermore, the projected reduced fuel expenditures more than offset the estimated increase in vehicle cost even with lower assumptions of fuel cost. EPA's analysis finds that 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 fifth year of

³⁶ Across eight sensitivity cases, average per-vehicle costs ranged from \$800-\$1,115. See Proposed Determination Table IV.5.

ownership. Consumers would realize net savings of \$1,650 over the lifetime of their new vehicle (i.e., net of increased lifetime costs and lifetime fuel savings).

This decrease in estimated per-vehicle cost is not surprising—technology to achieve environmental improvements has often proved to be less costly than EPA’s initial estimates.³⁷ Captured in these cost estimates, we project significant increases in the use of 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 15 percent and 18 percent, respectively, of the fleet. Similar to the analysis in the 2012 FRM, the EPA is projecting very low levels of strong hybrids (2 percent) and EV/PHEVs (5 percent) as absolute levels in the fleet (in the central case analysis, see Table ES-1).³⁸

The EPA has considered the feasibility of the standards under several different scenarios of future fuel prices and fleet mix, as well as other sensitivity cases (e.g., different assumptions about technologies or credit trading) (see Proposed Determination Section IV.A and Appendix C), which showed only very small variations in average per-vehicle cost or technology penetration mix. Thus, our conclusion that there are multiple ways the MY2022-2025 standards can be met with a wide range of technologies at reasonable cost, and predominantly with advanced engine technologies, holds across all these scenarios.

These technology pathway 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 noted above, were not even considered by the agencies in the 2012 rule yet are in production vehicles today. 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 2012.³⁹ Mild hybrid technology also 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 pace of innovation is likely to continue. The EPA expects that this trend will continue, likely affording

³⁷ 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/erm.nsf/vwAN/EE-0575.pdf/\\$file/EE-0575.pdf](https://yosemite.epa.gov/ee/epa/erm.nsf/vwAN/EE-0575.pdf/$file/EE-0575.pdf) including its literature review, Chapter 1.1.

³⁸ Note that a portion of the five percent EV/PHEV penetration is attributed to the California Zero Emission Vehicle (ZEV) program which is included in our reference case. See TSD Section 1.2.1.1. The incremental penetration of EV/PHEVs needed to meet the EPA GHG standards is projected to be less than one percent. See Proposed Determination Appendix C.1.1.3.2, Tables C.19-C.22, p. A-136-137.

³⁹ 77 FR 62852-62883; October 15, 2012.

manufacturers even more technology options, and at potentially lower cost, than the Administrator was able to consider at this time for the Final Determination.

EPA's analysis indicates that the effectiveness of the technologies evaluated provides manufacturers with a feasible, reasonable mix of technologies that are predominantly in production today, though not always in combination. For example, a manufacturer may have moved to an advanced turbo-downsized engine design and applied aerodynamic improvements, but not yet applied more advanced transmission or applied further mass reduction opportunities. In addition, there are some straightforward improvements to these technologies that are anticipated and well-documented in the record. See, e.g., Proposed Determination TSD Chapters 2.2.3.4 through 2.2.3.11, and 2.2.7.2 through 2.2.7.5. Most of the automaker comments to the Proposed Determination regarding feasibility did not account for the possibility of using a broad slate of technologies in combination. A few manufacturers have shared with the EPA confidential business information illustrating technology walks (or “techwalks”), which show the cumulative effects of the application of various technologies applied to a given vehicle model. However, while the techwalks provided include some of the same advanced technologies considered by EPA, none of the techwalks include a fuller range of conventional technologies in the combinations described in the Proposed (and Final) Determination. Some are missing very reasonable vehicle technologies, some are missing very reasonable engine technologies, and some are missing very reasonable transmission technologies. Because the manufacturer example techwalks don't include all technologies in the appropriate combinations and in some cases don't include the appropriate credit values, the examples show a shortfall (as would be expected) of about 20-40 g/mi depending on the vehicle. This resulting gap between the EPA and manufacturer-supplied projections would be eliminated if a broader set of the available technologies described in the Final Determination were included in their analysis and appropriate credit values were used.

Moreover, the EPA believes there is ample lead time between now and MY2022-2025 for manufacturers to continue implementing additional technologies into their vehicle production such that the MY2022-2025 standards can be achieved.

In considering whether lead time for the MY2022-2025 standards is adequate, the EPA recognizes that these standards were first established in 2012, providing the auto manufacturers with up to 13 years of lead time for product planning to meet these standards. In the 2012 rule, the EPA concluded that, “EPA agrees that the long lead time in this rulemaking should provide additional certainty to manufacturers in their product planning. The 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.”⁴⁰ As noted, in setting the standards in 2012, the 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 (see Proposed Determination Section II). The EPA's 2016 CO₂ and Fuel Economy Trends 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 period, GM and Ford have implemented turbocharged engines on 25 percent and 40 percent of their fleets,

⁴⁰ 77 FR 62880; October 15, 2012.

respectively. Given that the 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 clearly achievable given the pace with which some manufacturers have already implemented similar technologies.⁴¹ With respect to the issue of lead time for the Atkinson engine technology, many of the building blocks necessary to operate an engine in Atkinson mode are already present in the MY2016 fleet (including gasoline direct injection (GDI), increased valve phasing authority, higher compression ratios, and (in some instances) cooled exhaust gas recirculation (cEGR)). Some of the potential packaging obstacles mentioned in comments, such as exhaust manifold design, should not be an impediment because more conventional manifold designs (not requiring a revamping of vehicle architecture) are both available and demonstrated in non-hybrid Atkinson cycle applications. There thus should be sufficient lead time before MY2022 to adopt the technology, since it could be incorporated without needing to be part of a major vehicle redesign.

Indeed, 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 5 to 8 years of lead time until the MY2022-2025 standards, with at least 1-2 redesign cycles.⁴²

The EPA has also evaluated the progress of the existing fleet in meeting standards in future model years. See the Proposed Determination 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 CO₂ targets for MY2020 with current powertrains and air conditioning improvements. These figures do not include off-cycle credits in assessing compliance. In light of the fact that manufacturers are reporting an average of 3 g/mi of off-cycle credits across the fleet for 2015, with some manufacturers reporting more than 4 g/mi off-cycle credits, the share of the MY2016 fleet that can already meet the MY2020 footprint-based CO₂ targets -- four years ahead of schedule-- is actually even higher.

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 because of the fleetwide averaging structure of the standards, 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 indication that the fleet is on track to meet future standards, especially given the 5 to 8 years of lead time remaining to MY2022-2025.

Consequently, evaluating the factors the EPA is required to consider under 40 CFR 86.1818(h)(1) (i), (ii), and (iii) of the mid-term evaluation rules, based on the current record before the Administrator, there is available and effective technology to meet the MY2022-2025 standards, it is available at reasonable cost to the producers and purchasers of new motor

⁴¹ EPA 2016 CO₂ and Fuel Economy Trends Report, Figures 6.2, 6.3 and 6.5.

