State of California
Air Resources Board

Advanced Clean Cars II Proposed Amendments to the Low Emission, Zero Emission, and Associated Vehicle Regulations

Standardized Regulatory Impact Assessment (SRIA)

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1 Background and Introduction

The Advanced Clean Cars II regulatory proposal analyzed in this document would create a legally binding framework to transition to zero emission vehicles (ZEVs) for new car and light truck vehicle sales in California while cleaning up remaining internal combustion-powered vehicle sales. Doing so is critical to meeting California's public health goals, including its climate and state and federal air quality targets. This is because mobile sources are the greatest contributor to emissions of criteria pollutants and greenhouse gases (GHG) in California, accounting for about 80 percent of ozone precursor emissions and approximately 50 percent of statewide GHG emissions, when accounting for transportation fuel production and delivery.[1] Zero emission vehicles (ZEVs), meaning battery electric vehicles (BEV) and hydrogen fuel cell electric vehicles (FCEVs), have no tailpipe emissions and therefore are a clear solution to several public health and environmental threats. They reduce mobile source emissions that contribute to unhealthy regional ozone and particulate matter levels. They reduce local exposure to toxics. They reduce demand for petroleum production, delivery, and combustion that is destabilizing the climate. And while ZEVs do still have upstream emissions that are associated with the production of the electricity and hydrogen used to fuel them (and are accounted for in the analysis of this proposal), the criteria pollutants and carbon intensity of transportation electricity and hydrogen is already cleaner than gasoline in California and is aggressively becoming cleaner under state laws mandating renewable sources of fuel. The proposed regulation will drive the sales of ZEVs and the cleanest-possible plug-in hybrid electric vehicles (PHEVs) to 100 percent in California by the 2035 model year, all while reducing smog-forming and GHG emissions from new internal combustion engine vehicles (ICEVs).

The analysis below shows that doing so will produce substantial public benefits. The proposal would also see a shift towards employment in ZEV sectors, furthering California's efforts to foster green jobs. Resulting in 12 million cumulative ZEVs and PHEVs, staff expects the ACC II proposals to reduce cumulative TTW GHG emissions by an estimated 434 MMT of CO2 relative to the baseline from 2026 to 2040. The cumulative total emissions from 2026 to 2040 light- and medium-duty vehicles are estimated to be 54,254 tons of ROG, 65,577 tons of NOx, and 3,350 tons of $PM_{2.5}$relative to the baseline. For the individual vehicle owner, the results show that for BEVs, operational savings will offset any incremental costs. For example, a passenger car BEV with a 300-mile range will have a payback period of seven years for the 2026 model year technology. For the 2035 model year technology, the payback is nearly immediate and cumulative savings over ten years exceed $6,000. The proposal would also see a shift towards employment in ZEV sectors, furthering California's efforts to foster green jobs.

CARB staff based these projections on realistic but conservative estimates of costs and benefits grounded in the evidence currently available; as the ZEV sector continues to expand,

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[1] CARB 2020 Mobile Source Strategy. *https://ww2.arb.ca.gov/sites/default/files/2021-09/Proposed_2020_Mobile_Source_Strategy.pdf*

private sector investments accelerate technology development, and public investments continue, costs may drop further, or benefits increase. For instance, CARB anticipates that just as the private sector continues its rollout, supporting government actions will also accelerate, including continued investments in equitably distributed, accessible, and reliable charging infrastructure, and ongoing incentives programs to increase ZEV access will accompany this program, as they do today, though the precise design of these efforts will be determined over time. CARB staff will continue to further refine costs and benefits as they develop the final proposal and through continued conversations with stakeholders.

The benefits of a move away from ICEVs in new vehicle sales are, in sum, very substantial. Indeed, when CARB analyzed a range of alternatives for this analysis – including slower and faster ZEV deployments – slower deployments generally produced fewer benefits. CARB did not select the faster ZEV timetable alternatives in this proposal due to feasibility concerns, but their greater potential benefits suggest a need to further review options between the current proposal and the alternatives as regulatory development continues. CARB will continue reviewing options to capture enhanced public benefits and accelerate the ZEV transition throughout the course of this rulemaking and will update economic analyses as warranted as the public process continues.

1.1 Regulatory History

The proposal analyzed here builds upon many decades of CARB regulations seeking to reduce emissions from light-duty passenger cars and trucks. Each of those regulations ultimately yielded significant public benefits. We provide a brief overview of this history as context for the current effort which seeks to extend this positive history.

In 1990, the Air Resources Board (CARB or the Board) established the Low-Emission Vehicle (LEV) regulation which contained aggressive exhaust emission regulations for light-duty passenger cars and trucks and the first requirement for manufacturers to build ZEVs.[2] Building upon the success of the LEV regulation, CARB adopted the second phase of the regulations. These amendments, known as LEV II, set more stringent fleet average non-methane organic gas (NMOG) requirements for model years 2004 through 2010 for passenger cars and light-duty trucks. In 2004, CARB approved a landmark greenhouse gas (GHG) tailpipe standard, more commonly known as "the Pavley regulation", to require automakers to control GHG emissions from new passenger vehicles for the 2009 through 2016 model years. These were the first regulations in the nation to control greenhouse gas emissions from motor vehicles, one of the largest contributors to climate change emissions in the state.

[2] Meanwhile, manufacturers failed to develop ZEV technology quickly enough to meet the requirements set in LEV, and the Board withdrew all but the 2003 model year 10% ZEV production requirement in 1996. In subsequent rulemakings, cleaner technologies such as hybrid electric vehicles (HEV) came to market, prompting the Board to adopt changes to allow manufacturers to earn credit for those new technologies and offset their ZEV requirements.

In 2009, staff concluded that even widespread adoption of advanced conventional technologies, like non-plug-in hybrid electric vehicles (HEVs), would be inadequate to meet California's then-current 2050 GHG targets[3] of reducing emissions by 85 million tons per year. Staff determined that ZEVs would need to comprise nearly 100 percent of new vehicle sales between 2040 and 2050, and commercial markets for ZEVs would need to launch in the 2015 to 2020 timeframe. The Board heard staff's findings at its December 2009 hearing and adopted Resolution 09-66,[4] reaffirming its commitment to meeting California's long-term air quality and climate change reduction goals through commercialization of ZEV technologies.

Continuing its leadership role in the development of innovative and groundbreaking emission control programs and advancing ZEV technology, California developed the Advanced Clean Cars (ACC) program, which was finalized with Board action in 2012. The ACC program incorporated three elements that combine the control of smog-causing pollutants and GHG emissions into a single coordinated package of requirements for model years 2015 through 2025, assuring the development of environmentally superior cars that will continue to deliver the performance, utility, and safety vehicle owners have come to expect. These three elements included the LEV III regulations to reduce criteria pollutants and GHG emissions and another phase of ZEV requirements.[5]

When the Board adopted ACC in 2012, it committed to conducting a comprehensive midterm review (MTR) of three elements: 1) the ZEV regulation, 2) the 1 milligram per mile particulate matter standard, and 3) the light-duty vehicle GHG standards for 2022 and later model years. Staff's review was conducted at the same time as the United States Environmental Protection Agency (U.S. EPA) and National Highway Traffic Safety Administration (NHTSA) midterm evaluation (MTE) of the light-duty vehicle greenhouse gas and fuel economy standards for 2022 through 2025 model years at the federal level. Following completion of the MTR, the Board concluded the following at its March 2017 hearing:

- GHG tailpipe standards remain appropriate and achievable for 2022 through 2025 model years
- ZEV requirements as adopted in 2012 are appropriate and will remain in place to develop the market
- Complementary policies are needed and should be expanded to help support an expanding ZEV market

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[3] CARB, 2009. "White Paper: Summary of Staff's Preliminary Assessment of the Need for Revisions to the Zero Emission Vehicle Regulation". *CARB*. Accessed on October 24, 2018. *https://www.arb.ca.gov/msprog/zevprog/2009zevreview/zevwhitepaper.pdf*.

[4] Resolution 09-66. *CARB*. Accessed on October 24, 2018. *https://www.arb.ca.gov/msprog/zevprog/2009zevreview/res09_66.pdf*.

[5] Although the Clean Fuels Outlet regulation update was adopted by the Board as part of the ACC package, it was not finalized in response to Assembly Bill 8 (AB 8, stats. 2013, ch. 401), which included dedicated funding for hydrogen fueling infrastructure to support the market launch of hydrogen fuel cell vehicles.

- Particulate matter standard is feasible but further action is needed to ensure robust control
- Immediately begin rule development for 2026 and subsequent model years

The federal program was subsequently significantly modified under successive federal administrations, but CARB's work continued in response to the findings of the MTR.[6] Following the Board's direction to begin development of standards, staff developed the proposed ACC II regulations, with development continuing today. The proposals aim to maximize criteria and GHG emission reductions through increased LEV program stringency and real-world reductions, while accelerating the transition to ZEVs through both increased stringency of ZEV requirements and associated actions to support wide-scale adoption and use.

1.2 Current Certification Requirements and Vehicle Technology for Conventional Vehicles

These proposals would be implemented in tandem with corresponding certification requirements. For manufacturers to sell new light-duty vehicles in California, they must be certified by CARB under an Executive Order. To get this certification, a gasoline or diesel vehicle must demonstrate that its exhaust (also known as tailpipe) emissions and evaporative emission control systems (as applicable, depending on the specific vehicle category) comply with the emission standards for the vehicle's useful life, which is 15 years or 150,000 miles. The certification testing is carried out by the vehicle manufacturer, and the certification vehicle typically represents a group of similar vehicle models. Vehicles are lumped into test groups for exhaust emission testing, and into evaporative families for evaporative emission testing. Vehicles in the same test group share attributes such as similar engine size and the number and arrangement of cylinders, while vehicles in the same evaporative family share similar fuel tank size as well as common emission control components. As a reference point, for the 2021 model year, one major manufacturer grouped its 47 vehicle models into 28 test groups and 14 evaporative families. This method of grouping vehicle models into test groups and testing a representative vehicle streamlines the testing process for certification.

Each test group must meet emission standards set on different test cycles in a testing laboratory. The emission test cycles include the Federal Test Procedure (FTP) cycle which represents urban driving and the Highway (HWY) cycle which represents highway driving, as it is named. The FTP and HWY cycle are combined and referred to as a 2-cycle test. Vehicles must also be tested on the US06 cycle which represents aggressive driving and the SC03 cycle which accounts for air conditioning and cold conditions. These cycles are meant to

[6] The prior federal administration also took actions purporting to limit CARB's authority to implement portions of the existing ACC program. These actions are in the process of being reconsidered and have been partially repealed. CARB's analysis in this SRIA proceeds on the assumption that this process will be completed and CARB will implement the ACC2 regulation.

represent the worst-case emissions during cold and hot starts. These tests are collectively referred to as the 5-cycle tests and result in certification to specific emission standard bins.

In addition to emission standard bins for each test group, vehicle manufacturers must also meet a fleet-average standard based on the model year with their full fleet of vehicles. This is calculated by multiplying the emission bin value for the test group by the sales and divided by total sales for the manufacturer.

Plug-in hybrid-electric vehicles (PHEVs) are also subject to the exhaust and evaporative emission standards for the on-board conventional engines. Most PHEVs are "blended", meaning the engine will run to help power the vehicle before the battery is fully depleted. In many instances, the engine will start to meet high power demand. The engine emissions under this operation can be significantly higher than under normal operation. The other type of PHEV is commonly referred to as "non-blended", "US06 capable", or "extended range electric vehicle (EREV)". This vehicle depletes the battery first, and only when the battery is depleted, turns the engine on to power the vehicle. This minimizes instances when the conventional engine runs at high power, and the associated elevated emissions. PHEVs that have at least 10 miles all electric range and meet additional criteria such as the lowest emission bins and 10-year battery warranty are also counted towards the ZEV credit requirement, discussed below.

The emission control systems on production vehicles are warranted for the specified duration and disclosed at the time of certification. New vehicles are subject to compliance testing (by either the manufacturers or CARB), to ensure that the vehicles are durable and meet emission standards throughout their useful life, and warranty repairs reporting by the manufacturers, either of which can result in remedial actions.

Like light-duty, medium-duty vehicles must be certified with CARB and obtain an Executive Order to sell in California. Testing requirements are similar except the US06 cycle may not be applicable to some classes and they instead use the UC cycle. This category is divided into class 2a and class 3 by vehicle weight and each of these classes has its own fleet average standard.

1.3 Current Requirements for Zero-Emission Vehicles

In addition to tailpipe emission requirements, manufactures must also certify ZEVs and meet an annual zero emission vehicle credit requirement. Manufacturers earn credit, based on vehicle characteristic such as electric range, and use those credits to meet an increasing requirement. CARB adopted the current ZEV regulations as one element of Advanced Clean Cars rulemaking. Under the current regulation, ZEVs are not subject to warranty and durability requirements.

In conclusion, Table 1, below, summarizes the various vehicle categories and emission-related requirements.

Table 1: Vehicle Technologies and Requirements

TECHNOLOGY	FUEL	EXHAUST EMISSION STANDARDS	EVAPORATIVE EMISSION STANDARDS	FLEET AVERAGE STANDARDS	EARN ZEV CREDITS
ICEV	Gas/Diesel	YES	YES for gasoline; NO for Diesel	YES	NO
HEV	Gas	YES	YES	YES	NO
PHEV	Electric/Gas	YES	YES	YES	Maybe
BEV	Electric	NO – They must perform a range test	NO	YES	YES
FCEV	Hydrogen	NO - They must perform a range test	NO	YES*	YES

1.4 **Proposed Amendments**

The proposed amendments create a new ZEV and LEV regulation for 2026 and subsequent model year vehicles. Staff's proposal also creates new supporting ZEV and LEV test procedures, as well as establishes what are referred to as ZEV assurance measures, which include new durability, warranty, serviceability, data standardization, and battery labeling requirements for ZEVs, to ensure ZEVs are able to serve as true replacements to conventional ICEVs, thereby ensuring emissions reductions occur and providing consumer confidence needed to support ZEVs fully entry into new and used markets. The major proposed amendments are described in this section, beginning with the ZEV regulation that completes CARB's long effort to pivot its regulatory approach from reducing engines emissions in ICE vehicles to instead requiring nearly all new vehicles to be zero-emission by 2035.

1.4.1 ZEV Proposals

The proposed ZEV amendments would require sales of new light-duty vehicles to expand to 100% ZEV and heavily electrified PHEV sales by 2035. A simplified credit accounting system is an important foundation of the proposed rule.

In the current ZEV regulation, the manufacturers must meet a credit requirement for each model year based on their total California sales. Current ZEV requirements vary for manufacturers based on the number of vehicles they produce and deliver for sale in California, and credits per vehicle vary based on vehicle technology and performance attributes. Overcompliance with the current ZEV requirement has generated a bank of credits that the new regulation must account for, and the vehicle crediting structure must require a greater portion of overall sales. This structure must change to reach the goal of having nearly all new vehicles be zero-emission. To achieve the 100 percent goal set by Governor

Newsom's executive order N-79-20[7], the staff has therefore taken a new approach in this proposal compared to prior regulatory changes. Overall, the proposal would require manufacturers to continue to meet a growing percentage of new vehicle sales to be ZEVs and PHEVs. However, instead of earning variable credit for each vehicle produced, staff is proposing minimum technical requirements for BEVs and PHEVs to be eligible to count towards the annual percentage requirement. Functionally, this would mean that each vehicle compliant with these requirements would earn the same credit, allowing the market to create a strong incentive for manufacturers to improve overall vehicle quality, and hence protecting consumers, while also making the credit system simpler and more effective.

Furthermore, since these ZEVs and PHEVs would replace all new vehicle sales of ICEVs by 2035, the proposal contains further requirements for durability, warranty, electric charging standardization, battery labeling, and serviceability, which are collectively called the ZEV assurance measures. These measures guarantee emissions reductions by ensuring that the vehicles perform as needed to fully replace ICEVs, providing consumer confidence and reliability, and also supporting emission reductions as ZEVs penetrate both the new and used vehicle markets. Further details of each of the proposed amendments follow.

1. Annual Zero Emission Vehicle Percentage Requirement

As currently written, the ZEV regulation requires manufactures to annually deliver for sale in California an increasing percentage of ZEVs or PHEVs. The existing ZEV requirement applies to manufacturers who produce and deliver for sale at least 4,500 light-duty vehicles on average annually in California. This applies to manufacturers responsible for approximately 98% of new passenger cars and light trucks sold in California each year.

Starting in the 2026 model year, staff proposes the following annual percentage requirements for subject manufacturers to deliver ZEVs and PHEVs for sale, reaching 100% sales by 2035:

[7] Governor Newsom, G. (2020, September 23). Executive Order N-79-20. (web link: *https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf*)

Table 2. ZEV Percent Requirements for 2026 and Subsequent Model Years

Model Year	Percentage Requirement
2026	26%
2027	34%
2028	43%
2029	51%
2030	61%
2031	76%
2032	82%
2033	88%
2034	94%
2035 and subsequent	100%

Building on the success of electrification in the last 10 years, now is the appropriate time to require all light-duty vehicles to be zero- or near-zero emission by the middle of the next decade. Every major manufacturer that sells light-duty vehicles in California has announced electrification commitments and meaningful climate stability targets to meet not only California's goals, but that of the United States and globally. Additionally, falling costs of lithium batteries and other electrification components, discussed in Section 4.1.2, would impose only modest incremental costs that the market can readily sustain. The requirements have a trajectory that is slightly more aggressive in the first 6 years of the regulation, then moderating in the final years to 2035. This is because staff expect the largest-sized vehicle segments will take longer to electrify as costs continue declining. However, most full-line manufacturers have publicly announced new vehicle models across most segments in the next 3 model years, with goals to electrify all vehicles by 2040, if not sooner.

Staff propose to treat "small volume manufacturers" – essentially makers of custom and specialty vehicles like some high-end sedans – slightly differently. Because small volume manufacturers certify one or two test groups and represent less than 3% of California's light duty vehicle market, therefore have more limited emissions, and have distinct performance and design requirements, staff proposes to require manufacturers who deliver for sale less than 4,500 light-duty vehicles in California to submit a compliance plan by the end of 2032 and to meet the requirement no later than the 2035 model year. This would ensure a path for all manufacturers certifying light duty vehicles in California to be in compliance with 100% ZEV and PHEV sales beyond 2035 model year.

a. Requirement Structure

Currently, manufacturers are allowed to earn credits for qualifying vehicles and to use and bank credits beyond the current model year's requirement for use in future model years or to sell to other manufactures. Manufacturers are currently over complying with the standard and amassing such extra credits for use toward future standards. Though over compliance does represent desired market growth, it also risks diminishing future ZEV volumes and prolonging the elimination of combustion emissions, especially for those manufacturers that have not fully committed to zero-emission platforms. Current rules allow manufacturers to both add new ZEV credits into a pre-filled bank account, and then spend from that account to meet the requirement. This has made sense in past versions of the ZEV regulation when volumes were low and more flexibility was required of manufacturers iterating on products. To that end, staff is proposing to restructure the ZEV requirement beginning in model year 2026.

For 2026 and subsequent model years, staff proposes to determine a manufacturers compliance based on methods in fleet average standards. This means a manufacturer's current model year production of ZEVs and PHEVs meeting technical criteria discussed below. will be accounted for first. Staff is proposing manufacturers could fulfill up to 20% of their annual requirement with PHEVs intended to emphasize their ZEV functionality. If the manufacturer over complies with their annual requirement based on ZEVs and PHEVs produced within the same model year, the manufacturer will be allowed to bank credits for use for up to 4 additional model years. In this case, no historical, banked, or pooled credits would allowed to be used toward compliance. However, for manufacturers that fail to produce an adequate number of ZEVs and PHEVs, staff is proposing to allow manufacturers to fulfill their requirement by other means: historical credits, banked credits, and pooled credits.

With regard to these historical credits, staff propose to limit use in ways that reward past efforts while emphasizing continuing ZEV efforts. Staff proposes manufacturers would be allowed to fulfill a portion of their annual requirement, in the case that not enough ZEVs and PHEVs were produced in the model year, with vehicles that generated ZEV credit prior to the 2026 model year. Staff has three proposals related to this flexibility. First, staff proposes to convert pre-2026 banked credits to align with the per-vehicle value under the proposed new regulatory structure. Pre-2026 ZEV credit banks are proposed to be divided by 4, which represents the maximum number of credits earned by a ZEV under the existing regulation and would be most like a ZEV meeting the assurance measures. Pre-2026 PHEV[8] credit banks are proposed to be divided by 1.1, which represents the maximum number of credits earned by a PHEV under the existing regulation. After the credit banks are converted, staff proposes to further limit the use of these credits, first by placing a 15% cap on each portion of the requirement annually, and second by expiring these converted credits after the 2030 model year. In the case where manufacturers fail to produce an adequate number of current model year ZEVs and PHEVs, staff also proposes to allow manufacturers to comply with banked 2026 and subsequent model year credits. Allowing for manufacturers to bank and use excess vehicle credits in subsequent model years would continue to help manage year to year fluctuations in annual vehicle volumes and still allow for full compliance. Limiting the life of banking within the program would help ensure manufacturers make progress toward future

[8] PHEV credit banks are referred to as "transitional zero emission vehicle credits" or "TZEV credits" in existing section 1962.2, title 13, CCR. PHEV would be the nomenclature going forward, and TZEV would no longer be used in future regulations.

requirements rather than accumulate large compliance banks to stave off further deployment of ZEVs.

2. The Minimum Technical Requirements for Vehicles that Count Towards the Requirement

a. Minimum ZEV Technical Requirements

A ZEV is defined as a vehicle that produces zero exhaust emissions of any criteria pollutant (or precursor pollutant) or greenhouse gas under any possible operational mode or condition. Currently, BEVs and FCEVs meet the definition of a ZEV, and can qualify to meet a manufacturers ZEV requirement, so long as other technical minimum requirements[9] are also satisfied. Staff is proposing updating the technical minimum requirements of a ZEV to a 200-mile all-electric certified combined city and highway test range. Additionally, staff is proposing that BEVs must have direct current (DC) fast charge capability, with inlets that conform with the Society of Automotive Engineers (SAE) J1772 Combined Charging Standard (CCS). To guarantee appropriate charging speeds, BEVs would be required at minimum to have a 5.76-kilowatt (kW) on-board charger and be equipped with a 20-foot Underwriter Laboratory (UL) 2594 certified convenience cord capable of both level 1 and level 2 electrical charging. Additionally, manufacturers would be required to comply with the durability, warranty, service information, and battery label requirements described below.

b. Minimum PHEV Technical Requirements

Staff propose to impose stringent PHEV technical requirements that functionally emphasize the ZEV capabilities of these vehicles, while limiting the overall use of PHEVs in the market. A PHEV is defined as a vehicle that can draw propulsion power from multiple on-board sources including a combustible fuel internal-combustion engine and a traction battery, with the ability to charge the battery from an off-vehicle power source, such as the electric power grid. Currently, PHEVs are required to have at least 10 miles all electric range, meet super-ultra-low emission vehicle (SULEV) emission standards for the engines, and have an extended warranty on emission-related parts. However, staff has found consumer operation of PHEVs to be highly variable, with a commensurate effect on actual emission reductions and electric vehicle miles traveled. To that end, staff is proposing updated technical minimum requirements for PHEVs to qualify to be counted toward a manufacturer's annual ZEV requirement (capped at 20% of the requirement). Staff is proposing a minimum 50-mile all electric EPA label range, and the ability to do at least 40 miles on an aggressive drive cycle to demonstrate the strength of the vehicle's electric capability. As with current PHEVs that count toward manufacturers' requirements, 2026 and subsequent model year PHEVs would need to be certified to super ultra-low (SULEV) bins and have an extended warranty on emission related components for 15 years or 150,000 miles (whichever occurs first). As would be required of BEVs, PHEVs would be required at minimum to have a 5.76 kW onboard

[9] ZEVs currently earn credit for having an electric range of 50 miles or more on the Urban Dynamometer Drive Schedule (UDDS), utilizing a credit equation that scales with increased electric range.

charger and be equipped with a 20-foot UL certified convenience cord capable of both level 1 and level 2 electrical charging. Additionally, PHEVs only could toward the manufacturers' requirements if they comply with the durability, warranty, and battery label requirements described below.

3. ZEV Assurance Measures

CARB has long designed its regulations and certification systems to ensure that vehicles, including their emissions controls, perform properly throughout their life. In the ZEV context, this proposal continues this approach. ZEVs themselves reduce emissions by replacing an internal combustion vehicle. This means that the ZEV system is critical to pollution control, and if it fails, a vehicle may be replaced with an emitting vehicle – a concern that intensifies as vehicles age and compete on the used vehicle market. To secure the emissions benefits of this proposal, ZEVs thus must meet continuing assurance requirements throughout their lives. Such requirements also have important distributional equity implications, as they can improve the performance of vehicles bought used – when most people buy vehicles, and when vehicles are more affordable for lower-income consumers. Thus, the ZEV assurance measures can support access to reliable ZEVs in communities that may not be buying new vehicles, but which do need reliable and durable mobility options. These "ZEV assurance" measures are described here.

Currently, ICEVs are required to not only meet criteria pollutant standards, but can be recalled if they don't meet certification standards throughout the vehicle's defined useful life, which are broadly called durability standards. Manufacturers are also required to provide a minimum warranty on the emission control systems, and vehicles must be equipped with on-board diagnostics (OBD) to track and diagnose emission failures over the defined useful life of the vehicle. Lastly, manufacturers must provide repair information and make available the necessary tooling to non-dealer repair shops. Together these requirements help to control the emissions of the ICEVs over the life of the vehicles and ensure that emission control failures are diagnosed and able to be repaired quickly.

ZEVs have not previously been brought into these types of requirements because volumes have been low and technology has been quickly changing. Staff has prioritized providing time for the technology to mature and data to be collected about the potential to reduce emissions. However, to support a full transition to clean technology in the light duty fleet, it is time to include these vehicles in CARB's traditional durability and assurance approach. Failing to do so would significantly weaken the overall benefits of this proposal. Staff is proposing the following ZEV Assurance Measures meant to ensure ZEVs, both as an option for new vehicle buyers and used vehicle buyers, will provide the functionality and reliability to be a full replacement for an ICEV in every household in California. The measures described here are the ones developed in the staff proposal; CARB will continue to calibrate these assurance measures in response to public comment.

a. Durability

Staff proposes that BEV and FCEV test groups must be designed to maintain 80% of certified combined city and highway test range for 10 years or 150,000 miles, whichever occurs first.

Manufacturers would be required to submit battery state of health data at age 3 and age 6 of each vehicle to show compliance with the standard over its useful life. CARB would retain the right to conduct verification testing on 10 vehicles in a given test group to determine compliance with these requirements. If 3 or more of the vehicles fail durability testing, the manufacturer would be required to submit a compliance plan, which could include remedies up to a recall of all the vehicles within the test group.

b. Warranty

Staff proposes that manufacturers provide a minimum warranty for ZEVs, meaning BEVs and FCEVs, of 3 years or 50,000 miles (or 7 years, 70,000 miles for high-priced parts, or those that are more than a specified consumer price index (CPI) adjusted number of $650) for all powertrain or propulsion-related components, excluding the traction battery. For traction batteries in BEVs and PHEVs, staff proposes a minimum 8 year or 100,000-mile 80% state of health warranty.

In addition to the minimum warranty length, staff proposes BEVs and FCEVs would be subject to the same warranty reporting requirements applicable to ICEVs and PHEVs. Additionally, as with ICEVs, if a manufacturer reports more than 4% warranty failures of any single component within a test group, the manufacturer would be required to submit a corrective action plan that could include remedies up to a recall.

c. Service Information and Standardized Data Parameters

Staff is proposing to require the same access and disclosure of repair information to independent repair shops as is required for ICEVs. For ZEVs, this would be information for propulsion-related component repairs. As with ICEVs, manufacturers would be required to comply with the same tooling standardization requirements to be able to reprogram the vehicle electronic control unit. Staff is proposing to require standardized data related to vehicle usage as well as access to propulsion-related fault codes. Staff is proposing to require that vehicles be equipped with a standardized data connector and follow standardized communication protocols to be able to access this subset of information on the vehicle.

d. Battery Label

Staff's proposal would result in high volumes of batteries that would eventually go into second life applications or would need to be recycled or disposed. Ensuring the success of endeavors to avoid waste would help increase the recycled content available for future battery development and decrease the demand for new critical mineral resources. Staff perceives that requiring information to be made known on the battery itself can help enable these second use and recycling processes. To this end, staff proposes requiring a battery label for all vehicles with a traction battery, or a battery used to power the electric motors of hybrid electric vehicles, battery electric vehicles, and fuel cell electric vehicles. The proposed required label would contain four key pieces of information:

- Cell cathode chemistry
- Capacity performance

- Composition and voltage
- Digital identified (QR Code) linked to a digital repository that can be updated with current information relevant to secondary users, vehicle dismantlers, and recyclers.

4. ZEV Regulatory Flexibilities

A. Environmental Justice Flexibilities

Staff's approach to environmental justice in this proposal is multi-faceted. The significant pollution reductions from the proposal as a whole will reduce exposure to vehicle pollution in communities throughout California, including in low-income and disadvantaged communities that are often disproportionately exposed to vehicular pollution. ZEVs can also be cheaper to own and maintain, reducing transportation costs that comprise a disproportionate share of the spending for lower-income Californians. Further, the ZEV assurance measures, such as minimum warranty and durability standards, will ensure these emissions benefits are realized and long-lasting, while supporting more reliable ZEVs in the used vehicle market. Durable and better performing used ZEVs can help increase access to clean vehicle technologies for communities that may not be buying new vehicles, but which do need reliable mobility options. CARB's many incentive programs, though beyond the scope of this proposal, also further enhance ZEV access. As part of this overall portfolio approach to equity measures, staff have also proposed regulatory flexibilities that will further enhance ZEV access.

Staff are proposing that optional environmental justice (EJ) allowances be awarded to manufacturers under the ZEV regulation who help increase affordable access to ZEVs for disadvantaged communities as part of the portfolio of equity approaches described above. The environmental justice allowances would be a distinct category under the ZEV regulation where vehicle values earned can be banked, traded, and used in the 2026 through 2031 model years, further speeding affordable ZEV access in these communities during the critical early years of the program. Staff is also proposing a 5% cap on EJ allowances that could be used in any given year to fulfill a manufacturer's annual ZEV requirement under the regulation. After the 2031 model year these optional EJ allowances would expire. The EJ allowances are aimed at providing manufacturers additional vehicle values for voluntary actions that would help achieve more equitable outcomes and that would increase access and exposure to ZEV technologies for underserved communities. Staff will continue to review the EJ allowances throughout the course of the regulatory process to explore ways to further enhance equity in the final rule.

Under the proposal, EJ allowances can be earned in two ways:

- <u>Allowance for ZEVs and PHEVs remaining in California after leasing term</u>. A 2026 through 2028 model-year ZEV or PHEV could earn an additional 0.25 or 0.20 vehicle value, respectively, after the vehicle is registered for operation on public roads in California beyond its first qualifying lease term and placed with a household located in a disadvantaged community.

- Discounted ZEVs and PHEVs placed in a community-based clean mobility program. 2026 through 2031 model-year ZEVs and 6-passenger (or more) PHEVs that are sold at a minimum discount of 25% off of the manufacturer's suggested retail price to a community mobility program could earn an additional 0.50 and 0.40 vehicle ZEV credit value, respectively.

B. Pooling with California and Section 177 States

Section 177 of the federal Clean Air Act allows other States to adopt California's regulations to help attain criteria emission reductions. At present, 13 states have adopted California's ZEV regulation: Colorado, Connecticut, Maine, Maryland, Massachusetts, Minnesota, Nevada, New Jersey, New York, Oregon, Rhode Island, Vermont, and Virginia. Three additional states have adopted California's LEV regulations: Delaware, Pennsylvania, and Washington. Though it is unknown which states will adopt the proposed Advanced Clean Cars II regulation for 2026 and subsequent model years, it can be assumed that many states will still exercise their right to adopt California's ZEV regulation. The decision whether to adopt California's regulation is solely that of the other states. This analysis, accordingly, only considers the potential costs of the proposed regulation on California individuals and businesses, as required by the Administrative Procedure Act and its implementing requirements.

If other states adopt California's standards, market demand for ZEVs will increase and costs will tend to decline faster than they otherwise would. This will tend to further increase sales in California, and further reduce emissions sooner than they would otherwise occur. To incentivize this and maximize the potential to reduce emissions in California, staff propose to provide flexibility to manufacturers in the 2026 through 2030 model years, by allowing manufacturers to transfer or "pool" ZEVs delivered for sale in excess of their individual state requirement. Manufacturers could use such pooling to meet up to 15 percent of their annual requirement in 2026, declining thereafter, as shown in *Table 3_Ref84534804*. For example, ZEVs earned in excess of a manufacturer's requirement in one state could be transferred to meet the manufacturers requirement, up to the allowed cap, in another state. "Pooling" maintains the overall stringency of the ZEV regulation while allowing for minor state to state variability in vehicles sales.

Table 3. Maximum Percent of Annual Requirement Allowed using Pooled ZEVs

Model Year	2026	2027	2028	2029	2030
Pooling Cap	15%	14%	12%	11%	10%

1.4.2 LEV Proposals

The suite of proposed regulations guide the light-duty vehicle segment toward 100% electrification by 2035, signifying that the last new conventional ICEVs will be sold in

California during the implementation period of this regulation. However, these ICEVs may remain in-use on California's roads well beyond 2035. As such, the proposed regulation includes three primary elements aimed to mitigate the air quality impacts of ICEVs. First, it would prevent emission backsliding of ICEVs as more ZEVs are sold in California by applying the exhaust and evaporative emission standards exclusively to combustion engines. Second, it would lower maximum exhaust and evaporative emission rates. Third, it would reduce cold-start emissions by applying the emission standards to a broader range of in-use driving conditions. (Starts after the vehicle engine has been shut-off for more than 12 hours are considered cold-starts.) The combination of these three elements would help deliver real-world emission benefits from the ICEVs that would complement more significant emission reductions gained by more widespread ZEV technology.[10]

For the medium-duty vehicle segment of ICEVs, the proposal would first provide better emission control over a broader range of in-use driving conditions under the moving average in-use standard for towing vehicles. Second, the proposal would force the fleet to be cleaner by lowering the current fleet average standard. Third, the proposal would clean up the worst emitting vehicles by lowering the maximum emission rate from medium-duty vehicles.

Further details of the specific LEV criteria proposals are outlined below.

1. Prevent emission backsliding of the internal combustion engine vehicle light-duty fleet

Existing LEV III standards stipulate that the light-duty vehicle fleet must meet a declining fleet average standard for non-methane organic gases and oxides of nitrogen (NMOG+NOx) that reaches 0.030 grams per mile in the 2025 model year. Currently, manufacturers factor in all ICEVs, PHEVs, and ZEVs when calculating their compliance with the LEV regulation. As ZEV sales grow, automakers could (under the current standards) increase emission rates from conventional vehicles and continue to meet the existing emission standards. To prevent any potential backsliding, staff is proposing to phase-out ZEVs from inclusion in the NMOG+NOx fleet average by the 2028 model year, while maintaining the fleet average at 0.030 grams per mile for ICEVs being sold beyond the 2025 model year. This proposal will guarantee that ICEVs will not backslide on emissions, as they will be required to meet a fleet average of 0.030 grams per mile on their own, regardless of how many ZEVs are sold in a model year.

2. Clean up the worst emitting vehicles in the light-duty fleet

Staff is proposing new rules that will clean up or eliminate the highest emitting vehicles in the fleet. To control emissions during urban driving, existing regulations allow manufacturers to certify ICEVs on the urban Federal Test Procedure (FTP) test cycle as meeting the emission

[10] Although not covered by the ZEV rulemaking in this regulatory package, the Advanced Clean Trucks Regulation requires 50 percent electrification by 2035. (Title 13, CCR §1963)

standards in discrete emission bins, ranging from maximum emission rates of 0.020 grams per mile to 0.160 grams per mile. Staff proposes to eliminate the dirtiest FTP emission certification bins and to add cleaner emission bins to provide more options for manufacturers to certify vehicles at lower emission levels and preclude certification at higher emission levels. As a result, this proposal will move the ICEV fleet to cleaner emission bins by reducing the upper limit to 0.070 grams per mile and extending the lower limit to 0.015 grams per mile.

CARB will also propose changes to the certification options and emission standards for aggressive driving to better control criteria emission during rapid accelerations and high speeds. For particulate matter emissions, staff's analysis found that the majority of vehicles emit less than 3 milligram per mile on the aggressive US06 cycle, even though the current standard for light duty vehicles is 6 milligrams per mile. Beginning in the 2026 model year, staff proposes to reduce the US06 emission standard from 6 to 3 milligram per mile for all vehicles.

For NMOG+NOx emissions, current rules allow aggressive driving emissions, such as US06 cycle, to be certified using a composite standard that averages results from US06, SC03 and FTP. However, staff's analysis found that the composite average method allowed for poor emission control during aggressive driving for a small portion of the fleet. Therefore, staff proposes to eliminate the composite average certification option and require all vehicles to certify using a stand-alone standard for the aggressive US06 cycle that is equivalent to the urban driving FTP cycle. These changes will clean up the highest emitting vehicles in the fleet by ensuring all vehicles have good emission control during aggressive driving.

3. Reduce cold-start emissions from light-duty vehicles

Emissions from cold-starts are generally higher in gasoline vehicles since the emissions controlling catalyst has not warmed up yet. Lab tests require vehicles to be "soaked", meaning the vehicle is placed in a 68 to 86 degrees Fahrenheit chamber for 12-36 hours before a cold-start emission test, which was believed to result in the highest emissions. However, vehicle testing revealed that partial soaks caused higher emissions than full soaks of 12 to 36 hours, caused by poor vehicle emission control calibration, but that it is possible to control emissions under these conditions. Therefore, staff proposes new emission standards for partial soaks based on test data of the lowest emitting vehicles. The new testing requirements will lead to real-world emission benefits by ensuring vehicles have good emission control for additional real-world driving conditions.

Staff also found differences in how long drivers typically idle their vehicles before driving as compared with the idle time specified in emission tests. The FTP cold-start certification test begins by turning on the vehicle and idling the engine for 20 seconds before the first acceleration. Current vehicles designed to meet this test heavily rely on those first 20 seconds of engine idle to gradually warm-up the engine's emission control catalyst before the first acceleration. However, in-use data revealed much shorter idling periods, where drivers initially idled for 14 seconds or less before at least 50% of their trips, and for 8 seconds or less before at least 25% of their trips. Vehicle testing showed that shorter idles led to higher emissions than were shown on certification tests. Therefore, staff proposes cold-start emissions to be certified using the current FTP test and an additional FTP cold-start certification test that has a shorter initial idle of 8 seconds. The emission standards for this new test will be based on the potential for reducing emissions demonstrated by the lowest-emitting vehicles tested by CARB. The addition of a new cold-start test with a shorter initial idle will ensure better emission control over a broader range of real-world driving conditions and result in lower in-use cold-start emissions.

Finally, staff also found PHEVs can have higher in-use cold-start emissions if the combustion engine is started in response to a demand for high power, such as accelerating onto a freeway. High-power cold-starts represent an emission concern that is unique to blended PHEVs[11], since non-blended PHEVs can drive fully electric even during high-power demand. Therefore, staff proposes blended PHEVs must meet a new cold-start emission standard for the more aggressive US06 test. The emission targets for this new test will be based on emission testing by CARB that shows the best emission rates from PHEV engines. The new requirements will lead to better vehicle calibration and reduce cold-start emissions during high-power engine starts.

4. Clean up the worst emitting evaporative systems in the light-duty fleet

Running loss emissions are a kind of evaporative emissions that encompasses the fuel vapors escaping from the vehicle during driving. The current standard has not been changed since its introduction in the 1990s. Based on manufacturers' 2019 model year certification data, most of the vehicles (87%) were certified as emitting at or below 0.01 gram of hydrocarbons per mile. Therefore, staff proposes to reduce the evaporative emission running loss standard from 0.05 grams per mile to 0.01 grams per mile of hydrocarbons. The goal of the proposed amendments to the evaporative running loss standards is to reduce emissions from a small proportion of vehicles that are currently certifying to higher emission standards.

