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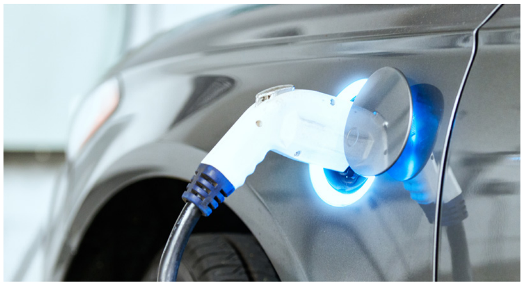
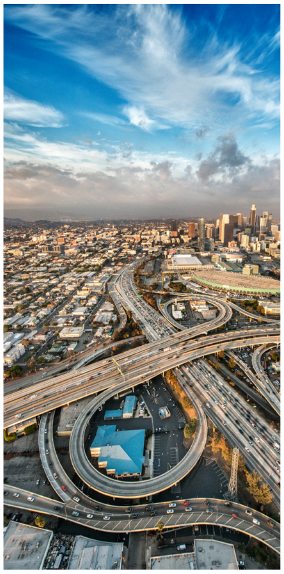


California's Advanced Clean Cars Midterm Review

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

Program	***Board Resolution Direction***
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 requirements[1] 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 configurations[4] 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.

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[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 8[5]) 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 CO_2 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 CO_2 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.

<u>1 milligram per mile particulate matter emission standard</u>

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.

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[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.

<u>ZEV regulation requirement for Section 177 ZEV states</u>

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 Plan[7] (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?Dockey=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*

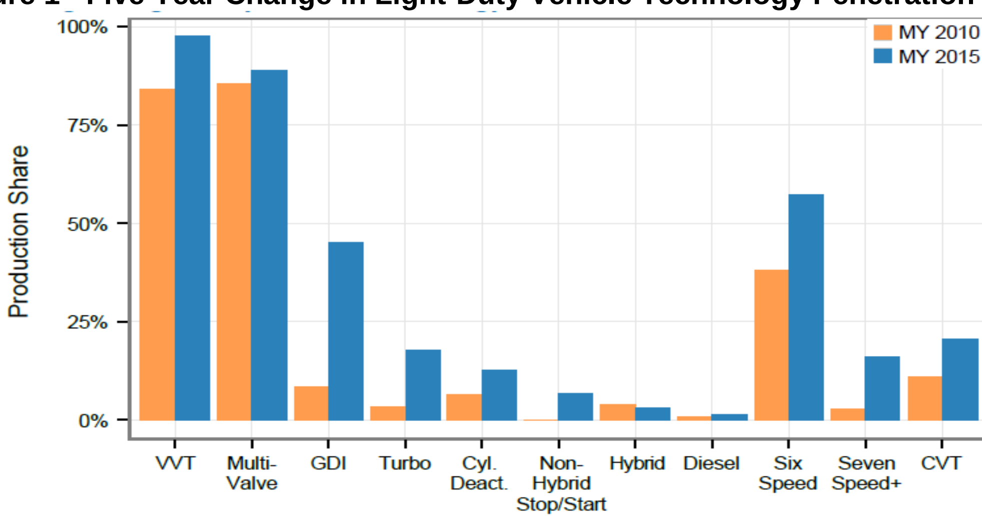
Analysis of trends in the California's light-duty vehicle (LDV) fleet to assess the car/truck split and vehicle footprint effects since the adoption of the ACC regulations.

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) CO_2 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_2e/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 CO_2 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 it's "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/eerm.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 CO_2 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

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[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. Younkins, 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_matthew_younkins.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

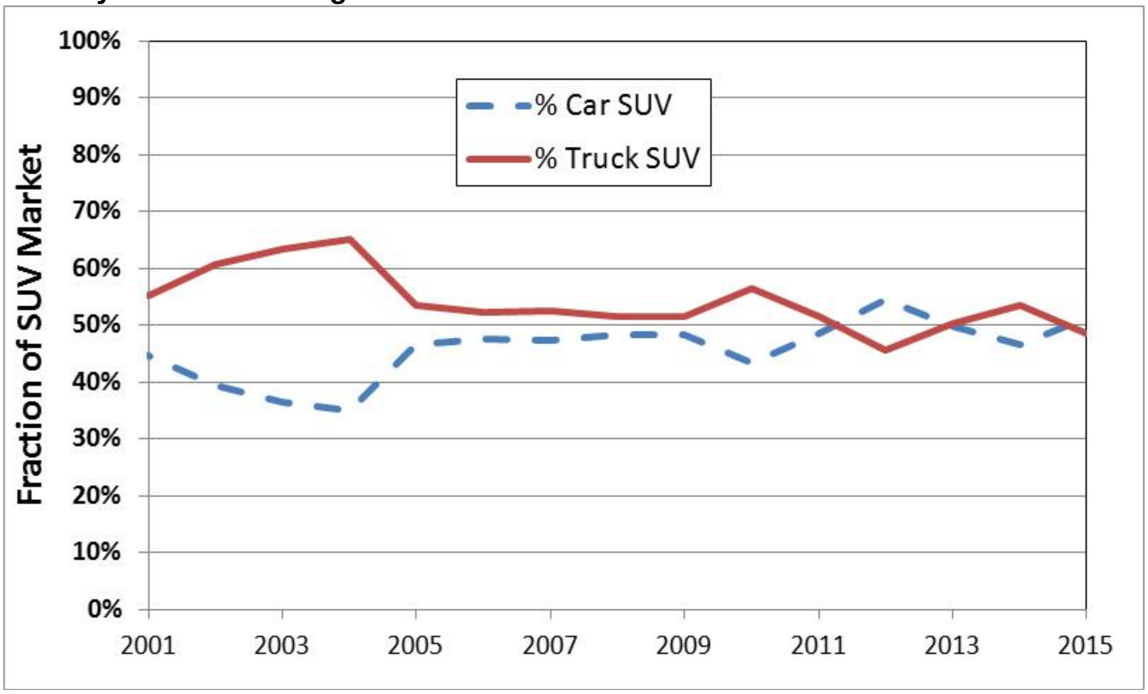
Model Year	Car Footprint (square feet)	Truck Footprint (square feet)
2008	45.3	54.0
2009	45.1	54.0
2010	45.4	53.8
2011	46.0	54.4
2012	45.7	54.5
2013	45.9	54.7
2014	46.1	55.0
2015 (preliminary)	46.1	55.5