⁴² Redesign cycles are summarized in the Proposed Determination Appendix A and are discussed in greater detail in the 2012 FRM final Joint Technical Support Document, EPA-420-R-12-901, at Chapter 3.5.1.

vehicles or new motor vehicle engines, there is adequate lead time to meet those standards, and the standards are thus feasible and practicable. Moreover, this most recent analysis remains consistent with the key conclusions reached in the 2012 FRM: there are multiple compliance paths based chiefly on deployment of advanced gasoline engine technologies with minimal needed penetration of strong hybrid or full electric vehicles, projected per vehicle costs are lower than in the 2012 FRM, and the cost of the lower emitting technology is fully paid back by the associated fuel savings.

(iv) The impact of the standards on reduction of emissions, oil conservation, energy security, and fuel savings by consumers

The 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. Light-duty vehicles are significant contributors to the U.S. GHG emissions inventory—responsible for 61 percent of U.S. transportation GHG emissions and 16 percent of total U.S. GHG emissions in 2014—and thus must be a critical part of any program to reduce U.S. GHG emissions. EPA projects that the MY2022-2025 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 Proposed Determination Section IV.A.4, Table IV.6, and Appendix C.2. These projected GHG reductions associated with the MY2022-2025 standards are significant compared to total light-duty vehicle GHG emissions of 1,100 MMT in 2014.⁴³ See Proposed Determination Section IV and Table IV.6.

These standards are projected to reduce oil consumption by 50 billion gallons and to save U.S. consumers nearly \$92 billion in fuel cost over the lifetime of MY2022-2025 vehicles. See Proposed Determination Table IV.8 and IV.13, respectively. 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 vehicle's lifetime, with a net savings of \$1,650 after taking into consideration the upfront increased vehicle costs. See Proposed Determination Table IV.12, 3 percent discount rate case. 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 projected to far outweigh the costs, with net benefits totaling nearly \$100 billion over the lifetime of MY2022-2025 vehicles (3 percent discount rate). See Proposed Determination Section IV.A.6 and Table IV.13. As was the case when the EPA first established the MY2022-2025 standards in the 2012 rule, this analysis also supports a conclusion that the standards remain appropriate – and indeed will provide enormous benefits -- from the standpoint of impacts of the standards on emissions, oil conservation, energy security, and fuel savings.

(v) The impact of the standards on the automobile industry

EPA has assessed the impacts of the standards on the automobile industry. We have estimated the costs required to meet the MY2022-2025 standards at about \$33 billion (see

⁴³ Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014, EPA 430-R-16-002, April 15, 2016.

Proposed Determination Section IV.A and Table IV.13), with an average per-vehicle cost of about \$875 (see Proposed Determination Section IV.A and Tables IV.4 and IV.5). These costs are less than those originally projected when the 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). The Administrator found those (higher) projected costs to be reasonable in the 2012 rule, and finds the lower projected costs shown in our current analysis continues to support the appropriateness of the standards.

In addition to costs, the EPA has assessed impacts on the auto industry in terms of potential impacts on vehicle sales. See Proposed Determination Section III and Appendix B and TSD Chapter 4. As part of these assessments, the EPA has evaluated a range of issues affecting consumers' purchases of vehicles, which also addresses a portion of the factor, "the cost on the producers or purchasers of new motor vehicles or new motor vehicle engines" (emphasis added, 40 CFR 86.1818-12(h)(ii)). 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, with annual increases for seven straight years, through 2016, for the first time in 100 years, and record sales in 2016. These sales increases are likely due not to the standards, but rather to economic recovery from the 2008-2009 recession. Nevertheless, at the least, we find no evidence that the standards 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. See Proposed Determination Appendix B.1.4 and B.1.5.2. Similarly, we have not identified significant effects on vehicle affordability to date. See Proposed Determination Appendix B.1.6. 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 vehicle model choices for consumers at any particular price point, including the lowest price vehicle segment. *Id.* at Appendix B.1.6.1. 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, the EPA expects that any effects of the standards on the vehicle market will be small relative to market responses to broader macroeconomic conditions.

The main argument in the public comments on both the Draft TAR and the Proposed Determination that the standards will have an adverse impact on the industry is that the standards, although achievable, will require extensive electrification of the fleet to do so, and this will result in more expensive vehicles -- and an emerging technology -- which consumers will be reluctant to purchase. Our analysis, however, indicates that there are multiple compliance pathways which would need only minimal (less than 3 percent) of strong hybrids and electric vehicles, and that the great bulk of technologies used would be based on improvements to gasoline internal combustion engines. This is true not only in the agency's primary analysis, but also in a series of sensitivity analyses (assuming, among other things, significantly less use of the Atkinson engine technology, and a wide range of fuel prices). See Table ES-1 and the Proposed Determination Section IV.A.3 and Appendix C.1. This analysis is also consistent with findings of the 2015 NAS study (as well as each agency's findings in the 2012 FRM).⁴⁴ Consequently, the EPA does believe that the evidence supports the claim of the comments on this point.

⁴⁴ "Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles," National Research Council of the National Academies, June 2015.

The EPA also carefully considered the issue of whether there has been consumer acceptance of the new fuel efficiency technologies. As noted, industry sales are at a record high, with sales increasing for seven consecutive years for the first time since the 1920's. These sales trends provide no evidence of consumer reluctance to purchase the new technologies. Moreover, professional auto reviews found generally positive associations with the existence of the technologies. See Section B.1.5.1.2 of the Appendix to the Proposed Determination. The evidence to date thus supports consumer acceptance of the new technologies.

Another potential impact on the automobile industry that the EPA has assessed is the potential for impacts on employment. EPA's assessment projects job growth in the automotive manufacturing sector and automotive parts manufacturing sector due specifically to the need to increase expenditures for the 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 of the standards 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. We further note that, under conditions of full employment, any changes in employment levels in the regulated sector due to the standards are mostly expected to be offset by changes in employment in other sectors. See the Proposed Determination Appendix B.2. The Administrator finds 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 will be unable to be distinguished from other factors affecting employment, especially macroeconomic conditions and their effect on vehicle sales.

The Administrator thus finds, based on the current record, that the standards will impose reasonable per vehicle costs (and less than those projected in the 2012 FRM), that there is no evidence of the standards having an adverse impact on vehicle sales or on other vehicle attributes, or on employment in the automotive industry sector. Given these assessments of potential impacts on costs to the auto industry and average per-vehicle costs, consumers' purchases of vehicles, and employment, the Administrator finds that the potential impacts on the automobile industry support a conclusion that the MY2022-2205 standards remain appropriate and should not be changed.

(vi) The impacts of the standards on automobile safety

The EPA has assessed the potential impacts of the standards on automobile safety. In the Proposed Determination, consistent with the Draft TAR's safety assessment, the EPA 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. The EPA used this updated analysis⁴⁵ in the Proposed Determination to calculate the estimated safety impacts of the modeled mass reductions over the lifetimes of new vehicles in response to MY2022-2025 standards. See the Proposed

⁴⁵ 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.

Determination Section III.C.1 and Appendix B.3.1. EPA's analysis finds 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. The 2015 NAS study further found that the footprint-based standards are likely to have little effect on vehicle and overall highway safety.⁴⁶ Therefore, the Administrator finds that the existing MY2022-2025 standards will have no adverse impact on automobile safety. There is no evidence in the public comments that suggests a different conclusion.