The second part of the evaporative emission proposal involves controlling emissions unique to gasoline tanks fitted with a sealed non-integrated refueling canister only system (NIRCOS). These tanks are common on PHEVs (and some HEVs). The carbon canister is one of the main components of the evaporative-emission control system. It absorbs gasoline vapors before they can escape into the ambient air. Because of the way these vehicles are tested, staff has found that these canisters may be undersized for adequately capturing real-world emissions. Instead of adding additional testing requirements, staff is proposing a formula to determine a minimum canister size for vehicles with a NIRCOS fuel system and other vehicles which have fuel tank pressure exceeding a specified threshold. About 6% of vehicles in the California fleet have this type of fuel system and these numbers are expected to grow in the future due

[11] "Blended" PHEVs refer to those that require the engine to meet the full power demands of the vehicle before the battery has been depleted and enters charge sustaining mode.

to staff's proposed ZEV regulation. Manufacturers would demonstrate compliance using a CARB defined evaporative model and a defined calculation without adding testing burden.

5. Control in-use emissions for MDVs while towing

The proposed regulation will require that chassis certified medium duty vehicles with a gross combined weight rating (GCWR) over 14,000 pounds to meet a new in-use requirement moving average window (MAW) requirement. The test procedures and standards for this new in-use requirement are similar to those that CARB recently adopted as part of the HD Low NOx Omnibus rulemaking[12] at the August 2020 board hearing. Medium- and heavy-duty vehicles have similar powertrain design and performance and use patterns. Consistency between the standards for heavy- and medium-duty vehicles will reduce costs and increase compliance rates with requirements that will ensure emissions are adequately controlled during all engine operations that occur on-road, especially during towing.

The new in-use requirement for chassis certified MDVs will require automakers to test in-use chassis certified MDVs in class 2b and 3 on-road using a Portable Emissions Measurement System or PEMS installed on the vehicle driving on-road. The PEMS unit would measure and record emissions data from the vehicle tailpipe exhaust outlet. The method for analyzing the PEMS emissions test data collected is referred to as the Moving Average Window (MAW) method. This method analyzes the PEMS data over continuous five-minute windows that start at every second. Each window is binned based on engine load into its own specific bin and compared to the in-use emission threshold. The test procedures and standards for this new in-use requirement will be similar to those adopted as part of the HD Low NOx Omnibus rulemaking[13] adopted by the board at the August 2020 board hearing. This requirement is new to MDVs and takes the testing outside the lab to measure emissions during on-road driving.

6. Propose lower fleet average standards for medium-duty fleet and delete high emission bins

Under the current regulation, similar to LEV III light duty vehicles, LEV III medium duty vehicles (MDVs) in Class 2b and Class 3 must meet fleet average standards that decrease each model year through 2022. In 2022 the fleet average standard is 0.178 g/mile and 0.247 g/mile for Class 2b and 3 respectively. The vehicles today certify to lower bins and the technology exists to further reduce emissions. The proposed regulation will reduce both fleet average standards to 0.150 g/mile and 0.175 g/mile for class 2b and 3 respectively starting in 2026. In addition, this proposal includes the removal of medium duty ZEVs from the fleet average in 2026 for both class 2b and class 3, as ZEVs are expected to comprise 50 percent

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[12] CARB Heavy-Duty Omnibus Regulation. *https://ww2.arb.ca.gov/rulemaking/2020/hdomnibuslownox*
[14] CARB 2020 Mobile Source Strategy.

of MDV sales to comply with the Advance Clean Truck (ACT) regulation (California Code of Regulations, title 13, § 1963).

The current regulations also allow automakers to certify ICEV MDVs on the FTP test cycle for urban driving in discrete emission bins, ranging from 0.015 grams per mile up to 0.250 grams per mile for Class 2b and 0.200 grams per mile to 0.400 grams per mile for Class 3. As with staff's proposal for passenger cars and trucks, staff propose to eliminate the dirtiest emission bins for MDVs and add lower emission bins to expand manufacturers options to certify vehicle at lower emission levels. As a result, this proposal will move the fleet to cleaner emission bins by reducing the upper limit to 0.070 grams per mile and expanding the lower limit to 0.015 grams per mile.

7. Limit emissions from medium-duty vehicles under aggressive driving conditions

As with passenger cars and trucks, staff also propose changes to the certification options and emission standards for aggressive driving for MDVs. For NMOG+NOx, carbon monoxide (CO), and particulate matter, current regulations allow aggressive driving emissions to be certified using a composite standard that averages aggressive driving emissions with urban driving emissions. However, staff's analysis found that the composite average method allowed for poor emission control during aggressive driving for a small portion of the fleet. Therefore, staff proposes to eliminate the composite average certification option and instead require all vehicles to certify they meet emission standards under aggressive driving conditions under either the US06 or hot 1435UC/LA92 cycle, depending on the category the vehicle is certified to. The stand-alone aggressive driving standard would require class 2b and class 3 MDVs to meet the same emission levels during aggressive driving tests as the FTP emission bins they currently certify under. These changes will clean up the highest emitting vehicles in the fleet by ensuring all vehicles have good emission control during aggressive driving.

1.5 Statement of the Need of the Proposed Regulation

According to the California 2020 Mobile Source Strategy, mobile sources including cars and trucks contribute a significant amount of smog-forming NOx and the largest portion of GHG emissions in California.[14] As shown in the updated 2020 Strategy baseline, on-road light-duty vehicles accounted for 13% of the total NOx emissions statewide in 2017. In the South Coast Air Basin specifically, light-duty vehicles comprised 18% of the 2017 NOx emissions inventory. This represents a smaller proportion of the inventory than in prior years as a result of the aggressive light-duty vehicle emission control regulations and incentives in effect.

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[14] CARB 2020 Mobile Source Strategy.
(web link: *https://ww2.arb.ca.gov/sites/default/files/2021-09/Proposed_2020_Mobile_Source_Strategy.pdf*, accessed on October 14, 2021)

The Proposed Regulation is a draft measure in the 2022 State Strategy for the State Implementation Plan[15] and a significant effort critical to meeting air quality standards that is still underway to cut emissions from new combustion vehicles while taking all new vehicle sales to 100 percent zero-emission no later than 2035, and was a measure in the 2016 State SIP Strategy. It is designed to reduce NOx emissions from today's light-duty vehicles by up to 90 percent, contributing nearly a third of the emission reductions committed in the SIP for attainment of ozone air quality standards in 2031. NOx is a precursor to ozone and secondary PM formation. Exposure to ozone and PM2.5 is associated with increases in premature death, hospitalizations, visits to doctors, use of medication, and emergency room visits due to exacerbation of chronic heart and lung diseases and other adverse health conditions

Also as shown in the 2020 Mobile Source Strategy, light-duty vehicles comprise 28% of the GHG emissions in California, or about 70% of the direct emissions from vehicles or equipment. The indirect or upstream emissions from fuel production (for all transportation modes) are 7% for refineries, 4.1% for oil and gas extraction, 0.9% for pipelines, and 0.7% for agriculture fuel production. When coupled with the direct emissions from all transportation sources, the total GHG emissions from mobile sources and their fuel production represent more than 50% of the total statewide GHG inventory. The light-duty vehicle portion of the upstream fuel emissions depends on the emission characteristics of producing gasoline, as opposed to diesel or other petroleum products, at refineries.

The 2020 Strategy reinforced the conclusions of the 2016 Mobile Source Strategy:[16] electrification of every on and off-road mobile sector is essential for meeting near and long-term emission reduction goals mandated by statute, with regard to both ambient air quality and climate requirements. The 2016 State SIP Strategy identifies that "electrification and progress toward zero emission is critical to address the remaining (from renewable fuels) localized risk of cancer and other adverse effects from major freight hubs, and (electrification) must play a growing role in reducing GHG emissions and petroleum use."[17]AB 32 required CARB to reduce GHG emissions in the state to 1990 levels by 2020. With the passage of SB 32 (statutes of 2016), a longer-term GHG reduction requirement was established at 40 percent below 1990 levels by 2030. Subsequently, Executive Order B-55-18 established a statewide goal of achieving carbon neutrality no later than 2045. Lastly, in support of the need for electrification, Governor Newsom signed Executive Order N-79-202 which established a goal that 100% of California sales of new passenger car and trucks be ZEVs by 2035.

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[15] California Air Resources Board, 2022 State Strategy for the State Implementation Plan: Draft Measures (web link: *https://ww2.arb.ca.gov/sites/default/files/2021-10/2022_SSS_Draft_Measures.pdf*, accessed on January 14, 2022)

[16] California Air Resources Board, 2016 Mobile Source Strategy (web link: *https://ww3.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf*, accessed on October 14, 2021)

[17] California Air Resources Board, 2016 Mobile Source Strategy, May 2016, pg. 77-79 (web link: https://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf, accessed June 2019).

The proposed ACC II regulation will help to achieve California's criteria pollutant and GHG reduction goals by accelerating ZEV technology and reducing real world emissions from combustion vehicles. The new proposed standards will also decrease hydrocarbons (HC), Carbon Monoxide (CO), and particulate matter, from the light-duty vehicle sector, as well as reduce GHG emissions as a result of increasing percentages of ZEVs on California's roads. Additionally, the proposed ZEV assurance measures, including staff's proposals to increase serviceability and durability of ZEVs, will help ensure consumers can replace all ICEVs within California households with new or used vehicles that meet their needs for transportation without harmful emissions.

1.6 Major Regulation Determination

Any agency that anticipates promulgating a regulation that will have an economic impact on California business enterprises and individuals in an amount exceeding $50 million in any 12-month period between the date it is filed with the Secretary of State through 12 months after it is fully implemented (defined as major regulation) is required to prepare a Standardized Regulatory Impact Assessment (SRIA).[18] The Proposed ACC II regulations would be fully implemented in 2035 and are estimated to result in an annual economic impact exceeding $50 million starting in 2026. CARB staff has estimated that the Proposed Regulation could result in direct annual costs to regulated entities of up to $5.83 billion by 2036.

1.7 Baseline Information

For this SRIA, the economic and emissions impacts of the Proposed Regulation are evaluated against a baseline scenario each year for the analysis period from the 2026 through 2040 model year, five years after the regulation takes full effect. The "modeled" baseline reflects implementation of currently existing state and federal laws and regulations including the existing ACC regulation and ACT. The baseline vehicle inventory includes the same vehicle sales and population growth assumptions currently reflected in CARB's latest version of its emission inventory tool, EMission FACtor 2021 (EMFAC2021).[19] EMFAC2021 reflects the latest planning assumptions, and CARB's current light-duty vehicle GHG and ZEV regulations. So as not to overstate the benefits and costs of the Proposed Regulation, the baseline considers the effects of the ACT regulation[20], which affects the way staff's proposal would apply to MDVs in particular. Benefits from ZEVs in the MDV fleet would be a result of the ACT regulation that has already been adopted and are not counted in the benefits of this proposed regulation.

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[18] *See* Cal. Code Regs., tit. 13, § 2001, et seq.

[19] EMFAC2021 is pending approval by U.S. EPA for planning required to meet the National Ambient Air Quality Standards.

[20] That rule requires manufacturers producing engines in vehicles with weight classes 8,500 pounds and greater to have 50% of new vehicles sales to be electrified by 2035.

The emission impacts also account for reductions from the production and delivery of transportation fuels. For the baseline projections, emission reductions from existing requirements are accounted for, including the Low Carbon Fuel Standard (LCFS), the electricity Renewable Portfolio Standard (RPS), and the longer-term requirements of the 100 Percent Clean Energy Act of 2018[21] that requires electricity be supplied by zero-carbon sources by 2045. The baseline of predicted new vehicle sales by vehicle technology, in the absence of the proposed regulation, are presented in *Table 4* below.

Table 4: Baseline LDV Sales and Sales Percentages by Vehicle Technology

	ICEV		**PHEV**		**BEV**		**FCEV**	
CALENDAR YEAR	**Vehicle Sales**	**Sales Percentage**	**Vehicle Sales**	**Sales Percentage**	**Vehicle Sales**	**Sales Percentage**	**Vehicle Sales**	**Sales Percentage**
2026	1,707,016	89.3%	62,564	3.3%	128,288	6.7%	13,916	0.7%
2027	1,709,751	89.0%	63,985	3.3%	133,826	7.0%	14,302	0.7%
2028	1,712,215	88.6%	64,928	3.4%	139,764	7.2%	14,754	0.8%
2029	1,715,115	88.4%	65,738	3.4%	145,156	7.5%	15,135	0.8%
2030	1,715,566	88.0%	66,660	3.4%	152,431	7.8%	15,716	0.8%
2031	1,723,372	88.0%	66,963	3.4%	153,125	7.8%	15,787	0.8%
2032	1,730,988	88.0%	67,259	3.4%	153,801	7.8%	15,857	0.8%
2033	1,738,331	88.0%	67,544	3.4%	154,454	7.8%	15,924	0.8%
2034	1,745,398	88.0%	67,819	3.4%	155,082	7.8%	15,989	0.8%
2035	1,752,197	88.0%	68,083	3.4%	155,686	7.8%	16,051	0.8%

1.8 **Public Outreach and Input**

Consistent with the Board's long-standing practice, staff have engaged in an extensive public process in development of the Proposed Regulation. Staff sought input from stakeholders through various outreach and engagement events, including public workshops, stakeholder working groups, informal meetings and phone calls, and a community listening session. Staff conducted meetings with manufacturers and component suppliers, environmental and equity advocacy organizations, community-based organizations, and other interested stakeholders. These informal pre-rulemaking discussions provided staff with useful information, particularly on the ZEV regulatory stringency, incremental vehicle costs and battery lifetime performance, that was considered during development of the Proposal.

CARB staff conducted four virtual public workshops to discuss regulatory concepts and to solicit feedback on the data and methods used to develop cost impacts. Staff notified stakeholders of all workshops via email distribution of a public notice at least two weeks prior to their occurrence. These notices were posted to the program's website and distributed through several public list serves. The public workshops were open to all members of the public. Meeting materials, including slide presentations, cost workbooks, draft regulatory

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[21] Senate Bill 100, stats. 2018, ch. 312.

documents, and event recordings were posted and available to the public. Staff solicited for regulatory alternatives at the August 11, 2021 public workshop. A complete listing of previously held public outreach events appears in Table 5.

Table 5. Dates and Objectives for Public Events held Previously

DATE	EVENT	OBJECTIVE
SEPTEMBER 16, 2020	Public Workshop 1	To present preliminary analyses and concepts for the LEV criteria pollutant regulation, measures to support wide scale adoption of new ZEVs, and projections of costs for battery electric vehicles.
MAY 6, 2021	Public Workshop 2	To present updated proposals for the LEV criteria regulation, the post-2025 ZEV regulation, and ZEV assurance measures, and projections of costs for ZEV technologies.
JUNE 29, 2021	Listening Session	To inform community members about what the State is doing to increase equitable access to clean transportation through the ACC II regulations and other programs, and to listen to community questions, thoughts, experiences, and suggestions.
AUGUST 11, 2021	Public Workshop 3	To provide updates on minimum technology requirements for ZEVs, to present new measures to increase access to ZEVs for priority communities, (i.e., disadvantaged communities, low-income communities, tribal communities, and low-income households), and to solicit for regulatory alternatives. This workshop also served as a California Environmental Quality Act (CEQA) scoping meeting.
OCTOBER 13, 2021	Public Workshop 4	To present updated proposals for the LEV criteria regulation, ZEV regulation, and ZEV assurance measures. To also present statewide costs and emission benefits for the full regulation proposal and two alternatives considered.

Starting in 2020, many meetings and public events were held using remote formats such as webinars and videoconferences. CARB staff virtually attended and presented at several community meetings of residents to communicate regulatory proposals and solicit input. These meetings included environmental justice advocacy organizations and community-based organizations. Furthermore, all public workshops and a community listening session were held virtually to solicit comments on the proposed regulations under development. Virtual or remote workshops and meetings are in many ways more accessible than a physical location, as they can be attended by anyone from anywhere with internet service or a cellular device. Holding remote workshops can help make events more widely available than merely involving parties who would be subject to the proposed regulations.

These informal pre-rulemaking engagement events and discussions provided staff with useful information that was considered during development of the Proposed Regulation and the impact assessment. CARB staff posted cost workbooks detailing cost data and the assumptions and methods used for determining incremental cost of ZEV technologies. Stakeholders provided input on various cost elements, such as battery costs, component costs, vehicle range assumptions, and vehicle design assumptions. This specific cost feedback, in addition to input from stakeholders in other forums, helped shape the data, methods, and assumptions for the impact assessment. Public input was also considered in determining regulatory alternatives for the Proposed Regulation. Staff will continue to engage stakeholders throughout the development of this regulation and the regulatory proposal.

2 Emission Benefits

Cars and light-trucks emit harmful pollutants, which this proposal would help to eliminate. These pollutants include NOx and $PM_{2.5}$. NOx is a precursor to ozone and secondary particulate matter formation. Exposure to ozone and to fine particulate matter ($PM_{2.5}$), which are inhalable particles with diameters that are generally 2.5 micrometers and smaller, is associated with increases in premature death, hospitalizations, visits to doctors, use of medication, and emergency room visits due to exacerbation of chronic heart and lung diseases and other adverse health conditions. California's South Coast air basin has the highest ozone pollution levels in the nation. The San Joaquin Valley has some of the highest levels of $PM_{2.5}$ in the nation. Reducing this pollution would benefit Californians by reducing emergency room and doctor's office visits for asthma, hospitalizations for worsened heart diseases, and premature deaths. This in turn would result in reduced asthma-related school absences, reduced sick days off from work, reduced health care costs and increased economic productivity.

Section 3.1 below discusses in greater detail the emission benefits of the Proposed Regulation. Section 3.2 discusses benefits to typical businesses. Section 3.3 discusses benefits to small businesses. Finally, section 3.4 discusses benefits to individuals.

2.1 Emission Benefits

2.1.1 Inventory Methodology

The emission benefits of the proposed ACC II regulation for LDVs and MDVs are estimated using CARB's latest version of its on-road vehicle emission inventory tool EMFAC2021[22] and

[22] CARB Emission Factor (EMFAC) Model. (web link: *https://arb.ca.gov/emfac/*)

CARB's Vision model, which can be used to quantify upstream emissions from the transportation fuel and electric power industries.[23] Light-duty vehicles are vehicles with less than 8,500 lbs. of gross vehicle weight rating, including passenger cars (LDA) and light-duty trucks (LDT1, LDT2, and LDT3). Medium Duty vehicles are vehicles greater that 8,500 lbs. and less than 14,000 lbs. of gross vehicle weight rating, including light-heavy duty trucks (LHDT1, and LHDT2). EMFAC2021 reflects the latest planning assumptions, and the preempted status of CARB's light-duty vehicle GHG emission and ZEV regulation. It reflects California-specific driving and environmental conditions, passenger vehicle fleet mix, and most importantly the impact of California's unique mobile source regulations. These include all currently adopted regulations such as the LEV, LEV II and LEV III programs, and California inspection and maintenance programs. The EMFAC2021 model is based on CARB's ACC regulations but also considers updated California Department of Motor Vehicles data through calendar year 2019 and improved projections of the ZEV market share to forecast future ZEV populations, which show overcompliance with the current ZEV requirements in the ACC regulations. It should be noted that the current model is only capable of representing business-as-usual conditions and is made using the best available data, and factors such as COVID-19 introduce both short- and long-range uncertainties in the ability of the model to accurately forecast future trends.

To assess the impact of the proposed regulation, the EMFAC2021 model with customized "annual average" settings was run to estimate statewide light-duty vehicle emissions by calendar year, vehicle category, fuel type, and model year projected to occur for the years of 2026 through 2050.

2.1.2 Modeling of ZEV Proposals

To assess the impact of the ZEV proposals, the EMFAC model was adjusted to reflect modified assumptions for BEV, FCEV, and PHEV sales fractions to account for the manufacturer requirements. The proposed regulations also have minimum requirements for PHEV to count towards the ZEV regulation requirements. To account for future PHEVs meeting these requirements, the model was updated to reflect an increase in electric miles travelled by a PHEV (utility factors) and sales fractions for blended vs. non-blended PHEVs were also modified.

To reflect proposed minimum technical requirements, which include an all-electric miles requirements, Table 6 shows the percent electric vehicle miles travelled (eVMT) for PHEVs. Electric VMT for PHEVs is an essential input to estimate the expected emissions and fuel and electric energy consumption for the PHEV fleet. Currently, EMFAC2021 assumes that the PHEV's eVMT percentage only vary by model year, while for modeling ACC II, staff incorporated eVMT fractions that vary by

[23] CARB Vision Scenario Planning. (web link: *https://ww2.arb.ca.gov/resources/documents/vision-scenario-planning*)

model year, vehicle class, and whether a PHEV is blended or non-blended, based on how the engine operates.

Table 6. ACC II Proposed Plug-in Hybrid Electric Vehicle (PHEV) eVMT Fractions

Model Year	**LDA** blended	**LDA** non-blended	**LDT** blended	**LDT** non-blended
2026	54%	66%	49%	59%
2027	57%	69%	51%	62%
2028	58%	71%	53%	64%
2029	60%	73%	55%	67%
2030	62%	75%	57%	69%
2031	63%	77%	59%	72%
2032 +	65%	79%	61%	74%

For blended PHEVs, also referred to as non-US06 capable, the engine starts and provides propulsion power when the driver's power demand is higher than what the electric powertrain and battery can provide. In contrast, the electric powertrain of non-blended (i.e., US06 capable) PHEVs provide propulsion regardless of the driver demand until the battery reaches a low level of charge and switches to charge sustaining mode. Blended PHEVs typically have smaller-sized batteries and show more frequent combustion engine start behavior compared to non-blended PHEVs. EMFAC2021 assumes that blended PHEVs account for 50% of PHEV sales. In modeling the ACC II regulatory proposal, staff assumed that starting with 2026 model year for cars and 2029 model year for trucks only 10% of new PHEV sales will remain US06 capable and the rest will be non-US06 capable to earn credits in the ZEV regulation.

Table 7: PHEV Sales Percentages for Blended and Non-blended PHEVs

Model Year	**PHEV %** Blended, non-US06 capable	**PHEV %** Non-blended, US06 capable
2026- 2028	50%	50%
2029-2035	10%	90%
2035+	0%	100%

The proposal scenario assumes full transition of new vehicle sales to ZEVs and PHEVs by the 2035 model year. It is noteworthy to mention that for the baseline scenario, EMFAC2021 utilizes ZEV projections using a consumer choice modeling approach as described in the EMFAC2021 Technical Document.[24] EMFAC2021 assumes that ZEVs account for 12% of light duty vehicle sales for 2030 and subsequent model years. Table 8 compares the ACC II projected electric

[24] EMFAC2021 Technical Document: *https://ww2.arb.ca.gov/sites/default/files/2021-08/emfac2021_technical_documentation_april2021.pdf*

(BEV+FCEV) and PHEV sales fractions by model year of the proposal scenario for 2026 and later model years.

Table 8: ZEV (BEV+FCEV) and PHEV Fractions for the Proposed Regulation

Model Year	BEV+FCEV	PHEV
2026	22.2%	3.3%
2027	30.7%	3.3%
2028	39.1%	3.4%
2029	47.6%	3.4%
2030	56.1%	3.4%
2031	72.6%	3.4%
2032	78.6%	3.4%
2033	81.3%	6.7%
2034	82.7%	11.3%
2035 +	82.7%	17.3%

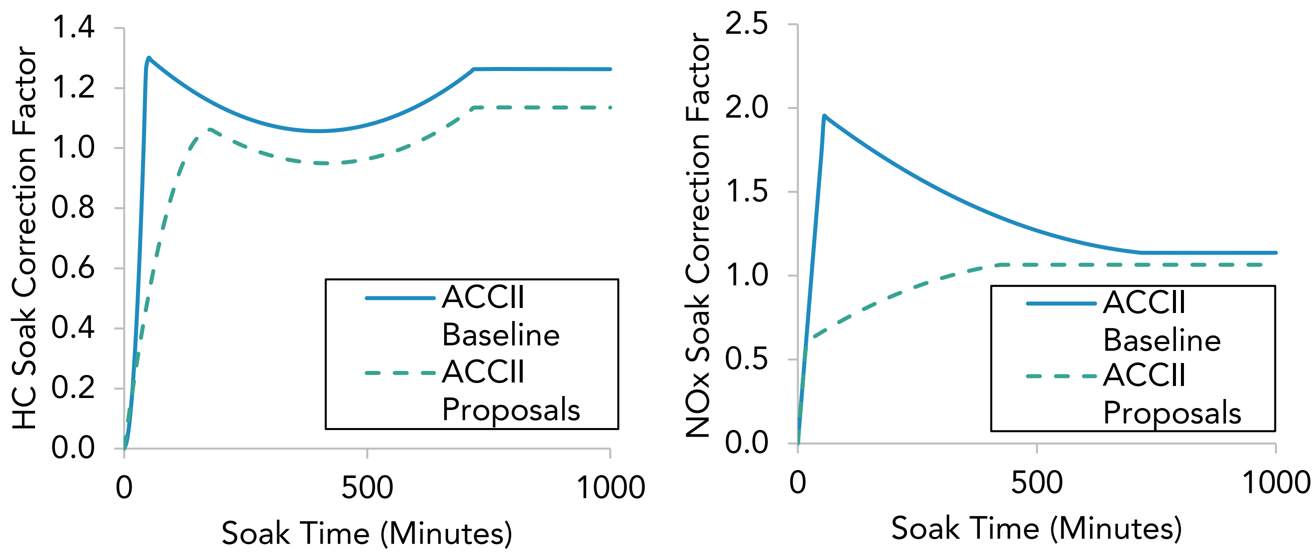
2.1.3 Modeling of LEV proposals

2.1.3.1 Light-duty

To assess impact of the LEV proposals for light-duty vehicles, the EMFAC model was updated with assumptions to account for the anticipated reduced emissions from cold starts by light-duty vehicles, resulting from meeting the proposed emission standards starting in 2026 for new vehicles only. This includes HC and NOx cold start emission rates for PHEVs, and changes to the "start emission soak correction factors (SoFs)" based on testing by CARB to account for emissions based on intermediate soaks, short idle times, and PHEV cold starts. The HC and NOx soak factors are presented in Figure 1.

Proposals for changes in intermediate soaks and shorter idles are reflected on the soak correction factor curves for the start emissions of HC and NOx. EMFAC assumes that a vehicle's warm-start emission rate is directly proportional to its odometer-equivalent cold-start emission rate. Therefore, a warm-start emission rate is computed by multiplying the cold-start emission rate by a non-dimensional soak correction factor, which is a function of soak time. Regression curves were fitted to the test data to derive SoF curves. For the proposed regulation, a three-domain approach was used. The plots were divided into shorter soak warm starts and longer soak warm starts, and separate curves were fitted to each domain. Beyond certain threshold soak time, the SoFs were assumed to flatten. The curves were forced through the y-intercept based on the assumption that starts emissions are zero for zero-minute soak tests. Staff assumed the light-duty technology groups beyond the 2026 model year will share the same revised SoF curves for the proposed regulation. The new HC and NOx SoF curves between the proposed and baseline scenarios are shown in Figure 1. As shown in Figure 1, the baseline assumptions are modified to account for better calibration of vehicles for shorter soaks and shorter idles based on the proposed regulation.

Figure 1: Soak Factors for EMFAC Baseline and Proposed Regulation for HC and NOx



The projected sales mix of light-duty vehicles, by emission bin under the proposed standards, was also modified to reflect the NMOG+NOx fleet average standard without ZEVs. As part of the LEV proposal, the fleet must meet the fleet average of 0.030 g/mi without ZEVs. The vehicle manufacturer must certify to emission bins and manage their sales mix to meet the weighted fleet average. To ensure that the ICEV fleet will continue meeting the fleet average emission standards without ZEVs, the technology group fractions (or what emission bins they certify to) was also changed to meet the LEV proposal. The fractions of the fleet that the ICE vehicles will certify to each emission bin are presented in Table 9.

Table 9: Proposed Emission Bins for the ICEV Fleet for 2026 MY and Beyond

Model Year	LDA		LDT1, LDT2, LDT3		
	ULEV 50	SULEV 30	ULEV 125	ULEV 50	SULEV 30
2026	5.0%	54.2%	2.1%	26.0%	64.6%
2027	5.0%	45.9%	2.1%	17.2%	64.6%
2028	-	43.1%	-	-	74.6%
2029	-	40.4%	-	-	59.3%
2030	-	28.5%	-	-	54.8%
2031	-	10.8%	-	-	39.6%
2032	-	2.6%	-	-	36.3%
2033	-	2.6%	-	-	23.2%
2034	-	-	-	-	13.2%
2035+	-	-	-	-	-

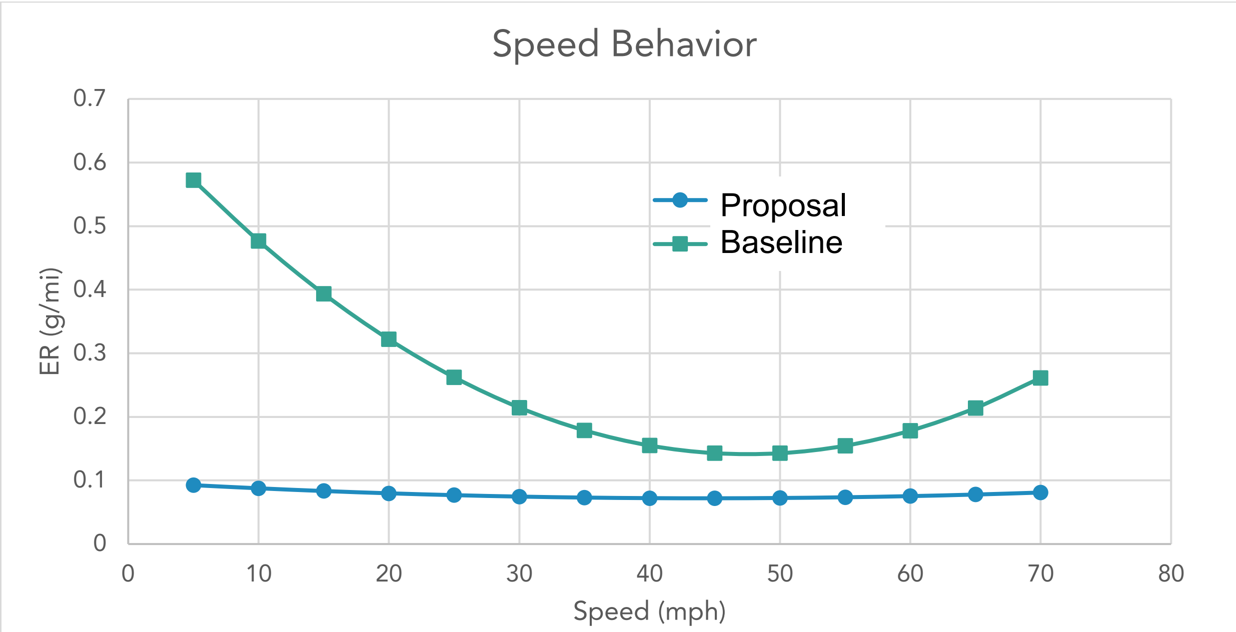
Combined with the proposed electric and PHEV fractions in Table 8, the percentages sum up to 100% for each vehicle class and model year beyond 2026 of the light-duty fleet. No new ICEVs can be sold starting in 2035 MY.

2.1.3.2 Medium Duty

To assess emission impacts, the proposed MDV changes can be summarized as two distinctly different measures. First is an in-use standard structured similarly to the heavy-duty MAW concept which results in a significant reduction in NOx from diesel vehicles. Second, staff is proposing lowering the fleet average standards which results in vehicles meeting lower emission bins. Much like the ACC regulation, these standards are comprised of discrete bins at different emission levels with phased-in fleet average requirements. These tightened standards will result in both ROG and NOx emission reductions.

The MAW standards will apply to all 2026 and newer model year trucks that have a gross combined weight rating (GCWR) of 14,000 pounds or greater. The GCWR represents the combined maximum weight for the vehicle, the cargo it can carry, and any trailer that it is pulling. Vehicles that are meant to tow a trailer have a larger GCWR than vehicles not meant to tow. EMFAC has previously modeled MDV emission rates based on vehicle operation and emission data collected by CARB. Past testing found a reasonable correlation between vehicle operating speed and emission rates such that EMFAC models emissions as a function of vehicle speed (e.g., higher vehicle speed typically means higher load on the engine and accordingly, higher mass emissions). However, the historic testing did not include emissions during towing operation which, relative to non-towing operation, represents much higher engine load operation (and thus emissions) at the same vehicle speeds. To model impacts of this proposal, staff looked both at vehicles that were and were not currently meeting the proposed MAW requirements and calculated the emission rates as a function of speed. Since EMFAC2021 does not yet include any benefits for MAW, the differences between the two curves can be used as an adjustment factor in EMFAC2021. The emission rates are graphed in Figure 2.

Figure 2: EMFAC NOx Emission Rates for the Baseline and MAW Proposal



As the intent of the MAW requirements is to ensure more consistent in-use emission rates, the flatter emission curve is consistent with expectations. Prior to the MAW requirements, an artifact of the current testing methods has meant that they do not adequately represent lower speed operation where less robust emission control solutions could operate less effectively. Likewise, at higher operation, the current methodologies are less protective of emission rates increasing disproportionally. For each model year, the ratio of these two curves was determined for each EMFAC speed bin. The emissions for each model year and speed bin were reduced accordingly, with the summed emissions representing the inventory for the compliant fleet during the regulatory timeframe.

To account for the lower fleet average, staff used a ratio of the new fleet averages compared to the current ACC fleet average which is the baseline for EMFAC2021 emission rates. Staff then used this as a correction factor to scale-down the current assumptions.

Table 10: Proposed MDV Fleet Average NMOG+NOx Standards (grams/mile)

	Class 2**b**		Class 3	
MY	EMFAC2021	ACC2	EMFAC2021	ACC2
2026	0.176	0.174	0.247	0.232
2027	0.176	0.166	0.247	0.212
2028	0.176	0.158	0.247	0.193
2029+	0.176	0.150	0.247	0.175

For each model year of the regulation, the ratio is applied to the EMFAC2021 inventory to adjust the tons per day to reflect the new standards.

2.1.4 Upstream Emission Benefits

Given the potentially large impacts of this specific regulation upon transportation fuels as a result of its scope and ambition, an upstream fuels discussion was deemed appropriate in this instance, and is provided here with appropriate caveats and transparency as to its assumptions. In particular, separate policy, regulatory, or industry actions – such as changing import/export balance decisions at refineries -- could cause different results. A complete policy portfolio of both technology and upstream regulations will affect the ultimate outcome. This analysis reflects one reasonable scenario.

To determine emission impacts from the production and delivery of transportation fuels, CARB's Vision model was utilized with emission factors for the varying fuel types. In-use fleet fuel demand was derived from the three scenarios for each year of the analysis, including fuel demand for gasoline (California E10 blend), electricity, and hydrogen. This fuel demand was then multiplied by the fuel type emission factors that vary by each year based on baseline assumptions of existing fuel policies and projected market activities. As gasoline demand declines in the regulatory scenario and alternatives, CARB assumed that statewide emissions resulting from in-state oil development and gasoline refinery activity also decline proportionally at the existing refinery locations for purposes of this discussion. This assumption does not reflect other market or regulatory actions that may change oil production and refinery emissions in the future. Assumptions of what proportion of the fuels are produced in-state are also discussed in the appendix of the 2020 Mobile Source Strategy.

The upstream, or well-to-tank (WTT), emissions, were quantified via the same approach used in the 2020 Mobile Source Strategy[25] with updated assumptions for fuel and energy supply. WTT emissions include sources from fuel production facilities such as electricity power plants, hydrogen, biofuel production, and gasoline refineries, in addition to fuel feedstock collection (e.g. crude oil extraction from in-state wells) and finished fuel product transportation and distribution. The WTT emission factors capture criteria emissions emitted in California and GHG emissions within the scope of AB 32. WTT emission factors for gasoline, diesel, and hydrogen fuels were developed based on California-specific data, including Low Carbon Fuel Standard (LCFS) data[26], CEIDARS/CEPAM[27], and CA-GREET[28], while considering LCFS

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[25] CARB Mobile Source Strategy Appendix A – Upstream Energy Emission Factors for Scenario Modeling. *https://ww2.arb.ca.gov/sites/default/files/2021-09/Proposed_2020_Mobile_Source_Strategy.pdf*

[26] Data includes crude supply, carbon intensity, and in-state production from LCFS data dashboard and LCFS compliance scenario, refer to:
https://ww3.arb.ca.gov/fuels/lcfs/dashboard/dashboard.htm and
https://www.arb.ca.gov/fuels/lcfs/2018-0815_illustrative_compliance_scenario_calc.xlsx?_ga=2.155021808.917945968.1597354480-1389483658.1577128071

[27] CARB, 2018. Criteria Pollutant Emission Inventory Data. (web link: *https://ww2.arb.ca.gov/criteria-pollutant-emission-inventory-data*)

[28] CARB, 2019. CA-GREET3.0 Model. Available at: *https://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet30-corrected.xlsm?_ga=2.247817287.1944131420.1600710547-1389483658.1577128071*

compliance scenarios and SB 1505[29]. Electricity emission factors reflect compliance with SB 100 Renewable Portfolio Standard targets[30].

The proposed regulation, compared to the BAU, increases electricity and hydrogen consumption while reducing conventional liquid fuels consumption. The upstream criteria emissions associated with increased electricity and hydrogen fuel consumption are spatially distributed according to the location of combustion electricity power plants and hydrogen production facilities[31]. The emission reductions associated with reduced gasoline/diesel consumption are spatially distributed according to the locations and activities of existing refineries and biofuel production facilities throughout California. Specifically, the reductions occur in the air basins where existing fuel production facilities reside. Staff also model criteria emissions from the fuel product transportation phase via heavy-duty trucks that deliver fuel. The emissions are allocated proportionally by the fraction of state-wide fuel consumption for each air basin.

Table 11 shows the estimated NOx, fine particulate matter ($PM_{2.5}$) and GHG upstream emission benefits resulting from the proposed regulatory scenario for light-duty cars and trucks in California. The cumulative upstream emission reductions from 2026 to 2040 is estimated to reduce NOx emissions by 14,892 tons and $PM_{2.5}$ emissions by 1,806 tons relative to the baseline for the proposed scenario. Staff expects the ACC II proposals to reduce cumulative WTT GHG emissions by an estimated 5.60 MMT of CO2 relative to the baseline from 2026 to 2040 for the proposed scenario.

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[29] SB 1505 requires at least 33.3 percent of the hydrogen dispensed by fueling stations that receive state funds be made from eligible renewable energy resources, refer to:
https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=200520060SB1505
Based on current hydrogen supply from LCFS reporting data and future production investments, the supply of renewable hydrogen can be, at least, maintained at 40% of hydrogen fuel demand.

[30] SB 100 requires renewable energy and zero-carbon resources supply 100 percent of electric retail sales to end-use customers by 2045. For renewable source targets in 2030 and 2045, refer to following link. The renewable mix was assumed to scale linearly between 2030 and 2045. *https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB100*

[31] Facility information for refineries, power plants, hydrogen production was looked up through CARB Pollution Mapping Tool, refer to: *https://www.arb.ca.gov/ei/tools/pollution_map/*

Table 11: Proposed ACC II Upstream NOx, PM2.5, and GHG Benefits Relative to Baseline*

Calendar Year	NOx (tpd)	PM2.5 (tpd)	CO2 (MMT/year)
2026	0.07	0.00	(0.07)
2027	0.18	0.00	(0.14)
2028	0.34	0.01	(0.23)
2029	0.55	0.02	(0.31)
2030	0.85	0.06	(0.44)
2031	1.31	0.12	(0.47)
2032	1.81	0.18	(0.42)
2033	2.34	0.25	(0.29)
2034	2.92	0.33	(0.08)
2035	3.53	0.42	0.21
2036	4.15	0.51	0.58
2037	4.76	0.61	1.02
2038	5.38	0.71	1.52
2039	6.00	0.81	2.07
2040	6.62	0.92	2.68

* Note values in ( ) represent an increase in emissions.