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

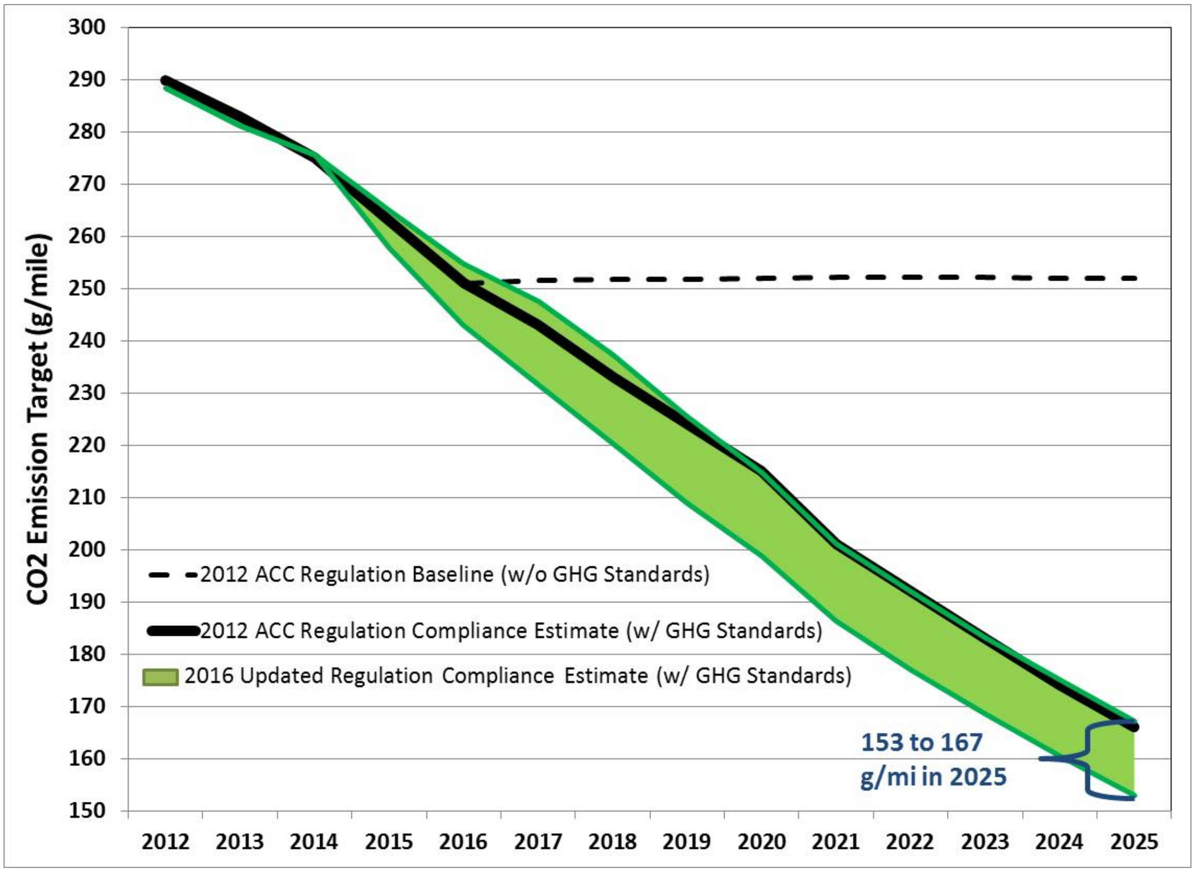
analysis by applying the same growth trends in the nationwide 2016 AEO to the California-specific fleet.[26] The reader can refer to Appendix M for further details.

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) CO_2 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 CO_2 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 CO_2).

[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 (gCO_2/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 PM2.5 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 CO_2, 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 CO_2-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.

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[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%20_particulate_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

	FTP		US06	
Vehicle	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/leviiighg2012/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.