(vii) The impact of the greenhouse gas emission standards on the corporate average fuel economy standards and a national harmonized program

The EPA has assessed the impacts of the standards on the CAFE standards and a national harmonized program. EPA notes that NHTSA has established augural standards for MY2022-2025 and must by statute undertake a *de novo* notice and 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.⁴⁷ That statute requires the Secretary of Transportation to consult with the EPA Administrator in establishing fuel economy standards.⁴⁸ 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."⁴⁹ 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. The EPA believes that by providing information on our evaluation of the current record and our determination that the existing GHG standards for MY2022-2025 are appropriate, 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.

The EPA recognizes that in 2012, when we discussed the mid-term evaluation, we expressed an intent that if EPA's determination was that the standards should not change, the EPA would issue its final determination concurrently with NHTSA's final rule adopting fuel economy standards for MY2022-2025. See 77 FR at 62633. Our intent was to align the agencies' proceedings for MYs 2022-2025 and to maintain a joint national program. *Id.* The EPA remains committed to a joint national program that aligns, as much as possible, the requirements of EPA, NHTSA, and CARB. The Administrator concludes, however, that providing her determination that the GHG standards remain appropriate now, rather than waiting until after NHTSA has proposed standards, allows NHTSA to fully account for the GHG standards and is more likely to align the agencies' determinations. Thus, the Administrator finds that her determination takes

⁴⁶ "Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles," National Research Council of the National Academies, June 2015, Finding 10.2.

⁴⁷ 42 U.S.C. 32902(a).

⁴⁸ 42 U.S.C. 32902(b)(1).

⁴⁹ 42 U.S.C. 32902(f).

account of the relationship between GHG standards and fuel economy standards and supports the goal of a national harmonized program.⁵⁰

In an action separate from this Final Determination, the EPA will be responding to a petition received from the auto industry trade associations, the Alliance of Automobile Manufacturers and Global Automakers, regarding several provisions that they request be harmonized between the EPA GHG standards and the NHTSA CAFE standards.⁵¹ On December 21, 2016, NHTSA signed a Federal Register notice signaling its plan to consider the NHTSA-specific requests from the auto industry petition. The EPA likewise intends, in the near future, to continue working together with NHTSA, the Petitioners and other stakeholders, as we carefully consider the requests made in the June 2016 petition, and possible ways to further harmonize the national program.

(viii) The impact of the standards on other relevant factors

In addition to the above factors, the Administrator has also considered the factor of regulatory certainty -- which relates closely to the issue of lead time discussed above. Regulatory certainty gives the automakers the time they need to conduct long-term planning and engineering to meet future standards. Indeed, the 2012 standards covered a long period of time – 13 years—in order to provide the industry with a lengthy period of stability and certainty. Thus, the Midterm Evaluation called for rule changes only if the Administrator found the existing standards to be no longer feasible and appropriate. Clearly, as discussed above, the automakers’ response to technology development and deployment in the face of the regulatory certainty provided by the MY2012-2021 standards, which are not subject to the midterm evaluation, has exceeded EPA’s projections set out in the original 2012 rule. Having the same certainty on the level of the MY2022-2025 standards can now enable manufacturers to continue unimpeded their existing long-term product planning and technology development efforts, which, in turn, could lead to even further, and perhaps sooner, breakthroughs in technology. These efforts could contribute to the continued success of the industry and the GHG standards program, which in turn would benefit consumers through fuel savings and the public through reduced emissions. Initiating a rulemaking now to change the standards would disrupt the industry's planning for future product lines and investments. Thus, the Administrator finds that regulatory certainty is an important consideration in assessing the appropriateness of the standards.

⁵⁰ The MTE rules themselves do not require concurrent timing with any aspect of NHTSA’s rulemaking. Moreover, there is uncertainty as to whether the NHTSA rulemaking would be complete by the date on which EPA is mandated to make a final determination, so that the expressed hope (in the 2012 preamble) of concurrent proceedings may be overtaken by events in any case.

⁵¹ “Petition for Direct Final Rule with Regard to Various Aspects of the Corporate Average Fuel Economy Program and the Greenhouse Gas Program,” submitted by the Alliance of Automobile Manufacturers and the Association of Global Automakers to EPA and NHTSA, June 20, 2016.

III. Final Determination

Having considered available information on each of the above factors required by the regulations, under 40 CFR 86.1818-12(h)(1), the Administrator is determining that the GHG standards currently in place for MYs 2022-2025 are appropriate under section 202(a)(1) and (2) of the Clean Air Act. The Administrator has fully considered public comments submitted on the Proposed Determination, and there has been no information provided through the comments that compels or persuades the Administrator to alter her Proposed Determination. The consequence of this final determination is a continuation of the current regulatory status quo. The regulations themselves are unaltered as a result of this 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 MY2022-2025 standards at reasonable cost that will achieve the significant GHG emissions reduction goals of the program, while delivering significant reductions in oil consumption and associated fuel savings for consumers, significant benefits to public health and welfare, and without having material adverse impact on the industry, safety, or consumers. The Administrator recognizes that not all of the technologies available today have been implemented in a widespread manner, but she 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. The industry's vibrancy, initiative, and ingenuity is to be commended. The Administrator concludes that the MY2022-2025 standards could be largely met simply by implementation of these technologies, but we recognize that we are at the mid-point of these standards phasing-in 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 MY2022-2025 vehicles. In the Draft TAR and Proposed Determination, the EPA was not even able to consider all of the technologies being developed because of the rapid pace of development. As discussed in the Proposed Determination (see Section II and Appendix B), the EPA did not consider several technologies that we know are under active development and may potentially provide additional cost-effective technology pathway options for meeting the MY2025 standards; examples of such technologies include electric boosting, dynamic cylinder deactivation, and variable compression ratio. A significant difference between the industry analysis and that of the EPA is over the extent to which electric vehicle production will be needed to meet the standards. Many of industry's comments regarding cost, consumer acceptance, and other factors primarily stem from their view that significant EV penetration will be required. As discussed earlier, the Administrator has considered the report of the National Academy of Sciences and information and data from the auto industry, and she has determined based on the technical record before her that the industry's conclusions do not take into account the possibility of applying the full range of road load reduction and non-electrified powertrain technologies broadly across high volume models, and in the combinations, that the EPA assessed in the Proposed Determination and Draft TAR. In addition, the automotive industry has been

characterized throughout its history by continued innovation and adoption of ever-improving technologies to improve fuel economy and lower emissions while simultaneously providing a range of vehicles to customers with the features they desire (safety, driveability, etc.). Thus, in light of the pace of progress in reducing GHG emissions since the MY2022-2025 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 the record does not support a conclusion that the MY2022-2025 standards should be revised to make them less stringent.