The statewide NOx, PM2.5, and GHG upstream emissions and the contributions by sector under the proposed ACC II scenario are presented relative to the baseline in Figure 3. NOx and PM2.5 emissions for the proposed scenario share similar trends and are projected to be reduced as vehicle technology in the on-road fleet shifts from ICEVs to ZEVs. Although emissions from electricity power and hydrogen sectors increase due to a ramp-up of demand, emission reductions from the associated activities of the liquid fuels sector, as the gasoline and diesel fuel demand drops, more than offset the impacts and provide a net emission benefit.

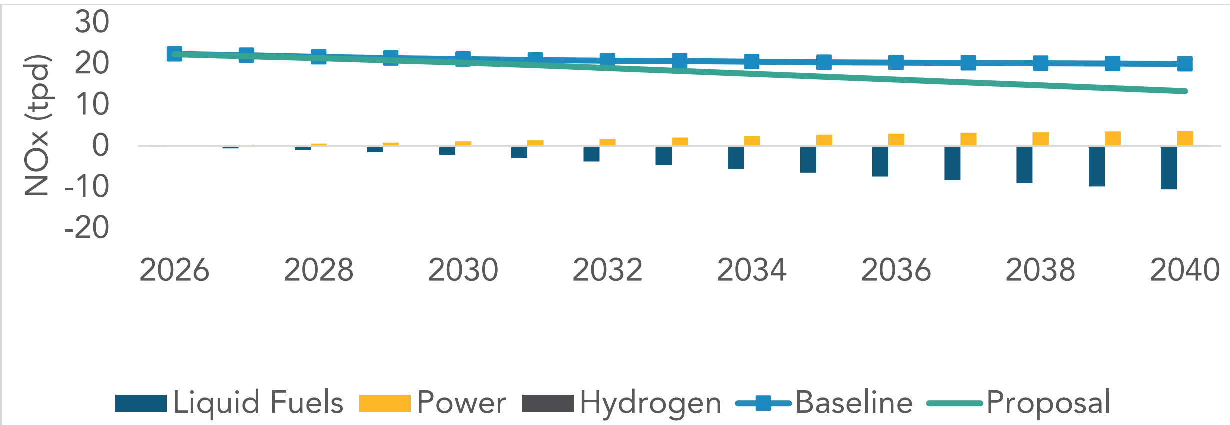
For upstream GHG emissions, a small net increase is found for the proposal before 2030 as increases from electricity and hydrogen production do not fully offset reductions at gasoline production facilities. even as the renewable portfolio of electricity reaches 60% by 2030, as mandated by SB100 [32]. Nevertheless, as the fraction of renewable power grows along with the proposed vehicle requirements, the upstream emissions result in net benefits. Overall, the proposed regulatory scenario projects an important drop of upstream emissions of more

[32] SB 100 requires that 100 percent of retails sales of electricity come from Renewables Portfolio Standard-eligible and zero-carbon resources by 2045. SB 100 does not define zero-carbon resources. SB 100 requires the Energy Commission, Public Utilities Commission and Air Resources Board to use programs under existing laws to achieve 100 percent clean electricity and issue a joint policy report on SB 100 by 2021 and every four years thereafter. The first report was released March 15, 2021. Refer to: https://www.energy.ca.gov/sb100 for more information about this process.

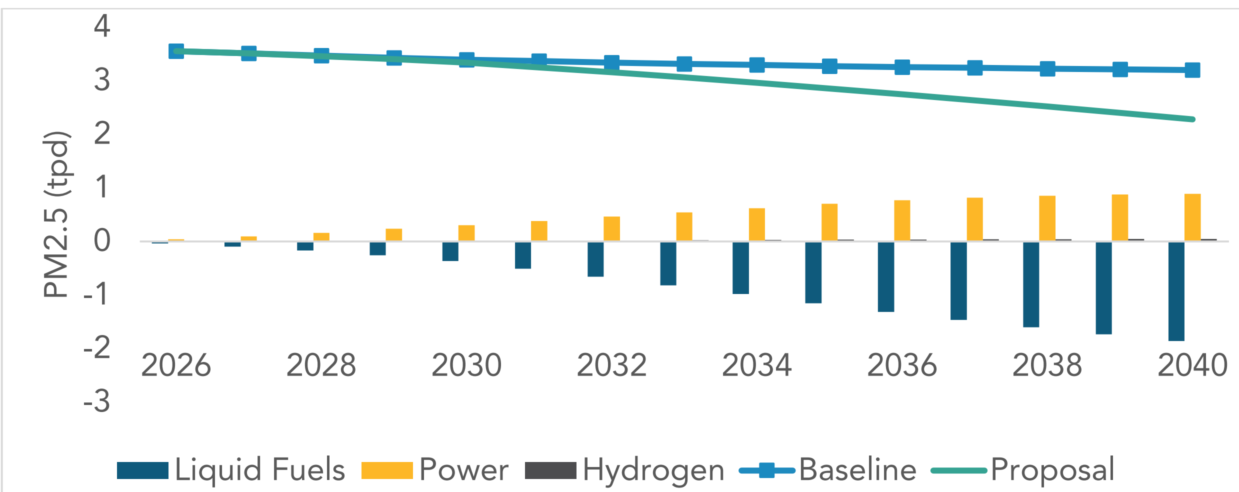
than 30% of baseline upstream criteria emissions and nearly 15% of baseline upstream GHG emissions by 2040.

Figure 3: Projected Upstream (a) NOx and (b) PM2.5 Emissions in Tons per Day and (c) GHG Emissions in Million Metric Ton per Year between Proposed ACC II Scenario and Baseline and Contribution by Sector[33]

(a)

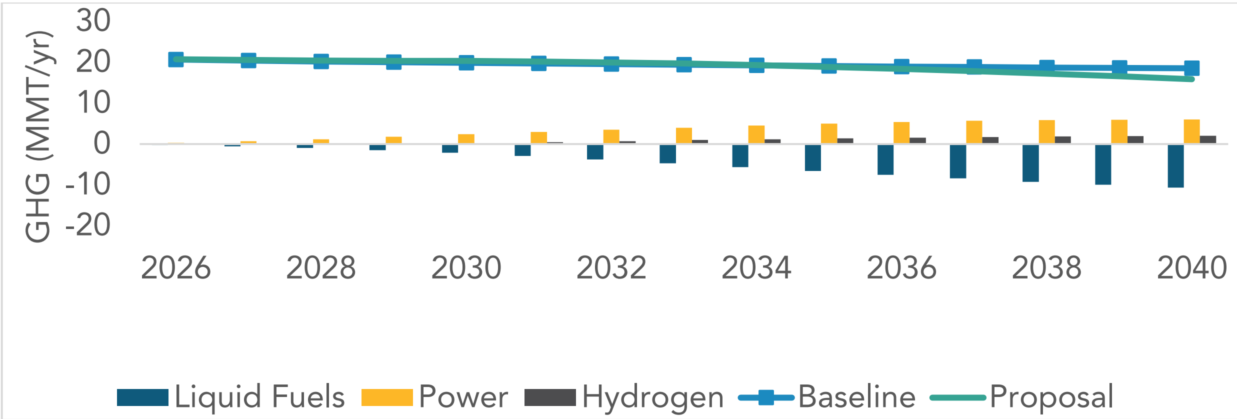


(b)



(c)

[33] Covered criteria emission sources include refinery, biofuel production, and fuel product transportation for liquid fuel sector; combustion power generation (i.e. natural gas and biomass power generation) for power sector; hydrogen production (i.e. fossil and renewable hydrogen) and hydrogen transportation for hydrogen sector



2.1.5 Tailpipe Emission Benefits

The projected emission benefits of the proposed ACC II regulation are evaluated for the proposed scenarios described earlier. The emissions benefits are equivalent to emissions reductions resulting from the proposed regulatory concepts relative to the baseline "Business-As-Usual" (BAU). For the baseline scenario, EMFAC2021 utilizes ZEV projections using a consumer choice modeling approach, as described in the EMFAC2021 Technical Document.[34] EMFAC2021 assumes that ZEVs account for 12% of light duty vehicle sales for 2030 and subsequent model years. Table 12 shows the estimated ROG, NOx, fine particulate matter ($PM_{2.5}$), and GHG emission benefits resulting from the proposed regulatory scenario for light-duty cars and trucks in California. The cumulative total emissions from 2026 to 2040 light- and medium-duty vehicles are estimated to be 54,254 tons of ROG, 65,577 tons of NOx, and 3,350 tons of $PM_{2.5}$relative to the baseline.

GHG benefits are expressed as million metric tons per year (MMT per year) of carbon dioxide (CO2). The GHG benefits presented in this table are solely tank-to-wheel (TTW) meaning upstream emission reductions are not included. Staff expects the ACC II proposals to reduce cumulative TTW GHG emissions by an estimated 434 MMT of CO2 relative to the baseline from 2026 to 2040.

[34] EMFAC2021 Technical Document: *https://ww2.arb.ca.gov/sites/default/files/2021-08/emfac2021_technical_documentation_april2021.pdf*

Table 12: Proposed ACC II Light-duty and Medium-duty Statewide ROG, NOx, PM2.5, and GHG Benefits Relative to Baseline, accounting for vehicle emissions and fuel production and delivery emissions

Calendar Year	ROG (tpd)	NOx (tpd)	PM2.5 (tpd)	CO2 (MMT/year)
2026	0.35	0.59	0.03	1.08
2027	0.94	1.46	0.07	2.87
2028	1.82	2.57	0.12	5.29
2029	2.91	3.90	0.19	8.34
2030	4.19	5.42	0.27	11.9
2031	5.82	7.29	0.37	16.6
2032	7.60	9.33	0.48	21.7
2033	9.47	11.5	0.60	27.0
2034	11.4	13.8	0.72	32.6
2035	13.4	16.2	0.85	38.4
2036	15.5	18.7	0.97	44.0
2037	17.6	21.1	1.09	49.2
2038	19.7	23.4	1.20	54.0
2039	21.8	25.7	1.30	58.6
2040	23.91	27.96	1.39	62.70

The statewide tailpipe NOx and $PM_{2.5}$ emissions in tons per day under the proposed ACC II light- and medium-duty scenario are presented relative to the baseline in Figure 4. Generally, since BEVs and FCEVs have zero tailpipe emissions and PHEVs show reduced tailpipe emissions, due to a fraction of their VMT being driven on electric power, the emissions are projected to decrease as the ZEV sales fractions increase over time. The ACC II proposed scenario showed significantly lower emissions than the baseline in both tailpipe NOx and $PM_{2.5}$. Additionally, regenerative braking of ZEVs and PHEV results in lower PM emissions from brake wear and thus the ACCII scenario brings in non-exhaust $PM_{2.5}$ emission benefits. Additionally, while the EMFAC model assumes similar particulate matter tire wear for all light duty vehicles (ICEVs and ZEVs), the model assumes lower brake wear particulate matter emissions for ZEVs and PHEVs given the increased use of regenerative braking on electric drive platforms (reduced use of traditional brakes). Additionally, regenerative braking of ZEVs and PHEV results in lower brake wear PM emissions and thus the ACCII scenario brings in non-exhaust $PM_{2.5}$ emission benefits.

The results show important NOx reductions that are needed to meet the National Ambient Air Quality Standards (NAAQS). In 2031, the year when the South Coast air basin must attain the 75-ppb ozone standard, the ACC II proposal results in 5.8 tpd NOx reductions statewide, and 3.0 tpd in the South Coast air basin specifically (not shown in figure). In 2037, the attainment year for the 70-ppb ozone standard, ACCII results in 17.6 tpd NOx reductions statewide, and 8.4 tpd in the South Coast specifically.

Figure 4: Projected Statewide NOx Tailpipe Emissions in Tons per Day between Proposed Amendments and Baseline for Light- and Medium-duty Vehicles

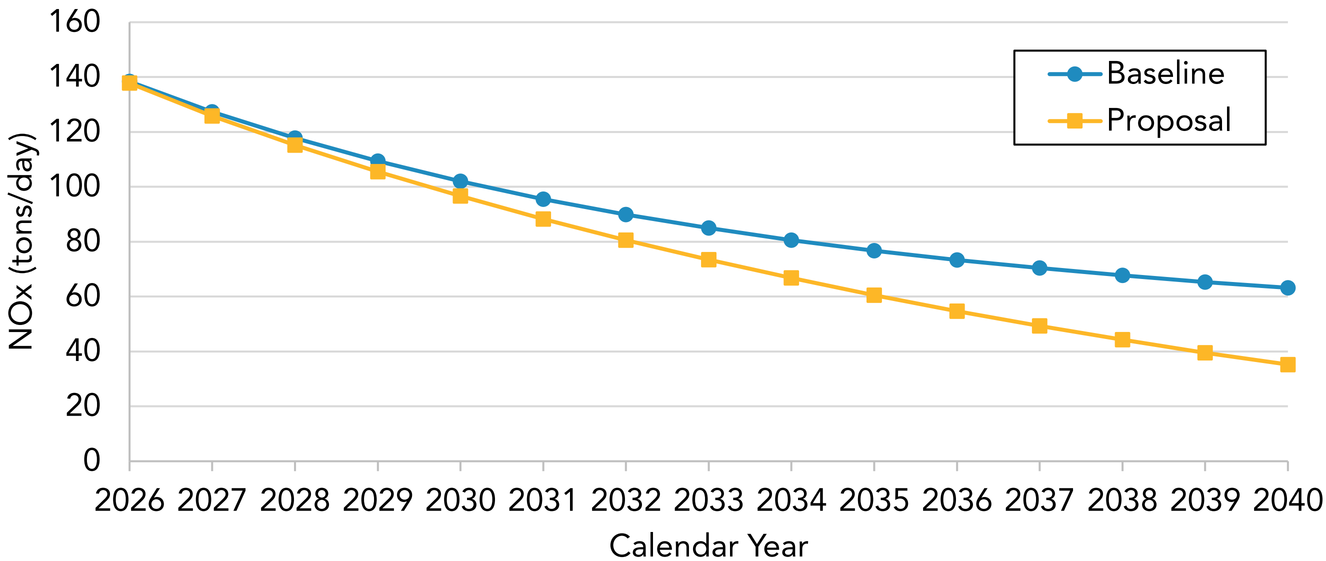


Figure 5: Projected Statewide PM2.5 Including Exhaust, Brake-Wear and Tire-Wear Emissions in Tons Per Day between Proposed Amendments and Baseline for Light- and Medium-duty Vehicles

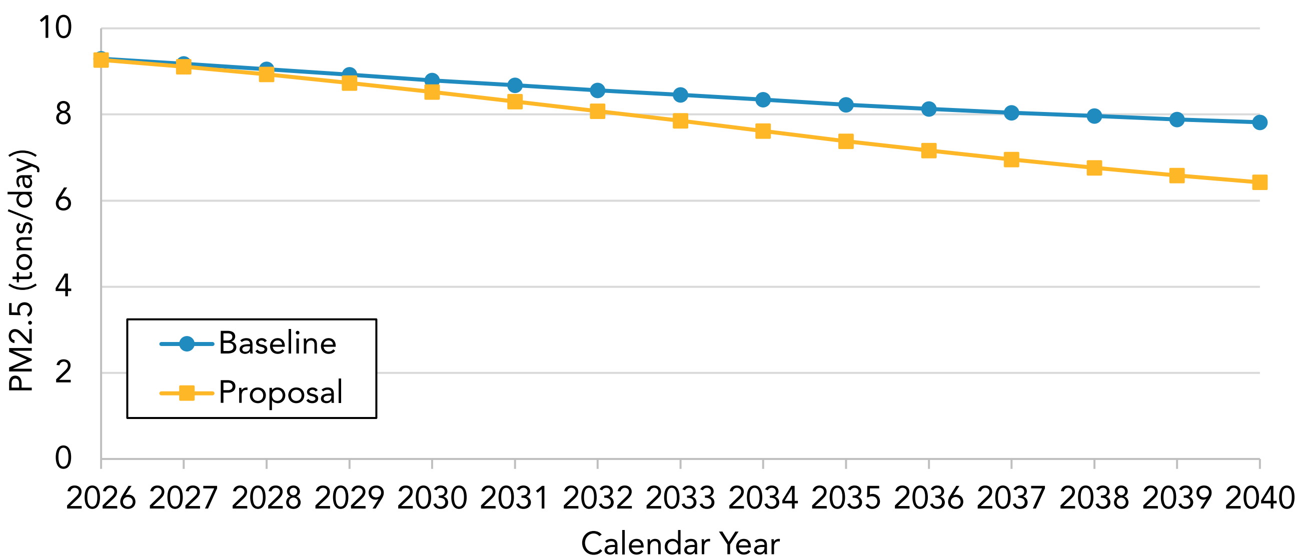
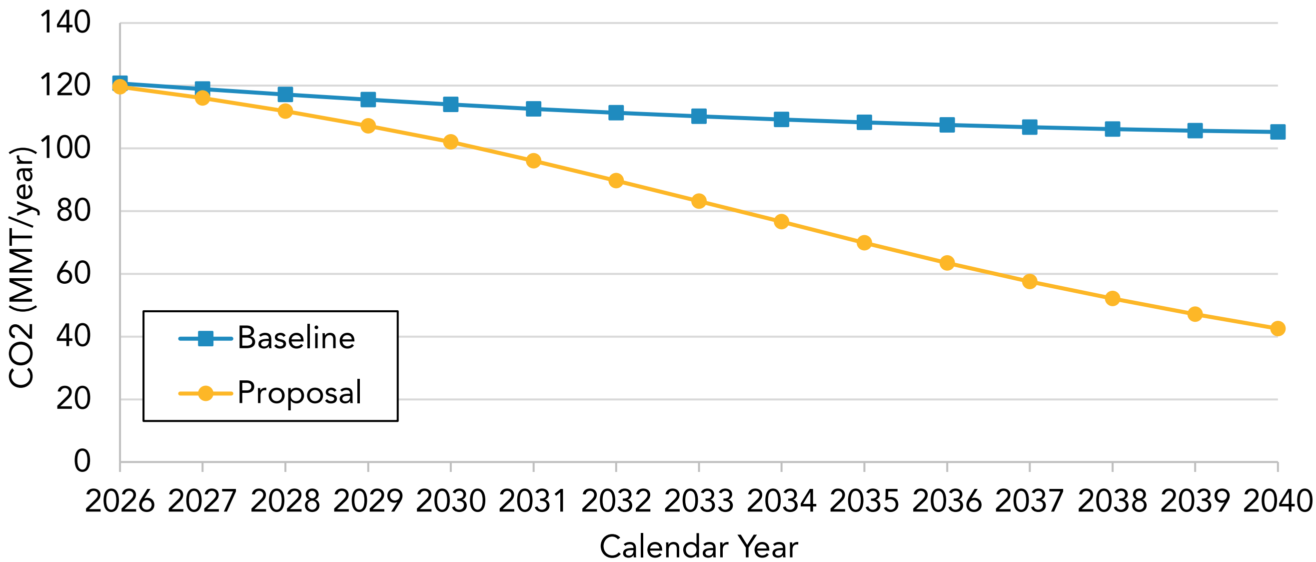


Figure 6 presents the estimated statewide TTW GHG emissions with the proposed ACC II scenario compared to the baseline in MMT per year of CO2. The trend follows the previous results for NOx and $PM_{2.5}$. In 2030, the ACC II proposal results in 27 MMT/yr reductions below the light- plus medium-duty vehicle 2021 levels when only accounting for the TTW emissions.

Although not shown below, when upstream well-to-tank (WTT) emissions are included, results show even greater GHG emission reductions in the later years due to the lower upstream emissions of electricity and hydrogen compared to gasoline and diesel.

Figure 6: Projected Statewide Vehicle Fleet CO_2 Emissions in Million Metric Tons Per Year between Proposed Amendments and Baseline for Light- and Medium-duty Vehicles



2.1.6 Total Emission Benefits

The combined emission benefits associated with upstream and tailpipe emissions (i.e. well-to-wheel) are summarized in the table below:

Table 13: Total Upstream and Tailpipe Emission Benefits of the Proposed Regulation

Calendar Year	NOx (tpd)	PM2.5 (tpd)	CO2 (MMT/yr)
2026	0.7	0.0	1.0
2027	1.6	0.1	2.7
2028	2.9	0.1	5.1
2029	4.5	0.2	8.0
2030	6.3	0.3	11.5
2031	8.6	0.5	16.1
2032	11.1	0.7	21.3
2033	13.9	0.9	26.7
2034	16.7	1.1	32.5
2035	19.8	1.3	38.6
2036	22.8	1.5	44.6
2037	25.8	1.7	50.2
2038	28.8	1.9	55.6
2039	31.7	2.1	60.6
2040	34.6	2.3	65.4

2.2 **Benefits to Typical Businesses**

Typical businesses that may directly benefit from the proposed amendments are ZEV-only manufacturers, while other typical businesses such as Tier 1 component suppliers, electric vehicle service providers, electric utility providers, and electric charging and hydrogen infrastructure providers, may indirectly benefit.

ZEV-only Manufacturers

Due to higher demand for ZEVs from the Proposed Regulation, production of ZEVs by businesses in California would likely increase, leading to increases in manufacturing and related jobs with manufacturers that specifically produce ZEVs. ZEV-only businesses, such as Tesla, Rivian, and Lucid, benefit from generating additional ZEV credits through their overcompliance and selling of credits to other manufacturers. While the value of these credits is uncertain, it is likely that the proposed increase in ZEV stringency will result in an increase in market value of these tradable credits over time. Other ZEV-only start-ups in California, such as Canoo, Karma Automotive, and Faraday Future, can also benefit from the trading of ZEV credits.

Tier 1 suppliers

Tier 1 component suppliers supply parts directly to auto manufacturers. They provide engine components and systems like cylinder deactivation technology, telematics, and engine management software, emission control systems, batteries, and motors. These businesses would benefit from increased opportunities created by the need to develop, sell, and support technology to decrease emissions from ICEVs. Many of these companies are also changing their business models to include components for vehicle electrification, as demand for conventional vehicle components declines.

Electric Utility Providers

The Proposed Regulation will increase the total amount of electric vehicle miles traveled in the state, which in turn will increase the amount of electricity produced. Electricity infrastructure needed to charge BEVs and PHEVs represents the single largest growth area for electric utility companies as traditional areas of growth have been dampened by energy conservation efforts. In recent years, the utility companies in California have been proactively shutting down large sections of the grid, at times for several days, in order to avoid starting wildfires during windy dry seasons. The use of ZEVs to provide grid services and decentralized backup power for California residents is feasible within the regulation period, creating another revenue stream for commercial ZEV fleet operators, and potentially reducing the costs to electric utilities compared to investments in stationary backup power systems.

The Proposed Regulation also helps the state's investor-owned utilities meet the goals of Senate Bill 350, the Clean Energy and Pollution Reduction Act of 2015, with a faster financial return on the infrastructure investments. Senate Bill 350 requires the state's investor-owned utilities to develop programs "to accelerate widespread transportation electrification," with goals to reduce dependence on petroleum, increase the adoption of zero-emission vehicles, help meet air quality standards, and reduce greenhouse gas emissions. Southern California Edison and San Diego Gas & Electric have both proposed programs that are awaiting CPUC decision to extend earlier light-duty PEV infrastructure pilots that use ratepayer funds to support investment in EV charging infrastructure. Pacific Gas & Electric has been approved for a direct current fast charging make-ready program, and the three smaller investor-owned utilities have also been approved for light-duty EV infrastructure programs. Furthermore, all three large investor-owned utilities have either proposed or have been approved to establish new electricity rates for commercial ZEV infrastructure use cases. By ensuring additional electric vehicles will be available to make use of these utility investments, the Proposed Regulation supports the utilities' programs and the goals of SB 350.

ZEV Infrastructure Providers and Installers

In addition to the electric utilities that will supply additional electricity to BEVs and PHEVs under the proposed regulation, ZEV infrastructure businesses will benefit as well. This includes companies that manufacturer, install, operate, and maintain EV charging stations and hydrogen dispensing equipment. Electric Vehicle Supply Equipment (EVSE) providers, and hydrogen station operators will all benefit from increased demand for their equipment with home and public fueling stations. The Proposed Regulation will increase the total amount of electric vehicle miles travelled in the state, which in turn could increase utilization of charging and hydrogen stations across the state and lead to increased revenue for these businesses, making the business model for their investment more stable and predictable. This allows investor capital and venture capital funds to be accessed for increased deployment rates of ZEV infrastructure. Increased use of public charging stations may also have benefits to retail businesses near charging stations. Many charging stations are located in areas with available shopping, food, or other services such as dry cleaning. Additionally, California businesses that are contracted to install stations will benefit from the rapidly growing network.

2.3 Benefits to Small Businesses

Staff's proposal would provide operational savings to small fleet owners, although the proposed regulation would increase vehicle prices and impose costs on small fleet owners in the early years of the regulation. The proposed ZEV assurance measures would help owners of small fleets by eliminating or greatly limiting out-of-pocket costs for vehicle repairs during the time the vehicle is under warranty. In addition, defining useful life and warranty reporting and battery warranty would encourage manufacturers to produce more durable components, resulting in fewer failures and less downtime for the small fleet owner. There are also operational and fuel savings discussed in Section 3.2.

2.4 Benefits to Individuals

The Proposed Regulation would benefit California residents mainly from the reductions in NOx resulting in reduced ozone exposure and reduced PM exposure from the secondary formation of NOx to $PM_{2.5}$, and from improvements in California air quality and reduced adverse health impacts. The reduction of GHG emissions, while being a global pollutant, will also benefit California residents monetarily by reducing carbon emissions in the future represented later as the social cost of carbon.

2.4.1 Health Benefits

The Proposed ACC II Regulation reduces NOx and $PM_{2.5}$ emissions, resulting in health benefits for individuals in California. CARB analyzed the value of health benefits associated with four health outcomes in the Proposed ACC II Regulation and alternatives: cardiopulmonary mortality, hospitalizations for cardiovascular illness, hospitalizations for respiratory illness, and emergency room (ER) visits for asthma. The proposal will lead to 1,448 fewer cardiopulmonary deaths; 237 fewer hospital admissions for cardiovascular illness, 283 fewer hospital admissions for respiratory illness; and 728 fewer emergency room visits for asthma.

These health outcomes and others have been identified by U.S. EPA as having a *causal* or *likely causal* relationship with exposure to $PM_{2.5}$ based on a substantial body of scientific evidence.[35] U.S. EPA has determined that both long-term and short-term exposure to $PM_{2.5}$

[35] U.S. EPA (2019). Integrated Science Assessment for Particulate Matter (Issue EPA/600/R-19/188). (web link: *https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=347534*)

plays a *causal* role in premature mortality, meaning that a substantial body of scientific evidence shows a relationship between $PM_{2.5}$ exposure and increased risk of death.[35] This relationship persists when other risk factors such as smoking rates, poverty and other factors are taken into account.[35] U.S. EPA has also determined a *causal* relationship between non-mortality cardiovascular effects and short- and long-term exposure to PM2.5, and a *likely causal* relationship between non-mortality respiratory effects (including worsening asthma) and short- and long-term $PM_{2.5}$ exposure.[35] These outcomes lead to hospitalizations and ER visits, and are included in this analysis.

Staff evaluated a limited number of statewide non-cancer health impacts associated with exposure to $PM_{2.5}$ and NOx emissions from light-duty vehicles. NOx includes nitrogen dioxide, a potent lung irritant, which can aggravate lung diseases such as asthma when inhaled.[36] The health impacts from NOx quantifiable by CARB staff occur from the conversion of NOx into fine particles of ammonium nitrate through atmospheric chemical processes. $PM_{2.5}$ formed in this manner is termed secondary $PM_{2.5}$. Both directly emitted (primary) $PM_{2.5}$ and secondary $PM_{2.5}$ from light-duty vehicles are associated with adverse health outcomes, such as cardiopulmonary mortality, hospitalizations for cardiovascular illness and respiratory illness, and ER visits for asthma. As a result, reductions in $PM_{2.5}$ and NOx emissions are associated with reductions in these health outcomes.

2.4.1.1 Incidence-Per-Ton Methodology

CARB uses the incidence-per-ton (IPT) methodology to quantify the health benefits of emission reductions in cases where modeled concentrations are not available. A description of this method is included on CARB's webpage.[37] CARB's IPT methodology is based on a methodology developed by U.S. EPA.[38,39,40]

Under the IPT methodology, changes in emissions are approximately proportional to resulting changes in health outcomes. IPT factors are derived by calculating the number of health outcomes associated with exposure to $PM_{2.5}$ for a baseline scenario using measured ambient concentrations and dividing by the emissions of $PM_{2.5}$ or a precursor. The calculation

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[36] U.S. EPA (2016), Integrated Science Assessment for Oxides of Nitrogen – Health Criteria, EPA/600/R-15/068, January 2016. (web link: *http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=526855*)

[37] CARB's Methodology for Estimating the Health Effects of Air Pollution. (web link: *https://ww2.arb.ca.gov/resources/documents/carbs-methodology-estimating-health-effects-air-pollution (Accessed February 9, 2021)*

[38] Fann N, Fulcher CM, Hubbell BJ., The influence of location, source, and emission type in estimates of the human health benefits of reducing a ton of air pollution, Air Quality, Atmosphere & Health, 2:169-176, 2019. (web link: *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2770129/*)

[39] Fann N, Baker KR, Fulcher CM., Characterizing the PM2.5-related health benefits of emission reductions for 17 industrial, area and mobile emission sectors across the U.S. Environ Int.; 49:141-51, November 15, 2012. (web link: *https://www.sciencedirect.com/science/article/pii/S0160412012001985*)

[40] Fann N, Baker K, Chan E, Eyth A, Macpherson A, Miller E, Snyder J., Assessing Human Health PM2.5 and Ozone Impacts from U.S. Oil and Natural Gas Sector Emissions in 2025, Environ. Sci. Technol. 52 (15), pp 8095–8103, 2018. (web link: *https://pubs.acs.org/doi/abs/10.1021/acs.est.8b02050*)

is performed separately for each air basin by multiplying the emission reductions from the Proposed Regulation in an air basin by the IPT factor then yields an estimate of the reduction in health outcomes achieved by the Proposed Regulation. For future years, the number of outcomes is adjusted to account for population growth. CARB's current IPT factors are based on a 2014-2016 baseline scenario, which represents the most recent data available at the time the current IPT factors were computed. IPT factors are computed for the two types of $PM_{2.5}$: primary and secondary $PM_{2.5}$ of ammonium nitrate aerosol formed from precursors.

Emission reductions from both tailpipe and upstream emissions sources were combined for health benefit quantification using the IPT method. To estimate the reductions in primary PM2.5 from non-mobile sources, relative statewide potency factors were applied specifically to the projected emissions from upstream sources, derived from a CARB contract report that had evaluated exposures from multiple sources in California.[37,41] Due to upstream emissions estimates being less certain than tailpipe emissions, the health benefits in the next section were calculated by the five major air basins as well as statewide. In the future, as CARB staff refine our ability to estimate upstream emissions, we hope to be able to provide the combined benefits calculations at a more refined scale.

2.4.1.2 Reduction in Adverse Health Impacts

CARB staff evaluated the reduction in adverse health impacts including cardiopulmonary mortality, hospitalizations for cardiovascular and respiratory illness, and emergency room (ER) visits for asthma. Staff estimates that the total number of cases statewide that would be reduced (from 2026 to 2040) from implementation of the Proposed Regulation are as follows:

- 1,448 cardiopulmonary deaths reduced (1,132 to 1,771, 95 percent confidence interval (CI));
- 237 hospital admissions for cardiovascular illness reduced (0 to 465, 95 percent CI);
- 283 hospital admissions for respiratory illness reduced (66 to 499, 95 percent CI); and
- 728 emergency room visits for asthma reduced (460 to 996, 95 percent CI).

Table 14 shows the estimated avoided cardiopulmonary mortality, hospitalizations, and emergency room visits because of the proposed ACC II regulations for 2026 through 2040, relative to the baseline. The largest estimated health benefits are expected to occur in the South Coast, San Francisco Bay, San Diego, San Joaquin Valley, and South Central Coast air basins. These five air basins comprise about 99% of the total health benefits. The benefits for the other ten air basins are presented as the "Rest of the State".

[41] Apte, J. S., Chambliss, S. E., Tessum, C. W., & Marshall, J. D. (2019). A Method to Prioritize Sources for Reducing High PM2.5 Exposures in Environmental Justice Communities in California. Contract Number 17RD006. (web link: *https://ww3.arb.ca.gov/research/single-project.php?row_id=67021*)

Note that because CARB staff are evaluating a limited number of health impacts, the full health benefits of the Proposed Regulation are expected to be underestimated. An expansion of the assessment of outcomes, including, but not limited to, reduction of additional cardiovascular and respiratory illnesses, nonfatal/fatal cancers, and lost workdays would provide a more complete picture of the benefits from reduced exposure to air pollution. Additionally, CARB's mortality and illness assessment is only calculated for a portion of $PM_{2.5}$ emissions, and there are other pollutants that can cause health issues. For instance, while NOx can lead to the formation of secondary $PM_{2.5}$ particles, NOx can also react with other compounds to form ozone, which can cause respiratory problems. And toxic air contaminants (TACs) present in emissions can cause cancer and other adverse health outcomes. Altogether, CARB's current $PM_{2.5}$ mortality and illness evaluation represent only a portion of the benefits of the proposal.

Lastly, the results presented in Table 14 are estimated at a regional scale, at the air basin level. In addition, it is important to consider that the proposed ACC II regulations may decrease the exposure to vehicular air pollution of those who live and work near roadways, which is especially important as these individuals are likely at higher risks of developing cardiovascular and respiratory issues as a result of vehicular PM emissions, compared to those who live further away from roadways. Therefore, although CARB staff cannot quantify the potential effect on near-roadway exposures, the proposal is expected to provide significant health benefits for these individuals.

Table 14: Avoided Mortality and Morbidity Incidents for the Five Major Air Basins and Statewide from 2026 to 2040 under the Proposed Regulation*

Air Basin	Avoided Cardiopulmonary Deaths	Avoided Ho**spitalizations for Cardiovascular Illness**	Avoided Ho**spitalizations for Respiratory Illness**	Avoided ER visits for **Asthma**
San Diego County	67 (52 - 81)	9 (0 - 19)	11 (3 - 20)	27 (17 - 37)
San Francisco Bay	208 (162 - 254)	33 (0 - 64)	39 (9 - 69)	113 (72 - 155)
San Joaquin Valley	46 (36 - 56)	6 (0 - 11)	7 (2 - 12)	17 (11 - 23)
South Central Coast	18 (14 - 22)	3 (0 - 5)	3 (1 - 6)	8 (5 - 11)
South Coast	1093 (854 - 1336)	184 (0 - 361)	220 (52 - 388)	556 (352 - 761)
Rest of the State	17 (13 – 21)	2 (0 – 4)	3 (1 – 5)	7 (4 – 9)
Statewide	1448 (1132 - 1771)	237 (0 - 465)	283 (66 - 499)	728 (460 - 996)

*Values in parentheses represent the 95% confidence interval. Totals may not add due to rounding. Except for the five major air basins, results for the rest of the state are presented at a more regional scale due to the uncertain nature of upstream emission estimates included in the calculations.

2.4.1.3 Uncertainties Associated with the Mortality and Illness Analysis

Although the estimated health outcomes presented in this report are based on a well-established methodology, they are subject to uncertainty. Uncertainty is reflected in the 95%

confidence intervals included with the central estimates in Table 14. These confidence intervals take into account uncertainties in translating air quality changes into health outcomes.

Other sources of uncertainty include the following:

- The relationship between changes in pollutant concentrations and changes in pollutant or precursor emissions is assumed to be proportional, although this is an approximation.
- Emissions are reported at an air basin resolution, and do not capture local variations.
- Future population estimates are subject to increasing uncertainty as they are projected further into the future.
- Baseline incidence rates can experience year-to-year variation.

2.4.1.4 Monetization of Health Impacts

Consistent with U.S. EPA practice, health outcomes are monetized by multiplying each incident by a standard value derived from economic studies.[42] The value per incident is shown in Table 15. The value for avoided premature mortality is based on willingness to pay, which is a statistical construct based on the aggregated dollar amount that a large group of people would be willing to pay for a reduction in their individual risks of dying in a year.[43] While the cost-savings associated with premature mortality is important to account for in the analysis, the valuation of avoided premature mortality does not correspond to changes in expenditures, and is not included in the macroeconomic modeling. As avoided hospitalizations and emergency room visits correspond to reductions in household expenditures on health care, these values are included in the macroeconomic modeling.

Unlike mortality valuation, the cost-savings for avoided hospitalizations and emergency room visits are based on a combination of typical costs associated with hospitalization and the willingness of surveyed individuals to pay to avoid adverse outcomes that occur when hospitalized. These include hospital charges, post-hospitalization medical care, out-of-pocket expenses, lost earnings for both individuals and family members, lost recreation value, and lost household production (e.g., valuation of time-losses from inability to maintain the household or provide childcare).[44] These monetized benefits from avoided hospitalizations and ER visits are included in macroeconomic modeling.

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42 U.S. EPA, Appendix B: Mortality Risk Valuation Estimates, Guidelines for Preparing Economic Analyses (240-R-10-001), 2010 (web link: *http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-22.pdf/$file/EE-0568-22.pdf*, accessed May 2021).

43 U.S. EPA, An SAB Report on EPA's White Paper Valuing the Benefits of Fatal Cancer Risk Reduction (EPA-SAB-EEAC-00-013), 2000 (web link: *https://yosemite.epa.gov/sab%5CSABPRODUCT.NSF/41334524148BCCD6852571A700516498/$File/eeacf013.pdf*, accessed May 2021).

44 Chestnut, L. G., Thayer, M. A., Lazo, J. K. and Van Den Eeden, S. K., The Economic Value Of Preventing Respiratory And Cardiovascular Hospitalizations, Contemporary Economic Policy, 24: 127– 143, 2006 (web link: *https://onlinelibrary.wiley.com/doi/abs/10.1093/cep/byj007*, accessed May 2021).

Table 15: Valuation per Incident for Avoided Health Outcomes

Outcome	Value per incident (2020$)
Avoided Premature Mortality	$10,030,076
Avoided Cardiovascular Hospitalizations	$59,247
Avoided Acute Respiratory Hospitalizations	$51,678
Avoided Emergency Room Visits	$848

Statewide valuations of health benefits were calculated by multiplying the value per incident by the statewide total number of incidents for 2026-2040. The total statewide health benefits derived from criteria emissions reductions is estimated to be $14.55 billion, with $14.52 billion resulting from reduced premature cardiopulmonary mortality and $0.03 billion resulting from reduced hospitalizations and ER visits. The spatial distribution of these benefits across the state follows the distribution of the health impacts by air basin.

Table 16: Statewide Valuation of Avoided Health Outcomes (million 2020$)

Year	Avoided Premature Mortality	Avoided Cardiovascular Hospitalizations	Avoided Acute Respiratory Hospitalizations	Avoided ER Visits	Total Health Benefit
2026	4	1	1	2	$35.8
2027	9	1	2	5	$91.5
2028	16	2	3	9	$164.6
2029	26	4	5	13	$256.4
2030	37	6	7	19	$368.6
2031	52	8	10	27	$519.0
2032	68	11	13	35	$683.5
2033	86	14	16	44	$861.0
2034	104	17	20	53	$1,050.1
2035	124	20	24	63	$1,251.0
2036	145	24	29	73	$1,454.9
2037	165	27	33	82	$1,656.4
2038	185	31	37	92	$1,858.2
2039	204	34	41	102	$2,055.1
2040	224	37	44	111	$2,247.5
Total	**1448**	**237**	**283**	**728**	**$14,553.7**

2.4.2 Social Cost of Carbon

Table 13 summarizes the estimated WTW GHG emissions from the proposed regulation, in units of MMT of CO_2 per year. Staff expects the proposed regulation to reduce cumulative

WTW GHG emissions by an estimated 453.4 MMT of CO_2 relative to the baseline from 2026 to 2040.

The proposed regulation is expected to result in significant GHG emission reductions, due to replacing ICEVs with ZEV technologies. The benefit of these GHG emission reductions can be estimated using the social cost of carbon (SC-CO_2), which provides a dollar valuation of the damages caused by one ton of carbon pollution, and represents the monetary benefit today of reducing carbon emissions in the future.