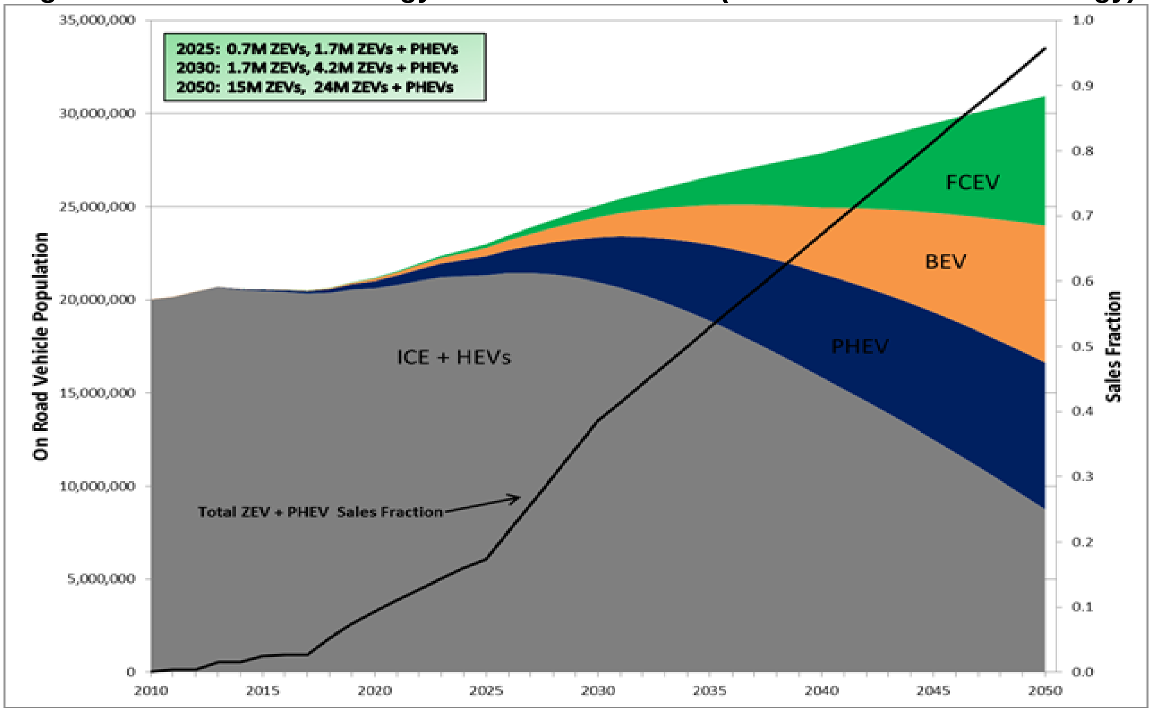
ZEV Review

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

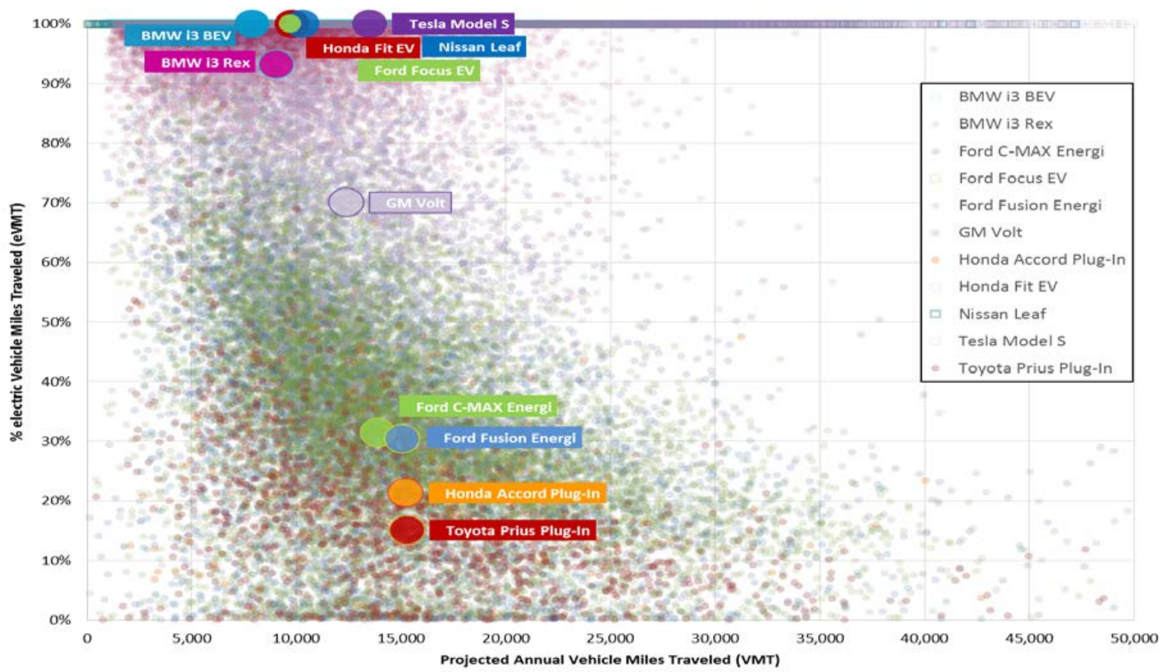
[34] Each manufacturer provided data set is fully described in Appendix G, Section II.

[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]