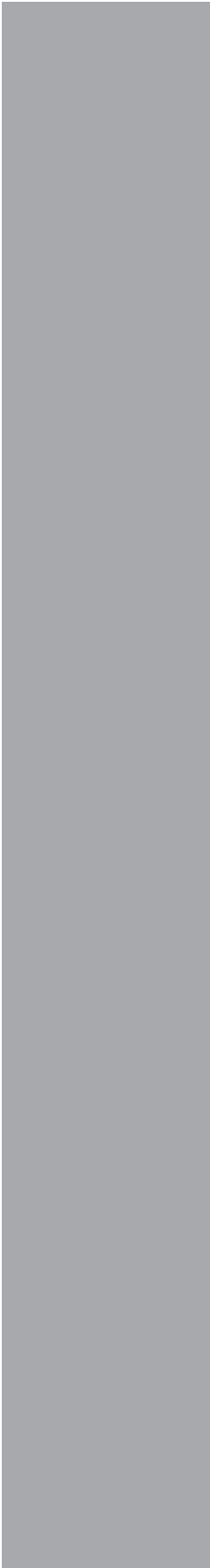
The Administrator has also considered whether, in light of these factors and the record (including public comments urging more stringent standards), it would be appropriate to make the standards more stringent. She recognizes that the current record, including the current state of technology and the pace of technology development and implementation, could support a decision to adopt more stringent standards for MY2022-2025 (or, put more precisely, could support a decision to initiate rulemaking proposing to amend the standards to increase their stringency). The EPA found in 2012 that the projected standards were feasible at reasonable cost, and the current record shows that the standards are feasible at even less cost and that there are more available technologies (particularly advanced gasoline technologies) than projected in 2012, and that the benefits outweigh the costs by nearly \$100 billion. These factors could be the basis for a proposal to amend the standards to increase the standards' stringency. Moreover, one could point to the overall need to significantly reduce greenhouse gases in the transportation sector even further, especially given expected growth in vehicle travel. The Administrator also recognizes, however, that regulatory certainty is an important and critical 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 MY2022-2025 standards and a harmonized national program. Thus, the Administrator has concluded that it is appropriate to provide the full measure of lead time for the MY2022-2025 standards, rather than initiating rulemaking to adopt new, more stringent standards with a shorter lead time and significant uncertainty in the interim which would impede on-going technological improvements and innovation.

Accordingly, the Administrator concludes that in light of all the prescribed factors, and considering the entire record, the current MY2022-2025 standards are appropriate.

Draft Technical Assessment Report:

Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025

Executive Summary



Draft Technical Assessment Report:

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Executive Summary

Office of Transportation and Air Quality
U.S. Environmental Protection Agency

National Highway Traffic Safety Administration
U.S. Department of Transportation

And

California Air Resources Board

Executive Summary

The Environmental Protection Agency (EPA) and the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) have established a coordinated program for Federal standards for greenhouse gas (GHG) emissions and corporate average fuel economy (CAFE) for light-duty vehicles.¹ This program was developed in cooperation and alignment with the California Air Resources Board (CARB) to ensure a single National Program. The National Program established standards that increase in stringency year-over-year from model year (MY) 2012 through MY2025 for EPA and through MY2021 for NHTSA. California adopted the first in the nation GHG standards for light-duty vehicles in 2004 for MY2009-2016, and in 2012 for MY2017-2025, followed by amendments that allow compliance with the Federal GHG standards as compliance with the California GHG standards, in furtherance of a single National Program. Under the National Program, consumers continue to have a full range of vehicle choices that meet their needs, and, through coordination with the California standards, automakers can build a single fleet of vehicles across the U.S. that satisfies all GHG/CAFE requirements. In the agencies' 2012 final rules establishing the MY2017-2025 standards for EPA and 2017-2021 final and 2022-2025 augural standards for NHTSA, the National Program standards were projected by MY2025 to double fuel economy and cut GHG emissions in half, save 6 billion metric tons of carbon dioxide (CO₂) pollution and 12 billion barrels of oil over the lifetime of MY2012-2025 vehicles, and deliver significant savings for consumers at the gas pump.

The rulemaking establishing the National Program for MY 2017-2025 light-duty vehicles included a regulatory requirement for EPA to conduct a Midterm Evaluation (MTE) of the GHG standards established for MYs 2022-2025.ⁱ The 2012 final rule preamble also states that “[t]he mid-term evaluation reflects the rules’ long time frame, and, for NHTSA, the agency’s statutory obligation to conduct a *de novo* rulemaking in order to establish final standards for MYs 2022-2025.” NHTSA will consider information gathered as part of the MTE record, including information submitted through public comments, in the comprehensive *de novo* rulemaking it must undertake to set CAFE standards for MYs 2022-2025.ⁱⁱ Through the MTE, EPA must determine no later than April 1, 2018 whether the MY2022-2025 GHG standards, established in 2012, are still appropriate under section 202 (a) of the Clean Air Act, in light of the record then before the Administrator, given the latest available data and information.ⁱⁱⁱ EPA’s decision could go one of three ways: the standards remain appropriate, the standards should be less stringent, or the standards should be more stringent. EPA and NHTSA also are closely coordinating with CARB in conducting the MTE to better ensure the continuation of the National Program. The MTE will be a collaborative, data-driven, and transparent process and must entail a holistic assessment of all the factors considered in the initial standards setting.^{iv}

This Draft Technical Assessment Report (TAR), issued jointly by EPA, NHTSA, and CARB for public comment, is the first formal step in the MTE process.^v In this Draft TAR, the agencies examine a wide range of technical issues relevant to GHG emissions and augural CAFE standards for MY2022-2025, and share with the public the initial technical analyses of those issues. This is a technical report, not a policy or decision document. The information in this

¹ The agencies finalized the first set of National Program standards covering model years (MYs) 2012-2016 in May 2010¹ and the second set of standards, covering MYs 2017-2025, in October 2012.

report, and in the comments we receive on it, will inform the agencies' subsequent determination and rulemaking actions. The agencies will fully consider public comments on this Draft TAR as they continue to update and refine the analyses for further steps in the MTE process.

In this Draft TAR, EPA provides its initial technical assessment of the technologies available to meet the MY2022-2025 GHG standards and one reasonable compliance pathway, and NHTSA provides its initial assessment of technologies available to meet the avarage MY2022-2025 CAFE standards and a different reasonable compliance pathway. Given that there are multiple possible ways that new technologies can be added to the fleet, examining two compliance pathways provides valuable additional information about how compliance may occur. NHTSA and EPA also performed multiple sensitivity analyses which show additional possible compliance pathways. The agencies' independent analyses complement one another and reach similar 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;
- Advanced gasoline vehicle technologies will continue to be the predominant technologies, with modest levels of strong hybridization and very low levels of full electrification (plug-in vehicles) needed to meet the standards;
- The car/truck mix reflects updated consumer trends that are informed by a range of factors including economic growth, gasoline prices, and other macro-economic trends. However, as the standards were designed to yield improvements across the light duty vehicle fleet, irrespective of consumer choice, updated trends are fully accommodated by the footprint-based standards.

Additionally, while the Draft TAR analysis focuses on the MY2022-2025 standards, the agencies note that the auto industry, on average, is over-complying with the first several years of the National Program. This has occurred concurrently with a period during which the automotive industry successfully rebounded after a period of economic distress. The industry has now seen six consecutive years of increases and a new all-time sales record in 2015, reflecting positive consumer response to vehicles complying with the standards.

A summary of each chapter of the Draft TAR follows.

Chapter 1: Introduction. This chapter provides a broad discussion of the National Program, explains further the MTE process and timeline, and provides additional background on NHTSA's CAFE program, EPA's GHG program, and California's GHG program. This chapter also includes an update on what the latest science tells us about climate change impacts, and the U.S.'s and California's commitments on actions to address climate change. Chapter 1 also provides a discussion of petroleum consumption and energy security.