In the analysis of the SC-CO_2 for the proposed regulation, CARB utilizes the current Interagency Working Group (IWG)-supported SC-CO_2 values to consider the social costs of actions taken to reduce GHG emissions. This is consistent with the approach presented in the Revised 2017 Climate Change Scoping Plan, is in line with U.S. Government Executive Orders including 13990 and the Office of Management and Budget's Circular A-4 of September 17, 2003, and reflects the best available science in the estimation of the socio-economic impacts of carbon.[45,46]

IWG describes the social costs of carbon as follows:

> *The SC-CO_2 for a given year is an estimate, in dollars, of the present discounted value of the future damage caused by a 1-metric ton increase in CO_2 emissions into the atmosphere in that year or, equivalently, the benefits of reducing CO_2 emissions by the same amount in that year. The SC-CO_2 is intended to provide a comprehensive measure of the net damages – that is, the monetized value of the net impacts from global climate change that result from an additional ton of CO_2.*
>
> *Those damages include, but are not limited to, changes in net agricultural productivity, energy use, human health, property damage from increased flood risk, as well as nonmarket damages, such as the services that natural ecosystems provide to society. Many of these damages from CO_2 emissions today will affect economic outcomes throughout the next several centuries.*[47]

The SC-CO_2 is year-specific, and is highly sensitive to the discount rate used to discount the value of the damages in the future due to CO_2. The SC-CO_2 increases over time as systems become more stressed from the aggregate impacts of climate change and as future emissions cause incrementally larger damages. This discount rate accounts for the preference for current costs and benefits over future costs and benefits, and a higher discount rate decreases the value today of future environmental damages. While the proposed regulation

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[45] California's 2017 Climate Change Scoping Plan, 2017 (web link: https://ww2.arb.ca.gov/sites/default/files/classic//cc/scopingplan/scoping_plan_2017.pdf, accessed May 2021).

[46] Office of Management and Budgets, Circular A-4, 2003 (web link: https://www.transportation.gov/sites/dot.gov/files/docs/OMB%20Circular%20No.%20A-4.pdf, accessed May 2021).

[47] National Academies of Sciences, Engineering, Medicine, Valuing Climate Damages: Updating Estimation of Carbon Dioxide, 2017 (web link: http://www.nap.edu/24651, accessed May 2021).

cost analysis does not account for any discount rate, this social cost analysis uses the IWG standardized range of discount rates from 2.5 to 5 percent to represent varying valuation of future damages. Table 17shows the range of IWG SC-CO_2 discount rates used in California's regulatory assessments, which reflect the societal value of reducing carbon emissions by one metric ton.[48]

Table 17: SC-CO_2 by Discount Rate (in 2020$ per Metric Ton of CO_2)

Year	5% Discount Rate	3% Discount Rate	2.5% Discount Rate
2020	$16	$55	$81
2025	$21	$66	$96
2030	$21	$66	$96
2035	$24	$72	$102
2040	$28	$79	$110

The avoided SC-CO_2 from 2026 to 2040 is the sum of the annual WTT and TTW GHG emissions reductions multiplied by the SC-CO_2 in each year. The cumulative WTW GHG emissions reductions along with the estimated benefits from the proposed regulation are shown in Table 18. These benefits range from about $10.9 billion to $46.0 billion through 2040, depending on the chosen discount rate.

[48] Interagency Working Group on the Social Cost of Carbon, Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 13990, 2021 (web link: *https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf*, last accessed May 2021).

Table 18: Avoided Social Cost of Carbon for the Proposed Regulation

Year	GHG Emission Reductions (MMT)	Avoided SC-CO2 (Million 2020$) 5% Discount Rate	Avoided SC-CO2 (Million 2020$) 3% Discount Rate	Avoided SC-CO2 (Million 2020$) 2.5% Discount Rate
2026	1.0	$18	$62	$91
2027	2.7	$53	$170	$248
2028	5.1	$100	$328	$475
2029	8.0	$157	$514	$756
2030	11.5	$241	$755	$1,102
2031	16.1	$338	$1,077	$1,563
2032	21.3	$475	$1,453	$2,096
2033	26.7	$596	$1,857	$2,663
2034	32.5	$768	$2,303	$3,284
2035	38.6	$912	$2,786	$3,951
2036	44.6	$1,112	$3,277	$4,624
2037	50.2	$1,252	$3,755	$5,336
2038	55.6	$1,459	$4,232	$5,983
2039	60.6	$1,590	$4,692	$6,600
2040	65.4	$1,802	$5,149	$7,209
Total	**439.9**	**$10,875**	**$32,411**	**$45,980**

3 Direct Costs

The proposed ACC II regulation will require manufacturers to produce and sell new vehicles that initially will have a higher incremental cost than the baseline (i.e., without the regulation) for most vehicle classifications. This incremental cost will come from both complying with the ZEV requirements, which affect passenger cars and light-duty trucks, and from the LEV requirements, which affect passenger cars, light-duty trucks, and MDVs. The direct costs to the vehicle manufacturers for complying with the regulation are presented in section 3.1 and divided into 3 main parts: cost of compliance with the ZEV proposal, the cost of compliance with the LEV proposals, and aggregate costs for the California fleet. In section 3.2 direct costs of ownership are presented for the end-user. Although currently there are a number of rebate and incentive programs in California that can offset some of the incremental cost of cleaner vehicles, none of these are included in the cost analysis (refer to section 3.5.1 below for further discussion). In subsequent sections, the costs are presented for typical and small businesses and for individuals considering total cost of ownership for these vehicles.

3.1 Direct Cost for Vehicle Manufacturers

The estimated direct costs from the Proposed Regulation will come from the regulated party, or the vehicle manufacturer, complying with each provision outlined in Section 3.1.1 for the ZEV regulation and Section 3.1.2 for the LEV regulation and costs associated with meeting each provision. In this section, staff will first provide the basis of the estimated incremental cost for each vehicle in each model year by technology for ICEVs, BEVs, PHEVs, and FCEVs.

These technologies will then be assigned to the California fleet mix to determine the estimated fleet compliance cost for the timeframe of the regulation. The total costs to the manufacturer to comply with the suite of proposed regulations through 2040 is $51.8 billion cumulatively, and is presented in Section 5.1.4.

3.1.1 Compliance Cost for the ZEV Regulation

In addition to the LEV proposal costs as it applies to the light-duty fleet, manufacturers will also incur the cost of meeting staff's ZEV proposals. The cost of complying with the proposed ZEV regulation can be broken into two parts: (1) the cost of complying with the vehicle percentage requirements for the fleet, shown in Table 2 and (2) the cost to comply with the ZEV assurance measures, described Section 3.1.1.4.

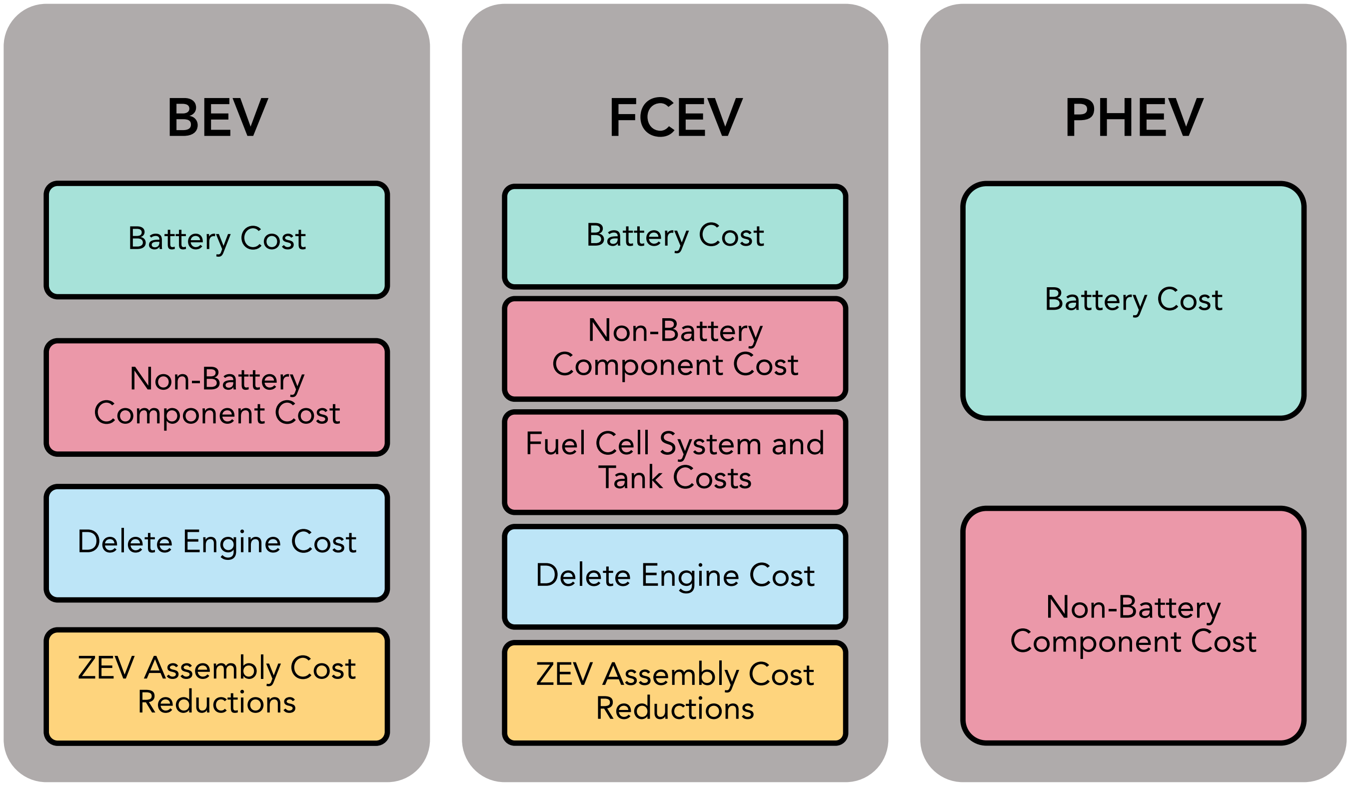
3.1.1.1 Cost to Comply with the vehicle percentage requirement

As described in section **Section 2.2.2**, manufacturers must annually produce an increasing minimum percentage of their fleet that are ZEVs and PHEVs that meet specific requirements. To calculate costs to manufacturers to comply with the ZEV regulation, it is assumed that manufacturers produce a BEV, FCEV or PHEV instead of an ICEV. Staff's compliance scenario assumes manufacturers will comply by applying the lowest cost technology packages available in each year that are still able to meet the performance requirements of each vehicle segment. This section will describe estimated costs for technology packages available during the regulatory timeframe.

3.1.1.2 ZEV Component Cost Assumptions

ZEV technology package costs described below are considered relative to a vehicle where a traditional baseline ICE powertrain is removed. The incremental cost is therefore determined by adding battery costs and non-battery ZEV component costs, while subtracting the costs associated with a compliant ICE (i.e. delete engine costs) and additional cost reductions for ZEV assembly (for BEVs and FCEVs only), as summarized in **Figure 7** below. Fixed costs of production like capital equipment are inherent and passed down through to the costs of development of each subsystem.

Figure 7. Incremental Cost Categories for BEVs, FCEVs, and PHEVs



a. <u>Battery Costs</u>

Battery costs, here for the traction battery that provides the power to move the vehicle, represent the largest portion of BEV technology incremental costs, and a significant portion of PHEV and FCEV technology incremental costs. Recent findings indicate a continuing trend of declining battery costs. Bloomberg New Energy Finance (BloombergNEF) industry surveys indicate that prices of automotive battery packs were $137/kWh by the end of 2020, representing a nearly 90 percent decline from 2010.[49] Additional analyses from BloombergNEF project that average battery pack costs for the transportation sector may reach as low as $101/kWh by 2023 and $58/kWh by 2030, but those analyses include less energy dense batteries used in the heavy-duty sector, where packaging volume or range may not be some of the primary design criteria as is the case for light-duty vehicles.[50] The National Academies of Sciences (NAS), a panel of academics, scientists, engineers, and other experts in the field, released an assessment of battery costs expecting automotive battery

[49] Bloomberg New Energy Finance (BloombergNEF) 2020 EV Outlook and Battery Price Survey. (web link: https://about.bnef.com/electric-vehicle-outlook-2020/)
[50] BloombergNEF 2020 Battery Price Survey

pack costs to decrease to $90-$115/kWh by 2025 and $65-$80/kWh by 2030. [51] Researchers credit falling prices to improved and simplified battery cell and pack designs, introduction of new battery chemistries, and new manufacturing techniques in addition to increasing production volumes.[52] [53] Staff developed battery pack costs of $95.3/kWh in 2026 and $72.5/kWh in 2030 using the midpoint presented in the NAS study due to the robustness and transparency of the analysis.[54]

Usable battery energy as a function of total, or gross, battery energy has been set to 95% rather than 97% or higher utilized by some current market leading products to account for improved future battery durability by staff. Lowering the usable battery energy percentage keeps the cells further from their upper and lower voltage bounds where accelerated degradation can take place. The midpoint costs of the NAS battery cost windows, as opposed to the minimum, was also used to capture potential costs associated with improving battery durability to meet staff's proposed ZEV assurance measures. Beyond 2030, projections are more difficult to identify based on current literature and technology. Therefore, staff applied a 5% year-over-year reduction from 2030 to 2035 based on best engineering judgment to get the resulting pack costs. Advanced lithium-ion batteries such as solid-state cells with lithium metal anodes could accelerate those cost reductions after 2030, but the technical feasibility of advanced technologies manufactured at the large scale that would be required has yet to be conclusively demonstrated by the industry. Thus, these cost estimates, though reasonable and well within the mid-range of available evidence, will continue to be reviewed as industry continues its efforts and may ultimately be lower if advanced technologies come online. The resulting battery pack costs assumptions for these technologies are presented in Table 19.

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[51] National Academies of Sciences, Engineering, and Medicine. 2021. Assessment of Technologies for Improving Light-Duty Vehicle Fuel Economy—2025-2035. Washington, DC: The National Academies Press. *https://doi.org/10.17226/26092*.
[52] BloombergNEF 2020 Battery Price Survey
[53] National Academies of Sciences, Engineering, and Medicine. 2021.
[54] Battery pack costs are representative of the direct manufacturing costs for each ZEV technology's battery pack for each year of the regulation and are inclusive of everything contained within that pack. The pack includes thermal systems and hook ups, battery management system components contained within the pack, and connectors and wiring internal to the pack.

Table 19. Battery Pack Costs in ($/kWh) for BEVs, PHEVs, and FCEVs for Model Years 2026 through 2035

	Model Year									
Technology	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
BEV	95.3	88.7	82.4	76.7	72.5	68.9	65.4	62.2	59.1	56.1
PHEV	133.5	124.1	115.4	107.3	101.5	96.4	91.6	87.0	82.7	78.5
FCEV*	832.8	824.5	816.2	808.1	800.0	792.0	784.1	776.2	768.5	760.8

* FCEV battery packs have much less total energy capacity, yet similar power demands to BEV and PHEV battery packs. This results in much higher power to energy ratios similar to conventional HEV battery packs which make specific costs much higher than BEV or PHEV battery packs.[55] Due to the small total energy capacity of FCEV battery packs, their total cost is much less than BEV or PHEV battery packs.

PHEV battery pack costs are assumed to be roughly 40% higher than BEV pack costs on a dollar per kWh basis. This assumption is based on findings from the 2017 Total Battery Consulting xEV Insider Report authored by globally recognized battery industry expert Dr. Menahem Anderman.[56] Dr. Anderman has provided expert testimony to CARB previously. The report draws upon industry supplied information and is backed by Dr. Anderman's extensive analyst experience to project future battery costs. Those costs are shown at a very granular level including things like cathode, anode, electrolyte costs, etc. FCEV battery packs are based on the Argonne National Laboratory (ANL) Autonomie Report and are put into the same cost format as the PHEV and BEV battery pack costs.[57]58

b. <u>Non- Battery Component Costs</u>

Non-battery components include the electric motor and gearbox, and the inverters associated with those electric motors. The list also includes the DC-DC converter, high voltage cabling and control unit, the on-board charger, additional thermal management components, and an included convenience charging cord set that meets staff's proposed requirements. Non-battery component costs are applied to each ZEV technology

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[55] Green Car Congress (November 18, 2014): *https://www.greencarcongress.com/2014/11/20141118-mirai.html*

[56] Total Battery Consulting (TBC) 2017 xEV *Insider Report (https://www.totalbatteryconsulting.com/industry-reports/xEV-report/overview.html)*

[57]Energy Consumption and Cost Reduction of Future Light-Duty Vehicles through Advanced Vehicle Technologies: A Modeling Simulation Study Through 2050, Argonne National Labs, ANL/ESD-19/10 (https://www.autonomie.net/publications/fuel_economy_report.html)

[58] ANL Autonomie, 2020 battery pack sizes are used for FCEVs, because CARB is using the fully modeled fuel cell systems from the ANL Autonomie report and those battery packs are specifically sized for those fuel systems to provide the modeled performance.

combination either as a variable cost based on the motor power (kW) or as a fixed cost applied per motor. Cost curves and/or fixed costs were developed using the best-in-class cost estimates from teardown studies.[59] These studies showed that the leading manufacturers on both cost and performance were taking an integrated approach to designing and manufacturing their non-battery components, such that many components are consolidated into shared housings, or even shared circuit boards. To incorporate this finding, costs need to account for electric motor, housing with heavily integrated power electronics, and the rest of the supporting items like cabling and cooling components. These costs are summarized in Table 20 below.

[59] Munro & Associates, Inc. Tesla Model 3 Cost Analysis – available at https://leandesign.com/, Munro & Associates, Inc. Tesla Model 3 Side-by-Side Analysis – available at https://leandesign.com/, UBS Evidence Lab Electric Car Teardown – Disruption Ahead?, 18 May 2017, https://neo.ubs.com/shared/d1wkuDlEbYPjF/, Munro & Associates, Inc. Twelve Motor Teardown and Benchmark Study – available at https://leandesign.com/ , Munro & Associates, Inc. Inverter Benchmark & Cost Study – available at https://leandesign.com/, Munro & Associates, Inc. Tesla Model Y Benchmark Report – available at https://leandesign.com/

Table 20. Summary of Non-battery Component Costs

Nominal component set	Tech Application (Yes/No)				Variable Cost $/x	Fixed cost	Scale by (x)
	BEV	PHEV Car-Based	PHEV Truck-Based	FCEV			
Traction motor (PMSM)[13]	Yes	Yes	Yes	Yes	$3.60		Motor kW
Traction motor (Induction) Dual motor only[13]	Yes	Yes	N	Yes	$2.10		Motor kW
Rest of motor (PMSM)[13]	Yes	No*	No*	Yes		$1.10	Multiplier
Rest of motor (Induction) Dual motor only[13]	Yes	No*	No	Yes		$1.30	Multiplier
Single-speed gearbox[13]	Yes	AWD	No	Yes		$400	-
Traction inverter (IGBT)[14]	No	Yes	No	No	$2.50		Motor kW
Traction inverter (Si-C)[14]	Yes	No	No	Yes	$3.80		Motor kW
Integrated onboard AC charger[10,11,12,15]	Yes	Yes	Yes	No	$62	$765	OBC kW
Integrated onboard DCFC circuitry[10,11,12,15]	Yes	No	No	No		$150	-
Integrated DC-DC converter[10,11,12,15]	Yes	Yes	Yes	Yes		$405	-
Integrated housing + other[10,,11,12,15]	Yes	Yes	Yes	Yes		$65	-
Integrated HV controller	Yes	Yes	Yes	Yes		$185	-
HV "orange cables"	Yes	Yes	Yes	Yes		$180	-
Powertrain cooling	Yes	Yes	Yes	Yes		$300	per motor
Second motor HV cables	Yes	Yes	No	Yes		$25	
Charging cord and adapters[10,11,12,15]	Yes	Yes	Yes	No		$200	-

*- Does not apply to single electric motor PHEV applications. The electric motor is integrated into the ICE powertrain. Does apply to second electric motor in dual motor, eAWD applications.

Electric motor power, i.e. a motor's kW, is one of the more influential specifications on non-battery costs. Electric motors are costed in two forms, Permanent Magnet Synchronous Machines (PMSM) and AC Induction (Induction), that typically correspond to vehicle design across all BEVs, FCEVs, and PHEVs. PMSMs are assigned to single motor applications. In dual motor, eAWD applications, the second motor is an induction machine, and the first motor remains a PMSM. Costs of the motors are scaled on a per kilowatt basis. Each motor is assigned a fixed cost for the single-speed gearbox and case that must house the motor along with supporting powertrain cooling. Car and truck based single motor PHEVs, and truck-based 4WD PHEVs do not add the gearbox cost, because the electric motors are integrated into those vehicles' ICE powertrains and a second electric motor is not necessary to make the vehicle 4WD capable. Single electric motor applications use silicon carbide (SiC) based inverters, and eAWD dual motor applications add an insulated-gate bipolar transistor (IGBT) based inverter to power the second, induction motor. Inverter costs are scaled on a per kilowatt basis. Lastly, each electric motor includes an additional fixed cost for cooling.

The integrated penthouse includes the integrated onboard AC charger, onboard DCFC circuitry and CCS inlet, HV controller, and housing plus other ancillary components. All four of those components are assigned fixed costs except for the onboard AC charger, which includes a cost component that scales on the power to a vehicle's battery size such that the vehicle is capable of charging in 8 hours on a level 2 EVSE. The other supporting fixed cost items includes the convenience charging cord and adapters, the high voltage "orange cables," and second motor high voltage cables and additional powertrain cooling in dual electric motor applications.

c. Fuel Cell and Hydrogen Storage Tank System Costs

Fuel cell and hydrogen storage tank system costs for FCEVs were based on cost studies and methodologies in ANL's 2020 publication[60] and analysis developed by staff at Strategic Analysis. ANL, in partnership with manufacturers and suppliers, has long been at the forefront of automotive fuel cell vehicle research. Strategic Analysis is a long-standing consultant to the United States Department of Energy on FCEV cost projections and annually publishes authoritative estimates of system costs. Strategic Analysis studies and ANL's Autonomie model are research efforts funded by US DOE to capture accurate pictures of current technology status and vetted methods for projecting future advancements.

FCEVs are very early in their commercial development with significant remaining opportunity for future cost reduction due to economies of scale and technology advancement. Accurate estimates of present and future costs for fuel cell and hydrogen storage systems need to reflect cost reductions that will occur as more FCEVs are produced each year and more advanced manufacturing processes and FCEV technology is developed.

CARB based its FCEV cost analysis on a methodology that accounts for present-day costs and both mechanisms of future cost reductions, based on the authoritative ANL and Strategic Analysis references. ANL's analysis implements the Autonomie[61] vehicle modeling platform and provides estimates of vehicle design, fuel efficiency, and cost of several types of light-duty vehicles in future years. The ANL analysis models cost reductions due to technology improvement but does not account for cost reductions due to growing production volume in future years. On the other hand, the Strategic Analysis model accounts

[60] ANL 2020, Energy Consumption and Cost Reduction of Future Light-Duty Vehicles through Advanced Vehicle Technologies: A Modeling Simulation Study Through 2050" *https://www.autonomie.net/publications/fuel_economy_report.html*

[61] Autonomie is a computer model for assessing the energy consumption and cost of multiple advanced powertrain technologies, developed by ANL and partners. Refer to: *https://www.anl.gov/es/autonomie-vehicle-system-simulation-tool*, Autonomie Vehicle System Simulation Tool | Argonne National Laboratory (anl.gov) for more information.

for cost reductions due to growing production volume but does so only for present-day state-of-the-art technology. In addition, the Strategic Analysis model provides present-day costs for high-durability fuel cells, which are not addressed by the ANL analysis.

CARB's cost estimation process begins with identifying vehicle specifications as determined by the Autonomie model for each vehicle class in model years 2025, 2030, and 2035. The primary data parameters provided by the Autonomie model include the fuel cell system power (in kilowatts) and hydrogen storage system size (in kilograms of hydrogen). These are defined for each vehicle class in each model year for 2025, 2030, and 2035. Data for model years between those provided by Autonomie were evaluated according to simple linear interpolation. Over time this model assumes the vehicles become lighter and require a smaller tank; therefore, the tank and fuel cell stack gets slightly smaller. Fuel cell system power and hydrogen fuel tank size for all vehicles in all years are shown in Table 21 and Table 22, respectively, and are based on the Autonomie results for the "Premium" version of each vehicle.[62]

Table 21: Fuel Cell System Power (kW)

Vehicle Type	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Small Car	88	87	86	85	83	82	82	81	80	79
Medium Car	131	129	126	124	121	118	117	115	113	111
Small SUV	123	121	119	118	116	115	113	112	110	109
Medium SUV	139	137	135	133	131	129	127	126	124	122
Pickup	162	159	156	153	150	148	146	144	142	140

[62] Premium FCEV versions were used from the ANL Autonomie work, because the base versions were underpowered relative to existing and future expected FCEV models and the premium versions are more representative of existing and future FCEVs.

Table 22: Hydrogen Fuel Tank Size (Kg)

Vehicle Type	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Small Car	4.4	4.3	4.3	4.2	4.1	4.0	3.9	3.8	3.7	3.6
Medium Car	5.0	4.9	4.8	4.7	4.6	4.5	4.4	4.2	4.1	4.0
Small SUV	5.6	5.5	5.4	5.3	5.2	5.1	4.9	4.8	4.7	4.5
Medium SUV	6.2	6.1	6.0	5.9	5.9	5.7	5.5	5.4	5.2	5.0
Pickup	7.3	7.2	7.1	7.0	6.8	6.7	6.5	6.3	6.1	5.9

Cost for present-day technology, which is equivalent to a model year 2025 FCEV, were evaluated by combining the Strategic Analysis cost model with Autonomie vehicle data. Including the Strategic Analysis model requires an estimation of annual FCEV production rates. CARB developed a growth projection for the number of FCEVs produced for model years 2025 to 2035. CARB's projection begins with an annual production volume of 20,000 FCEVs per manufacturer in 2025 that grows linearly to 50,000 FCEVs per manufacturer in 2030 and expands to 100,000 FCEVs per manufacturer in 2035. The 2025 annual production rate in this projection was based on known current FCEV production capacities at individual manufacturers' facilities. The rate of future growth in annual FCEV production was developed to match well with projections of future on-the-road FCEVs, including iterative evaluation to match with ACC II fleetwide projections.

Autonomie data (which are not corrected for production volume and high-durability fuel cells) demonstrate cost reductions over time due to technology advancement. CARB analyzed the cost reduction trends in the Autonomie data (for the "High Technology" improvement case in that reference) and found that cost reductions due to technology advancement follow a simple two-step linear model. Between model years 2025 and 2030, fuel cell system costs decrease at a rate of $2/kW per year. Afterward, fuel cell system costs decrease at a rate of $0.51/kW per year. Cost reductions for the hydrogen storage system are also simple linear functions of time but are also dependent on the total amount of hydrogen stored. This represents a strong dependence on economies of scale, as larger storage tanks require more raw materials and contribute more strongly to reducing the cost of these materials.

Costs for future FCEVs were then evaluated by first calculating costs in model years 2030 and 2035, then linearly interpolating for the intervening years. For example, model year 2030 FCEV costs were calculated by assuming the parameters shown in Table 21 and Table 23 and an annual production volume of 50,000 FCEVs, per the CARB-defined annual production estimate. These values were then incorporated into a modified version of the Strategic Analysis cost model. The modified cost model assumed the Strategic Analysis 2025 high-durability cost for FCEV systems (at 50,000 FCEVs per year) was reduced annually to 2030 due to technology advancement according to the Autonomie-derived rates. The same process was completed for model year 2035 FCEVs at a production rate of 100,000 per year and linear interpolation was used for intervening model years. The resulting fuel cell and hydrogen storage system costs are shown in and Table 24, respectively.

Table 23: Fuel Cell System Cost ($/vehicle)

Vehicle Type	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Small Car	6,842	6,315	5,801	5,298	4,806	4,632	4,461	4,292	4,125	3,960
Med Car	9,523	8,692	7,886	7,106	6,352	6,113	5,878	5,648	5,422	5,201
Small SUV	8,801	8,077	7,370	6,679	6,003	5,795	5,590	5,389	5,192	4,997
Med SUV	10,477	9,630	8,803	7,998	7,213	6,945	6,682	6,423	6,169	5,920
Pickup	13,977	12,925	11,902	10,909	9,946	9,520	9,101	8,690	8,287	7,892

Table 24: Hydrogen Tank Cost ($/vehicle)

Vehicle Type	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Small Car	2,818	2,565	2,312	2,058	1,805	1,738	1,672	1,605	1,538	1,471
Med Car	3,035	2,751	2,468	2,185	1,901	1,827	1,753	1,678	1,604	1,529
Small SUV	3,211	2,912	2,613	2,314	2,016	1,937	1,858	1,780	1,701	1,623
Med SUV	3,439	3,113	2,787	2,461	2,135	2,050	1,965	1,880	1,794	1,709
Pickup	3,813	3,441	3,069	2,697	2,325	2,231	2,137	2,044	1,950	1,856

d. Delete Engine costs

ZEV manufacturers can save money by avoiding the costs of internal combustion engine manufacture. These “Delete engine costs,” or the avoided cost to manufacturers from a vehicle not using an internal combustion engine, fall into two categories: (1) Avoided engine and transmission costs, and (2) avoided cost of compliance with existing LEV III criteria and GHG regulations.

Engine and Transmission Removal Costs for BEV and FCEV

Developing ZEV technology cost packages that are incremental to ICEV technologies requires accounting for the ICE cost and removing that from the total ZEV package cost. ICEs remain in PHEVs, so this cost reduction only applies to BEVs and FCEVs.

The basis for the Engine and Transmission removal costs are the 2018 NHTSA CAFE Model technology input costs, and EPA estimates.[63] [64] For car-based vehicle classes (small car, medium/large car, and medium SUVs), a base 2015 model year inline 4-cylinder dual overhead cam (DOHC) engine was used. For the truck-based SUVs and pickups, a base 2015 model year DOHC V8 was used. Model year 2015 is used as the basis, because it allows the for the application of the avoided GHG emissions cost estimates in 2026MY from ACC I to be applied as a simple, single value to the engine and transmission costs estimated by NHTSA and EPA for that model year. Other model years would require more complex accounting with no added benefit. The estimated costs are comprehensive and include all the associated components, such as fuel tanks, lines, and calibration costs. The transmission cost presumed for both vehicle classes is for a 5-speed automatic transmission. The values are listed inTable 25.

Current LEV III Criteria and GHG Emissions Costs

Estimated Advanced Clean Cars I LEV III criteria pollutant compliance costs are found in the 2012 ISOR for 2025 model year vehicles.[65] The removal of those costs has been applied to BEVs and FCEVs and are assumed to be the same fixed cost from model years 2025 to 2035. The costs were converted to 2021 dollars from 2010 dollars such that the car-based cost is a fixed $68.00, and the truck-based cost is a fixed $145.66.

The GHG compliance costs from the Advanced Clean Cars I LEV III GHG are also avoided with ZEV technologies. These costs are determined to be $965 in 2021 dollars for 2025 model year vehicles and beyond and are applied to all ZEV technology combinations from 2025 to 2035 model years.

Table 25. Summary of ZEV Delete Costs ($)

Cost Reduction Category	Applies to BEVs	Applies to FCEV	Applies to PHEV	Cost Reduction Car based (2021$)	Cost Reduction Truck based (2021$)
ICE Removal	Yes	Yes	No	-$3500	-$5000
Transmission Removal	Yes	Yes	No	-$1500	-$2000
LEV III Criteria Compliance	Yes	Yes	No	-$68	-$145
Current GHG Compliance	Yes	Yes	Yes	-$965	

[63] US DOT NHTSA CAFE Compliance and Effects Modeling System, Technology input file retrieved from: https://www.nhtsa.gov/filebrowser/download/178091
[64] Safoutin, 2018, Predicting Powertrain Costs for Battery Electric Vehicles Based on Industry Trends and Component Teardowns, U.S. EPA
[65] 2012, CARB ISOR ACC I https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2012/leviiighg2012/levisor.pdf
[66] Conversion factor reference

e. ZEV Assembly Cost Reductions

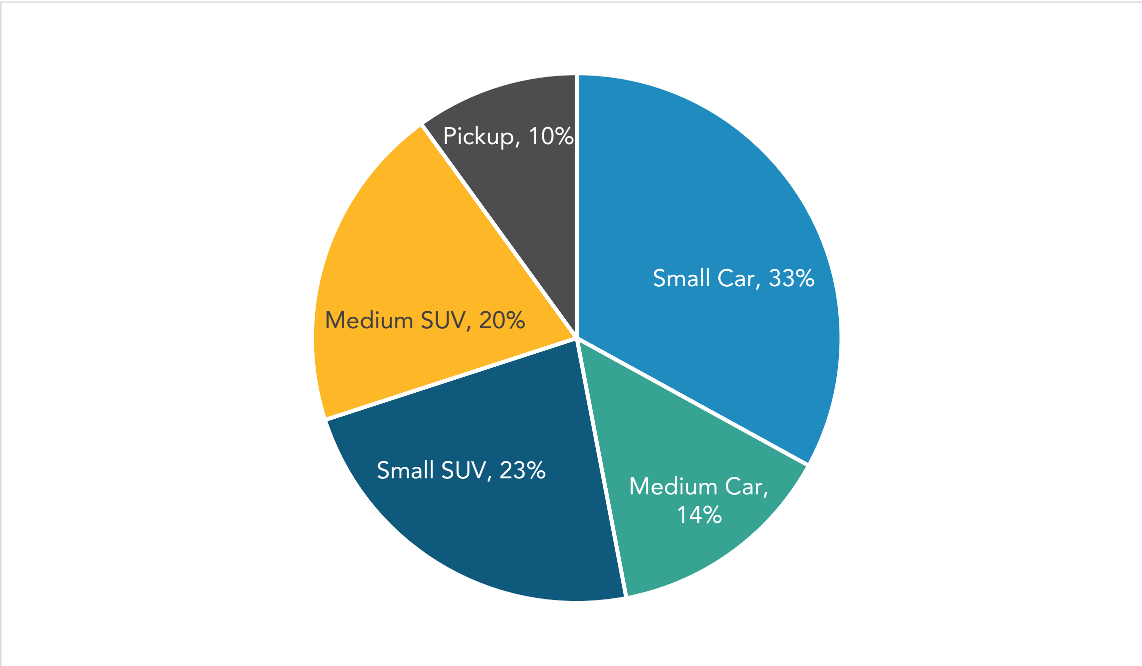
ZEV assembly cost reductions are cost savings due to a less complex assembly process and lower associated Research and Development and logistical costs for ZEV technologies starting in 2025. These costs are subtracted from each technology package. The International Council on Clean Transportation's work on incremental BEV costs found a total of $1600 in cost reduction for BEVs due to their lower complexity, and that reduction has been applied to BEVs in this analysis.[67] FCEVs, while more complex than BEVs, are still simpler to assemble than conventional ICEVs and are assigned half the cost reduction assigned to BEVs, which is $800.

3.1.1.3 ZEV Technology Package Assumptions

Taking the component costs for [explain or list what these are – the reader will not recall from the cross-reference], outlined in Section 3.1.2.2, staff looked at the baseline vehicle types to develop technology packages for various vehicle types, and across different performance specifications. These technology packages were developed, and costs determined for each model year of the regulation and by vehicle type in **Figure 8** below. The basis for these vehicle type splits was MY 2017 California sales data provided by manufacturers for the purpose of allowing CARB staff to track compliance with California GHG regulations. This will be updated for the analysis in the ISOR with 2019 data.

[67] Lutsey, N., Nicholas, M., 2018, Electric Vehicle Costs and Consumer Benefits in Colorado in the 2020-2030 Time Frame, ICCT, Electric vehicle costs and consumer benefits in Colorado in the 2020–2030 time frame (theicct.org)

Figure 8. Market Split by Vehicle Type



A set of ZEV technology packages were developed for these vehicle types that include base and extended range BEV, FCEV, and PHEV options. To ensure that the ZEV technologies address the majority of the expectations of consumers in the market, additive packages were created that included eAWD, cold weather, and towing packages for the appropriate ZEV technology. Those ZEV packages are shown in Table 27 for model year 2026.

Table 26. MY2026 ZEV Technology Packages

Package	BEV	FCEV	$PHEV_{car}$	$PHEV_{truck}$
Base	300-mile range	320-mile range	50-mile all-electric range	
Extended Range	400-mile range			
eAWD/4WD	additional electric motor at the undriven axle and all necessary componentry			N/A[68]
Cold weather (10% of the fleet)	More efficient heat pump and additional battery heating components	N/A	N/A	N/A
Towing (6% of the fleet)	440 mile trip range[69]	N/A	N/A	N/A

Surveys of prospective buyers show they desire vehicles with longer electric ranges.[70] Most current electric passenger vehicles have EPA label ranges[71] of between 250 and 350 miles.[72] Several announcements and recently certified vehicles from various manufacturers indicate identified ranges of approximately 400 miles or even higher.[73] Accordingly, staff assume that base BEVs in 2026 and beyond will average out to 300 miles of range. Lower range would result in cheaper vehicles and lower direct costs to the manufacturers; however, for this analysis a more reasonable and conservative range of 300 miles was used. PHEV all-electric range stays fixed at 50 miles from 2026 through 2035, because the engines provide the desired range.

Targets for range and power were developed from an assessment of current ZEVs and future expected technical feasibility. Resultant vehicle mass, battery capacity, power, and efficiency for each technology package is assessed from existing BEV and PHEV models to help size

[68] Larger PHEV SUVs and pickups do not require an additional motor, because it is assumed that many will utilize a P2 style electric drive system. P2 electric motors reside in a conventional transmission and can operate the vehicle electrically through a conventional truck based 4-wheel drive system removing the need for a second electric motor.

[69]Assuming towing load cuts efficiency in half and only requires one 20-minute charging stop at a fast-charging station that is able to provide 350kW charging.

[70] Consumer Reports (December 18, 2020) *https://www.consumerreports.org/hybrids-evs/cr-survey-shows-strong-interest-in-evs-a1481807376/*

[71] The all-electric range listed on the EPA Monroney fuel-economy label

[72] U.S. DOE Vehicle Technologies Office (January 4, 2021) *https://www.energy.gov/eere/vehicles/articles/fotw-1167-january-4-2021-median-driving-range-all-electric-vehicles-tops-250*

[73] General Motors (January 5, 2022) *https://media.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2022/jan/ces/0105-2024-silverado.html*; Lucid Motors (September 16, 2021) https://www.lucidmotors.com/stories/lucid-air-achieves-520-miles-of-range

specific ZEV components. FCEV component sizing comes from ANL's 2020 publication[74] as explained in section 3.1.2.2c. Where existing models are not available in a vehicle class, the National Renewable Energy Laboratory's (NREL) Future Automotive Systems Technology Simulator (FastSim) tool was used to convert existing conventional vehicles to a BEV or PHEV technology and size the ZEV components.[75] NREL's FastSim tool is an effective and efficient tool to quickly model vehicle fuel economy and performance and has been validated against real world vehicles.[76] Those specific components, such as the battery, the electric motor and gearbox, inverters, DC-DC converters, on-board chargers, and other non-battery components are costed according to the cost criteria shown in Table 20.

Recognizing that the base ZEV and PHEV technologies are not fully representative of consumers' preferences for certain technology attributes, staff developed additional technology packages that are added on top of the base PHEVs, BEVs, and FCEVs to meet the needs of 100% of California drivers. The additive technology packages include electric AWD/4WD, cold weather, and towing options.

PHEVs and FCEVs do not require additional technology for operation in colder weather due to their additional waste heat from fuel combustion that can be utilized. PHEVs and FCEVs can fully refuel quickly and do not require the additional range for towing that is applied to BEVs in the form of a tow package.

To put this into context, Table 27is an example of how these component costs are then added to make a small car package in 2026.

Table 27: Component Costs and Total Incremental Costs, for a Small Car in 2026 MY ($)

Cost Category	BEV300	BEV400	PHEV	FCEV
Battery Cost	$6,889	$9,385	$2,273	$1,170
Non-Battery Cost	$3,983	$4,343	$2,331	$2,259
Fuel Cell Stack and Tank Cost	$0	$0	$0	$9,660
Delete Engine Costs	-$6,033	-$6,033	-$965	-$6,033
ZEV Assembly Cost Reductions	-$1,600	-$1,600	$0	-$800
Total Incremental Cost	**$3,239**	**$6,095**	**$3,639**	**$6,256**

For the incremental ZEV package costs for all ZEV technology over all years of the regulation, refer to Appendix A.