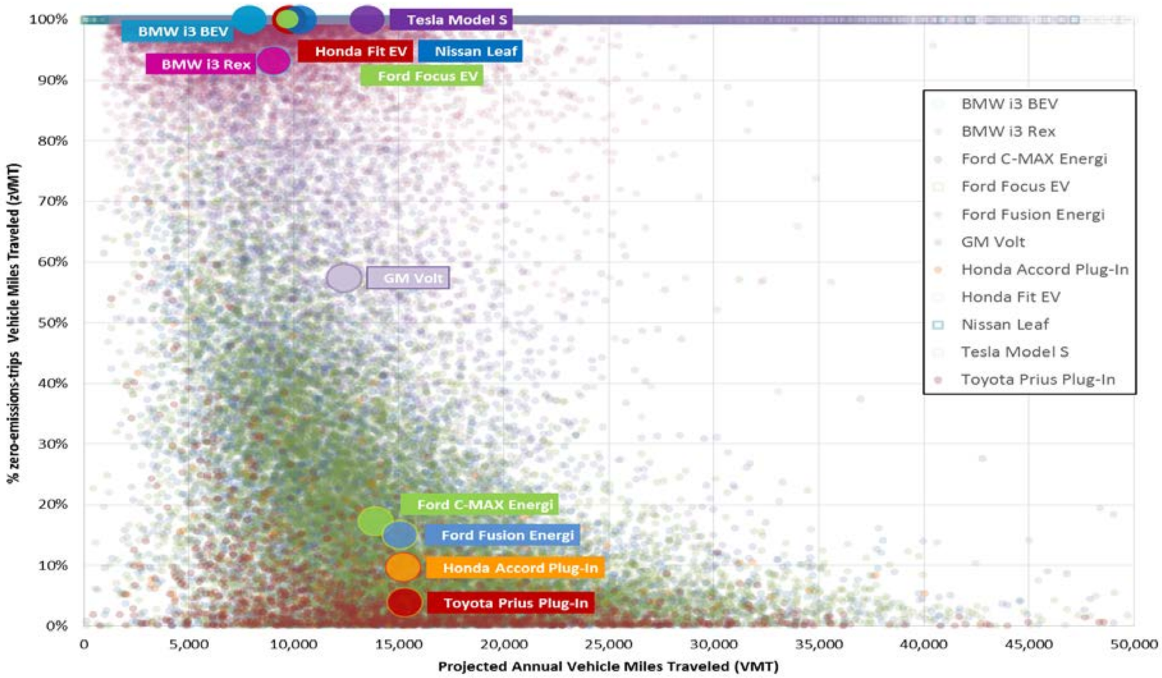
Table 9 shows average eVMT and zVMT for each PEV analyzed in staff's analysis. Averages, however, do not fully capture the model's potential environmental benefit or impact. These factors (both eVMT and zVMT) are highly driver dependent and based on daily trip distance, daily trip count, and electric 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.

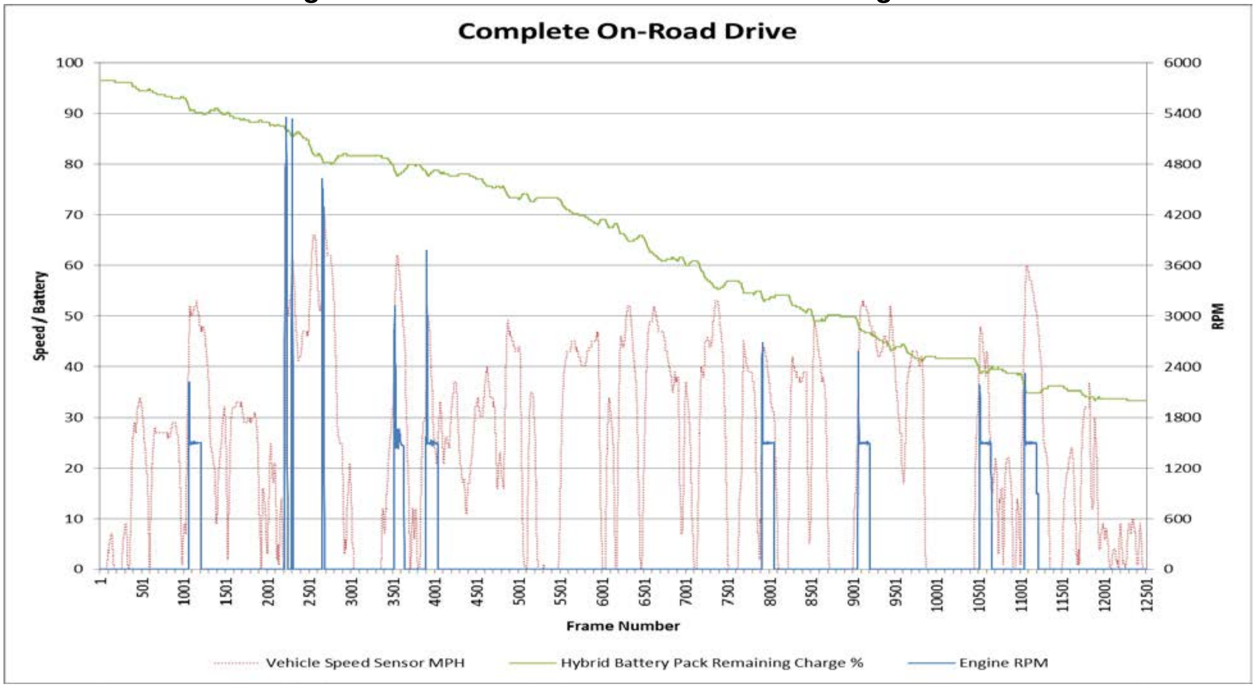
Figure 6 - zVMT variation across PEVs



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?