Chapter 2: Overview of Agencies' Approach to Draft TAR Analysis. The agencies are committed to conducting the MTE through a collaborative, data-driven, and transparent process. In gathering data and information for this Draft TAR, the agencies drew from a wide range of sources to evaluate how the automotive industry has responded into the early years of the National Program, how technology has developed, and how other factors affecting the light-duty vehicle fleet have changed since the final rule in 2012. The agencies found that there is a wealth of information since the 2012 final rule upon which to inform this Draft TAR, and this

information is detailed throughout the document. Chapter 2 describes these sources, including extensive state-of-the-art research projects by experts at the EPA National Vehicle and Fuel Emissions Laboratory, as well as consultants to the agencies, data and input from stakeholders, and information from technical conferences, published literature, and studies published by various organizations. A significant study informing the agencies' analyses is the National Academy of Sciences 2015 report^{vi} on fuel economy technologies, which the agencies highlight in Chapter 2, and discuss throughout this document.

The analyses presented in this Draft TAR reflect the new data and information gathered by the agencies thus far, and the agencies will continue to gather and evaluate more up-to-date information, including public comments on this Draft TAR, to inform our future analyses. The agencies have conducted extensive outreach with a wide range of stakeholders – including auto manufacturers, automotive suppliers, non-governmental organizations (NGOs), consumer groups, labor unions, automobile dealers, state and local governments, and others.

Chapter 3: Recent Trends in the Light-Duty Vehicle Fleet since the 2012 Final Rule.

This chapter summarizes 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 agencies provide the latest available projections for vehicle sales, gasoline prices, and fleet mix out to 2025, and compare those to projections made in the 2012 final rule. This chapter also highlights compliance to date with the GHG and CAFE standards, where, for the first three years of the program (MY2012-2014), auto manufacturers have over-complied with the program.

Chapter 4: Baseline and Reference Vehicle Fleets. This chapter describes the agencies' methodologies for developing a baseline fleet of vehicles and future fleet projections out to MY2025. The GHG analysis uses a baseline fleet based on the MY2014 fleet, the latest year available for which there are final GHG compliance data. The CAFE analysis uses a MY2015 baseline fleet based on MY2015 data and sales projections provided by manufacturers in the latter half of MY2015, when production was well underway. These data sets complement one another and each yield important perspective, with the MY2014 data having the benefit of validation through compliance data, and the MY2015 data providing more recent perspective. The GHG and CAFE analysis fleets utilized similar, but separate, purchased projections from IHS-Polk for the future vehicle fleet mix out to 2025, thereby representing some of the uncertainty inherent in all reference case projections. Both analyses used data from the Energy Information Administration's Annual Energy Outlook 2015 (AEO 2015) as the basis for total vehicle sales projections to 2025, as well as for the car and truck volume mix. Although the agencies have relied on different data sources in development of the baseline fleets, we believe this combination of approaches strengthens our results by showing robust results across a range of reference case projections.

Chapter 5: Technology Costs, Effectiveness, and Lead-Time Assessment. This chapter is an in-depth assessment of the state of vehicle technologies to improve fuel economy and reduce GHG emissions, as well as the agencies' assessment of expected future technology developments through MY2025. The technologies evaluated include all those considered for the 2012 final

rule, as well as new technologies that have emerged since then. Every technology has been reconsidered with respect to its cost, effectiveness, application, and lead-time considerations, with emphasis on assessing the latest introductions of technologies to determine if and how they have changed since the agencies' assessment in the 2012 final rule. These efforts reflect the significant rate of progress made in automotive technologies over the past four years since the MY2017-2025 standards were established. Technologies considered in this Draft TAR include more efficient engines and transmissions, aerodynamics, light-weighting, improved accessories, low rolling resistance tires, improved air conditioning systems, and others. Beyond the technologies the agencies considered in the 2012 final rule, manufacturers are now employing several technologies, such as higher compression ratio, naturally aspirated gasoline engines, and greater penetration of continuously variable transmissions (CVTs); other new technologies are under active development and are expected to be in the fleet well before MY2025, such as 48-volt mild hybrid systems.

In Chapter 5, the agencies also provide details on the specific technology assumptions used respectively by EPA for the GHG assessment and by NHTSA for the CAFE assessment in this Draft TAR, including the specific assumptions that EPA and NHTSA each made for each technology's cost and effectiveness, and lead-time considerations. The agencies' estimates of technology effectiveness were informed by vehicle simulation modeling approaches; NHTSA utilized the Autonomie model developed by Argonne National Laboratories for the Department of Energy (DOE), and EPA used its Advanced Light-duty Powertrain and Hybrid Analysis (ALPHA) model. The agencies look forward to public comment in this and other areas to help advance collective forecasting of technology effectiveness in the out years of the program.

It is clear that the automotive industry is innovating and bringing new technology to market at a rapid pace and neither of the respective agency analyses reflects all of the latest and emerging technologies that may be available in the 2022-2025 time frame. For example, the agencies were not able for this Draft TAR to evaluate the potential for technologies such as electric turbo-charging, variable compression ratio, skip-fire cylinder deactivation, and P2-configuration mild-hybridization. These technologies may provide further cost-effective reductions in GHG emissions and fuel consumption. The agencies will continue to update their analyses throughout the MTE process as new information becomes available.

Chapter 6: Assessment of Consumer Acceptance of Technologies that Reduce Fuel Consumption and GHG Emissions. This chapter reviews issues surrounding consumer acceptance of the vehicle technologies expected to be used to meet the MY2022-2025 standards. Since the program has been in effect since MY2012, the agencies focus on the evidence to date related to consumer acceptance of vehicles subject to the National Program standards. This evidence includes an analysis of how professional auto reviewers assess fuel-saving technologies. For each technology, positive evaluations exceed negative evaluations, suggesting that it is possible to implement these technologies without significant hidden costs. To date, consumer response to vehicles subject to the standards is positive. Chapter 6 also discusses potential impacts of the standards on vehicle sales and affordability, which are closely interconnected with the effects of macroeconomic and other market forces. Based on the agencies' draft assessments, the reduced operating costs from fuel savings over time are expected to far exceed the increase in up-front vehicle costs, which should mitigate any potential adverse effects on vehicle sales and affordability.

Chapter 7: Employment Impacts. This chapter discusses the effects of employment in the automotive sector to date, and the projected effects of the MY 2022-2025 standards on employment. Employment in the automotive industry dropped sharply during the Great Recession, but has increased steadily since 2009. 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. The MY2025 standards are likely to have some effect on employment, due to both the effects of the standards on vehicle sales, and the need to produce new technologies to meet the standards. Nevertheless, the net effect of the standards on employment is likely to be small compared to macroeconomic and other factors affecting employment.