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[74] ANL 2020, "Energy Consumption and Cost Reduction of Future Light-Duty Vehicles through Advanced Vehicle Technologies: A Modeling Simulation Study Through 2050" *https://www.autonomie.net/publications/fuel_economy_report.html*

[75] Brooker, A., Gonder, J., Wang, L., Wood, E. et al., "FASTSim: A Model To Estimate Vehicle Efficiency, Cost, and Performance," SAE Technical Paper 2015-01-0973, 2015, doi:10.4271/2015-01-0973.

[76] Baker, Chad, Matthew Moniot, Aaron Brooker, Lijuan Wang, Eric Wood, and Jeffrey Gonder. 2021. Future Automotive Systems Technology Simulator (FASTSim) Validation Report – 2021. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400- 81097. (web link: *https://www.nrel.gov/docs/fy22osti/81097.pdf*)

3.1.1.4 ZEV Assurance Costs

The proposed ACC II regulations will require BEVs, FCEVs, and PHEVs to meet a suite of ZEV assurance measures, which include requirements related to durability, battery warranty, battery labeling, service information, on-board data standardization, charging standardization, and convenience cords. Most of these costs are incurred in the technology packages cost of these measures will affect vehicle manufactures differently if they only produce ZEVs today because they are currently not subject to these requirements and manufactures who currently meet these requirements with ICEVs. For ZEV-only manufacturers that are not subject to requirements to ensure the integrity and durability of emission control systems on conventional engines, there will be some additional recordkeeping and reporting costs due to these proposals, as well as costs added for staff's battery labeling proposal. Manufacturers that have produced ICEVs historically would continue to incur these costs for all their vehicles, whether powered by conventional engines or ZEV technology, and thus would not incur increased costs for ZEVs.

1. **Costs Accounted for in Technology Packages**

As noted in the battery cost assumptions, the proposal accounts for other measures manufacturers are expected to take to comply with both this durability proposal and the warranty proposal. Specifically, the sizing (and thus the cost) of battery packs for BEVs assumed a usable battery energy of 95 percent of the nominal battery capacity rather than utilizing 97 percent as being used by some industry leaders[77].

The proposed durability standard requires 70 percent or more of a manufacturer's vehicles to meet the requirements and allows for vehicles that have been subject to unusual usage to be excluded when testing for compliance. The majority of BEVs currently offered for sale are expected to comply with this proposal, incurring no additional costs. Public data from Tesla shows vehicles introduced over 4 years ago are projected to exceed this durability standard.[78]

Similar to durability requirements, staff is proposing minimum warranty requirements for ZEVs: one set of requirements for propulsion related parts not including the battery and a separate set for the battery. Staff's proposals are similar to what manufacturers are currently offering on ZEVs. Many of these propulsion-related part coverages offered today are already for terms that exceed the proposed requirements for 7 years /70,000 miles such as 8yr/100k+ or 10/100k. Staff assumed the slight differences in coverage would be offset by the shorter term and assigned no incremental cost for the powertrain component warranty. For the battery warranty coverage, many manufacturers offer an 8 year/ 100,000 mile warranty

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[77] *https://iaspub.epa.gov/otaqpub/display_file.jsp?docid=40001&flag=1*
[78] *https://www.tesla.com/ns_videos/2020-tesla-impact-report.pdf*

period with a 70% threshold on today's ZEVs. Requiring coverage for batteries falling below 80% state of health would not be triggered for many customers.

Staff assumes no additional cost for proposals related to charging standardization, including DCFC inlet standardization and convenience cords because they are accounted for in the BEV technology package. Proposed requirements apply to minimum standards for BEVs and PHEVs that would count toward meeting a manufacturers ZEV requirement.

2. **Costs to Manufacturers Replacing ZEVs with ICEVs**

In-use compliance testing and warranty reporting

Staff expects ZEV in-use compliance and warranty reporting required by the proposal to be much less onerous than in-use compliance testing and warranty reporting currently required for ICEVs by manufacturers. Relative to the current requirements for ICEVs that include borrowing actual customer vehicles for several days and bringing them into specialized chassis dynamometer emission testing laboratories for testing, compliance with the ZEV proposal would require far less time and manufacturer resources; therefore, the analysis assumes the proposal for in-use compliance testing and warranty reporting incurs no incremental cost on manufacturers.

Service Information

Staff is proposing to require manufacturers to provide repair service information to independent repair shops for ZEVs. Staff assumes no additional costs for traditional manufacturers who produce ICEVs and therefore are subject to CARB's existing service information rule. Additionally, those manufacturers, largely as a result of a Massachusetts law known as the Right-to-Repair Act,[79] already make available all repair information for many systems and components, beyond emission-related or propulsion-related systems, for all their vehicles through a Memorandum of Understanding (MOU) that provides for access in all states to this information.[80]

3. **Reporting Costs for ZEV-only Manufacturers**

In-use compliance

To measure manufacturers against the proposed ZEV durability standard, staff is proposing to collect data from manufacturers over the vehicles' useful life.

Warranty Reporting

Tesla already provides a warranty for consumers, which means it has an existing system in place to track and pay for warranty repairs, including knowing what parts are being replaced

[79] Massachusetts Bill H.4362 (web link: *https://malegislature.gov/Bills/187/H4362*, accessed on 11/4/2021)
[80] *https://wanada.org/wp-content/uploads/2021/01/R2R-MOU-and-Agreement-SIGNED.pdf*

on which vehicle models. This leaves a smaller subset of components per test group that potentially reach reporting levels, and an even smaller subset of those that reach the next tier of the need to screen the claims to identify the true failure rate.

Service Information and Data Standardized Data Parameters

As mentioned above in estimating the costs to conventional manufacturers for compliance with the service information requirements, most manufacturers make service information available on all their vehicles, regardless of technology type. Tesla has not signed a similar MOU but has recently begun to provide access to some of its repair information and diagnostic tools.[81] The information required by the Massachusetts Right-to-Repair Act and the information Tesla appears to currently be making available could encompass the propulsion-related information that would be required by the proposal at no additional cost.

Table 28: Total ZEV Assurance Measures Costs by MY

2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
$452,886	$579,395	$707,104	$930,360	$1,060,300	$1,310,357	$1,499,857	$1,595,510	$1,691,688	$1,788,356

All Costs in Table 28 were calculated using engineering time in hours multiplied by the hourly rate of an engineer mostly for reporting cost incurred for a ZEV only manufacturer.

4. Battery Labeling for all Manufacturers

For battery labeling, the proposal requires that specific information be printed directly on the label, a QR code to be printed on the label that links to a website with additional information, and for such a label to be attached to each portion of the battery pack intended to be replaced separately. These labels are similar to those used on nearly every automotive part under the hood and the dash panel in a conventional ICEV. Manufacturers and suppliers already are commonly labeling virtually every component, so staff does not expect incremental costs from creation of a new process for labels. The incremental cost is limited to the actual cost, estimated at $0.01 per label or $0.05 per average vehicle based on availability of preprinted custom labels for less than $0.02 to $0.03 per label, even at much lower quantities than typical for the production run of a vehicle model.

A related part of the label requirement is that the manufacturer must include a QR code on the label that links to a free website containing information about the battery. The analysis focused on engineering time to create and assign the unique QR code for each battery/test group, identify and enter the appropriate information on the label and the website, coordinate implementation of the correct information on the label with suppliers, and verify the content and QR code.

[81] *https://service.tesla.com/service-subscription*, accessed 11/4/2021

3.1.1.5 ZEV Sales Costs

Once costs are completed for individual vehicle technologies and compliance requirements, these costs are rolled up to show impacts for the California vehicle fleet as a whole. To determine the most likely compliance scenario, staff determined new vehicle fleet costs assuming manufacturers would take the cheapest path to compliance during the regulatory timeframe (2026-2035). Specifically, staff assumed manufacturers would replace ICEV sales with ZEV and PHEV sales on an annual basis such that the minimum amount of ZEVs required for that year are produced at the lowest cost. The data required for the cost calculations included technology incremental costs provided in Appendix A for each technology package in each vehicle category, as well as light-duty vehicle technology sales projections (derived from EMFAC2021 and the NHTSA VOLPE model). The calculation steps include: 1) developing a baseline fleet, 2) projecting the fleet into future years, 3) use engineering judgment to determine the number and type of technology packages that will be picked annually, and 4) calculate the total costs incurred by manufacturers to comply based on the incremental costs described in sections 3.1.1.2_- 3.1.1.4. The details of this analysis are provided in the sections that follow. For MDVs, costs are added after this process to account for compliance with staff's LEV proposal.

Step 1. California Baseline Fleet Technology and Sales Profiles

The calculation of manufacturer costs first requires the characterization of specific ZEV technology sales in the future California fleet under a baseline (i.e., conditions in the absence of the ACC II regulation) and with the proposed regulation. Staff used the EMFAC2021 inventory to provide the baseline California fleet technology profile (both technology mix and sales) in the 2026-2035 calendar years for the light-duty vehicle categories PC, LDT1, LDT2, and LDT3 as described in Section 2.1.1. These vehicle classes represent aggregated vehicle classes of cars and trucks distinguished by test weight and gross vehicle weight.

The EMFAC vehicle classes were not sufficient to accurately map available ZEV technologies to the various vehicle types in the California fleet. As a result, further allocation of the fleet into vehicle classes (i.e., small car, medium car, small SUV, medium SUV and pickup truck) and allocation of specific vehicle characteristics (i.e., AWD vs. 2WD, towing vs. non-towing) was required in order to match a ZEV technology package from Appendix A to each of the ICEVs in the baseline fleet. This allocation was achieved using the market input file of the NHTSA VOLPE model used for the 2020 SAFE rule.[82] Staff then used California sales data to generate the California light-duty vehicle profile, which served as the basis for the next steps in the total incremental cost analysis. Table 34 summarizes the final allocation of the California fleet according to the pertinent vehicle classes and characteristics described

[82] This file tabulated numerous characteristics pertaining to all light-duty vehicle models produced and sold in the 2017 model year and included several key characteristics required for this analysis: vehicle class, drivetrain type, and engine size. The drivetrain parameter allowed staff to distinguish between 2WD and AWD vehicles. For the towing vs. non-towing distinction, staff assumed that any medium-size SUVs, or pickup trucks with eight or more engine cylinders, had towing capabilities.

previously. Staff used the latest sales data available to assign sales fractions to each vehicle class, as presented in Table 1Table 29, and assumed that fraction does not change throughout the regulation.

Table 29. Baseline vehicle segment allocations (%)

	Small Car	*Medium Car*	*Small SUV*	*Medium SUV*	*Pickup*	*Total*
Base	29.3	12.5	17.9	9.2	3.6	72.6
AWD/4WD	0.3	2.5	6.7	9.4	2.1	21.1
Towing	0.0	0.0	0.0	0.8	2.1	2.9
AWD/4WD and Towing	0.0	0.0	0.0	1.5	2.0	3.5
Total:	29.6	15.1	24.6	21.0	9.7	100.0

Step 2: Allocation of ZEV Sales

The second step in the calculation of total costs for the fleet requires the allocation of ZEV technology packages in the fleet in a manner that minimized the total incremental cost of compliance each year during the regulation. Staff achieved this by allocating ZEV technology packages to vehicle sales in vehicle classes that lead to the lowest cost to the vehicle fleet taking into account the ZEVs that already exist in the baseline. This process was performed in each successive model year until the fleet was fully converted to ZEV technology in 2035.

As an example, for the 2030 model year, the ZEV proposed requirement is 60%. The baseline fleet already projects 12% ZEV sales without the regulation reflecting natural market demand. To meet the proposed ZEV requirements, staff assumed manufacturers incurred costs, described in Appendix A, to comply and the cheapest path is presented in Table 35. As seen in the table, manufacturers achieved converting large portions of their ICEV fleet to 300-mile BEVs and other ZEV technologies (i.e. PHEVs and FCEVs). Although 400-mile BEVs are an option for the manufacturers, they are not chosen as a compliance option in 2030 because they are more expensive (i.e. less cost-effective) than the other ZEV technology options.

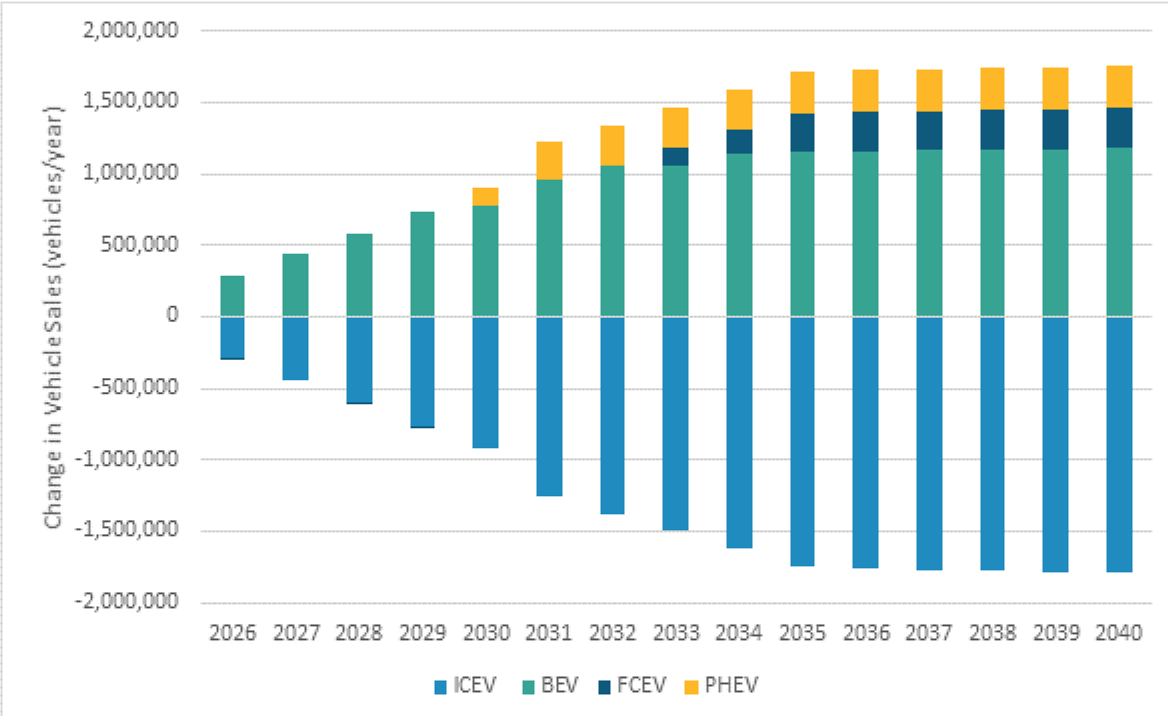
Table 30. Percentage of packages in the fleet to meet the 60 percent ZEV requirement for 2030

	Package	*Small Car*	*Medium Car*	*Small SUV*	*Medium SUV*	*Pickup*	*Total*
Baseline	All ZEV Packages:	8	21	16	10	3	12
Proposed Regulation	BEV(300mi):	46	39	41	43	24	41
	BEV(400mi):	0	0	0	0	0	0
	Additional packages:	22	0	0	0	0	6
	Total:	75	61	57	54	27	60

Step 3. Manufacturer Cost Calculations

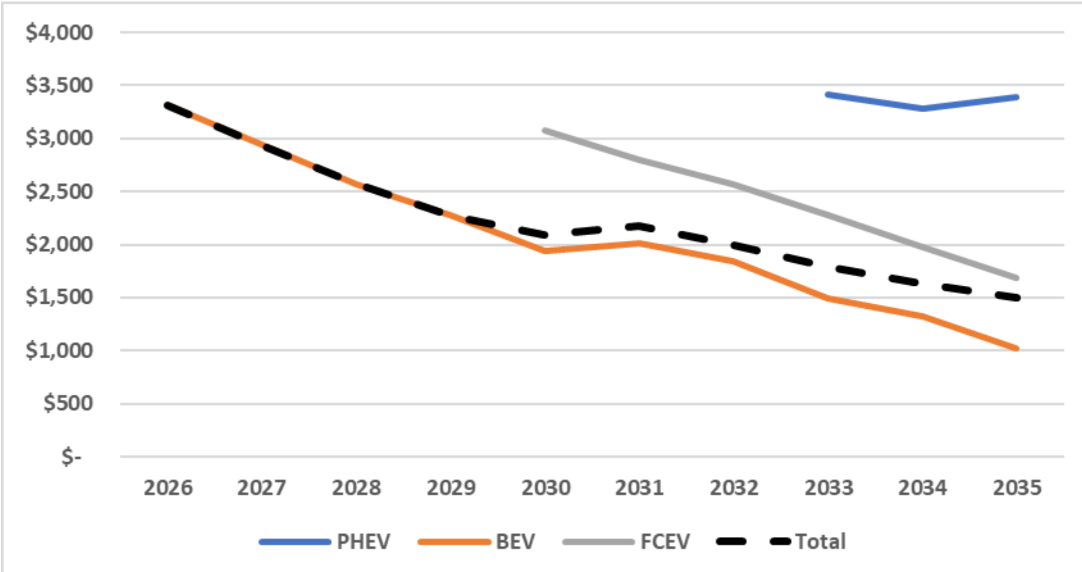
For each model year, staff calculated the total manufacturer incremental costs by multiplying the total number of ZEVs added to the fleet beyond the baseline to meet the ZEV requirement for that model year by the incremental cost associated with the conversion of an ICEV to a particular ZEV technology listed in Appendix A. Figure 9 provides a summary of the ZEV technology sales added to the fleet to comply with the proposed ZEV by year. For example, in 2030 the figure shows a reduction of about 925,000 ICEV vehicle relative to the baseline, which are projected to be replaced with ZEVs.

Figure 9: Net Change in Vehicle Sales by Technology Type (2026-2035)



The average incremental costs (calculated according to steps 1-3 described previously) associated with ZEVs and PHEVs sold in 2032 are presented in Figure 10. As shown in the figure, BEV sales are responsible for total incremental costs between 2026 and 2029. After 2029, FCEVs begin to contribute to the total incremental cost and PHEVs begin to contribute in 2033.

Figure 10: Average Incremental Cost by Technology Type and Calendar Year



3.1.2 Cost to Comply with the LEV Amendments

This section summarizes the cost associated with complying with the LEV regulation per vehicle and total costs per year will be presented for LDV and MDV fleets.

3.1.2.1 Cost to Comply with the Light-Duty Vehicle Regulations

1. Maintain emission standards for internal combustion engines

The proposed changes to the NMOG+NOx fleet average requirements that maintain the standards while taking ZEVs out of the fleet average are not expected to have any additional costs relative to the baseline. The prior LEV III rulemaking included the costs of converting all vehicles in the light-duty fleet from the existing LEV and ULEV emission levels down to SULEV30 emission levels by 2025. In that analysis, no portion of the light-duty vehicle fleet was assumed to be ZEVs, meaning the prior rulemaking already accounted for meeting the fleet average without any ZEVs. Therefore, staff is assuming no additional cost beyond that previously accounted for to phase out ZEV from the fleet average as part of this proposed regulation.

2. Clean up the worst emitting vehicles in the light-duty fleet

Staff is proposing new rules to both require all vehicles to be certified to the US06 emission standards for NMOG+NOx. The aim of this proposal is to clean up the highest emitting vehicles in the fleet, so the proposed standards for all vehicles were set at levels that most vehicles in the fleet are already able to meet. Analysis of certification data revealed that only 6.9% of the fleet currently exceeds the proposed emission targets for the stand-alone US06

NMOG+NOx standards, as shown in the chart below. Therefore, the costs associated with the proposed changes only apply to a relatively small percentage of the fleet.

Table 31: Percentage of fleet exceeding the proposed emission targets for stand-alone US06 standards

US06 Emissions Relative to Proposed US06 standards for NMOG+NOx	Percentage of Fleet
>1.0	6.9
<1.0	93.1

To comply with the proposed standards, these vehicles would likely need calibration work, and some may need to upgrade the emission control hardware, namely, the catalyst system. For the calibration work, these vehicles are not expected to incur additional calibration work relative to what is already done, such as determining optimal fuel injection timing, fuel quantity, fuel atomization/mixing, spark timing, and other intake and exhaust air flow management through variable valve timing and electronic throttle control. Instead, the expectation is, like the vast majority of vehicles that already comply, that a higher emphasis will be placed on maintaining low emissions when developing and optimizing the calibration among other competing factors such as drivability, performance, and noise/vibration mitigation. Further, these calibration costs are typically done only once, or in some cases twice, over a vehicle model's typical 5-year product life so any such calibration costs would be spread across 3 to 5 model years of vehicle sales. Accordingly, no incremental cost is assigned to the already present calibration work.

For the emission control hardware, staff analysis of confidential data provided by manufacturers at the time of certification revealed that vehicles expected to be in compliance with the proposed standards had on average, a catalyst that was more heavily loaded with precious metals compared to the 6.9% of the fleet that is expected to be out-of-compliance. Given the dominant factor in catalyst system costs is the content of key precious metals, the analysis focused on differences in platinum, palladium, and rhodium content. Using 5-year average prices for each of these catalyst precious metals, as shown in Table 32, and multiplying by the average incremental catalyst loading observed in the certification data, staff found an average incremental cost of $77 to upgrade the catalyst system to meet the proposed US06 NMOG+NOx standards.

Table 32: Cost of precious metals per gram

Precious Metal	Platinum	Palladium	Rhodium
Price – 5-year average [$2021 per gram]	$30	$51	$231

Using the $77 cost as a 2021 baseline, a 3% annual cost reduction is applied to future catalyst costs as improvements in catalyst technology, such as improved washcoats that are more durable and provide the same or higher conversion efficiencies with less precious metal content, are expected to continue to decrease precious metal content and thus, these ongoing costs. Moreover, while the proposal includes a three-year phase-in of these new US06 standards, staff expect manufacturers to utilize vehicles that already meet the requirement to satisfy the first two years of the phase-in and wait until the final year when 100 percent compliance is required to address the small percentage of higher-emitting vehicles. Accordingly, costs are only projected for the 2028 and subsequent model years, and those costs are only assigned to 6.9 percent of the total new vehicles sold with a combustion engine each model year, as summarized in Table 33. With this approach, the total cost to comply with the proposed US06 NMOG+NOx standards is estimated to be $20.6 million or $2.59 per each ICEV sold from 2026-2035.

Table 33: Total cost to comply with the proposed US06 NMOG+NOx standards

Model Year	Vehicles Affected	Annual Cost [$2021]
2028	81,472	5,077,158
2029	70,471	4,259,891
2030	59,360	3,480,572
2031	37,227	2,117,315
2032	29,209	1,611,443
2033	29,271	1,566,422
2034	24,179	1,255,124
2035	23,854	1,201,073
Total	355,042	20,568,998

CARB is also proposing to reduce the US06 PM standard from 6 mg/mile to 3 mg/mile during higher speeds and acceleration rates. Certification data indicate that over 80% of current vehicles already emit below 3 mg/mile on the US06 cycle. A lower emission standard will clean up the highest emitting vehicles and ensure vehicles already meeting the proposed standard do not get worse. CARB expects that the percentage of vehicles in compliance with the proposed 3 mg/mile US06 standard will continue to grow towards 100% as vehicles are redesigned to meet the more stringent 1 mg/mile FTP standard that is required by the LEVIII regulations, which are currently in effect, where much of the same technology will be applied to meet both standards and CARB's own testing shows reducing emissions under the FTP test cycle corresponds to reduced emissions under the US06 test cycle. Reducing the standards under both tests will ensure emissions are reduced under a wider range of operating conditions. For instance, approaches that only focus on reducing PM emissions at initial start-up such as adjusting early fuel injection pressure and timing as well as spray pattern with injector design, orientation, and split injections could have a large impact on emissions under FTP conditions representative of normal driving but no impact on emissions under the US06 procedures that exclude start-up emissions. Tightening the US06 PM standard provides further assurance that all vehicles will utilize hardware and software solutions that achieve low PM emissions under broader driving conditions, such as by ensuring good air-fuel control during transient operating events or rapid acceleration and avoiding or mitigating the use of fuel enrichment under acceleration, which tends to increase PM emissions.

Given that vehicles will be required to meet the existing 1 mg/mile FTP standard before the proposed 3 mg/mile US06 standard phase-in, no incremental costs are projected to meet the proposed standard. In the rare cases where a test group may have planned to implement, or inadvertently implemented, a less robust solution that would not have resulted in meeting the proposed US06 standards, the manufacturer would be expected to be aware of this during engine design or certification to meet the existing 1 mg/mile FTP standard and so would be able to design and calibrate the engines to meet the proposed 3 mg/mile US06 standard too. With the phase-in of the proposed standard purposely staggered to start and lag two years after the 1 mg/mi FTP standard, even a manufacturer that discovered the issue late in the design process would be expected to have sufficient time to redesign the system at a normally scheduled vehicle refresh three years later and still meet the required phase-in. Accordingly, no further costs are projected incremental to the costs to meet the 1 mg/mile FTP standard that were already analyzed in the LEVIII rulemaking.

3. Reduce start emissions from light-duty vehicles

Staff is proposing three new requirements to reduce cold-start emissions from light-duty vehicles. These new requirements include a new standard to control partial cool down start emissions, a new standard to regulate early drive-away cold-start emissions, and a new standard to control high-power cold-start emissions from plug-in hybrid electric vehicles. CARB testing of existing vehicles showed the proposed standards for all three requirements can be met by improving cold-start emission calibration, without needing any hardware upgrades. Since all three requirements will be phased in simultaneously, staff expect that the re-calibration for all three requirements will be performed at the same time. Furthermore, as all three proposals will be phased in over three years, 2026-2028, beyond the lead time before the start of the phase-in, it is expected that the bulk of the calibration efforts will occur during normal existing vehicle redesign cycles. Therefore, the costs assigned to this rulemaking will only consider additional incremental calibration effort that may be required for the new proposals.

The projected calibration costs are estimated as engineering work billed at $66.58 per hour using the Bureau of Labor and Statistics (BLS) estimates of $45.94 per hour for mechanical engineering work plus $20.64 per hour in additional benefits. Assuming 160 hours of additional calibration work per vehicle test group, the estimated incremental calibration cost is $10,653. Analysis of certification data revealed that there are 315 different ICEV emission certification groups in the current light-duty fleet. However, as the proposed requirements will be phased in over three model years, the projected calibration efforts will also be spread out over three years from 2026-2028. Thereafter, the calibration efforts are expected to continue to add cost as the vehicles are redesigned every 5 years, according to a typical vehicle model's lifecycle. Using these estimates, the total costs are projected to be $2.8 million, as shown in the Table 34, or $0.35 for every ICEV sold from 2026-2035.

Table 34: Total annual calibration costs to comply with start emissions

Model Year	Total ICEV Test Groups	Number of Test Groups Affected	Annual Cost [$2021]
2026	253	77	615,199
2027	230	62	495,355
2028	205	66	527,314
2029	179	37	295,615
2030	154	31	231,698
2031	103	21	151,802
2032	85	18	127,834
2033	75	23	143,813
2034	65	18	106,528
2035	55	15	79,896
Total			2,775,054

4. Vehicle Testing Costs

Staff's light-duty criteria emission proposals include a new certification test for a short idle FTP test for all vehicles and a new cold-start US06 test for plug-in hybrid electric vehicles. To offset the additional testing required by the two new certification tests, staff's proposals include a couple of testing flexibilities to reduce testing burden. First, the proposal will include an exemption from the new cold-start US06 requirement for all PHEVs that can drive the US06 cycle using only electric power. Since this electric power capability is also a proposed requirement for future PHEVs to be used for compliance with the ZEV regulation, staff estimates that the vast majority of future model year PHEVs will be exempt from cold-start US06 testing. Second, to further offset the additional vehicle testing required by the new ACCII requirements, staff's proposal will eliminate the current certification testing requirements for the separate SC03 test for all vehicles and instead allow automakers to include an attestation that the vehicle will meet the SC03 standards. Since the proposal includes fully removing the certification SC03 testing requirement for all combustion engine vehicles in 2026 and the SC03 test requires a specialized high temperature testing facility resulting in much higher per test costs to run than a traditional test cell for FTP and US06 testing, it is expected that the removal of the SC03 test requirements will completely offset the additional certification testing required by the proposal. Further, the cumulative testing costs associated with criteria emission testing are also projected to decline over time as the number of vehicles with combustion engines and thus subject to these new requirements in the fleet decline while ZEV and exempt PHEV sales increase.

5. Ensure all vehicles in the light-duty fleet implement designs consistent with optimal control of evaporative emissions

To meet the proposed running loss standard, staff estimates a one-time redesign cost for the minority of vehicles not already capable of meeting the proposed running loss standard today, which is 6 percent of new vehicles based on analysis of 2019 model year certification data. The primary driver for this cost is expected to come from re-configuring the vehicle's layout to provide more space around the fuel tank. More space around the fuel tank will result in less heating of the fuel tank from neighboring components and also allow for better air circulation while driving, which will cool the fuel tank. This should ultimately result in less fuel vapors being generated and escaping to the atmosphere while the vehicle is driving (running loss emissions).

The estimated cost for the auto industry to meet the tighter running loss standard is $0.28 / vehicle.

The following assumptions were used to estimate the cost:

1. Assume that one vehicle will be tested, and that redesign work will be carried across to all vehicles in the evaporative family.
2. Estimate 80 hours of engineering time at $66.58 per hour. The Bureau of Labor and Statistics (BLS) estimates the mean hourly wage for a mechanical engineer nationwide to be $45.94 in 2020, not including benefits.[83] This figure must be adjusted to include benefits and other component of total compensation to provide a complete labor cost estimate. According to the latest BLS report, hourly wages accounted for 69% of total compensation in private industry and benefits accounted for 31% of total compensation.[84] Thus, the total hourly cost for a mechanical engineer is $66.58 (i.e., $45.94 + $20.64). Even vehicles needing improvement are already subject to the current evaporative emission standards and thus, have a full complement of engineering work associated with the design, calibration, and testing already accounted for in costs with prior rulemakings. Accordingly, the 80 hours represents an incremental amount of calibration work above this level to further refine the design, rather than a complete design and implementation of a compliant system. Further, given that nearly 95 percent of current vehicles already meet these tighter proposed standards with no additional calibration work, any additional hours estimated should

[83] Bureau of Labor and Statistics, Occupational Employment and Wages, May 2020 (web link: *https://www.bls.gov/oes/current/oes172141.htm#nat*)

[84] Bureau of Labor and Statistics, New Release, Employer Costs for Employee Compensation, June 2021 (web link: *https://www.bls.gov/news.release/pdf/ecec.pdf*)

represent a conservative estimate to bring the remaining designs up to par with the rest of industry. Finally, since the nature of the changes are primarily expected to be in the design layout, rather than incurring additional hardware, it is expected that once these refinements are made, they will be able to be carried over to subsequent design iterations and new vehicle models without adding any significant costs.

3. Number of vehicle models that will need changes based on current certification data: 21 evaporative families.

4. No added certification testing cost: evaporative families needing improvement would likely have a normally scheduled fuel system redesign due to vehicle redesign during the phase-in and lead time. and would already be required to undergo certification testing as a result.

5. Negligible cost for future model year PHEVs to comply. since the majority of the PHEVs on the market today already meet this and would be expected to continue to do so without further incremental costs.

Based on certification data the total cost would be:

(21 evap families) X (80 hr) X ($66.58/hr) = $111,854 total cost

Assume this is a one-time cost for the evaporative family, and that cost would get spread out over the expected 5 years of sales of that evaporative family. And since a small percentage of vehicles are affected, staff assume that manufacturers will wait to make these changes until near the end of the 2026-2028 model year phase-in. Cost per model year:

Table 35: Cost to comply with the evaporative requirements for this proposal

Model Year	2028	2029	2030	2031	2032	2033+
Cost	$22,371	$22,371	$22,371	$22,371	$22,371	$0

Total Cost of Light-Duty Vehicle Exhaust and Evaporative Emission Proposals

The total annual costs for the LEV criteria emission proposals are outlined in Table 36. The combined costs are estimated to be $23.5 million or $2.95 per ICEV sold from 2026-2035.

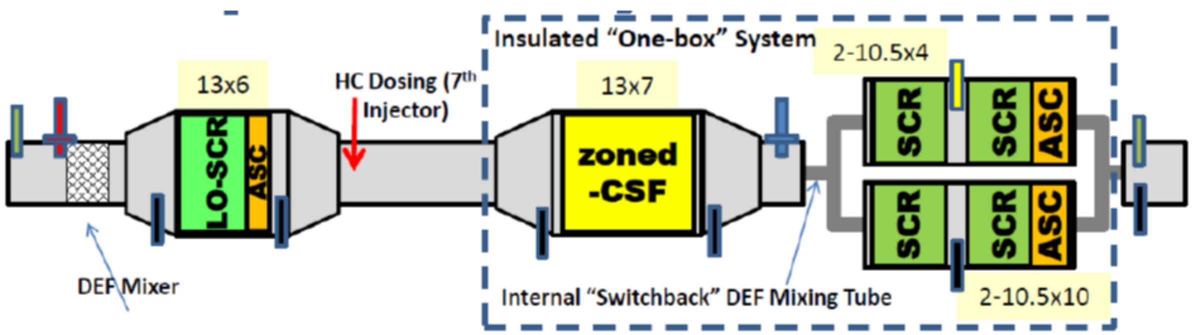
Table 36: Total annual cost ($2021) of compliance with the LEV light-duty regulations

Model Year	US06 NMOG+NOx	Cold-Start	Running Loss	Total Cost
2026	0	615,199	22,371	637,570
2027	0	495,355	22,371	517,726
2028	5,077,158	527,314	22,371	5,626,842
2029	4,259,891	295,615	22,371	4,577,877
2030	3,480,572	231,698	22,371	3,734,642
2031	2,117,315	151,802	0	2,269,118
2032	1,611,443	127,834	0	1,739,276
2033	1,566,422	143,813	0	1,710,235
2034	1,255,124	106,528	0	1,361,652
2035	1,201,073	79,896	0	1,280,969
Total	20,568,998	2,775,054	111,855	23,455,907

3.1.2.2 Cost to Comply with the Medium-Duty Vehicle Regulations

For chassis-certified MDVs over 14,000 lbs. GCWR, which are mostly diesel vehicles, meeting the proposed on-road PEMS in-use test procedures and standards would require hardware and calibration changes. Given the proposed requirement is essentially identical to the newly adopted PEMS requirement for HD engines pursuant to the HD Low NOx Omnibus regulations, and even applies to a subset of MDVs that are engine-certified instead of chassis-certified, the costs estimated in the HD rulemaking were used as a starting point. For the HD Low NOx rulemaking, CARB funded several research programs with SwRI and contracted with NREL to conduct a cost analysis to estimate cost associated with the hardware changes and research and development needed to meet the proposed HD standards. 85Figure 11 shows an example technology package for a diesel vehicle equipped with multiple Selective Catalytic Reduction (SCR), Diesel Exhaust Fluid (DEF), and Ammonia Slip Catalyst (ASC) systems which was demonstrated to meet the HD PEMS in-use standards. Table 3785 shows the associated costs estimated as needed to meet the HD PEMS in-use standards which is based on the technology package from Figure 11. For the proposed MDV regulation, staff believes that similar technologies would be needed but adjusted the costs to more accurately represent what would be incremental to the emission controls typically already implemented on chassis-certified MDVs.

Figure 11: SwRI Stage 3 Final Aftertreatment System[85]



The cost for adding multiple SCR systems, ASC, and multiple DEF dosing system similar to the diesel technology package (Figure 11) in the dotted line for the insulated "one-box" system demonstrated in the HD Low NOx rulemaking would have the most significant impact on reducing emissions for diesel chassis-certified MDVs. The moving average window (MAW) in-use requirement will require vehicles be tested on-road with a PEMS. The data will be analyzed using the MAW method and compared to the proposed MAW in-use standards. The cost of these technologies needed to meet the MAW standards is described in Table 37:

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[85] "Standardized Regulatory Impact Assessment (SRIA): Proposed Heavy-Duty Engine and Vehicle Omnibus Regulation and Associated Amendments." *DOF*, CARB, 2020, *www.dof.ca.gov/Forecasting/Economics/Major_Regulations/Major_Regulations_Table/documents/CARB%20SRIA%20Heavy%20Duty%20Engine%20Standards.pdf.*

Table 37: Incremental cost of technology to meet the (Moving Average Window) MAW standards[85]

		6/7 Liter Diesel	6-Liter Gasoline
Engine Technology	EGR Cooler Bypass, Cylinder Deactivation, Light-Off SCR	$0*	
	DOC (subtotal)	$13	
	DPF Savings (2018 baseline system only)	(-$23)	
	SCR+Ammonia Slip Catalyst + DEF Dosing (subtotal)	$727	
	OBD sensors and controllers (NOx, Ammonia, temp sensors)	$74	
	TWC		$381
Research and Development Cost	Engineering Cost	$250	$100
Total Incremental Cost		$1,041	$481

*Chassis certified MDVs are already typically equipped with some of these technologies such as EGR cooler bypass, therefore these costs were not included in the final total incremental cost. Other technologies such as cylinder deactivation and light-off SCR may not be necessary for chassis certified MDVs as these vehicles already have hardware and calibration strategies to deal with low temperature emissions. These emissions occur mainly during lower engine load operation and current chassis certification test cycles substantially include these areas of operation for which these new specific technologies were intended for primarily.

For chassis-certified gasoline MDVs, the proposed regulation will likely require changes to the catalyst system as well as calibration work. These costs are covered in the previous table and are substantially less than the cost for diesel engines. This approach is consistent with CARB's testing and analysis that has shown that gasoline chassis-certified MDV emissions are already much better controlled than diesel engines and will require much less improvement to meet the proposed PEMS in-use standard. Based on the projected sales for EMFAC and the MY2021 certification data identifying which vehicles would be over 14,000 lbs. GCWR, staff projected number of MDVs in class 2b and class 3 that would be required to meet the proposed PEMS in-use standards.

MDVs that are required to meet the proposed PEMS in-use standard will also have to meet proposed more stringent fleet average standards. However, as the PEMS standard covers a broader spectrum of engine operating conditions than these test cycles, the implementation of emission solutions to comply with the PEMS standard is expected to adequately reduce emissions during these cycles to meet the more stringent proposed standards. Accordingly, no further incremental costs are assumed above and beyond the costs to comply with the proposed PEMS standard.

MDVs that are exempt from the proposed PEMs requirement (i.e., MDVs less than 14,000 lbs GCWR) would potentially need to make additional hardware or calibration changes to meet the more stringent FTP and SFTP standards. The costs for meeting the proposed standards would be associated predominantly with changes needed in the catalyst system and/or engine calibration. However, based on certification data and testing by CARB, many of these MDVs appear capable of already meeting the proposed standards. Staff has analyzed certification data to determine what fraction of test groups under 14,000 lbs. GCWR would likely be required to make changes to meet the proposed standards. Based on certification data, 1 of 3 diesel test groups and 6 of 9 gasoline test groups are estimated to need hardware changes and/or calibration changes. Table 38 below shows the changes and cost required based on fuel type and engine size for those test groups. The cost was determined by analyzing the catalyst precious metal loading and sizing for the vehicles in each class. By comparing the catalyst information between test groups that were already meeting the proposed standards and those that were not, staff found that most test groups that could not meet the proposed standards had directionally lower precious metal loadings than those that could meet the proposed standards. For such vehicles, an incremental cost associated with the higher catalyst loadings was calculated based on the same 5-year average cost for precious metals as those used for the light duty cost. For a few of the test groups that appeared to already have equivalent catalyst loading to the better performing vehicles, staff assumed that only calibration work would be needed. This assumption is consistent with data in CARB's testing where vehicles in a test group were subsequently subject to an emission-related recall that involved only an update to the software in the engine control module and after the update, achieved emission levels far below the proposed standards without any hardware change.

Table 38: Incremental cost for MDVs (Under 14,000 lbs. GCWR) only requiring changes to meet the proposed fleet average and standalone standards

Aftertreatment Changes	2 Liter Diesel	3 Liter Gasoline
Engine Recalibration	$0*	$0*
SCR/TWC	$0*	$183** average cost (applies to 78% of fleet)

*A zero cost for calibration was assumed for test groups where manufacturers were using the same sized catalyst with other test groups that already meet the proposed standards for NMOG+NOx and CO.