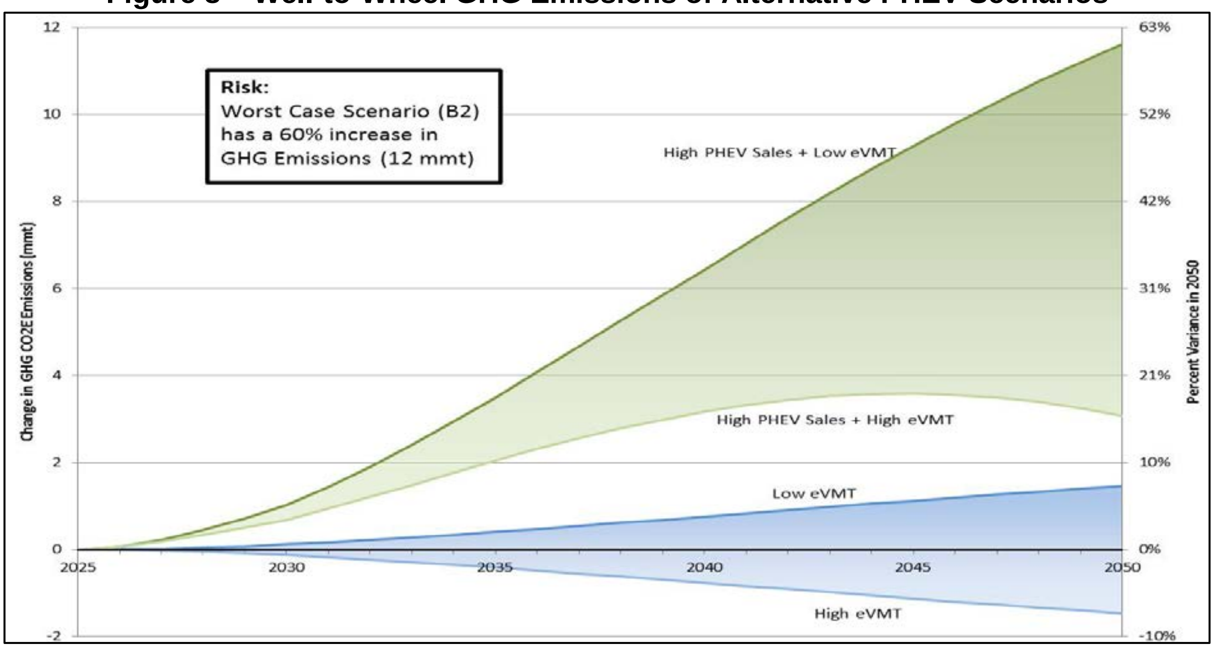
ARB's latest long-term scenario released in the Mobile Source Strategy (called the Cleaner Technologies and Fuels, or CTF, scenario) showed PHEVs could be a significant share of the

[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

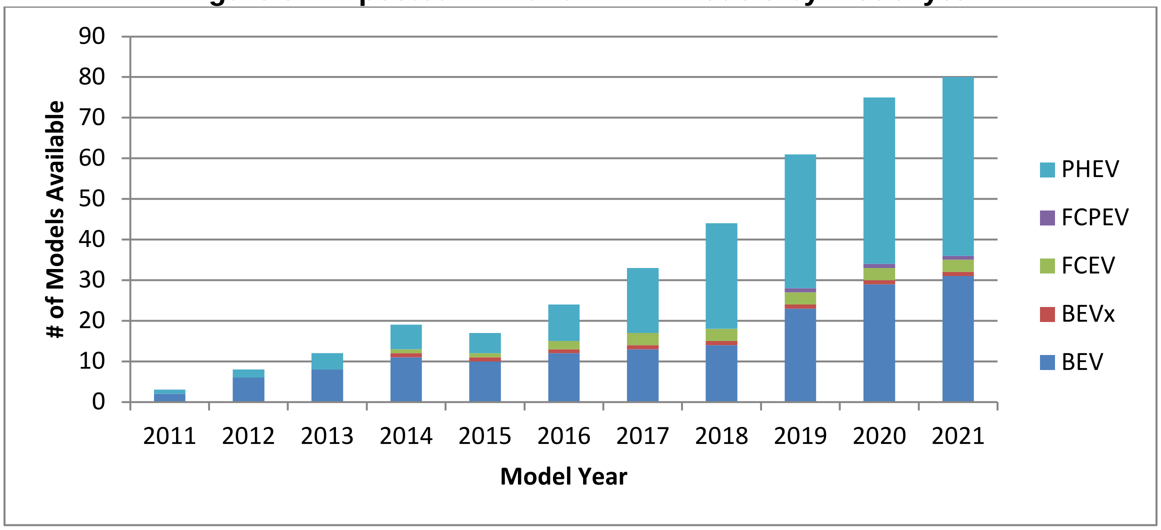


This suggests that, though PHEVs can be a significant share of the future fleet, there are limitations that make it necessary to still pursue substantial BEV and FCEV volumes and that there is additional risk associated with PHEVs dependent on user behavior due to their flexible nature.

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 charging[39]. 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

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[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 factor*[47]

** *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 PHEV[49], 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.

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[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.