Chapter 8: Assessment of Vehicle Safety Effects. This chapter assesses the estimated overall crash safety impacts of the MY 2022-2025 standards. In this chapter, the agencies first review the relationships between mass, size, and fatality risk based on the statistical analysis of historical crash data, which includes the new analysis performed by using the most recent crash data. The updated NHTSA analysis develops five parameters for use in both the NHTSA and EPA assessments to calculate the estimated safety impacts of the modeled mass reductions over the lifetimes of new vehicles in response to MY 2022-2025 GHG standards and augural CAFE standards. Second, to examine the impact of future lightweight vehicle designs on safety, the agencies also reviewed a fleet crash simulation study that examined frontal crashes using existing and future lightweight passenger car and cross-over utility vehicle designs. The study found a relationship between vehicle mass reduction and safety that is directionally consistent with the overall risk for passenger cars from the NHTSA 2016 statistical analysis of historical crash data. Next, the agencies investigate the amount of mass reduction that is affordable and feasible while maintaining overall fleet safety and as well as functionality such as durability, drivability, noise, vibration and handling (NVH), and acceleration performance. Based on those approaches, the agencies further discuss why the real world safety effects might be less than or greater than calculated safety impacts, and what new challenges these lighter vehicles might bring to vehicle safety and potential countermeasures available to manage those challenges effectively.

Chapter 9: Assessment of Alternative Fuel Infrastructure. This chapter assesses the status of infrastructure for alternative fueled vehicles, with emphasis on two technologies the agencies believe will be important for achieving longer-term climate and energy goals – plug-in electric vehicles (PEVs) and fuel cell electric vehicles (FCEVs). The agencies also discuss infrastructure for ethanol (E85) flex-fueled vehicles and natural gas vehicles. The agencies' assessment is that, as we concluded in the 2012 rule, high penetration levels of alternative fueled vehicles will not be needed to meet the MY2025 standards, with the exception of a very small percentage of PEVs, and that infrastructure is progressing sufficiently to support vehicles from those manufacturers choosing to produce alternative fueled vehicles to meet the MY2022-2025 standards. The majority of PEV charging occurs at home, and national PEV infrastructure in public and work locations is progressing appropriately. Hydrogen infrastructure developments are addressing many of the initial challenges of simultaneously launching new vehicle and fueling infrastructure markets, and current efforts in California and the northeast states will facilitate further vehicle and infrastructure rollout at the national level.

Chapter 10: Economic and Other Key Inputs Used in the Agencies' Analyses. This chapter describes many of the economic and other inputs used in the agencies' analyses. This

chapter discusses the methodologies used to assess inputs such as the real-world fuel economy/GHG emissions gap, vehicle miles traveled (VMT), vehicle survival rates, the VMT rebound effect, energy security, the social cost of carbon and other GHGs, health benefits, consumer cost of vehicle ownership, and others.

Chapter 11: Credits, Incentives and Flexibilities. The National Program was designed with a wide range of optional compliance flexibilities to allow manufacturers to maintain consumer choice, spur technology development, and reduce compliance costs, while achieving significant GHG and oil reductions. Chapter 11 provides an informational overview of all of these compliance flexibilities, with particular emphasis on those flexibility options likely to be most important in the MY2022-2025 timeframe.

Chapter 12: Analysis of the MY2022-2025 GHG Standards; and Chapter 13: Analysis of Augural CAFE Standards. Chapters 12 and 13 provide results, respectively, of EPA's initial technical assessment of the technologies available to meet the MY2022-2025 GHG standards (i.e., the footprint-based standard curves) and their costs, and NHTSA's initial technical assessment of technologies capable of meeting CAFE standards corresponding to the augural standards for MY2022-2025, and these technologies' costs. CARB has not conducted an independent analysis, but has participated in both EPA's and NHTSA's analyses. Although all three agencies have been working collaboratively in an array of areas throughout the development of this Draft TAR, the EPA GHG and NHTSA CAFE assessments were done largely independently. These independent analyses were done in part to recognize differences in the agencies' statutory authorities and to reflect independent choices regarding some of the modeling inputs used at this initial stage of our evaluation. The agencies believe that independent and parallel analyses can provide complementary results. The agencies further believe that, for this Draft TAR which is the first step of the Midterm Evaluation process, it is both reasonable and advantageous to make use of different data sources and modeling tools, and to show multiple pathways for potential compliance with the MY 2022-2025 GHG standards and augural CAFE standards.

As noted above, although CARB did not perform its own modeling assessment of the costs and technologies to meet the 2022-2025 GHG and CAFE requirements, it was integrally involved in analyzing the underlying technology cost and effectiveness inputs to the EPA and NHTSA modeling. CARB believes that the analyses presented in this Draft TAR appropriately present a range of technologies that could be used to meet the requirements. However, as discussed above, there are, and will continue to be, emerging technologies that may well be available in the 2022-2025 timeframe and could perform appreciably better or be lower cost than the technologies modeled in this Draft TAR. Such technologies are exemplified by recent advancements already seen in the marketplace yet not anticipated by the agencies' rule four years ago (e.g., expanded use of higher compression ratio, naturally aspirated gasoline engines). Vehicle manufacturers have historically outpaced agency expectations and CARB believes it is likely that industry will continue to do so.

In this Draft TAR, NHTSA does not present alternatives to the augural standards because, as the first stage of the Midterm Evaluation process, the TAR is principally an exploration of technical issues -- including assumptions about the effectiveness and cost of specific technologies, as well as other inputs, methodologies and approaches for accounting for these issues. The agencies seek comment from stakeholders to further inform the analyses, in advance

of the NHTSA rulemaking and the EPA Proposed Determination. For the purposes of clearly reflecting the impacts of updated technology assumptions relative to a familiar point of comparison, both agencies have run their respective models using the stringency levels included in NHTSA's augural standards, and EPA's existing GHG standards through MY2025. However, the technology assumptions and other analyses presented in this Draft TAR, which will be informed by public comment, will support the development of a full range of stringency alternatives in the subsequent CAFE Notice of Proposed Rulemaking.

In this Draft TAR, the EPA GHG and NHTSA CAFE assessments both show that the MY2022-2025 standards can be achieved largely through the use of advanced gasoline vehicle technologies with modest penetrations of lower cost electrification (like 48 volt mild hybrids which include stop/start) and low penetrations of higher cost electrification (like strong hybrids, plug-in hybrid electric vehicles, and all electric vehicles). Given the rapid pace of automotive industry innovation, the agencies may consider effectiveness and cost of additional technologies as new information, including comments on this Draft TAR, becomes available for further steps of the Midterm Evaluation.