**The $183 cost is the incremental cost for higher catalyst loadings based on the 5-year average cost for precious metals. This cost applies to only gasoline MDV test groups requiring changes to their catalyst based on staff analysis of current certification data.

Total Cost of Medium-Duty Vehicle Emission Proposals

Table 39 shows the projected sales of MDVs that will require changes to meet the proposed standards for model year 2026-2035. The projected sales were based on the EMFAC 2021 model and current certification data. The vehicles in the greater than 14K lbs. GCWR category are vehicles requiring changes to meet the proposed PEMS in-use standard, and the less than 14K lbs. GCWR category are vehicles requiring changes to meet the proposed FTP and SFTP standards.

Table 39: Projected Sales for medium-duty vehicles by GCWR

	Greater than 14K lbs. GCWR		*Less than 14K lbs. GCWR*		*Total*
Model Year	**Diesel**	**Gasoline**	**Gasoline**	**Diesel**	
2026	22,861	17,387	10,368	14	50,630
2027	21,704	16,508	9,844	13	48,069
2028	20,532	15,617	9,312	12	45,473
2029	19,343	14,713	8,773	12	42,841
2030	18,140	13,797	8,228	11	40,176
2031	16,920	12,871	7,675	10	37,476
2032	15,688	11,934	7,116	9	34,747
2033	14,442	10,985	6,551	9	31,987
2034	13,182	10,028	5,980	8	29,198
2035	11,910	9,061	5,403	7	26,381

The incremental cost from Table 37 and Table 38 are applied to the projected sales in Table 39 to determine the total cost for that model year, and the costs are shown in Table 23. Costs per vehicle are then calculated for the fleet using total cost for the fleet per year for each provision and dividing by the total vehicles for that year in Table 40. The projected sales numbers are taken from the EMFAC 2021 model.

Table 40: Total Cost of Compliance with MDV proposals

	Greater than 14K lbs. GCWR		Less than *14K lbs. GCWR*	Total Cost	Cost Per Vehicle
Model Year	**Diesel***	**Gasoline***	**Gasoline**		
2026	$23,798,301	$8,363,147	$1,482,783	$33,644,231	$660
2027	$18,563,434	$7,461,025	$1,407,839	$27,432,299	$567
2028	$17,097,032	$7,004,627	$1,331,824	$24,101,659	$527
2029	$15,688,834	$6,548,570	$1,254,758	$23,492,162	$545
2030	$14,329,898	$6,093,430	0	$20,423,328	$505
2031	$13,025,341	$5,645,124	0	$18,670,466	$495
2032	$11,766,631	$5,197,689	0	$16,964,321	$485
2033	$10,546,433	$4,750,792	0	$15,297,225	$475
2034	$9,365,577	$4,306,260	0	$13,671,838	$465
2035	$8,226,275	$3,863,315	0	$12,089,591	$455

*A learning curve was applied to the incremental cost which was used in the HD Omnibus SRIA[85] and based on previous U.S. EPA analyses[86] to reflect improvements and cost reductions in the manufacturing process over time.

3.1.2.3 Summary of Direct Cost to the Manufacturer for LEV LDV and MDV Proposals

Table 41: Total Cost of Compliance with the LEV proposals

Model Year	*LEV LDV Costs*	*LEV MDV Costs*	*Total LEV Costs*
2026	$637,570	$33,644,231	$34,281,801
2027	$517,726	$27,432,299	$27,950,025
2028	$5,626,842	$24,101,659	$29,728,501
2029	$4,577,877	$23,492,162	$28,070,039
2030	$3,734,642	$20,423,328	$24,157,970
2031	$2,269,118	$18,670,466	$20,939,584
2032	$1,739,276	$16,964,321	$18,703,597
2033	$1,710,235	$15,297,225	$17,007,460
2034	$1,361,652	$13,671,838	$15,033,490
2035	$1,280,969	$12,089,591	$13,370,560

[86] (U.S. EPA, 2016) "Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles – Phase 2," Regulatory Impact Analysis, United States Environmental Protection Agency, EPA-420-R-16-900, August 2016. *https://nepis.epa.gov/Exe/ZyPDF.cgi/P100P7NS.PDF?Dockey=P100P7NS.PDF*

3.1.3 Total Incremental Vehicle Cost and Pricing

The combined total costs of the LEV Amendments and ZEV regulation provisions described in the previous sections are provided in Table 42. The table includes the direct manufacturing costs, marked up by a retail price equivalent (RPE) multiplier of 1.5, which represents the indirect costs incurred by manufacturers and puts it in the retail price scale that a consumer would see at the time of purchase. The rationale for using such a multiplier is described in detail in the 2016 Draft Technical Assessment Report associated with the federal Proposed Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards under the Midterm Evaluation.[87]

Table 42: Annual Costs of ACCII Regulation

Year	*ZEV Costs*	*LEV Costs*	*Total Direct Cost (DMC)*	*Total Costs (RPE)*
2026	$938,296,907	$34,281,801	$972,578,708	$1,458,868,062
2027	$1,299,198,072	$27,950,025	$1,327,148,097	$1,990,722,146
2028	$1,547,178,849	$29,728,501	$1,576,907,350	$2,365,361,025
2029	$1,739,419,489	$28,070,039	$1,767,489,528	$2,651,234,292
2030	$1,936,143,665	$24,157,970	$1,960,301,635	$2,940,452,452
2031	$2,734,693,819	$20,939,584	$2,755,633,403	$4,133,450,105
2032	$2,741,500,716	$18,703,597	$2,760,204,313	$4,140,306,470
2033	$2,689,828,696	$17,007,460	$2,706,836,156	$4,060,254,235
2034	$2,662,191,102	$15,033,490	$2,677,224,592	$4,015,836,889
2035	$2,634,539,341	$13,370,560	$2,647,911,936	$3,971,864,851

Though the cost for manufacturers to comply is estimated in detail as described above, it is not straightforward to predict how these costs would be passed on to consumers. Vehicle pricing is complex, and different manufacturers could use different strategies to pass on all, some, or none of these costs in the prices of their various products, including ZEV and non-ZEV vehicles. As a simplifying assumption, the cumulative incremental costs per manufacturer are divided equally over all new vehicles sold in California (**Table 43**) to provide an average incremental retail price increase per car. In the early years where the requirement is lower, the incremental costs for an individual ZEV are higher but they are spread out across a fleet that still includes a large fraction of conventional vehicles. In later years when the requirement is nearly all ZEVs, the incremental costs for an individual ZEV are lower but

[87] (U.S. EPA, 2016a) "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" (web link: *https://nepis.epa.gov/Exe/ZyPDF.cgi/P100OXEO.PDF?Dockey=P100OXEO.PDF*, last accessed January 14, 2022)

virtually every car incurs such an incremental cost as there are very few remaining conventional vehicles. The compliance scenario assumes that the least expensive vehicles to convert to ZEVs are done so in the earlier years so as the requirement increases, a higher proportion of the larger vehicle classifications, which are more expensive, are converted to ZEVs. Accordingly, the table shows that overall costs generally increase in the early years as the increasing number of vehicles that need to be converted to ZEVs outpaces the cost reductions in converting an individual vehicle to a ZEV. However, in the latter years, overall costs start to come down as the individual vehicle cost reductions overtake the increasing volume of vehicles converted to ZEVs. In all cases, the incremental cost of any particular type of ZEV in a vehicle size decreases over time as shown in Figure 10.

Table 43: Total Cost Across All New Vehicle Sales

Model Year	Total Sales	Total Costs	Average Incremental Cost ($/vehicle)
2026	1,962,415	$1,458,869,062	$743
2027	1,969,934	$1,990,722,146	$1,036
2028	1,977,134	$2,365,361,025	$1,225
2029	1,983,985	$2,651,234,292	$1,366
2030	1,990,548	$2,940,452,452	$1,508
2031	1,996,723	$4,133,450,105	$2,110
2032	2,002,652	$4,140,306,470	$2,104
2033	2,008,240	$4,060,254,235	$2,055
2034	2,013,485	$4,015,836,889	$2,024
2035	2,018,398	$3,971,864,851	$1,968
2036	2,028,490	$3,991,724,175	$1,968
2037	2,038,632	$4,011,682,796	$1,968
2038	2,048,826	$4,031,741,210	$1,968
2039	2,059,070	$4,051,899,916	$1,968
2040	2,069,365	$4,072,159,416	$1,968
Average Annual	2,011,193	$3,459,170,536	$1,732
Total	**30,167,898**	**$51,887,558,040**	

3.2 Direct Cost Inputs for Vehicle Ownership

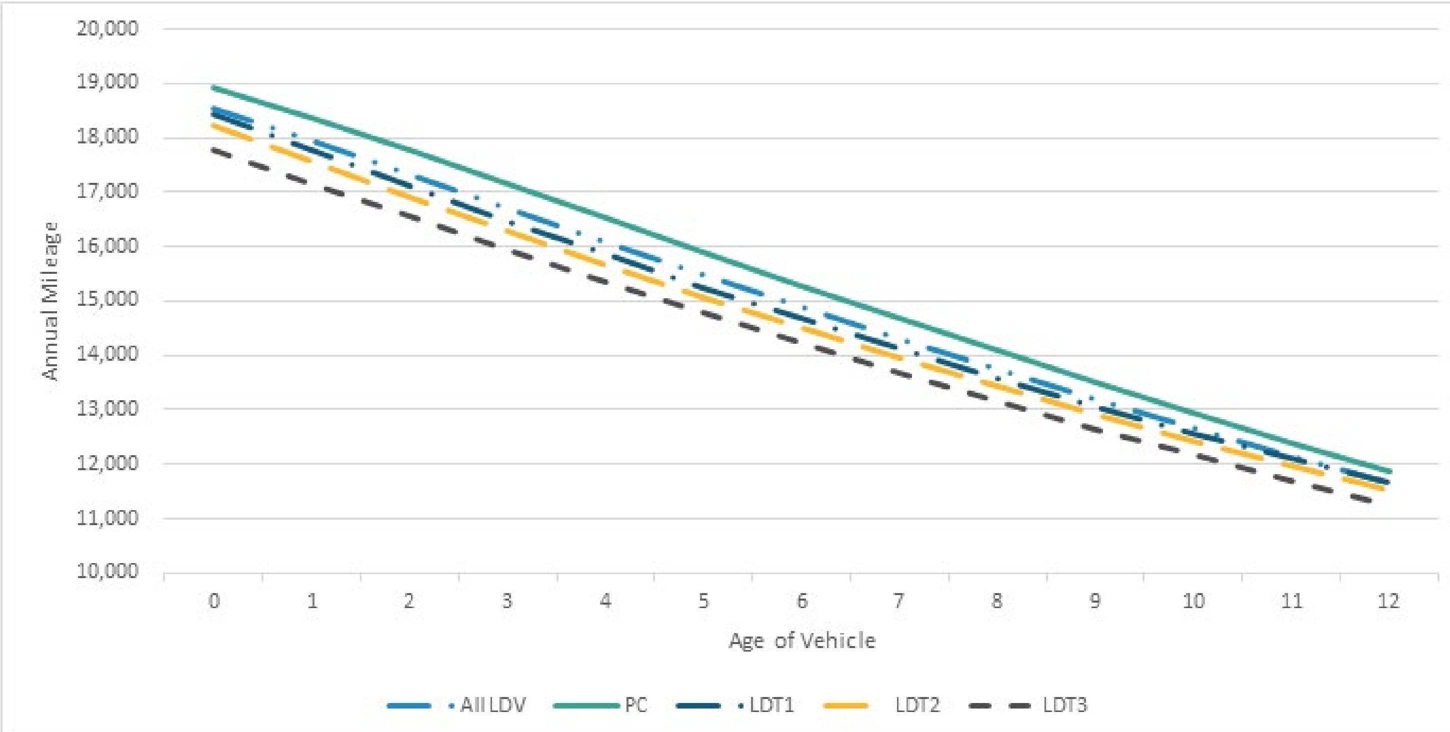
The proposed regulation will have an impact on vehicle operating and ownership costs for vehicle owners in California. This section describes the categories of costs included in the analysis, and Appendix 9 describes the assumptions in greater detail. Operating and ownership costs include the cost impacts of installing an electrical receptable for electric vehicle supply equipment (EVSE) (in homes where that is feasible) for purchasers of ZEVs, fuel costs, differences in maintenance costs, registration costs, and insurance costs over a ten-year period. In the next section, ownership and operational costs will be combined with the incremental vehicle prices to estimate the total cost of ownership (TCO) during the period of the regulation.

The results for this TCO analysis with individual vehicle owners will be described later in Section 3.5. However, as a preview, the results show that for BEVs, operational savings will offset any incremental costs over the ten-year period evaluated. For example, a passenger car BEV with a 300 mile range will have a payback period of seven years for the 2026 model year technology. For the 3035 model year technology, the payback is nearly immediate and cumulative savings over ten years exceed $6,000. The resulting trends are different for the FCEV and PHEV technologies. In most of the model years, neither of these technologies will have a payback within the ten year period.

3.2.1 Annual Mileage

Annual mileage factors into a number of cost components in this analysis including fuel, electricity, and maintenance costs, to determine annual costs for these variables that are dependent on mileage. The annual mileage data used here are from CARB's EMFAC2021 vehicle inventory model, which projects how vehicle mileage varies between classifications and declines with the age. The data vary by vehicle type, age, and model year (See Appendix A for detailed data). These data are illustrated in Figure 12, representing an average forecast for model years covered during the regulatory horizon, which is defined as going from 2026 to 2040 for this assessment.

Figure 12: Annual Mileage Accrual Rates by Vehicle Type



The annual mileage decreases as vehicles age and are driven less on average, and passenger cars are driven more miles on average than light-duty trucks (LDT1-3).

3.2.2 Vehicle Efficiency

The fuel and energy efficiency of vehicles is a key component in determining the change in fuel use and costs when moving from ICEVs to ZEVs. For this analysis, vehicle efficiency values are unique for each vehicle classification and powertrain technology and can vary by year based on projections for industry compliance with the existing federal fuel economy vehicle regulations. Table 4442 shows the average of the efficiencies over model year 2026-2035 in standard units and Table 45 shows them in energy equivalent units (Gasoline Gallon Equivalent).

Table 44: Average Vehicle Efficiency by Vehicle Type

Vehicle Type	ICEV (mpg)	BEV (mi/kWh)	FCEV (mi/kg)	PHEV-Gas (mpg)	PHEV-Electric (mi/kg)
PC	35.1	3.7	79.5	28.5	2.7
LTD1	30.7	3.6	70.1	28.2	2.4
LTD2	28.7	3.2	60.8	28.1	2.2
LTD3	23.7	2.9	56.5	27.8	2.0

Table 45: Average Vehicle Efficiency by Vehicle Type (Miles per Gasoline Gallon Equivalent)

Vehicle Type	ICEV	BEV	FCEV	PHEV-Gas	PHEV-Electric
PC	35.1	124.0	79.3	28.5	91.4
LTD1	30.7	121.9	69.9	28.2	81.7
LTD2	28.7	107.1	60.6	28.1	72.8
LTD3	23.7	98.4	56.4	27.8	68.3

3.2.3 Fuel and Energy Costs

Total fuel expenditures depend on vehicle efficiency, vehicle mileage, and vehicle fuel type. This information is combined with the annual mileage estimates by age of vehicle in EMFAC2021 for each vehicle size classification to create projections of the quantity of fuel consumed by fuel type over the period of the regulation.[88] By combining vehicle efficiency and fuel price, projections of fuel costs per mile are determined and are used to provide final estimates of total fuel expenditures over the period of the regulation. Details on the annual mileage by vehicle age and fuel price projections can be found in Appendix A.

3.2.3.1 Gasoline Prices:

The projected gasoline prices used for this analysis are from the California Energy Commission (CEC) transportation fuel forecasts published in the draft IEPR 2021 proceedings (Figure 13).[89,90] The CEC IEPR fuel price projections consistently are used in state policy development, utilizing projections based on stakeholder input, fuel demand modeling, and federal fuel price projections.

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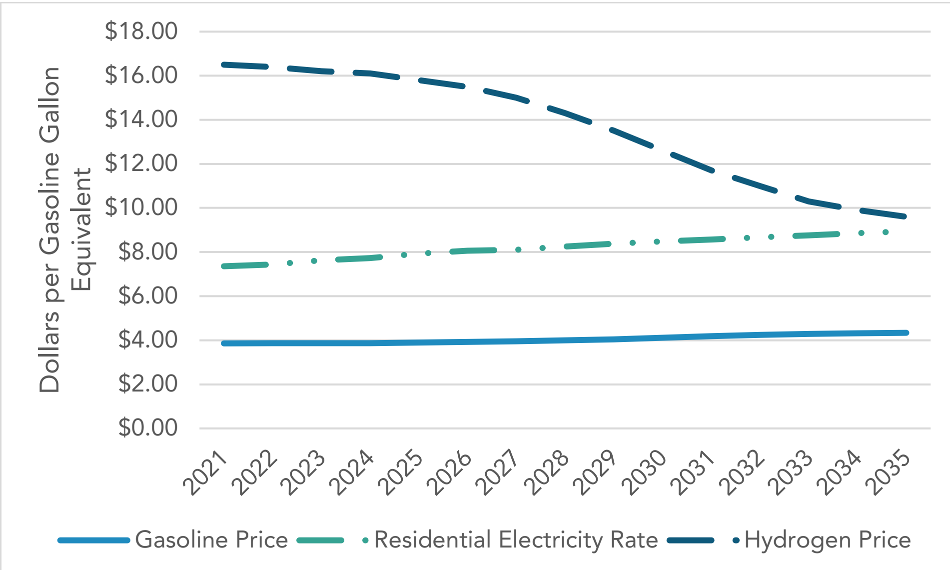
88 *https://arb.ca.gov/emfac/*

89 See staff presentation here: *https://www.energy.ca.gov/event/workshop/2021-12/session-2-iepr-commissioner-workshop-electricity-and-natural-gas-demand*

90 Where calculations require fuel cost estimates beyond 2035, staff assume fuel costs flatline at the 2035 levels.

Figure 13: CEC 2021 IEPR Transportation Energy Price Forecast, "Mid Demand" Scenario.



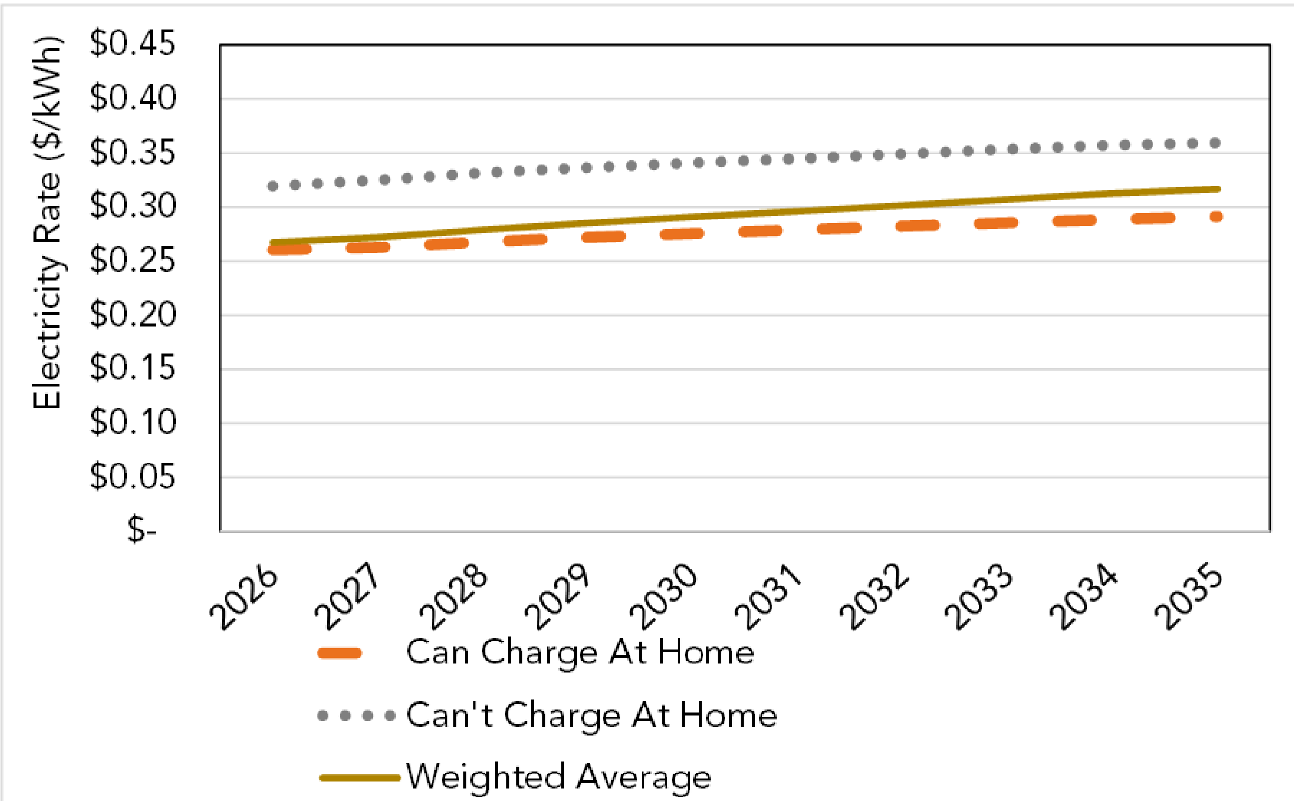
3.2.3.2 Electricity Costs

Electricity costs developed for this analysis rely on the electricity rate projections from the CEC (Figure 13), along with data and assumptions account for varying prices drivers pay at varying charging locations (home versus public charging). Electricity prices for public DC Fast Charging (DCFC) are particularly higher than either home or public Level 2 charging, as is shown below. Note that Figure 15 above shows the cost per unit of fuel, with electricity higher than gasoline. However, the average electricity cost per mile is lower than the gasoline cost per mile when accounting for the higher vehicle efficiency of BEVs compared to ICEVs.

To estimate the average electricity cost for the BEV or PHEV buyers each year of the regulation, projections of how many drivers can and cannot charge at home are needed. Those who live in a single-family residence are more likely to be able to charge at home than those who live in a multi-unit dwelling, for example. An estimate for the distribution of housing stock for California new ZEV buyers is projected for each year of the regulation. A model developed by the CEC and NREL predicts, for each type of home, the percent of those who have access to charging. A separate model from CEC of BEV or PHEV driver charging behavior for those who both have and don't have access to home charging by housing type, projects how often the new ZEV buyers use home chargers, Public L2, and DCFCs.

Each type of charger has an associated projected cost for electricity for each year of the regulation. In this way, the price of electricity is calculated for drivers who purchase new BEVs or PHEVs into three groups: the statewide average overall, the average driver who can charge at home, and the average driver who can't charge at home. These electricity prices are summarized in Figure 14, which includes the weighted average of both and serves as the average electricity price paid for by a PEV driver in California over the period of the regulation. The electricity price data sources used to develop the weighted average are detailed in the following sub-sections.

Figure 14: Estimated Statewide Average Electricity Prices



Details of how these weighted average electricity prices are derived are described in Appendix 9.

Finally, vehicle-to-grid (V2G) services[91] is accounted for in this analysis, though only applied to a small portion of the BEV population. This is because V2G services are not expected to enter the market in a large way until 2030, and even at that point, will depend on a BEV driver having access to a smart bi-directional charging device with vehicle compatibility. Staff assumed 1-2% of drivers in a single-family home will be able to take advantage of this service through 2030, and that it scales up to 25% by 2035. Details are described in Appendix 9.

[91] Defined as the vehicle exporting electricity to the home, an energy storage device, or the grid.

3.2.4 Capital Cost of Installing a Home Charger Outlet

For BEV and PHEV owners, the capital cost of installing a home 220-volt receptacle is estimated and applied to a portion of the new vehicle buyer population based on estimates of which drivers can install one in their home. For example, some drivers may live in a duplex or other kind of multi-unit dwelling building with no off-street parking designated and are unable to install a charging circuit or may rent their home and do not have the ability to install a charger on the property. The direct cost of purchasing a home charger (that connects to the 220-volt receptacle) is not included in the ownership calculations but is accounted for in the incremental vehicle costs (given the regulation proposal includes a requirement on vehicle manufacturers to provide a charging "convenience cord" that can be used for both 110-volt or 220-volt receptacles). See Appendix 9.3.3 for details on this cost.

As noted earlier, this analysis assumes some homeowners will add a home charger to their residence to access lower cost electricity and add convenience of home refueling. The home upgrade costs account for installing a new dedicated 220-volt electrical circuit and receptacle. Homeowners may then choose to add a home charger unit or use the convenience cord supplied by the automakers. For this analysis, this cost is accounted for in the incremental vehicle cost given we are proposing that automakers must provide convenience cords for all BEV and PHEV buyers.

Table 46 below shows the assumed California costs, taken from a recent ICCT study[92], for installing the wiring and circuit in a single-family home and the smaller types of multi-unit dwellings. For larger apartments, the home charging configurations will vary significantly depending on what the parking facility looks like. For this analysis, staff assumed that multi-dwelling unit chargers would be Level 2 and that the electricity would be available at the same retail price to residents as publicly available Level 2 chargers. This price would account for installation costs and could be amortized over a full electric utility territory (as noted in an earlier section). Similarly, for DC fast charging we do not assume any installation costs.

Table 46: Cost of installing home Level 2 Circuit and Wiring

Housing Type	*Receptacle Upgrade**	*EVSE Unit ***	*Total/home*
Single Family Home (SFH) - Detached	$680	---	$680
SFH - Attached, Duplex, Triplex, Quad	$2,000	---	$2,000

** Costs are constant over regulation period*

*** No direct costs assumed given convenience cord requirement*

[92] 2021 ICCT Charging Up America

3.2.5 Maintenance/Scheduled Repair Costs

The costs of maintenance and scheduled repairs for ZEVs and PHEVs are expected to be lower than that of an equivalent ICEV. The Argonne National Laboratory (ANL) has provided estimates of incremental maintenance costs that are below that of an ICEV based on vehicle technology type and miles driven.[93] For BEVs, the average cost of maintenance and planned repairs is approximately 40% lower than a conventional passenger car (PC), for example, due to fewer oil changes, oil filters, timing belts and other replacement parts (spark plugs and oxygen sensors, for example). The ANL study assumes that FCEV and BEV vehicle types experience the same maintenance costs as there is limited data to base estimates on for FCEVs. However, due to the complexity of FCEVs, for this study, FCEVs are assumed to have maintenance and repair costs more similar to PHEVs. The per-mile maintenance savings for this analysis was extracted from the ANL study for passenger vehicles of each drivetrain type and then adjusted using incremental vehicle costs to estimate the per mile savings for the other vehicle types.

The incremental maintenance cost values used in the TCO calculations are shown in Table 47 This data is from the 2021 ANL study on comprehensive total cost of ownership for varying vehicle types.[94] The methodology used by ANL included a detailed comparison of owners' manuals for each vehicle technology type to compare recommended maintenance services and service intervals. The analysis estimated actual costs for each type of service, combined all services per vehicle technology type, and averaged them over a 15-year vehicle life to estimate an average cost per mile. For this analysis, CARB staff utilized the difference in maintenance costs between the vehicle technology types to create an incremental savings relative to ICEVs.

[93] ANL 2021 Report: *https://publications.anl.gov/anlpubs/2021/05/167399.pdf*

[94] ANL (2021) "Comprehensive Total Cost of Ownership Quantification for Vehicles with Different Size Classes and Powertrains"

Table 47: Estimated incremental maintenance costs for each vehicle classification and powertrain type, in dollars per mile (values in parentheses are negative values, indicating savings relative to a comparable internal combustion engine vehicle)

Vehicle Types	2026 - 2035
BEV-PC	$ (0.040)
BEV-LT1	$ (0.039)
BEV-LT2	$ (0.053)
BEV-MDV	$ (0.091)
PHEV-PC	$ (0.007)
PHEV-LT1	$ (0.009)
PHEV-LT2	$ (0.007)
PHEV-MDV	$ (0.007)
FCEV-PC	$ (0.007)
FCEV-LT1	$ (0.008)
FCEV-LT2	$ (0.007)
FCEV-MDV	$ (0.010)

3.2.6 Insurance/Registration Costs

Estimates of insurance and registration costs are expressed in terms of incremental costs to a comparable ICEV. Specifically, incremental annual insurance costs are estimated to be 5% of the incremental vehicle costs, consistent with insurance costs in today's market for conventional vehicles.[95] The insurance costs in this analysis represent the additional annual insurance a vehicle owner would pay based on the ZEV or PHEV incremental vehicle price.

Incremental registration costs compared to an ICEV include the existing road improvement fee of $100 per year of ownership required of all ZEVs regardless of vehicle classification or weight,[96] and the Vehicle License Fee of 0.65 percent of the vehicle's purchase price.[97] The incremental registration fees used in the total cost of ownership (TCO) calculations, above what a comparable ICEV would pay.

3.2.7 Statewide Total Costs of Ownership for Vehicle Owners

This section summarizes the total cost of ownership (TCO) estimates for vehicle owners in California, combining the incremental retail purchase prices, and the vehicle operation and ownership costs. The section summarizes the TCO estimates at a statewide average for all vehicles sold as a result of the regulation, whereas a later section describes select vehicle ownership examples to show how costs can vary with two key parameters: vehicle

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[95] Fulton, Lawrence. "Ownership cost comparison of battery electric and non-plugin hybrid vehicles: a consumer perspective." Applied Sciences 8, no. 9 (2018): 1487.
[96] Vehicle Code sec. 9250.6; Cal. Code Regs., title 13, sec. 423(b)(4).
[97] *https://www.dmv.ca.gov/portal/vehicle-registration/registration-fees/*, accessed 9/30/21.

classification and whether a plug-in electric vehicle owner has access to home charging. For the statewide average, the results show that beginning in 2032, annual total savings exceed total costs, creating a statewide net cost benefit beginning in that year.

Capital expenses (CapEx) are amortized over five years at 5% interest. CapEx includes the incremental vehicle price along with costs of installing a 220V receptacle at the home. Operating expenses (OpEx) include all other expenses incurred each year of operating and owning the vehicle including fuel, maintenance, registration, and insurance as described previously.

Table 48 below shows the results of the statewide average TCO results during the period of increasing requirements for the proposed regulation, 2026 to 2035, and extends it five years further to 2040 where the requirements remain the same as 2035. Specifically, the calculations here account for the cumulative sales of ZEVs and PHEVs as a result of the proposed regulation during each year 2026 to 2040, and any annual mileage and costs incurred during those years specifically. It does not include capital and operating costs beyond 2040 for vehicles still in operation after the regulation period. For example, with a 2035 model year vehicle, a portion of the five-year amortized purchase cost is not included, nor are any operating costs or savings in the years beyond 2040. In a similar way, the costs in 2026 only account for the first year of payments on a five-year amortized loan for the vehicle, along with that year's operating costs.

Figure 15 illustrates the results annually for each year of the regulation period, while Table 48 shows the detailed results. The results show that beginning in 2032, annual total savings exceed total costs, creating a statewide net cost benefit beginning in that year. Note that although per vehicle incremental costs for ZEVs are declining over time as technology and manufacturing scale improve (as shown in Figure 10), fleetwide incremental costs from the sale of ZEVs increase over time. This occurs for two reasons. The compliance scenario assumes that as ZEV and PHEV sales increase, the proportion of their sales that are larger vehicle classifications increases, which are more expensive. Additionally, the incremental ZEV and PHEV costs are spread out over all fleet sales, including conventional ICEVs. Each year, there are less ICEVs to include in this fleet cost assessment.

Figure 15: Statewide TCO for the Proposed Regulation for 2026-2040

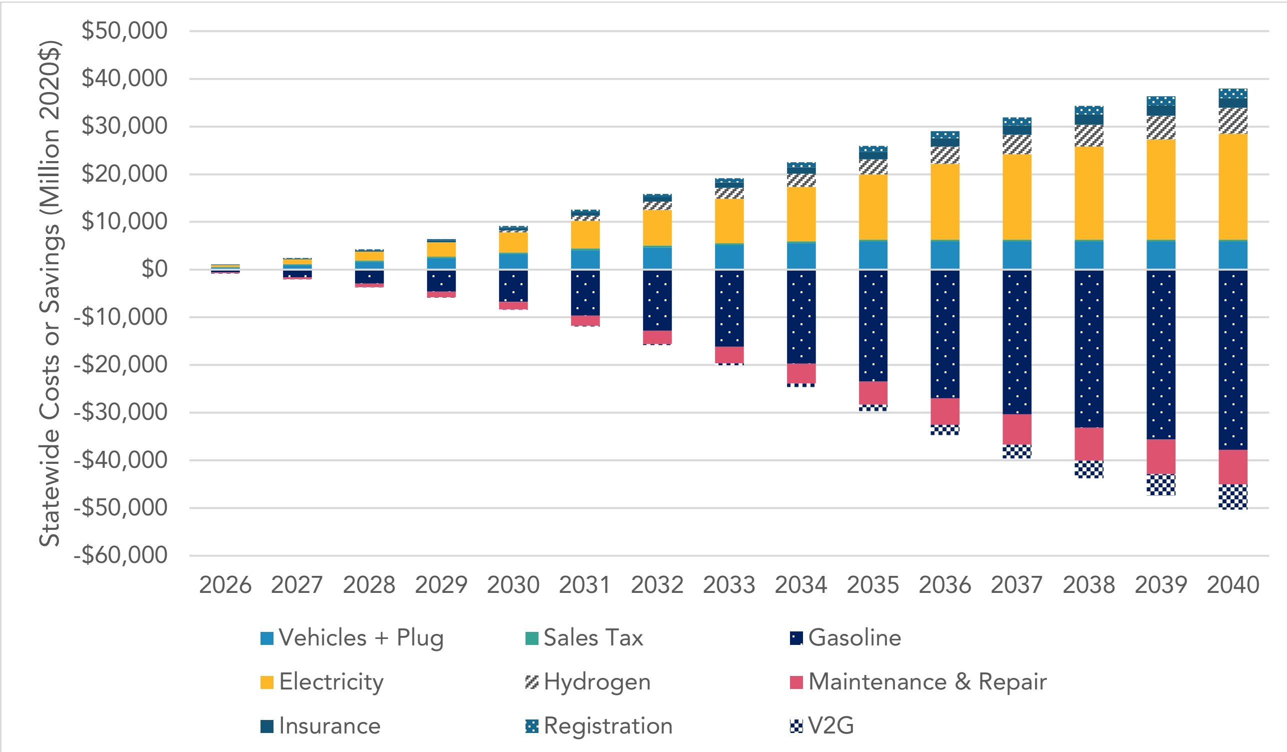


Table 48: Statewide TCO for the proposed regulation, relative to baseline, 2026 to 2040 (Million 2020 $)

Year	Vehicle Price and Plug	Sales Tax	Gasoline	Electricity	Hydrogen	Maintenance and Repair	Insurance	Registration	V2G	Total Cost	Total Savings	Net Cost
2026	$412	$140	-$605	$388	$0	-$156	$70	$37	$0	$1,048	-$762	$287
2027	$982	$193	-$1,569	$1,001	$0	-$400	$168	$94	-$2	$2,438	-$1,971	$467
2028	$1,667	$233	-$2,906	$1,881	$0	-$732	$284	$169	-$6	$4,234	-$3,644	$590
2029	$2,446	$264	-$4,630	$3,034	$0	-$1,153	$414	$263	-$14	$6,421	-$5,797	$623
2030	$3,298	$289	-$6,744	$4,248	$384	-$1,608	$559	$374	-$26	$9,153	-$8,377	$776
2031	$4,059	$398	-$9,644	$5,753	$1,093	-$2,179	$764	$526	-$104	$12,592	-$11,927	$666
2032	$4,672	$401	-$12,821	$7,421	$1,735	-$2,811	$970	$691	-$209	$15,890	-$15,841	$49
2033	$5,160	$398	-$16,153	$9,307	$2,251	-$3,462	$1,171	$867	-$419	$19,154	-$20,034	-$879
2034	$5,552	$397	-$19,691	$11,402	$2,728	-$4,162	$1,371	$1,055	-$770	$22,505	-$24,624	-$2,119
2035	$5,867	$396	-$23,448	$13,700	$3,155	-$4,884	$1,568	$1,256	-$1,315	$25,943	-$29,647	-$3,704
2036	$5,862	$396	-$26,955	$15,911	$3,647	-$5,609	$1,767	$1,458	-$2,105	$29,041	-$34,669	-$5,628
2037	$5,851	$398	-$30,336	$17,926	$4,121	-$6,337	$1,966	$1,661	-$2,896	$31,923	-$39,569	-$7,646
2038	$5,855	$399	-$33,173	$19,576	$4,578	-$6,912	$2,096	$1,827	-$3,687	$34,331	-$43,772	-$9,441
2039	$5,865	$401	-$35,656	$21,003	$5,017	-$7,247	$2,129	$1,938	-$4,476	$36,352	-$47,380	-$11,027
2040	$5,884	$402	-$37,789	$22,198	$5,439	-$7,254	$2,047	$1,974	-$5,261	$37,944	-$50,304	-$12,359
Total	$63,434	$5,104	-$262,120	$154,748	$34,148	-$54,906	$17,345	$14,191	-$21,291	$288,970	-$338,317	-$49,347

3.2.8 Cost-Effectiveness

The metric to quantify cost-effectiveness of the proposed regulation is the ratio of total monetized benefits divided by total monetized costs. A comparison of this type is an appropriate cost-effectiveness measure if the harm associated with increased emissions is fully captured in the estimates of monetized health impacts. A benefit-cost ratio greater than 1 implies that a regulation's benefits are higher than its costs. Benefits to California include both health benefits and cost savings after subtracting tax impacts to State and local governments. Table 49 indicates that the proposed regulation has a total cost of $288.97 billion and total benefit of $337.54 billion over the regulatory horizon. This results in a net benefit of $48.03 billion for the proposed regulation and a Benefit-Cost ratio of 1.17, indicating that the benefits are 17 percent greater than the costs.

Table 49:Benefit-Cost Ratio of the Proposed Regulation for 2026-2040 (Millions of 2020 dollars)

Total Costs	Cost Savings (benefit)	Health Benefits	Tax and Fee Revenue	Total Benefit	Net Benefit	Benefit-Cost Ratio
$288,970	$338,317	$14,553	-$15,867	$337,003	$48,033	1.17

When the social cost of carbon, quantified in Section 2.4, is included, the total benefits of the proposed regulation increase up to $382.98 billion and the benefit-cost ratio to 1.33, based on a 2.5 percent discount rate.

3.3 Direct Costs on Typical Businesses

Light- and medium-duty vehicle manufacturers are the typical businesses that will be affected by the proposed regulations because they are entities directly regulated and required to comply. On average, staff analysis shows manufacturers will incur $199.4 million annually, and a cumulative cost of about $3.2 billion through 2040. Although most of these manufacturers, except Tesla, are located outside of California, staff assumed the direct costs imposed on these manufacturers by California regulation would be passed on through higher vehicle prices to end-users in California. Due to this structure of the expected impacts, an analysis is provided here for both vehicle manufacturers, who are typical businesses that would be directly affected under the proposed regulation, and for vehicle rental businesses (rather than individual vehicle buyers) in California, that would be affected by these regulations as costs are passed through to them.

3.3.1 Vehicle Manufacturers

These costs include compliance with the LEV proposal for light- and medium-duty vehicles and costs to comply with the ZEV proposal by vehicle manufacturers.

It is estimated that there are 17 typical manufacturers that would be affected by the proposed regulations, with all except one a California business. Based on the total direct compliance cost estimated for all vehicle manufacturers shown in **Table 43** and dividing by the 17 typical manufacturers, it is estimated that the average typical business would see direct costs as show in Table 50 below.

Table 50: Annual Compliance Costs for a Typical Vehicle Manufacturer

Model Year	Incremental Vehicle Costs
2026	$84,099,511
2027	$114,759,277
2028	$136,356,106
2029	$152,835,859
2030	$169,508,435
2031	$238,281,241
2032	$238,676,491
2033	$234,061,715
2034	$231,501,185
2035	$228,966,327
2036	$230,111,158
2037	$231,261,714
2038	$232,418,023
2039	$233,580,113
2040	$234,748,013
Average Annual	**$199,411,011**
Total	**$3,190,576,179**

The direct costs for a typical business increase over time corresponding with the increasing stringency of the proposed regulation. This results in an average annual cost of $199.4 million and a cumulative cost of about $3.2 billion through 2040. As discussed in the previous section it is assumed that these direct costs are ultimately passed through to end-users in California, who also realize operational savings that more than offset the incremental cost over the vehicle lifetime.