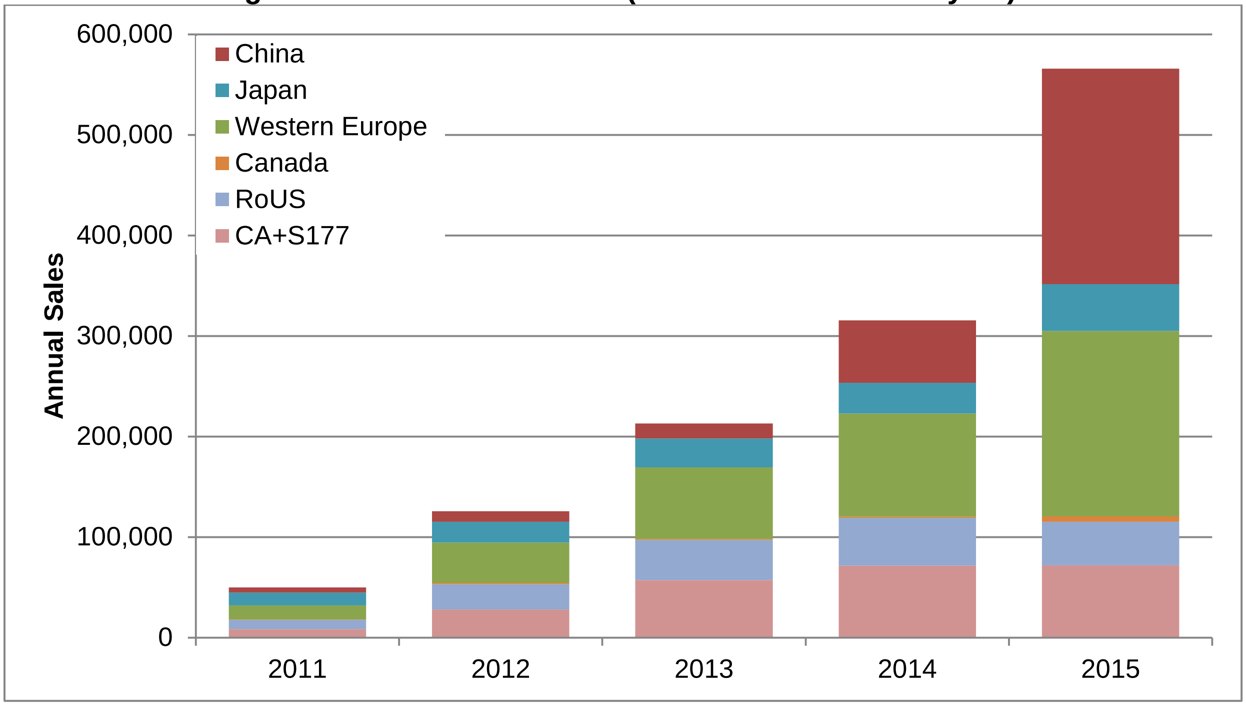
Where does California and Section 177 ZEV states fit into a growing global ZEV market?

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.

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[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 recipients[59], 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

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[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

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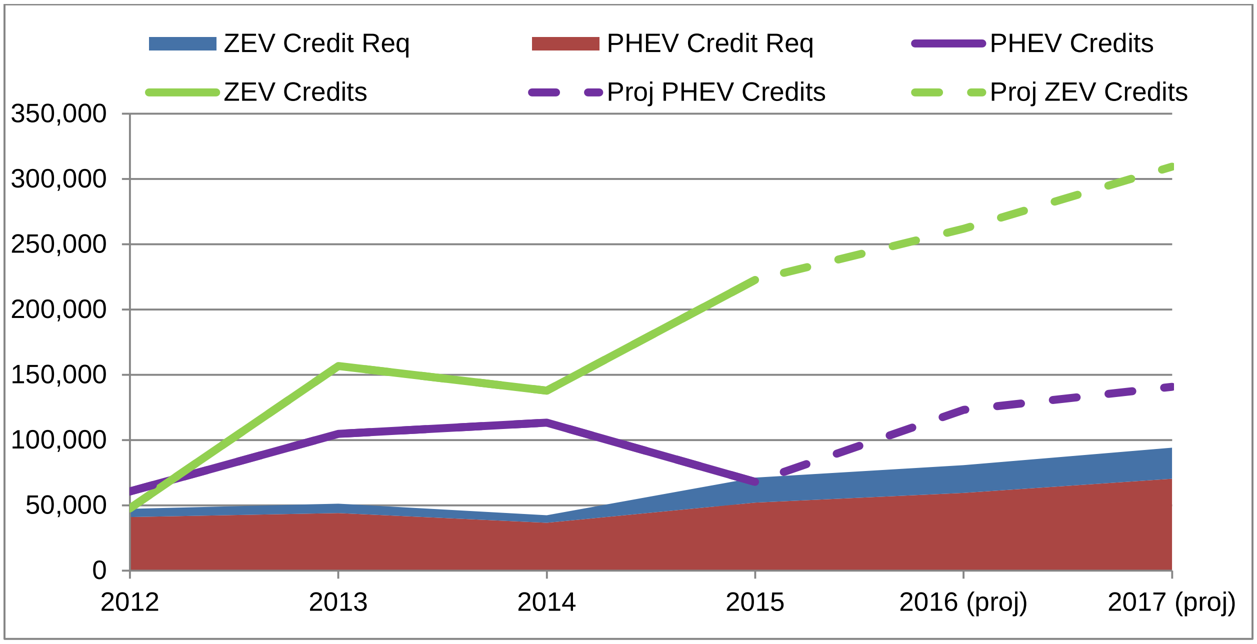
[62] See Appendix D for staff's infrastructure assessment.
[63] See Appendix C for staff's technology assessment.
[64] Calculated from historical sales trends discussed in Appendix B, Section III.A.2.c.
[65] MassEEA 2016. Massachusetts Department of Energy and Environmental Affairs. Press Release. "Baker-Polito 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)