Based on various assumptions including the Annual Energy Outlook 2015 (AEO 2015) 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 CO₂ target of 175 grams/mile (g/mi) in MY2025, and the augural CAFE standards are projected to result in average CAFE requirements increasing from 38.3 mpg in MY2021 to 46.3 mpg in MY2025. The projected fleet average CO₂ target represents a GHG emissions level equivalent to 50.8 mpg (if all reductions were achieved exclusively through fuel economy improvements).²

Table ES-1 below compares two additional AEO 2015 scenarios in addition to the AEO 2015 reference case: a low fuel price case and a high fuel price case. As shown, 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 estimated fleet wide CAFE requirements and GHG CO₂ targets and MPG-e levels projected for MY2025, from 169 g/mi (52.6 mpg-e) under the high fuel price case to 178 g/mi (49.9 mpg-e) under the low fuel price case. These estimated GHG target levels and CAFE requirements reflect changes in the latest projections about the MY2025 fleet mix compared to the projections in 2012 when the agencies first established the standards. Under the footprint-based standards, the program is designed to ensure significant GHG reductions/fuel economy improvements 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 the agencies' current analyses for this Draft TAR, we are applying the same footprint-based standards established in the 2012 final rule to the updated fleet projections for MY2025. It is important to keep in mind that the updated MY2025 fleet wide projections reflected in this Draft TAR are still just projections (as were the fleet projections in the 2012 rule) -- based on the latest available information, which may continue to change with future projections -- and that the actual GHG emissions/fuel economy level achieved in MY2025 won't be determined until the

² The projected MY 2025 target of 175 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 data that many automakers are earning air conditioner refrigerant GHG credits that reduce GHG emissions, but do not increase fuel economy. Accordingly, the projected MY 2025 target of 175 g/mi represents slightly less than a doubling of fuel economy relative to the standards that were in place in 2010.

manufacturers have completed their MY2025 production. The agencies will continue to assess the latest available projections as we continue the Midterm Evaluation process.

Table ES- 1 Projections for MY2025: Car/Truck Mix, CO₂ Target Levels, and MPG-equivalent¹

		AEO 2015 Fuel Price Case		
	2012 Final Rule	AEO Low	AEO Reference	AEO High
Car/truck mix	67/33%	48/52%	52/48%	62/38%
CAFE (mpg) ²	48.7	45.7	46.3	47.7
CO ₂ (g/mi)	163	178	175	169
MPG-e	54.5	50.0	50.8	52.6

Notes:

¹ The CAFE, CO₂ and MPG-e values shown here are 2-cycle compliance values. Projected real-world values are detailed in Chapter 10.1; for example, for the AEO reference fuel price case, real-world EPA CO₂ emissions performance would be 220 g/mi and real-world fuel economy would be 36 mpg.

² Average of estimated CAFE requirements.

³ 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.

The agencies' updated assessments provide projections for the MY2022-2025 standards for several key metrics, including modeled "low-cost pathway" technology penetrations, per-vehicle average costs (cars, trucks, and fleet, by manufacturer and total industry-wide), industry-wide average costs, GHG and oil reductions, consumer payback, consumer fuel savings, and benefits analysis.

Based on the extensive updated assessments provided in this Draft TAR, the projections for the average per-vehicle costs of meeting the MY2025 standards (incremental to the costs already incurred to meet the MY2021 standard) are, for EPA's analysis of the GHG program, \$894 - \$1,017, and, for NHTSA's analysis of the CAFE program, \$1,245 in the primary analysis using Retail Price Equivalent (RPE), and \$1,128 in a sensitivity case analysis using Indirect Cost Multipliers (ICM). In the 2012 final rule, the estimated costs for meeting the MY2022-2025 GHG standards (incremental to the costs for meeting the MY2021 standard in MY2021) was \$1,070.^{3,vii}

³ This cost estimate from the 2012 final rule was based on the use of Indirect Cost Multipliers (ICMs) in 2010\$.

Table ES- 2 Per-Vehicle Average Costs to Meet MY2025 Standards: Draft TAR Analysis
Costs Shown are Incremental to the Costs to Meet the MY2021 Standards

	GHG ¹ in MY2025		CAFE in MY 2028	
	Primary Analysis	RPE Sensitivity Case ³	Primary Analysis ²	ICM Sensitivity Case ³
Car	\$707	\$789	\$1,207	\$1,156
Truck	\$1,099	\$1,267	\$1,289	\$1,096
Combined	\$894	\$1,017	\$1,245	\$1,128

Notes:

¹The values reported for the GHG analysis to account for indirect costs reflect the use of Indirect Cost Multipliers for the primary analysis, and Retail Price Equivalent for the sensitivity case.

² The values reported for CAFE primary analysis reflect the use of RPE and include civil penalties estimated to be incurred by some OEMs as provided by EPCA/EISA. Estimated technology costs (without civil penalties) average \$1,111, \$1,246, and \$1,174, respectively for MY2028 passenger cars, light trucks, and the overall light-duty fleet.

³ Note that Chapter 12 (GHG) and Chapter 13 (CAFE) include a wide range of additional sensitivity cases.

In Table ES-2, NHTSA's estimates are provided for MY2028 because NHTSA's analysis, which is conducted on a year-by-year basis, indicates that manufacturers could make use of EPCA/EISA's provisions allowing credits to be earned and carried forward to be applied toward ensuing model years. Therefore, NHTSA's analysis indicates that a "stabilized" response to the augural standards might not be achieved until approximately 2028 (see Chapter 13 for additional detail). EPA estimates are provided for MY2025 because EPA's analysis projects that each manufacturer would comply in MY2025 with that year's standards (see Chapter 12 for additional details).

Table ES-3 shows fleet-wide penetration rates for a subset of the technologies the agencies' project could be utilized to comply with the MY2025 standards. While all three agencies have been working collaboratively on an array of issues throughout this initial phase of the Midterm Evaluation, much of the EPA GHG and NHTSA CAFE assessments were done largely independently, as reflected in the different technology pathways shown in Table ES-3 (see Chapter 2.3 for additional detail). The agencies' analyses each project that the MY2022-2025 standards can be met largely through improvements in gasoline vehicle technologies, such as improvements in engines, transmissions, light-weighting, aerodynamics, and accessories. The analyses further indicate that only modest amounts of hybridization, and very little full electrification (plug-in hybrid electric vehicles (PHEV) or electric vehicles (EV)) technology will be needed to meet the standards. This initial assessment of potential technology paths is similar to the agencies' projections made in the 2012 final rule, and is consistent with the findings of the National Academy of Sciences report from June 2015 (discussed in Chapter 2).

Table ES- 3 Selected Technology Penetrations to Meet MY2025 Standards¹

	GHG	CAFE
Turbocharged and downsized gasoline engines	33%	54%
Higher compression ratio, naturally aspirated gasoline engines	44%	<1%
8 speed and other advanced transmissions ²	90%	70%
Mass reduction	7%	6%
Stop-start	20%	38%
Mild Hybrid	18%	14%
Full Hybrid	<3%	14%
Plug-in hybrid electric vehicle ³	<2%	<1%
Electric vehicle ³	<3%	<2%

Notes:

¹ Percentages shown are absolute rather than incremental. These values reflect both EPA and NHTSA's primary analyses; both agencies present additional sensitivity analyses in Chapter 12 (GHG) and Chapter 13 (CAFE). For EPA this includes a pathway where higher compression ratio naturally aspirated gasoline engines are held at a 10% penetration, and the major changes are turbocharged and downsized gasoline engines increase to 47% and mild hybrids increase to 38% (See Chapter 12.1.2)

² Including continuously variable transmissions (CVT)

³ In EPA's modeling, the California Zero Emission Vehicles (ZEV) program is considered in the reference case fleet; therefore, 3.5% of the fleet is projected to be full EV or PHEV in the 2022-2025 timeframe due to the ZEV program and the adoption of that program by nine additional states.