3.3.2 Passenger Car Rental Businesses

The passenger car rental industry (NAICS 532111) comprises businesses engaged in renting passenger cars, usually for short periods of time. The costs of the proposal are expected to be passed on to the businesses in this industry in California. It is estimated that there are about 645 passenger car rental businesses in California.[98] Based on the estimate that the overall light-duty rental fleet makes up about one percent overall fleet, this suggests businesses in this industry purchase about 15,300 vehicles annually in California. On average, each car-rental business would purchase about 24 vehicles annually in California. Given the average incremental cost per vehicle shown in **Table 43**, the increase in upfront costs for the typical car-rental business is shown in Table 51 below.

Table 51: Potential Costs for a Typical Passenger Car Rental Business (2020$)

Year	Vehicle Cost	Sales Tax	Maintenance & Repair	Insurance	Registration	Total Cost	Total Savings	Net Cost
2026	$3,911	$1,439	-$1,940	$847	$461	$6,657	-$1,940	$4,717
2027	$9,274	$1,974	-$3,011	$1,161	$696	$13,105	-$3,011	$10,095
2028	$15,597	$2,327	-$4,438	$1,369	$917	$20,209	-$4,438	$15,772
2029	$22,635	$2,590	-$5,687	$1,523	$1,132	$27,880	-$5,687	$22,193
2030	$30,398	$2,857	-$6,007	$1,681	$1,344	$36,280	-$6,007	$30,273
2031	$37,427	$4,026	-$7,317	$2,368	$1,825	$45,646	-$7,317	$38,329
2032	$42,932	$4,000	-$8,171	$2,353	$1,965	$51,250	-$8,171	$43,079
2033	$47,570	$4,034	-$9,696	$2,373	$2,110	$56,087	-$9,696	$46,392
2034	$51,274	$3,953	-$11,131	$2,325	$2,246	$59,799	-$11,131	$48,668
2035	$54,135	$3,910	-$11,741	$2,300	$2,385	$62,730	-$11,741	$50,989
2036	$53,820	$3,910	-$11,741	$2,300	$2,385	$62,415	-$11,741	$50,674
2037	$53,820	$3,910	-$11,741	$2,300	$2,385	$62,415	-$11,741	$50,674
2038	$53,820	$3,910	-$11,741	$2,300	$2,385	$62,415	-$11,741	$50,674
2039	$53,820	$3,910	-$11,741	$2,300	$2,385	$62,415	-$11,741	$50,674
2040	$53,820	$3,910	-$11,741	$2,300	$2,385	$62,415	-$11,741	$50,674
Annual Average	**$38,950**	**$3,377**	**-$8,523**	**$1,987**	**$1,800**	**$46,115**	**-$8,523**	**$37,592**
Total	**$584,253**	**$50,660**	**-$127,844**	**$29,800**	**$27,006**	**$691,718**	**-$127,844**	**$563,877**

An average typical rental car business would see increasing incremental purchase costs for vehicles over the course of the regulation as stringency increases. However, the rental firms would benefit from operational savings due to the reduction in repair and maintenance. There may also be an increased cost for electricity depending on whether the rental business or the driver ends up bearing the costs of vehicle charging, though reduced gasoline usage leads to net fuel savings in nearly all cases. It is estimated the rental companies would incur an average annual cost of about $37,600 over the course of the regulatory horizon.

3.4 Direct Costs on Small Businesses

The small businesses for this regulation may be the small manufacturers that produce less than 4,500 vehicles in California. As these manufacturers are located outside of California, it is assumed that the direct costs imposed on these manufacturers would be passed on through higher vehicle prices to end-users in California. Due to this structure of the expected

[98] Based on data from Dun & Bradstreet Market Insight. Accessed 10-20-21.

impacts, an analysis is provided here for both vehicle manufacturers, who are small businesses that would be directly affected under the proposed regulation, and for small businesses that purchase light-duty vehicles for a various business purpose in California, that would be affected by these regulations as costs are passed through to them.

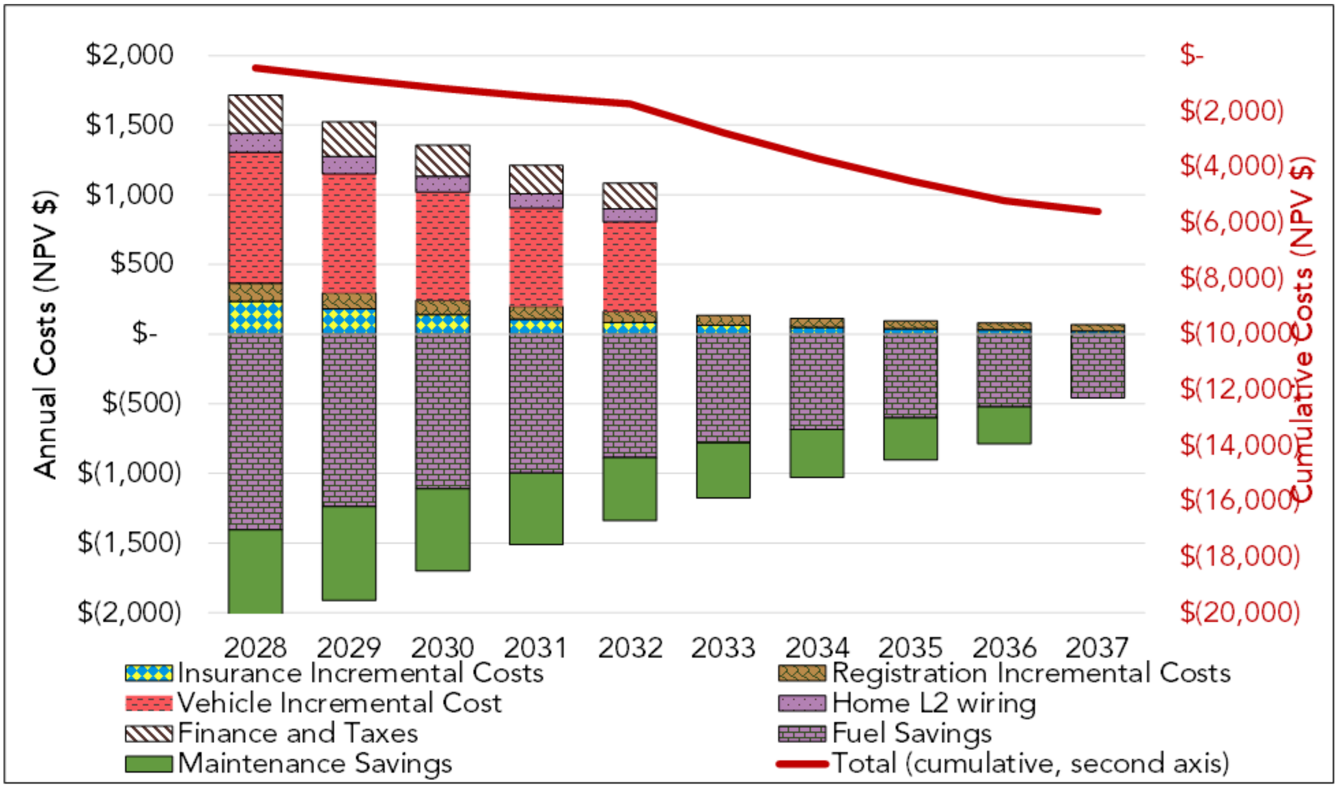
3.4.1 Vehicle Manufacturers (OEMs)

Small manufacturers, which represent 2 percent of the affected vehicle population, will not be subjected to the ZEV phase-in schedule from 2026 through 2034, but will be required to have 100 percent ZEV sales by 2035. This gives the small manufacturers enough time to take advantage of cost reductions and learning curves achieved by the larger vehicle manufacturers. There are estimated to be nine small manufacturers that would be affected by the proposed regulation, and they would incur compliance costs starting in model year 2035. Based on the direct compliance cost, it is estimated that the average small manufacturer would see direct costs of about $882,000 in 2035 and 2036, for a cumulative cost of $1.76 million over the regulatory horizon. As discussed in the previous section, it is assumed that these direct costs are ultimately passed through to end-users in California and those end-users will ultimately see cost-savings in 2035 based on the total cost of ownership.

3.4.2 Other Small Businesses

Light-duty vehicles are purchased by businesses in many different industries across the California economy for various business uses. Here we consider a cost example for a small business that purchases a typical full-size light truck (LTD3) for business use. The figure shows the TCO costs annually, splitting out each cost element of the TCO depicted on the left side vertical axis (positive values are expenses, and negative values are savings annually). The annual cost of the vehicle purchase and building wiring upgrade only occurs in the first five years as this is the period of a loan repayment. Also shown with the right-side vertical axis is the cumulative costs over time. This result shows the owner breaks even at year six as annual savings accumulate sufficient to compensate for expenses by that point. By the tenth year, the owner has saved nearly $5,500 from total ownership costs.

Figure 16: Summary Figure: 2028MY LDT3 Annual Costs (full TCO), and Cumulate Net Costs (NPV $)



3.5 Direct Costs on Individuals

There are no direct costs on individuals as a result of this Proposed Regulation. Staff estimates that manufacturers will see increased costs as a result of this rule and will likely pass the costs through to individuals in the state through increased incremental prices.

As discussed above, the proposed regulation increases the purchase price for a new vehicle, in part by requiring quality assurance measures to ensure that these vehicles can be resold into the used vehicle market. It is important to know the indirect cost to individual consumers.

This section presents a different form of TCO results, focusing on an individual vehicle and household type, and the operating and ownership costs over a ten-year period for that vehicle specifically. The intent in presenting this information is to describe TCO results from a consumer perspective and consider if incremental costs incurred are paid back over time with operational cost savings. For simplicity, only two examples are shown, both for a passenger car classification given its large proportion of the market in California. The examples also both use a single-family home type, but that assumption only affects the initial cost of a home charger and receptacle (apartment install costs are higher, as described in the appendix).

The two examples reveal differences in TCO results based on several key factors. First, TCO results vary dramatically for a vehicle sold at the beginning of the regulation period (2026) as compared to the end of the regulation period (2035), primarily because the vehicle incremental price is substantially lower in the later years as the technology matures and costs decline. Second, in both examples, results for a BEV driver are shown both for someone with a home charger and someone without a home charger. For someone with a home charger, they incur an additional capital cost of installing a home charger and receptacle, yet they have lower fuel costs given the cheaper retail price of residential electricity, as described in the appendix. The result of this tradeoff is that the payback period for the 2026MY BEV300 with a home charger is two years shorter compared to the BEV without a home charger. For the 2035MY BEV the payback period is nearly the same given the incremental vehicle cost is substantially lower. The ten-year TCO full cost savings are larger for the individual with a home charger in both model year examples. The third factor shown in these examples is the much different TCO ten-year result for FCEVs and PHEVs compared to BEVs. In both the 2026 and 2035 example, the BEV technology has a payback period within the ten-year period, whereas the FCEV and the PHEV in most of the model years will have a payback longer than ten years.

These results are shown in a table and two figures, with one set for 2026MY vehicles, and a second set for 2035MY vehicles. The first figure in each set only shows the cumulative costs over time for the three technology types, revealing the break-even period if it occurs. The second figure in each set shows additional detail but only for the BEV technology, similar to Figure 16 above, where annual TCO costs are shown on one vertical axis, and cumulative costs are shown on the second vertical axis.

Table 52: Total cost of ownership over 10 years for individual ZEV and PHEV buyer compared to baseline ICEV, 2026 MY Passenger Car (PC) in Single Family Home (SFH) *

	BEV (300 mile range)		FCEV	PHEV
	With home charger	No home charger		With home charger
Incremental vehicle price	$ 4,936	$ 4,936	$ 8,679	$ 7,068
Home Level 2 circuit (not including the charger)	$ 680			$ 680
Finance costs & sales tax (for incr veh price and Level 2 circuit)	$ 1,185	$ 1,042	$ 1,832	$ 1,635
Incremental Fuel costs	$ (4,871)	$ (2,912)	$ 7,158	$ (7)
Incremental Maintenance costs	$ (4,540)	$ (4,540)	$ (1,249)	$ (1,249)
Incremental Insurance	$ 1,003	$ 1,003	$ 1,765	$ 1,437
Incremental Registration	$ 806	$ 806	$ 905	$ 863
Total (10 years)	**$ (1,732)**	**$ (484)**	**$ 17,649**	**$ 9,141**
Payback period	**6 years**	**8 years**	**Never**	**Never**

*Finance costs include a 5 year loan at 5% interest; Operation and ownership costs over 10 yrs (~150,000 miles) shown as net present value for 2026 at a discount rate of 10%.

Figure 17: Cumulative Total Cost of Ownership Over 10 Years for Individual ZEV and PHEV Buyer Compared to Baseline ICEV, 2026 MY Passenger Car (PC) in Single Family Home (SFH)

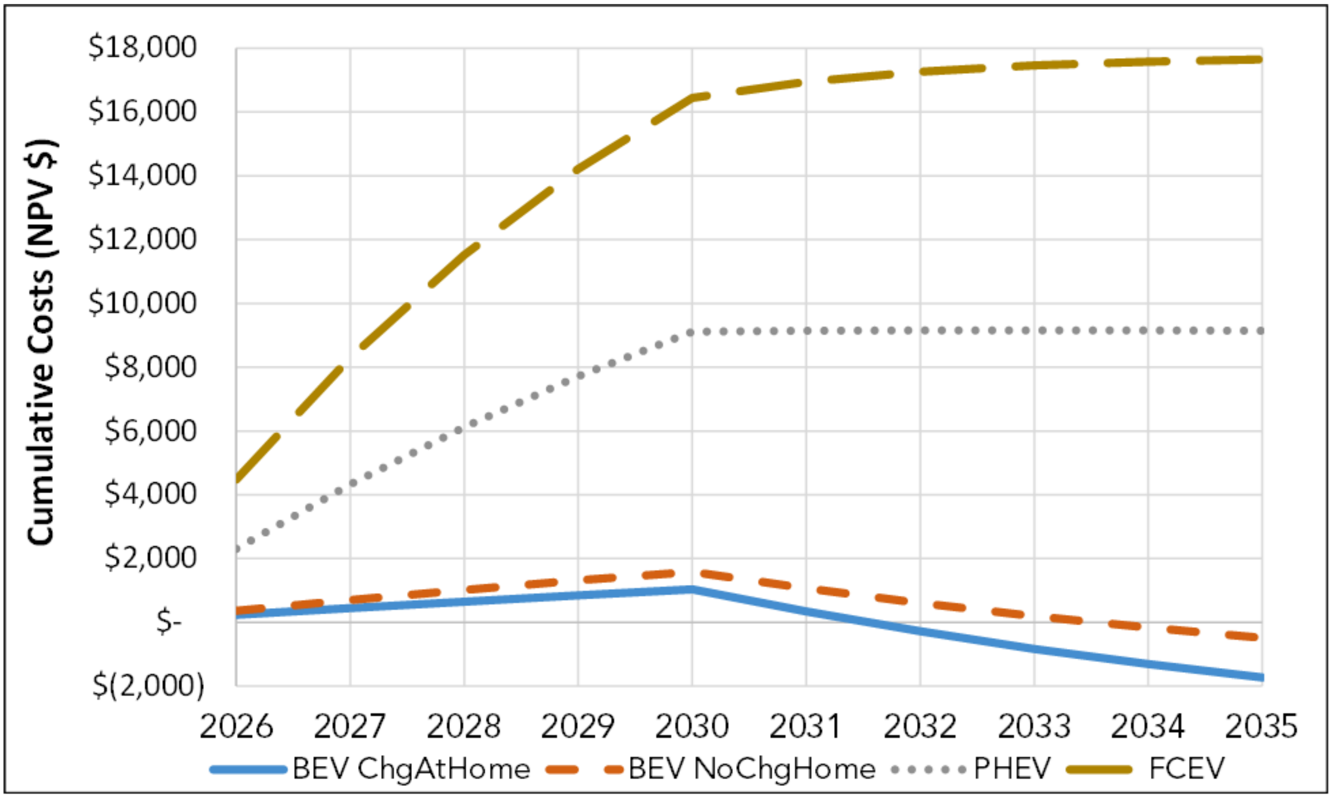
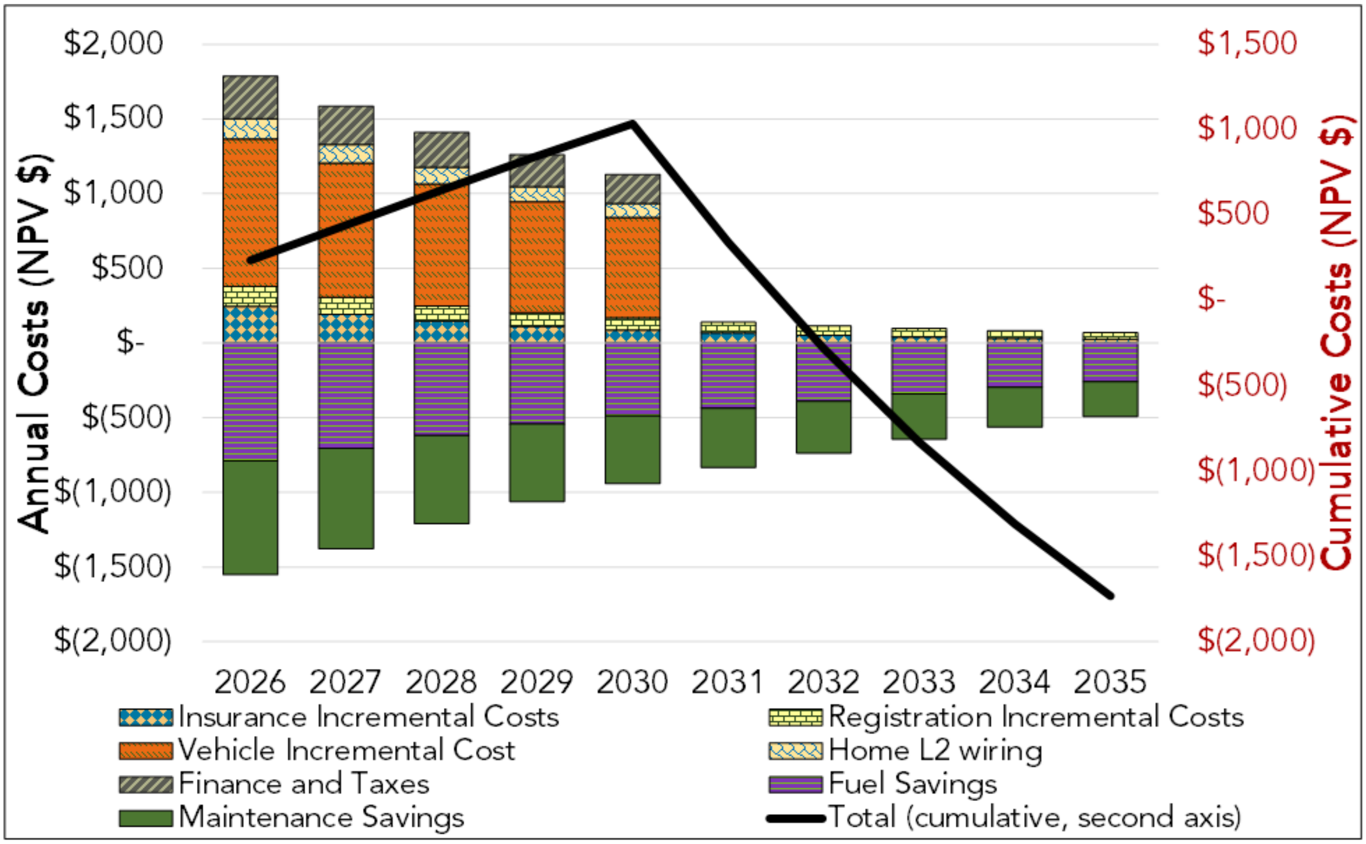


Figure 18:Annual and cumulative total cost of ownership over 10 years for a BEV300 in a single-family home, compared to baseline ICEV, 2026 MY Passenger Car (PC)



$2,000
$1,500
$1,000
$500
$-
$(500)
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Annual Costs (NPV $)
$1,500
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$500
$-
$(500)
$(1,000)
$(1,500)
$(2,000)
Cumulative Costs (NPV $)
2026 2027 2028 2029 2030 2031 2032 2033 2034 2035
Insurance Incremental Costs
Registration Incremental Costs
Vehicle Incremental Cost
Home L2 wiring
Finance and Taxes
Fuel Savings
Maintenance Savings
Total (cumulative, second axis)

Table 53: Total cost of ownership over 10 years for individual ZEV and PHEV buyer compared to baseline ICEV, 2035 MY Passenger Car (PC) in Single Family Home (SFH) *

	BEV (300 mile range)		**FCEV**	**PHEV**
	With home charger	**No home charger**		**With home charger**
Incremental vehicle price	$1,130	$1,130	$2,463	$5,935
Home Level 2 circuit (not including the charger)	$680			$680
Finance costs & sales tax (for incr veh price and Level 2 circuit)	$382	$474	$520	$1,396
Incremental Fuel costs	$ (5,022)	$(2,972)	$(1,676)	$(112)
Incremental Maintenance costs	$ (4,489)	$ (4,489)	$(1,234)	$(1,234)
Incremental Insurance	$230	$230	$501	$1,207
Incremental Registration	$706	$706	$741	$869
Total (10 years)	**$ (6,683)**	**$ (5,109)**	**$905**	**$7,642**
Payback period	**1 year**	**1 year**	**Never**	**Never**

*Finance costs include a 5-year loan at 5% interest; Operation and ownership costs over 10 years (~150,000 miles) shown as net present value for 2035 at a discount rate of 10%

Figure 19: Cumulative total cost of ownership over 10 years for individual ZEV and PHEV buyer compared to baseline ICEV, 2035 MY Passenger Car (PC) in Single Family Home (SFH)

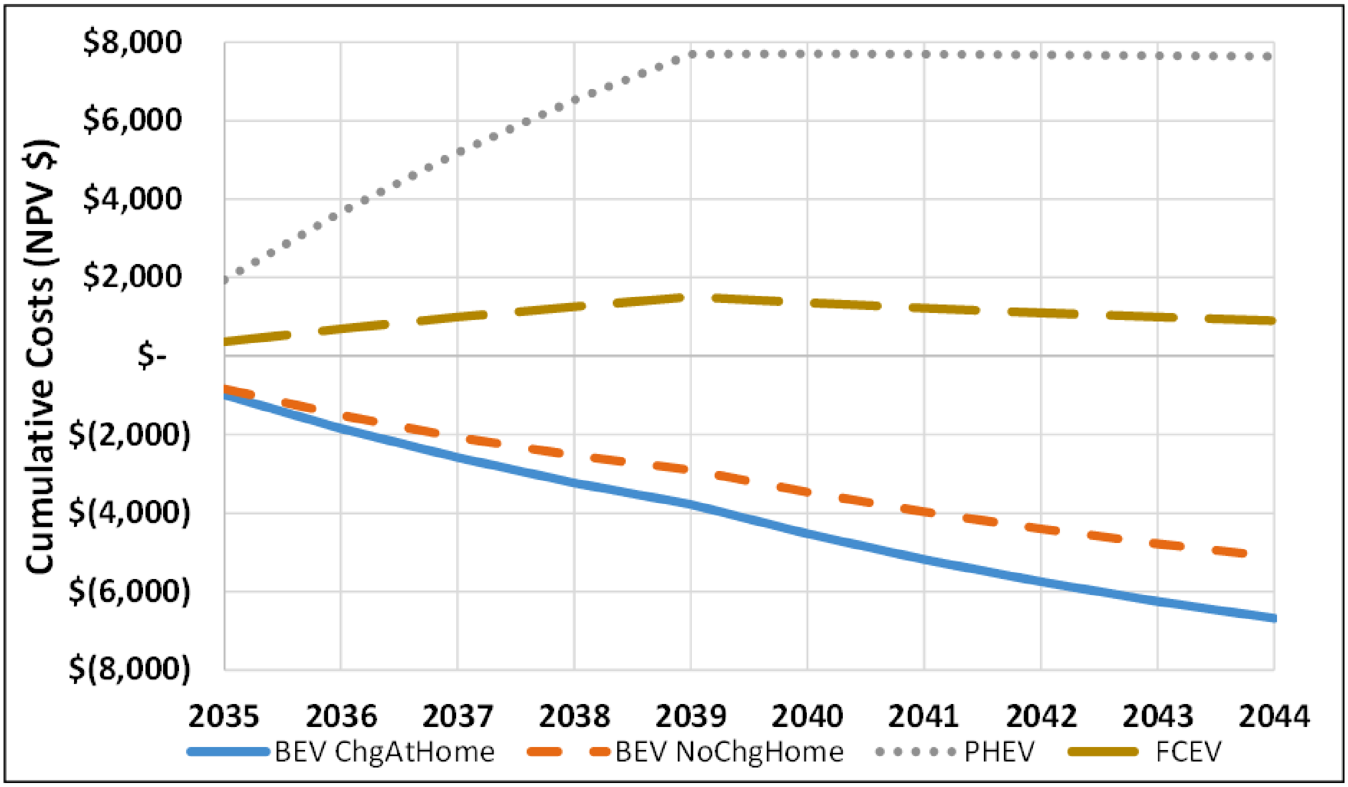
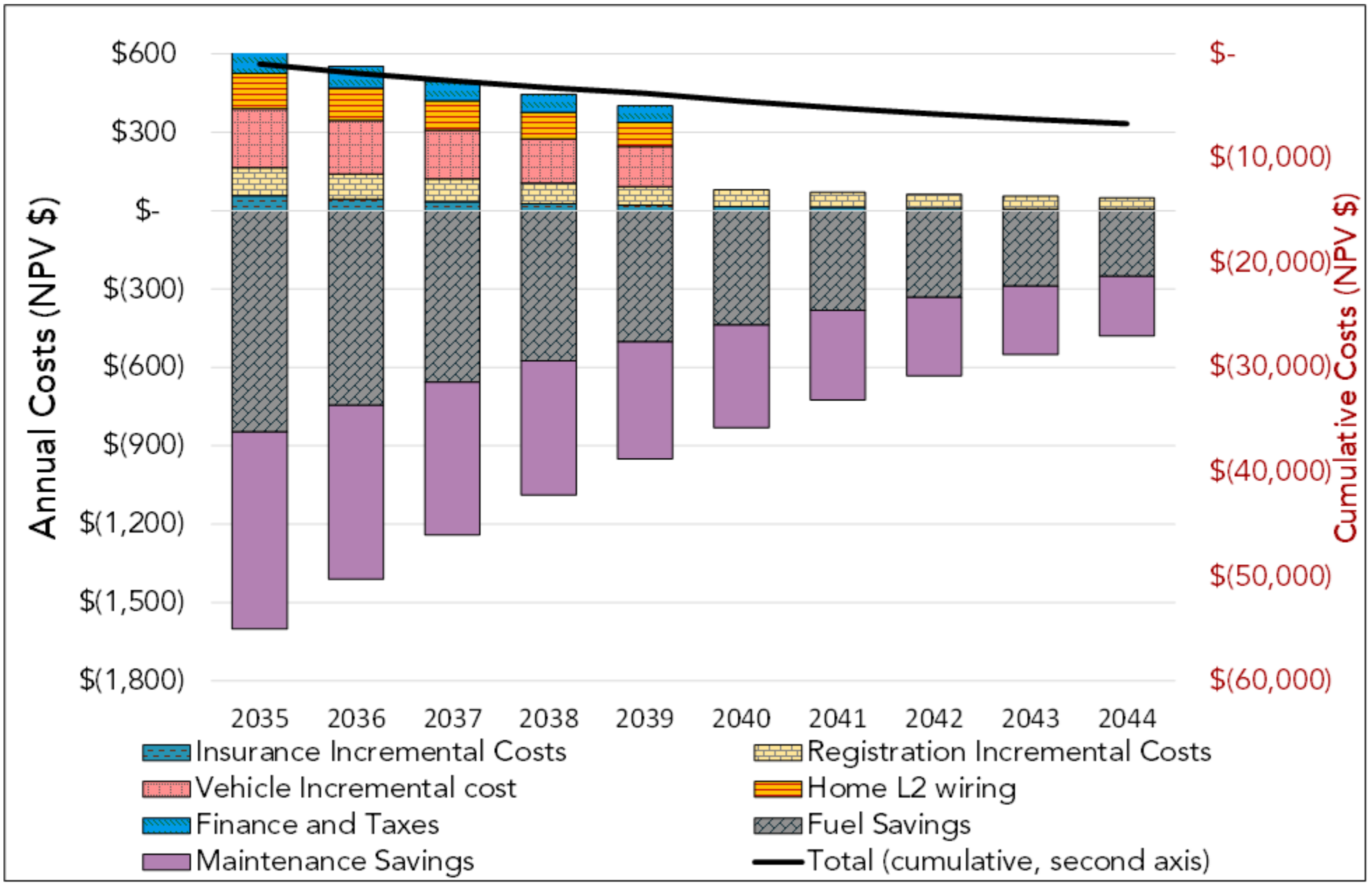


Figure 20:Annual and Cumulative Total Cost of Ownership Over 10 Years for a BEV300 in a Single-Family Home, Compared to Baseline ICEV, 2035 MY Passenger Car (PC)



3.5.1 Vehicle Purchase Incentives to Offset Cost to Consumers

There are several vehicle purchase incentives available to California ZEV and PHEV buyers today, though additional incentives exist for specific income groups: The federal tax credit, the California Clean Vehicle Rebate Project (CVRP), the California Clean Cars 4 All program, and the California Low Carbon Fuels Standard (LCFS) Clean Fuels Reward (CFR).[99,100] However, staff are not assuming any of these incentives in the TCO analysis due to the uncertainty that these incentives will be available during the time period of the regulation.

The federal tax credit is only for the first 200,000 cumulative vehicle sales by any given vehicle manufacturer and many of the major manufacturers will be over the limit by 2026,

[99] US DOE: *https://www.fueleconomy.gov/feg/taxevb.shtml*, accessed 10/1/21
[100] CARB Clean Cars 4 All: *https://ww2.arb.ca.gov/our-work/programs/clean-cars-4-all*, accessed 01/13/22

unless Congress changes the law. Additionally, applicants for the tax credit would need a tax liability of at least $7,500 to take full advantage of the program, which means a realistic analysis would need to estimate the varying household income and tax liability levels.

The California CVRP is subject to annual funding by the Legislature and the program itself is intended to phase out in the next few years. As the number of new ZEVs sold in California increases each year, the allocated funds will have to be stretched even further with stricter restrictions on household income and vehicle MSRP. It is unknown whether funds will be available during the time period of the regulation, of if they are, what amount of rebate may be available to different income groups for a ZEV or PHEV.

The California LCFS CFR provides money back at the point of sale of new ZEVs. However, funds for the CFR program are based on funds held by electric utility companies based on their LCFS credit holding, and the varying market value of LCFS credits. The amount of funds available in the long-term, including how electric utilities would allocate these funds, is unknown.

4 Fiscal Impacts

The Proposed Regulation will impact state and local government expenditures through the purchase and operation of new vehicles and will impact revenues generated from a variety of state and local taxes and vehicle registration fee revenues that are collected.

These revenues, particularly those from state and local gasoline taxes and registration fees, are used to fund transportation projects across the state including road maintenance, construction of state highways and local streets, transit facilities and operation, and active transportation projects as described in Table 54 below. Thus, increases or decreases will impact funds available for these projects at the State, county, and local levels for use on road and transportation infrastructure improvements.

Table 54: Transportation Funding Source and Purpose

Revenue Source	Account/Program	Allocation Funding Purpose
Gasoline Excise Tax	State Highway Account (SHA)	highway projects and transportation maintenance and operational needs
	Road Maintenance & Rehabilitation Account (RMRA)	prioritized road maintenance and rehabilitation projects for state and local transportation systems
	Highway Users' Tax Account (HUTA)	local streets and roads projects
Zero-Emission Vehicle Registration Fee	RMRA	basic road maintenance, rehabilitation, critical safety projects and other transportation initiatives, including complete street components for the state and local transportation systems
Motor Vehicle Registration Fees	California Highway Patrol (CHP) and Department of Motor Vehicles (DMV)	traffic law enforcement and regulations
Local Sales Tax Measures[101]	City/County Road Funds	Maintenance, new construction, engineering/administration, right of way, mass transit, and other
	Regional Transportation Planning Agencies (RTPAs)/Transit Operators	transit operations, transit planning

101 Counties can adopt a sales tax increase for transportation programs. The passage of a local sales tax measure requires 2/3 of local voter approval, generally lasting 20 to 30 years. Twenty-five counties have implemented sales tax measures for their transportation needs; and four transit authorities have approved permanent local tax measures.

4.1 **Local Government**

4.1.1 Local Government Fleet Cost Pass-Through

Local governments are assumed to incur an incremental cost from the purchase of new vehicles, while also realizing operational savings from the use of ZEVs. State and local government fleets are estimated to make up about one percent of the state's light-duty vehicle fleet Figure 21. Based on this and the local government share of employment, it is estimated that local government fleets would realize about 0.77 percent of the statewide vehicle cost and operational savings resulting from the proposed regulation.[102]

4.1.2 Local Sales Tax from Vehicle Sales

Sales taxes are levied in California to fund a variety of programs at the state and local level. The Proposed Regulation would increase the cost of each light- and medium-duty vehicle sold in the state in 2026 and subsequent model years. The average tax rate in California is 8.5 percent with 4.6 percent going to local governments.[103] Overall, state sales tax revenue may increase less than the direct increase from vehicle sales if overall spending does not increase.

4.1.3 Utility Users Tax

Many cities and counties in California levy a Utility Users Tax on electricity. This tax varies by jurisdiction and ranges from 0 to 11%. A value of 3.53% was used in this analysis, representing a population-weighted average.[104] By increasing the amount of electricity used, there will be an increase in the amount of utility user tax revenue collected by cities and counties.

4.1.4 Gasoline Taxes

Taxes on gasoline include a 51.1 cents per gallon state excise tax, an 18.4 cents per gallon federal excise tax, and a state and local sales tax that averages 3.7 percent across California.[105,106] Approximately 42 percent of the state excise tax is allocated to cities and counties and are used to fund transportation improvements in the state. The 3.7 percent

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[102] Based on REMI Policy Insight Plus (v 2.5), Local governments' share of State and Local government employment is 0.77 percent.

[103] (CARB, 2019c) Spreadsheet for California City and County Sales and Use Tax Rates, California Air Resources Board, July 2019, obtained from the California Department of Tax and Fee Administration website at *http://cdtfa.ca.gov/taxes-and-fees/sales-use-tax-rates.htm*

[104] California State Controller's Office, User Utility Tax Revenue and Rates (web link: https://sco.ca.gov/Files-ARD-Local/LocRep/2017-18_Cities_TOT.pdf, last accessed June 2020)

[105] California Legislative Analyst's Office, Transportation, Frequently Asked Questions (web page: *https://lao.ca.gov/Transportation/FAQs*, last accessed December, 2021)

[106] Gasoline is exempt from the portion of state sales tax that supports the state General Fund and 2011 Realignment. Of the 3.7 percent, 1 percent is under State jurisdiction but goes towards various local revenue funds and is therefore included with the impacts to local government.

sales tax revenue collected from gasoline sales goes to a variety of funds, some of which support transportation and local government operations, and others which support programs such as local criminal justice activities, local health, and social services programs.[107] Displacing gasoline fuel with electricity will decrease the amount of gasoline dispensed in the state, resulting in a reduction in tax revenue collected by local governments.

4.1.5 Fiscal Impacts on Local Government

Table 55 shows the estimated fiscal impacts to local governments due to the proposed regulation, based on the fiscal aspect explained above. The total fiscal impact, defined as the change in revenue minus change in costs, to local government is estimated to be a decrease of $60.4 million over the first three years of the regulation and a cumulative decrease of $14.52 billion over the regulatory horizon.

Table 55: Estimated Fiscal Impacts on Local Governments (Million 2020$)

Year	Vehicle Cost	Operational Cost	Operational Savings	Utility User Fee Revenue	Vehicle Sales Tax Revenue	Gasoline Sales Tax Revenue	Excise Tax Revenue	Total Fiscal Impact*
2026	$4.5	$3.5	-$5.9	$13.7	$75.0	-$22.4	-$34.0	$30.2
2027	$9.8	$9.0	-$15.2	$35.3	$103.6	-$58.1	-$87.2	-$9.9
2028	$15.9	$16.7	-$28.1	$66.4	$124.8	-$107.5	-$159.8	-$80.7
2029	$22.9	$26.6	-$44.6	$107.1	$141.7	-$171.3	-$252.0	-$179.4
2030	$30.5	$40.0	-$64.5	$150.0	$155.1	-$249.5	-$360.8	-$311.2
2031	$38.4	$58.6	-$91.9	$203.1	$213.4	-$356.8	-$507.2	-$452.7
2032	$44.4	$78.0	-$122.0	$262.0	$215.3	-$474.4	-$664.1	-$661.5
2033	$49.5	$98.0	-$154.3	$328.5	$213.5	-$597.7	-$829.9	-$878.8
2034	$53.9	$119.4	-$189.6	$402.5	$213.0	-$728.6	-$1,005.3	-$1,102.0
2035	$57.9	$141.9	-$228.3	$483.6	$212.4	-$867.6	-$1,189.5	-$1,332.6
2036	$59.4	$164.2	-$267.0	$561.7	$212.5	-$997.3	-$1,367.4	-$1,547.2
2037	$60.9	$184.9	-$304.7	$632.8	$213.3	-$1,122.4	-$1,538.9	-$1,756.4
2038	$62.2	$202.2	-$337.1	$691.0	$214.1	-$1,227.4	-$1,682.8	-$1,932.3
2039	$63.2	$216.8	-$364.9	$741.4	$215.0	-$1,319.3	-$1,808.8	-$2,086.8
2040	$63.6	$228.6	-$387.4	$783.6	$215.8	-$1,398.2	-$1,917.0	-$2,220.7
Total	**$637.1**	**$1,588.3**	**-$2,605.4**	**$5,462.6**	**$2,738.4**	**-$9,698.4**	**-$13,404.6**	**-$14,522.0**

[107] Counties can adopt a sales tax increase for transportation programs. The passage of a local sales tax measure requires 2/3 of local voter approval, generally lasting 20 to 30 years. Twenty-five counties have implemented sales tax measures for their transportation needs; and four transit authorities have approved permanent local tax measures. A detailed description of the funds for the sales and use tax rates can be found here: California Department of Tax and Fee Administration, Detailed Description of the Sales & Use Tax Rate (web link: *https://www.cdtfa.ca.gov/taxes-and-fees/sut-rates-description.htm*, last accessed December 2021)

*Total Fiscal Impact is defined as revenue minus costs.

4.2 State Government

4.2.1 State Fleet Cost Pass-Through

State government is assumed to incur an incremental cost from the purchase of new vehicles, while also realizing operational savings from the use of ZEVs. State and local government fleets are estimated to make up about one percent of the state's light-duty vehicle fleet Figure 21. Based on this and the state government share of employment it is estimated that state government fleets would realize about 0.23 percent of the statewide vehicle cost and operational savings resulting from the proposed regulation.[108]

4.2.2 State Sales Taxes from Vehicle Sales

Sales taxes are levied in California to fund a variety of programs. The Proposed Regulation would result in the sale of more expensive (higher upfront cost) vehicles. The entire population of new California-sold vehicles over the entire state was used for this analysis. California sales tax at 8.5 percent was used in this analysis with 3.94 percent going to state government. Overall, state sales tax revenue may increase less than the direct increase from vehicle sales if overall business spending does not increase.

4.2.3 Vehicle Registration and License Fees

As described in Section 3.2.6, State government would generate additional revenue from the existing Zero-Emission Vehicle Registration Fee and Vehicle License Fees. The Zero-Emission Vehicle Registration Fee is an existing road improvement fee of $100 per year of ownership required of all ZEVs regardless of vehicle classification or weight, and the Vehicle License Fee of 0.65 percent of the vehicle's purchase price.[109] The Zero-Emission Vehicle Registration Fee is used for basic road maintenance, rehabilitation, critical safety projects and other transportation initiatives, including complete street components. The Motor Vehicle License

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[108] Based on REMI Policy Insight Plus (v 2.5), State government's share of State and Local government employment is 23 percent.