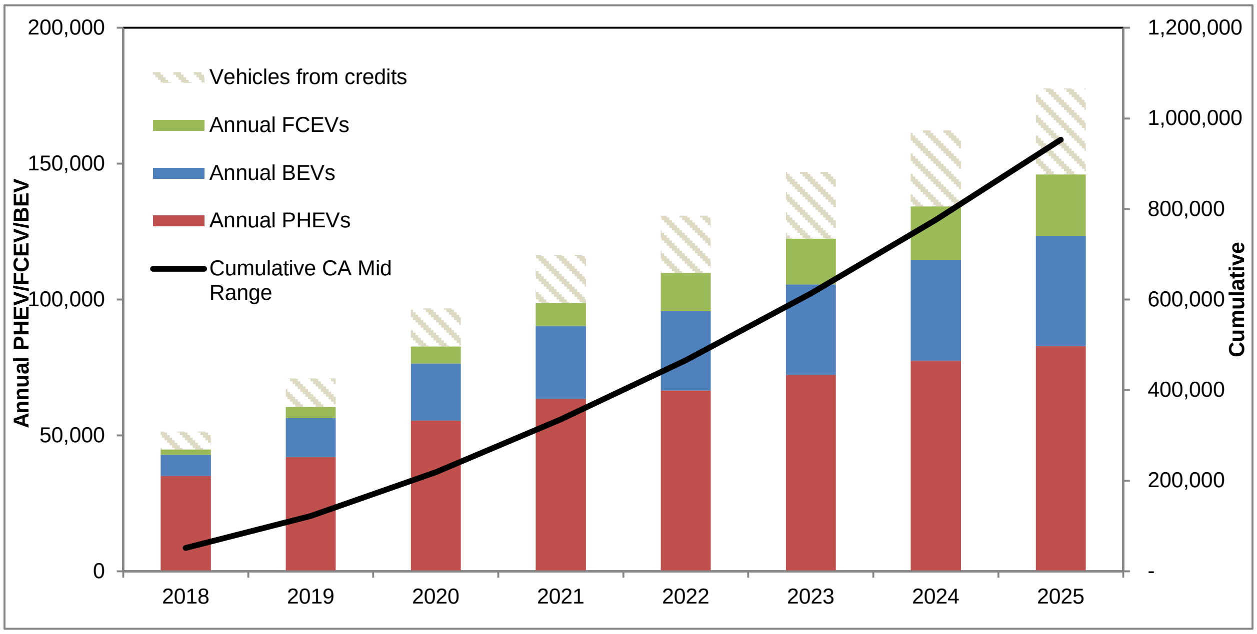
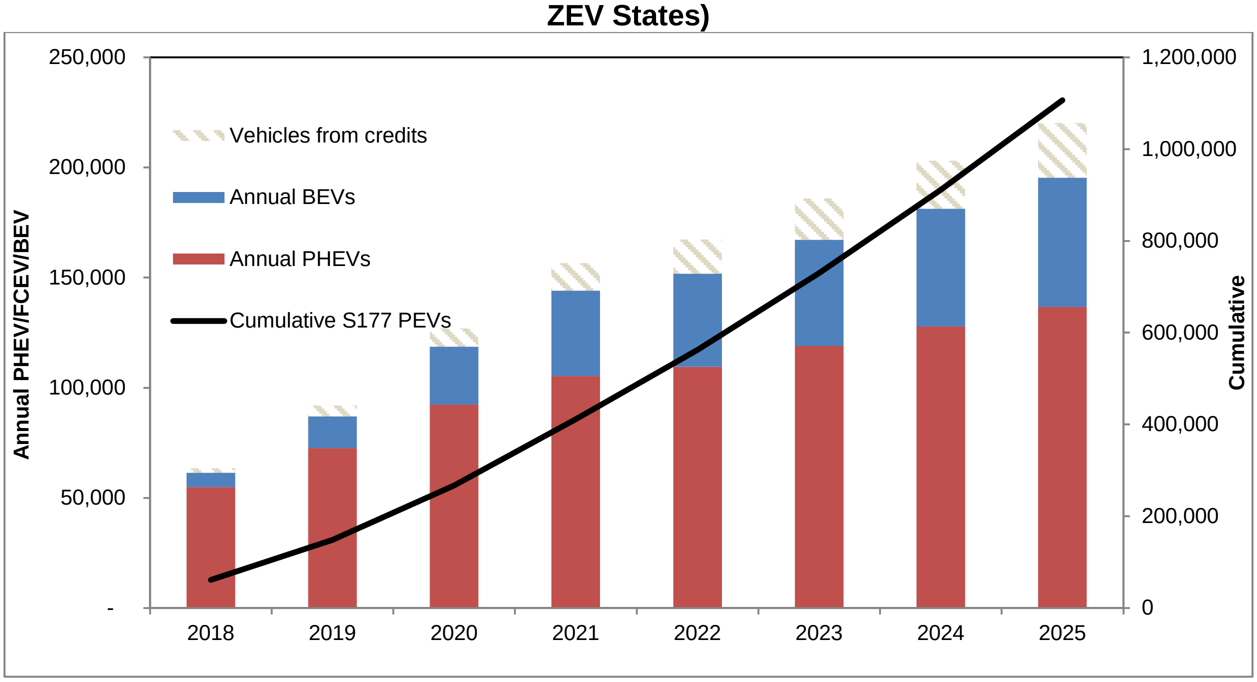


Figure 13 - Sales from mid-range scenario for ZEV regulatory compliance (Section 177 ZEV States)



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.