Although some of the differences in costs are expected as EPA and NHTSA conducted two independent analyses, the consideration of CARB's program also led to one important difference. As noted in the footnote for Table ES-3, EPA's analysis included consideration for compliance with other related state regulations including CARB's ZEV regulation that has also been adopted by nine other states under Section 177 of the Federal Clean Air Act. CARB's ZEV program requires a portion of new light-duty vehicle sales to be ZEVs and collectively, CA and these states represent nearly 30 percent of nationwide sales of light-duty vehicles. CARB worked with EPA to include ZEVs reflecting compliance with California's ZEV program within the reference fleet used by EPA. NHTSA's analysis did not. This accounts for at least part of the cost differences in the two agencies' analyses as well as for some of the difference in technology penetration rates for full hybrids.

EPA's analysis indicates that, compared to the MY2021 standards, the MY2025 standards will result in a net lifetime consumer savings of \$1,460 - \$1,620 and a payback of about 5 to 5 ½ years.⁴ NHTSA's primary analysis indicates that net lifetime consumer savings could average \$680 per vehicle, such that increased vehicle purchase costs are paid back within about 6 ½ years, and \$800 with payback within about 6 years in a sensitivity case analysis using ICMs.

⁴ Based on the AEO 2015 reference case gasoline price projections, 3 percent discount rate, and ICMs.

Table ES- 4 Payback Period and Lifetime Net Consumer Savings for an Average Vehicle Compared to the MY2021 Standards

	GHG MY2025 Vehicle		CAFE MY2028 Vehicle	
	Primary Analysis	RPE Sensitivity Case	Primary Analysis	ICM Sensitivity Case
Payback period (years)	5	5 ½	6 ½	6
Net Lifetime Consumer Savings (\$, discounted at 3%)	\$1,620	\$1,460	\$680	\$800

* Note that Chapter 12 (GHG) and Chapter 13 (CAFE) include a wide range of additional sensitivity cases.

Over the lifetimes of MY2021-2025 vehicles, EPA estimates that under the GHG standards, GHG emissions would be reduced by about 540 million metric tons (MMT) and oil consumption would be reduced by 1.2 billion barrels. Over the lifetimes of MY2016-2028 vehicles, NHTSA estimates that under the augural MY2022-2025 CAFE standards, GHG emissions would be reduced by about 748 MMT and oil consumption would be reduced by about 1.6 billion barrels. NHTSA's estimates span a wider range of model years for two reasons, as discussed in Chapter 13: first, the NHTSA analysis projects that manufacturers may take some "early action" prior to MY2022; second, as discussed above, the response to the augural standards might not be "stabilized" until after MY2025. Differences in these values also result from differences in the agencies' estimates of annual mileage accumulation by light-duty vehicles.⁵

Table ES- 5 Cumulative GHG and Oil Reductions for Meeting the MY2022-2025 Standards

Lifetime Reductions	GHG (MYs 2021-2025 vehicles)	CAFE (MYs 2016-2028 vehicles)
CO ₂ e reduction (million metric tons, MMT)	540	748
Oil reduction (billion barrels)	1.2	1.6

For the EPA GHG analysis, total industry-wide costs of meeting the MY2022-2025 GHG standards are estimated at \$34 to \$38 billion. Societal monetized benefits of the MY2022-2025 standards (exclusive of fuel savings to consumers) range from \$40 to \$41 billion. Consumer pre-tax fuel savings are estimated to be \$89 billion over the lifetime of vehicles meeting the MY2022-2025 standards. Net benefits (inclusive of fuel savings) are estimated at \$90 to \$94 billion. These values are all at a 3 percent discount rate; values at a 7 percent discount rate are shown in Table ES-6 below.

⁵ The agencies' methods for assessing vehicle mileage accumulation are discussed in Chapter 10.3 for EPA, and Chapter 13 for NHTSA.

Table ES- 6 GHG Analysis of Lifetime Costs & Benefits to Meet the MY2022-2025 Standards (for Vehicles Produced in MY2021-2025)* (Billions of 2013\$)

	3 Percent Discount Rate		7 Percent Discount Rate	
	Primary Analysis	RPE Sensitivity Case	Primary Analysis	RPE Sensitivity Case
Vehicle Program	-\$34	-\$38	-\$24	-\$27
Maintenance	-\$2	-\$2	-\$1	-\$1
Fuel	\$89	\$89	\$49	\$49
Benefits*	\$41	\$40	\$30	\$30
Net Benefits	\$94	\$90	\$54	\$51

Note:

*These values reflect AEO 2015 reference fuel price case. The Primary Analysis reflects ICMs and the Sensitivity Case reflects RPEs. All values are discounted back to 2015; see Chapter 12.3 for details on discounting social cost of GHG and non-GHG benefits. Note that Chapter 12 also includes a number of additional sensitivity cases.

NHTSA's primary analysis shows that compared to the No Action alternative, the augural CAFE standards could entail additional costs totaling \$87 billion during MYs 2016-2028 (reasons for this span of MYs are discussed above), and a sensitivity case using ICM shows total costs of \$79 billion. The primary analysis shows benefits totaling \$175 billion, and the ICM sensitivity case shows \$178 billion. Consumer fuel savings are estimated to be \$67 billion to \$122 billion over the lifetime of vehicles meeting the MY2022-2025 standards. Thus, net benefits (inclusive of fuel savings) could total \$88 billion based on the primary analysis and \$99 billion for the ICM sensitivity case. These are estimates of the present value (in 2015) of costs and benefits, based on a 3 percent discount rate. NHTSA has also conducted analysis using a 7 percent discount rate, and a broader sensitivity analysis to examine the impact of other key analysis inputs, as discussed in Chapter 13. Below, Table ES-7 provides an overall summary of costs and benefits observed in NHTSA's analysis.

Table ES- 7 CAFE Analysis of Lifetime Costs & Benefits to Meet the MY2022-2025 Standards (for Vehicles Produced in MY2016-2028) (Billions of 2013\$)

	3 Percent Discount Rate		7 Percent Discount Rate
	Primary Analysis ²	ICM Sensitivity Case ³	Primary Analysis
Vehicle Program ^{1*}	-\$87	-\$79	-\$60
Benefits (Fuel)	\$120	\$122	\$67
Benefits (Other)	\$55	\$56	\$43
Net Benefits	\$88	\$99	\$50

Notes:

¹ Includes changes in maintenance costs (small relative to cost of additional technology).

² The Primary Analysis reflects RPE.

³ Note that Chapter 13 includes a wide range of additional sensitivity cases.

As noted above, because EPA and NHTSA developed independent assessments of technology cost, effectiveness, and reference case projections, the compliance pathways and associated costs that result are also different. Consideration of these two results provides greater confidence that compliance can be achieved through a number of different technology pathways.

References

ⁱ See 40 CFR 86.1818-12(h).

ⁱⁱ See 40 CFR 86.1818-12(h).

ⁱⁱⁱ See 40 CFR section 86.181-12(h).

^{iv} See 77 FR 62784 (Oct. 12, 2012).

^v See 40 CFR 86.1818-12(h)(2)(i).

^{vi} National Academy of Sciences, National Research Council to the National Academies, “Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles,” June 2015.

^{vii} Regulatory Impact Analysis: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards and Corporate Average Fuel Economy Standards, EPA-420-R-12-016, Table 5.1-8, page 5-8.