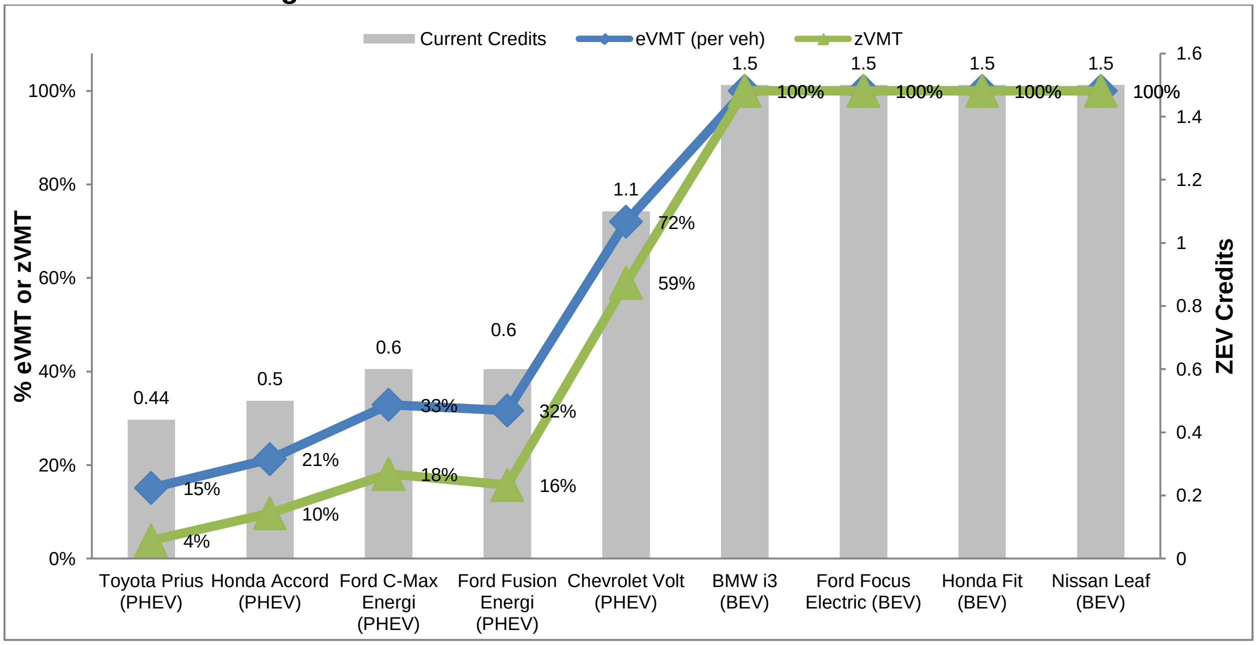
Though manufacturers have presented average eVMT numbers, data provided by the manufacturers to ARB show increasing overall VMT with unchanging eVMT each year for some models. According to early data received from General Motors[70] during the EV Project, 72 percent of the Volt miles qualify as eVMT. 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

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[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.

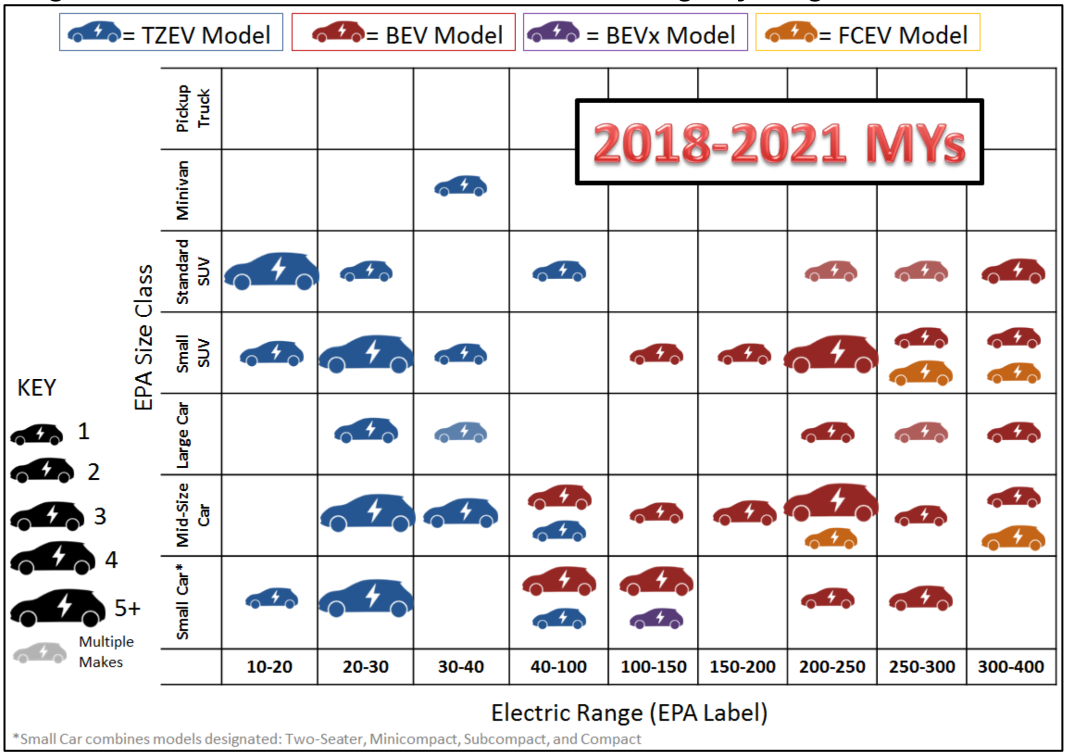
[80] ARB 2014. California Air Resources Board. Resolution 15-07. May 21, 2015 https://www.arb.ca.gov/regact/2014/zev2014/res15-7.pdf
[81] Mazda declined to meet with ARB staff regarding the review of the ZEV regulation.
[82] Greimel 2016. Hans Greimel. Automotive News, " Japan's holdouts begin to embrace 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 qualifications[84] 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 pollutant[85]) 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) research[86] 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.

<u>2022 through 2025 model year GHG emission standards</u>

- 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.

<u>1 milligram per mile particulate matter emission standard</u>

- 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.

<u>California's ZEV regulation</u>

- 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
NOx:	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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