[109] The Proposed Regulation could also potentially impact revenue collected by the Transportation Improvement Fee (TIF). The TIF charges vehicle owners' a registration fee of $25, $50, $100, $160, or $175 based on whether the market value of the vehicle falls between specific ranges of $0 to $4,999, $5,000 to $24,999, $25,000 to $34,999, $35,000 to $59,999, or $60,000 or higher, respectively. If the Proposed Regulation increases a vehicle's market value in a year such that it moves it into a higher vehicle value bin, there would be an increase in revenue collected for that specific vehicle. This would depend on the each vehicle's specific market value and the incremental impact of the Proposed Regulation. Due to the complex interactions between the Proposed Regulation and individual vehicle values, the impacts of the TIF are not included in this analysis.
More information on the Transportation Improvement Fee can be found at: Department of Motor Vehicles, Vehicle Industry News, VIN 2017-25, New Transportation Improvement Fee. (web link: *https://www.dmv.ca.gov/portal/uploads/2020/06/VIN-2017-25-New-Transportation-Improvement-Fee.pdf*, last accessed December 2021).

fees are allocated to California Highway Patrol and DMV for traffic enforcement and regulations.

4.2.4 Gasoline Taxes

Approximately 58 percent of the 51.1 cent per gallon state excise tax is allocated state funds such as the State Highway Account, State Highway Operation and Protection Program, State Transportation Improvement Program, and the Highway Users' Tax Account. These revenues are used to fund highway projects, prioritized road maintenance and rehabilitation projects, and local street and road projects. As discussed above, displacing gasoline fuel with electricity will decrease the amount of gasoline dispensed in the state, resulting in a reduction in excise tax revenue that is collected.

4.2.5 Energy Resources Fee

The Energy Resources Fee is a $0.0003/kWh surcharge levied on consumers of electricity purchased from electrical utilities. The revenue collected is deposited into the Energy Resources Programs Account of the General Fund, which is used for ongoing electricity programs and projects deemed appropriate by the Legislature, including but not limited to, activities of the California Energy Commission (CEC). Increased use of ZEVs will result in increases in electricity use and increased revenue from the Energy Resources Fee.

4.2.6 CARB Staffing and Resources

The Proposed Regulation would have a small impact on State staffing resources. The Proposed Regulation is not expected to require more positions; existing staff who implement the current emission control program and who are developing this proposal will transition to implementing the new program.

4.2.7 Fiscal Impacts on State Government

Table 56 shows the estimated fiscal impacts to state government due to the proposed regulation. The fiscal impact, revenues minus costs, to state government is estimated to be an increase of $193.3 million over the first three years of the regulation and a cumulative decrease of $851.2 million over the regulatory horizon.

Table 56: Estimated Fiscal Impacts on State Government (Million 2020$)

Year	Vehicle Cost	Operational Cost	Operational Savings	Registration and License Fee Revenue	Energy Resource Fee Revenue	Vehicle Sales Tax Revenue	State Portion of Excise Tax Revenue	Total Fiscal Impact*
2026	$1.4	$1.1	-$1.8	$37.4	$0.4	$64.8	-$44.8	$57.2
2027	$2.9	$2.7	-$4.5	$94.2	$1.1	$89.5	-$114.9	$68.8
2028	$4.8	$5.0	-$8.4	$169.4	$2.0	$107.8	-$210.7	$67.3
2029	$6.8	$7.9	-$13.3	$262.8	$3.2	$122.4	-$332.2	$54.7
2030	$9.1	$11.9	-$19.3	$374.2	$4.4	$134.0	-$475.5	$35.3
2031	$11.5	$17.5	-$27.4	$526.2	$5.8	$184.3	-$668.5	$46.3
2032	$13.3	$23.3	-$36.4	$690.6	$7.4	$186.0	-$875.4	$8.5
2033	$14.8	$29.3	-$46.1	$866.9	$9.1	$184.4	-$1,093.9	-$31.5
2034	$16.1	$35.6	-$56.6	$1,055.5	$10.9	$184.1	-$1,325.1	-$69.8
2035	$17.3	$42.4	-$68.2	$1,256.4	$13.0	$183.5	-$1,568.0	-$106.6
2036	$17.7	$49.0	-$79.7	$1,458.2	$14.9	$183.6	-$1,802.5	-$132.8
2037	$18.2	$55.2	-$91.0	$1,660.9	$16.8	$184.3	-$2,028.6	-$149.0
2038	$18.6	$60.3	-$100.6	$1,827.2	$18.4	$185.0	-$2,218.3	-$166.0
2039	$18.9	$64.7	-$108.9	$1,937.5	$19.7	$185.7	-$2,384.3	-$216.0
2040	$19.0	$68.2	-$115.6	$1,973.6	$20.8	$186.5	-$2,527.0	-$317.6
Total	**$190.2**	**$474.1**	**-$777.7**	**$14,191.0**	**$148.1**	**$2,366.1**	**-$17,669.7**	**-$851.2**

*Total Fiscal Impact is defined as revenue minus costs.

5 Macroeconomic Impacts

5.1 Methods for Determining Economic Impacts

This section describes the estimated total impact of the Proposed Regulation on the California economy. The Proposed Regulation will result in incremental costs and cost-savings for individuals, businesses, and governments that purchase new vehicles, through changes in their upfront and operational expenditures. These changes in expenditures will indirectly affect employment, output, and investment in sectors that supply goods and provide services to affected businesses. A summary of the results are provided in Section 5.3.9.

The direct impacts of the Proposed Regulation would lead to additional indirect and induced effects, like changes in personal income that affect consumer expenditures across other spending categories. The incremental total economic impacts of the Proposed Regulation are simulated relative to the baseline using cost data described in Section 3 of the SRIA. The analysis focuses on incremental change in major macroeconomic indicators from 2026 to 2040 including employment, output growth, and Gross State Product (GSP). The years of the analysis are used to simulate the Proposed Regulation through more than 12 months post full implementation.

REMI Policy Insight Plus Version 2.5.0 is used to estimate the macroeconomic impacts of the Proposed Regulation on the California economy. REMI is a structural economic forecasting and policy analysis model that integrates input-output, computable general equilibrium, econometric and economic geography methodologies. REMI Policy Insight Plus provides year-by-year estimates of the total impacts of the Proposed Regulation, pursuant to the requirements of the California Administrative Procedure Act and the California Department of Finance (DOF) implementing that act. Staff used the REMI single region, 160 sector model with the model reference case adjusted to reflect California DOF's most current publicly available economic and demographic projections.

Specifically, the REMI model's National and Regional Control was updated to conform to the most recent California DOF economic forecasts which include U.S. Real GDP, income, and employment, as well as California population and civilian employment by industry. These forecasts were released as part of the May 2021 State budget revision on May 14, 2021. The DOF forecasts extend through 2024. For subsequent years, CARB staff assumed economic variables would continue to grow at the same rate projected in the REMI baseline forecasts.

5.2 Inputs and Assumptions of the Assessment

The estimated economic impact of the Proposed Regulation is sensitive to modeling assumptions. This section provides a summary of the assumptions and inputs used to determine the suite of policy variables that best reflect the macroeconomic impacts of the Proposed Regulation. The direct costs and savings estimated in Section 3 and the non-mortality related health benefits estimated in Section 2 are translated into REMI policy variables and used as inputs for the macroeconomic analysis.110

The direct costs and cost-savings of the Proposed Regulation, as described in Section 5, include changes in upfront costs to individuals, businesses, and governments that purchase new vehicles. While these costs and cost-savings are directly incurred by manufacturers, it is assumed that these costs and cost-savings will be passed to vehicle purchasers in California through a change in the average price of all vehicles sold by the manufacturers in California. The net change in vehicle costs is input into the economic model as an increase in the consumer price for new vehicles purchased by individuals (see Table 57).

The consumer price policy variable affects the economy through changes in expenditures on goods and services based on consumers' response to a price increase for this consumption category. Staff evaluates the consumer response based on an inelastic consumer demand for new motor vehicles, meaning that for a given percentage increase in price, consumer demand will decrease by a smaller percentage.[111] Specifically, a demand elasticity of -0.4 is used in this analysis, which implies that a price increase of one percent decreases new vehicle

[110] Refer to the Macroeconomic Appendix for a full list of REMI inputs for this analysis.

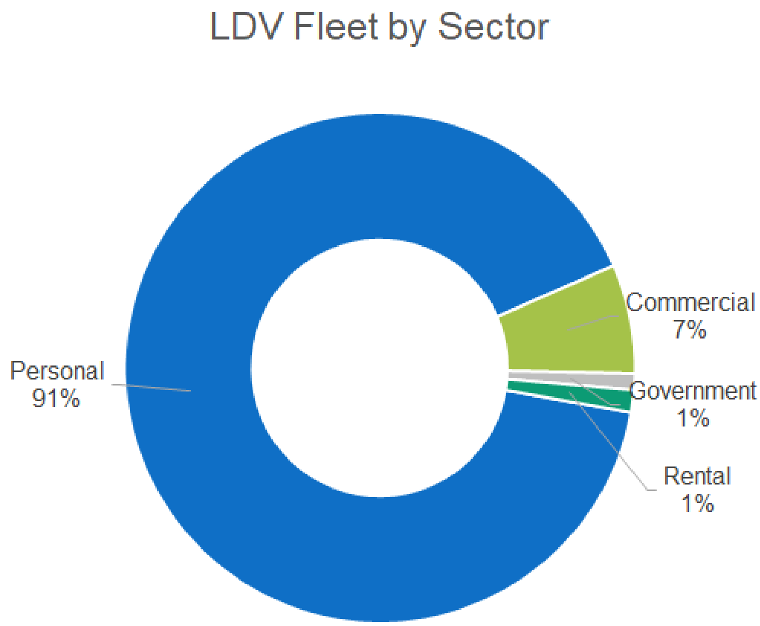
[111] Based on the definition of inelastic demand, where a percent change in quantity demanded is less than the percent change in price, for a given good. This implies that a price increase, increases total expenditures on this good.

demand by 0.4 percent. The choice of this parameter follows recent regulatory analysis and research from U.S. EPA. Given inelastic demand, an increase in the price of new vehicles is associated with increases total expenditures on new motor vehicles and results in an equivalent reduction in expenditures on all other goods, services, and savings.[112] This input reflects the logic of a behavioral response to an increase in the price of vehicles, as illustrated in Section 3.1.3. In other words, the more people spend on their vehicles, the less they'll spend on other goods and services. For business end-users the net change in vehicle costs is input as an increase in production costs for all industries in California that may purchase vehicles.

End-users of ZEVs will also realize operational savings related to their change in fuel mix, operations costs, and maintenance and repair costs. The operational cost savings are input into the model as a change in consumer spending, for individuals and as a reduction in production costs for businesses. Similarly, individuals and businesses will see changes in taxes and fees paid, these changes are modeled as consumer spending for individuals and a change in production costs for businesses. All costs and savings are allocated to end-use sectors based on their current share of the light-duty vehicle (LDV) fleet (Figure 21).[113]

[112] The use of a demand elasticity of -0.4 to model consumers' response is consistent with recent regulatory impact analyses for light-duty vehicles performed by U.S. EPA:
U.S. EPA, 2021. Revised 2023 and Later Model Year Light Duty Vehicle GHG Emissions Standards: Regulatory Impact Analysis. *https://www.epa.gov/system/files/documents/2021-12/420r21028.pdf*
U.S. EPA, 2021. The Effects of New-Vehicle Price Changes on New- and Used-Vehicle Markets and Scrappage. *https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=543273&Lab=OTAQ*
[113] California Energy Commission, 2021. Light Duty Uptake in Government and Rental Fleets. (web link: *https://www.energy.ca.gov/media/5889*, accessed October 22, 2021)

Figure 21: Share of the Light Duty Vehicle Fleet by Sector



Source: California Energy Commission: "Light Duty Uptake in Government and Rental Fleets".

Costs and savings realized by end-users will result in corresponding changes in final demand for the industries supplying those particular goods or services, such as gasoline or vehicle repair, as shown in Table . Industries described below are followed by their North American Industry Classification System (NAICS) code in parenthesis.[114] As purchases of new ZEVs induced by the Proposed Regulation are estimated to be primarily from out of state manufacturers, demand changes for the corresponding ZEV supply chain, such as electric motors and batteries, cannot be directly modeled as a change in final demand in California. In order to account for this, staff estimates the share of demand that may be fulfilled by California businesses, based on California's share of national output the industry (electric component mfg.).[115] All other changes in demand are included in this analysis. The reduction in gasoline demand is modeled as a reduction in consumer spending for gasoline. This decreased demand for gasoline also results in decreases in demand for petroleum and coal products manufacturing (NAICS 324) and oil and gas extraction (NAICS 211), as well as the industries which support the retail sale of gasoline to consumers, such as retail trade (NAICS 44-45) and wholesale trade (NAICS 42). The increased demand for electricity and hydrogen fuel is assumed to be provided by the electric power generation, transmission, and

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[114] U.S. Census. North American Industry Classification System, 2017. (web link: *https://www.census.gov/naics/*, accessed 12/20/2021)

[115] Based on REMI Policy Insight Plus (v 2.5.0), California's share of national output is 4.6% for electrical component mfg. (3353) in 2019.

distribution industry (NAICS 2211) and basic chemical manufacturing industry (NAICS 3251), respectively. The reduction in demand for vehicle maintenance and repair is modeled as a change in consumer spending for motor vehicle maintenance and repair, which maps to the automotive repair and maintenance industry (NAICS 8111) and retail trade (NAICS 44-45).

Table 57: Sources of Changes in Production Cost and Final Demand by Industry

Source of Cost or Savings	Industries with Change in Production Cost or Prices (NAICS)	Industries with Changes in Final Demand (NAICS)
Vehicle prices and charging plug	Individuals, Businesses, and Government purchasers of new vehicles	*Upfront cost:* Electrical component mfg.[a] (3353)
Vehicle maintenance and repair		*Recurring cost:* Automotive repair and maintenance (8111)
Gasoline		*Recurring cost:* Petroleum and coal products mfg. (324), retail trade (44-45) and wholesale trade (42), and oil and gas extraction (211).
Electricity (including V2G savings)		*Recurring cost:* Electric power generation, transmission and distribution (2211)
Hydrogen		*Recurring cost:* Basic chemical mfg. (3251)

[a] The Industry Sales policy variable is used here rather than Exogenous Final Demand.

In addition to these changes in production costs and final demand for businesses, there will also be economic impacts as a result of the fiscal effects, primarily from changes in fuel and sales tax revenue, and registration fees, as described in Section 3. The fuel costs savings, reduces the production costs for fleets, as described above, but also reduces government revenue from fuel taxes, this change in government revenue is modeled as a change in state and local government spending, assuming this revenue reduction is not offset elsewhere.

Besides direct economic benefits from factors like fuel and maintenance cost savings, the health benefits resulting from the emission reductions of the Proposed Regulation reduce healthcare costs for individuals on average. This reduction in healthcare cost is modeled as a decrease in spending for hospitals, with a reallocation of this spending towards other goods and increased savings.

The GHG emission reductions benefits as valued through the social cost of carbon emissions (SC-CO_2) represent the avoided damage from climate change worldwide per MT of CO2e. These benefits, or other ways to assess the benefits in California of reduced greenhouse gas emissions from the proposal, fall outside the scope and capability of our economic model and are not evaluated here.

5.3 Results of the Assessment

The results from the REMI model provide estimates of the impact of the Proposed Regulation on the California economy. These results represent the annual incremental change from the implementation of the Proposed Regulation relative to the baseline scenario. The California economy is forecasted to grow through 2036, therefore, negative impacts reported here should be interpreted as a slowing of growth and positive impacts represent an acceleration of growth resulting from the Proposed Regulation. The results are reported here in tables for every two years from 2026 through 2036.

5.3.1 California Employment Impacts

Table 58 presents the impact of the proposed regulation on total employment in California across all industries. Employment comprises estimates of the number of jobs, full-time and part-time, by place of work for all industries. Full-time and part-time jobs are counted at equal weight. Employees, sole proprietors, and active partners are included, but unpaid family workers and volunteers are not included. The employment impacts represent the net change in employment, which consist of positive impacts for some industries and negative impacts for others. The proposed regulation is estimated to have a negative employment impact beginning in 2026, which increases over time as the Proposed Regulation becomes more stringent. The results suggest that the estimated negative employment impact primarily results from the increased in upfront vehicle cost and changes in consumer spending induced by the proposed regulation; as more is expended on new motor vehicles, consumers will spend less on other goods and services within the economy. The results are further described at the industry level in the following paragraph. These changes in employment do not exceed 0.4 percent of baseline California employment across the entire regulatory horizon.

Table 58: Total California Employment Impacts

	2026	2028	2030	2032	2034	2036	2038	2040
California Employment	25,473,923	25,456,776	25,463,449	25,528,613	25,657,760	25,817,630	26,025,822	26,274,068
% Change	-0.02%	-0.12%	-0.24%	-0.31%	-0.34%	-0.34%	-0.36%	-0.33%
Change in Total Jobs	-6,102	-30,946	-60,084	-78,144	-86,929	-87,549	-93,117	-85,536

The total employment impacts shown above are net of changes at the industry level. The overall trend in employment changes by major sector are illustrated in Figure 22 and Table 59 shows the changes in employment by industries that are directly impacted by the proposed regulation. As the requirements of the Proposed Regulation go into effect, consumers and businesses must initially spend more on vehicle purchases, reducing spending elsewhere in the economy, which tends to reduce employment across many industries that serve and produce goods for consumers. Over time vehicle purchasers are estimated to realize operational cost-savings, shifting consumer spending away from categories such as, vehicle maintenance and repair, and gasoline and towards other areas. The reduced spending in these categories accounts for a significant portion of the employment impact (shown for year 2040), where the vehicle repair and maintenance industry sees about 32,000 jobs foregone (13.8 percent of baseline employment) and petroleum products manufacturing (i.e. refineries) industry sees about 1,700 jobs foregone (15.3 percent of baseline). The retail trade sector comprises a significant portion of the economy and is estimated to have about 47,300 jobs foregone (2.5 percent of baseline), resulting from the overall shift in consumer spending due to incremental vehicle costs and specifically due to reduced gasoline sales of which gasoline stations are expected of see negative impacts. As discussed in Section 4, the decrease in gasoline sales is estimated to significantly reduce fuel tax revenue at the state and local level this reduces government spending leading to about 37,900 jobs foregone (1.5 percent of baseline) in state and local government employment, if revenue decreases are not offset. This foregone revenue, which supports important programs in the state, may eventually be replaced by revenue from other sources, in which case these negative job impacts to state and local government would be diminished. However, this is outside the scope of the Proposed Regulation and not evaluated here. It is important to note that many of these negative job impacts represent a structural shift for these industries that directly corresponding to substantial benefits to ZEV owners who will have much lower operational costs from the lower fuel expenses of ZEVs and that they require much less maintenance and repair.

The results also suggest that the electric power industry is one of the main industries to benefit from the regulation seeing a gain of about 6,500 jobs (20 percent of baseline), as ZEV purchasers spend more of electricity to power their vehicles.

Figure 22: Employment Impacts by Major Sector

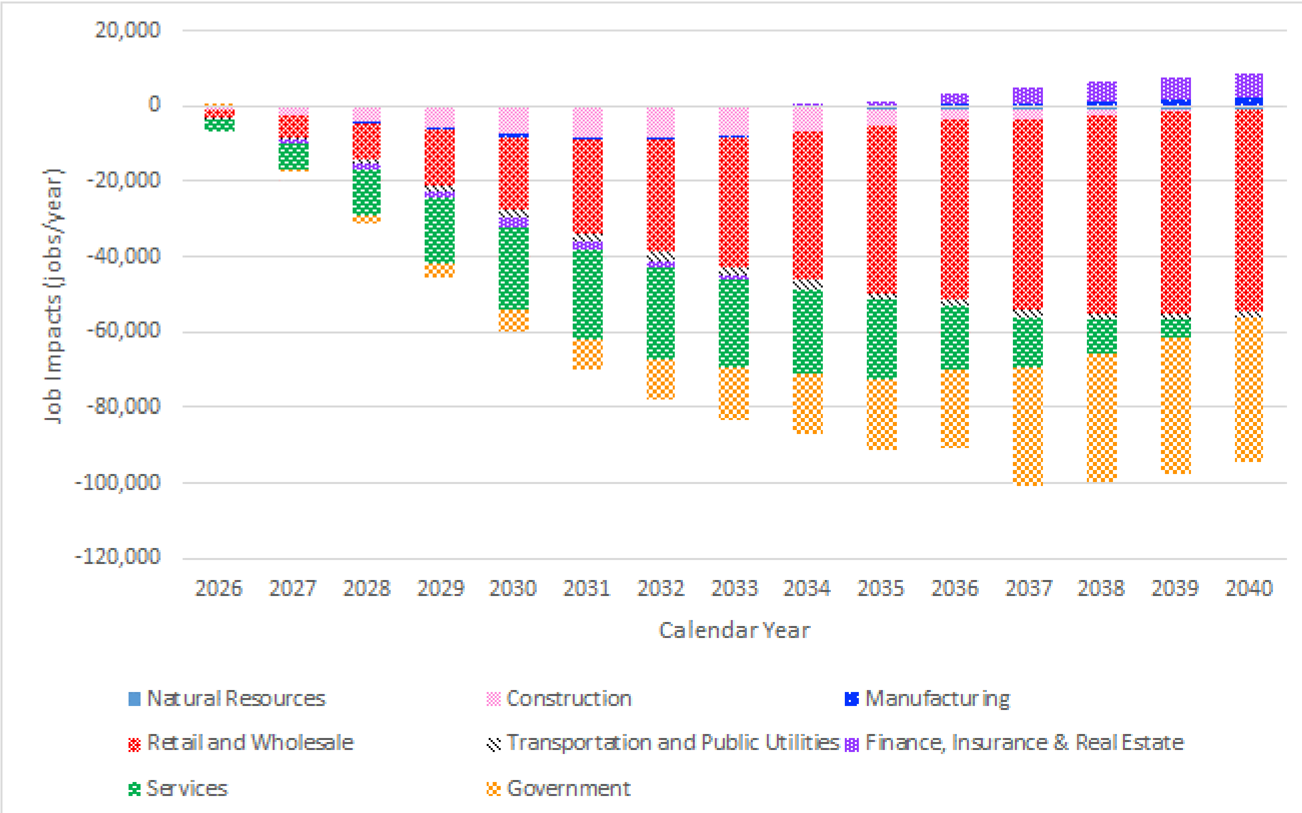


Table 59: Employment Impacts by Primary and Secondary Industries

Industry	Metric	2026	2028	2030	2032	2034	2036	2038	2040
Electric power generation, transmission and distribution (2211)	% Change	0.51%	2.46%	5.46%	9.23%	13.43%	17.14%	19.28%	20.01%
	Change in Jobs	193	897	1,948	3,219	4,585	5,734	6,330	6,450
Construction (23)	% Change	-0.06%	-0.31%	-0.56%	-0.62%	-0.48%	-0.22%	-0.14%	-0.02%
	Change in Jobs	-730	-3,929	-7,122	-7,938	-6,124	-2,877	-1,763	-245
Petroleum and coal products manufacturing (324)	% Change	-0.31%	-1.46%	-3.28%	-5.99%	-8.85%	-11.65%	-13.89%	-15.25%
	Change in Jobs	-37	-176	-389	-697	-1,013	-1,310	-1,536	-1,658
Basic chemical manufacturing (3251)	% Change	-0.02%	-0.12%	-0.18%	-0.08%	0.72%	3.30%	5.05%	6.58%
	Change in Jobs	-2	-9	-13	-5	52	241	370	486

Industry	Metric	2026	2028	2030	2032	2034	2036	2038	2040
Insurance carriers (5241)	% Change	0.03%	0.13%	0.27%	0.58%	0.91%	1.24%	1.54%	1.55%
	Change in Jobs	58	219	457	969	1,502	2,033	2,478	2,454
Retail trade (44-45)	% Change	-0.10%	-0.45%	-0.90%	-1.41%	-1.88%	-2.29%	-2.51%	-2.54%
	Change in Jobs	-2,009	-8,420	-16,649	-25,855	-34,335	-41,783	-46,099	-47,272
Automotive repair and maintenance (8111)	% Change	-0.37%	-1.68%	-3.60%	-6.05%	-8.66%	-11.32%	-13.55%	-13.83%
	Change in Jobs	-859	-3,907	-8,319	-13,989	-20,040	-26,189	-31,352	-31,982
State & Local Government	% Change	0.01%	-0.07%	-0.24%	-0.44%	-0.65%	-0.85%	-1.37%	-1.51%
	Change in Jobs	349	-1,816	-5,856	-10,754	-16,189	-21,065	-34,137	-37,924

5.3.2 California Business Impacts

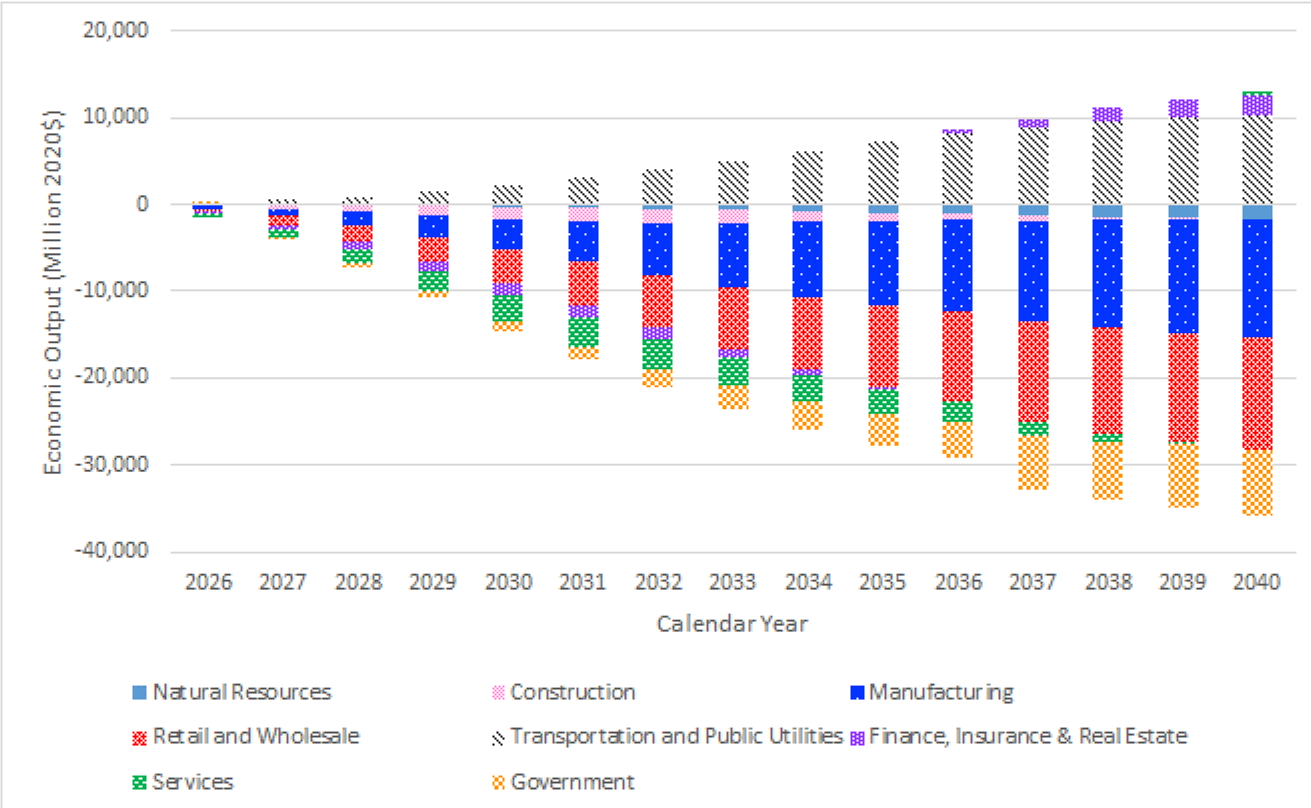
Gross output is used as a measure for business impacts because it represents an industry's sales or receipts and tracks the quantity of goods or services produced in a given time period. Output growth is the sum of output in each private industry and State and local government as it contributes to the state's gross domestic product (GDP), and is affected by production cost and demand changes. As production cost increases or demand decreases, output is expected to contract, but as production costs decline or demand increases, industry will likely experience output growth.

The results of the proposed regulation show a decrease in output of $12.4 billion in 2030 and an increase of $22.7 billion in 2040 as shown in Table 60. The trend in output changes is illustrated by major sector in Figure 23. Similar to the employment impacts, the negative impact to output grows over time as the requirements become more stringent, and consumer spending is reduced due to the incremental cost of vehicles. As described for the job impacts, industries which tend to see reduced consumer spending, such as vehicle repair and maintenance, petroleum product manufacturing, and retail sales (including gasoline stations), see negative impacts on economic output. While industries that are estimated to see increases in spending, such as the electric power industry and basic chemical (hydrogen) manufacturing see positive impacts.

Table 60: Change in California Output Growth by Industry

Industry	Metric	2026	2028	2030	2032	2034	2036	2038	2040
California Economy	Output (2020M$)	5,734,719	5,867,144	6,010,188	6,166,889	6,342,899	6,541,029	6,772,294	7,038,021
	% Change	-0.02%	-0.11%	-0.21%	-0.28%	-0.31%	-0.31%	-0.34%	-0.32%
	Change (2020M$)	-1,180	-6,220	-12,414	-17,037	-19,701	-20,503	-22,918	-22,722
Electric power generation, transmission and distribution (2211)	% Change	0.52%	2.46%	5.49%	9.28%	13.52%	17.28%	19.46%	20.23%
	Change (2020M$)	254	1,235	2,805	4,842	7,198	9,406	10,866	11,607
Construction (23)	% Change	-0.06%	-0.31%	-0.57%	-0.64%	-0.50%	-0.24%	-0.15%	-0.03%
	Change (2020M$)	-134	-736	-1,356	-1,537	-1,213	-597	-381	-76
Petroleum and coal products manufacturing (324)	% Change	-0.31%	-1.46%	-3.29%	-6.00%	-8.87%	-11.68%	-13.93%	-15.30%
	Change (2020M$)	-280	-1,378	-3,199	-6,012	-9,145	-12,408	-15,272	-17,340
Basic chemical manufacturing (3251)	% Change	-0.02%	-0.12%	-0.18%	-0.08%	0.72%	3.31%	5.07%	6.61%
	Change (2020M$)	-6	-32	-48	-21	199	946	1,495	2,020
Insurance carriers (5241)	% Change	0.03%	0.13%	0.27%	0.58%	0.92%	1.27%	1.57%	1.59%
	Change (2020M$)	20	79	171	375	603	847	1,073	1,110
Retail trade (44-45)	% Change	-0.11%	-0.45%	-0.91%	-1.44%	-1.92%	-2.34%	-2.57%	-2.61%
	Change (2020M$)	-279	-1,232	-2,556	-4,161	-5,790	-7,392	-8,577	-9,270
Automotive repair and maintenance (8111)	% Change	-0.37%	-1.70%	-3.65%	-6.15%	-8.82%	-11.55%	-13.85%	-14.18%
	Change (2020M$)	-94	-437	-950	-1,626	-2,371	-3,156	-3,855	-4,027
State & Local Government	% Change	0.01%	-0.07%	-0.24%	-0.44%	-0.65%	-0.84%	-1.36%	-1.50%
	Change (2020M$)	66	-347	-1,128	-2,090	-3,173	-4,168	-6,831	-7,688

Figure 23: Change in Output in California by Major Sector



5.3.3 Impacts on Investments in California

Private domestic investment consists of purchases of residential and nonresidential structures and of equipment and software by private businesses and nonprofit institutions. It is used as a proxy for impacts on investments in California because it provides an indicator of the future productive capacity of the economy.

The relative changes to growth in private investment for the Proposed Regulation are shown in Table 61 and shows a decrease of private investment of about $1.39 billion in 2030, which is followed by a positive trend resulting in an increase of $4.6 billion in 2040. These changes in investment do not exceed 0.8 percent baseline investment across the regulatory horizon.

Table 61: Change in Gross Domestic Investment Growth

	2026	2028	2030	2032	2034	2036	2038	2040
Private Investment (2020M$)	505,625	511,821	522,983	535,029	549,820	566,271	585,020	605,645
% Change	-0.04%	-0.17%	-0.27%	-0.20%	0.03%	0.34%	0.58%	0.76%
Change (2020M$)	-183	-872	-1,392	-1,084	161	1,927	3,413	4,573

5.3.4 Impacts on Individuals in California

The Proposed Regulation will impose no direct costs on individuals in California, as the regulation in on new vehicle manufacturers, as opposed to individuals. However, the direct costs incurred by vehicle manufacturers are expected to pass through to vehicle purchasers in California, who are primarily individuals. Typically, individuals within the new vehicle market are in higher income levels, who would bear the brunt of the incremental cost of the impacted vehicles. Those in the used market would also be affected by the increased incremental costs, but only a fraction of what will be experienced by the new vehicle market. Direct cost and savings from upfront and ongoing costs will also cascade through the economy and affect individuals through indirect and induced impacts.

One measure of this impact is the change in real personal income, which income received from all sources, including compensation of employees and government and business transfer activity, adjusted for inflation. This is an aggregate statewide measure of personal income change, representing a net of income lost from jobs foregone in some sectors and jobs gained in other sectors. Table 62 shows annual change in real personal income across all individuals in California. Total personal income growth decreases by about $9.4 billion in 2030 and follows a negative trend to 2040, with a decrease of $15.0 billion. This change represents about 0.4 percent of baseline personal income. These results follow from those discussed about the impacts on California businesses, where a negative impact on output and jobs reduces aggregate compensation, which is a component of personal income. The change in personal income estimated here can also be divided by the California population to show the average or per capita impact on personal income. The change in personal income growth is estimated to decrease of $137 per person in 2030 and decrease by $35 per person in 2040.

Table 62: Impacts on Individuals in California

	2026	2028	2030	2032	2034	2036	2038	2040
Personal Income (2020M$)	3,038,166	3,136,829	3,263,635	3,359,346	3,463,710	3,576,562	3,702,976	3,836,411
% Change	-0.04%	-0.16%	-0.29%	-0.38%	-0.42%	-0.41%	-0.41%	-0.39%
Change (2020M$)	-1,131	-4,885	-9,404	-12,697	-14,483	-14,751	-15,325	-15,010
Personal Income per capita (2020$)	72,938	74,787	76,425	78,390	80,127	82,093	84,364	86,936
% Change	-0.03%	-0.11%	-0.18%	-0.19%	-0.17%	-0.11%	-0.08%	-0.04%
Change (2020$)	-23	-83	-137	-150	-133	-91	-65	-35

5.3.5 Impacts on Gross State Product (GSP)

Gross State Product (GSP) is the market value of all goods and services produced in California and is one of the primary indicators of economic growth. It is calculated as the sum of the dollar value of consumption, investment, net exports, and government spending. Under the Proposed Regulation, GSP growth is estimated to decrease by about $6.2 billion in 2030 and by $7.3 billion in 2040 as shown in Table 63. This metric summarizes impacts discussed above, including consumer spending, investment, and government spending. This is why the results trend negative, as the decrease in consumer and government spending in California outweigh the increase in investment resulting from the proposed regulation. These changes do not exceed 0.3 percent of baseline GSP. Overall, the impact to GSP tends to trend downward, as described above the negative impacts to consumption and government spending, tends to offset the increase in investment.

Table 63: Change in Gross State Product

	2026	2028	2030	2032	2034	2036	2038	2040
GSP (2020M$)	3,419,092	3,511,119	3,616,944	3,732,363	3,856,643	3,988,391	4,131,724	4,287,234
% Change	-0.02%	-0.09%	-0.18%	-0.23%	-0.24%	-0.22%	-0.23%	-0.21%
Change (2020M$)	-614	-3,279	-6,479	-8,496	-9,253	-8,933	-9,612	-8,945

5.3.6 Creation or Elimination of Businesses

The REMI model cannot directly estimate the creation or elimination of businesses. However, changes in jobs and output for the California economy described above can be used to understand some potential impacts. The overall jobs and output impacts of the Proposed Regulation are small relative to the total California economy, representing changes of no greater than 0.4 percent. However, impacts to specific industries are larger as described in previous sections. The trend of increasing demand for electricity in the electric power sector similarly sees large increases in sales, but its services are provided primarily by existing utilities. New utilities are not expected to be created to meet this increased demand. The decreasing trend in demand for gasoline has the potential to result in the elimination of businesses in this industry and downstream industries, such as gasoline stations and vehicle repair businesses, if sustained over time. As described above the vehicle repair and maintenance service industry is estimated to see negative impacts, including dealerships that have service departments, as ZEVs become a greater portion of the fleet. This trend would suggest that the number of businesses providing the services may decrease along with the reduced demand.

5.3.7 Incentives for Innovation

The manufacturer sales requirement for ZEVs as part of ACCII provides flexibilities, giving manufacturers the incentive to innovate and identify lower cost strategies for achieving the zero-emission requirement. For example, manufacturers are allowed to comply by selling ZEVs across multiple vehicle classifications, allowing each manufacturer to focus on products and areas of the market where they typically compete. Innovations leading to lower cost ZEV models likely will result in increased sales within the mass market. Additionally, manufacturers are incentive to innovate and bring ZEV models to secure their place in popular or growing vehicle segments, with the signal that the entire market will be at 100% in 2035.

5.3.8 Competitive Advantage or Disadvantage

While CARB is not aware of any evidence of the extent to which this is occurring under existing requirements, automakers that are already producing ZEVs may have an advantage in growing market share under more stringent ZEV requirements over manufacturers that have not yet come to market with a widely available product. Though some consumers may be holding out for a specific manufacturer’s product, many consumers will purchase products that have wide distribution networks. As the requirements increase towards 100%, this advantage may decline as every automaker invests in ZEV technology and products at a wide scale.

5.3.9 Summary and Agency Interpretation of the Assessment Results

The results of the macroeconomic analysis of the Proposed Regulation are summarized in Table 64. As analyzed here, CARB estimates the Proposed Regulation is unlikely to have a significant impact on the California economy. Overall, the change in the growth of jobs, State GDP, and output is projected to not exceed 0.5 percent of the baseline. Both the electric power sector and chemical manufacturing industry see large positive growth by supplying energy to ZEV owners. The gasoline fuel savings for the individuals, businesses and governments represents decreased demand for gasoline statewide, implying a decrease in growth for the industry and downstream industries such as gasoline stations and vehicle repair. This analysis also shows the negative impact estimated for state and local government output and employment due to fuel tax revenue decreases, without any offsetting revenues.

This foregone revenue, which supports important programs in the state, may eventually be replaced by revenue from other sources, in which case these negative impacts to state and local government would be diminished.

Table 64: Summary of Economic Impacts of the Proposed Regulation

Indicator	Metric	2026	2028	2030	2032	2034	2036	2038	2040
GSP	% Change	-0.02%	-0.09%	-0.18%	-0.23%	-0.24%	-0.22%	-0.23%	-0.21%
	Change (2020M$)	-614	-3,279	-6,479	-8,496	-9,253	-8,933	-9,612	-8,945
Personal Income	% Change	-0.04%	-0.16%	-0.29%	-0.38%	-0.42%	-0.41%	-0.41%	-0.39%
	Change (2020M$)	-1,131	-4,885	-9,404	-12,697	-14,483	-14,751	-15,325	-15,010
Employment	% Change	-0.02%	-0.12%	-0.24%	-0.31%	-0.34%	-0.34%	-0.36%	-0.33%
	Change in Jobs	-6,102	-30,946	-60,084	-78,144	-86,929	-87,549	-93,117	-85,536
Output	% Change	-0.02%	-0.11%	-0.21%	-0.28%	-0.31%	-0.31%	-0.34%	-0.32%
	Change (2020M$)	-1,180	-6,220	-12,414	-17,037	-19,701	-20,503	-22,918	-22,722
Private Investment	% Change	-0.04%	-0.17%	-0.27%	-0.20%	0.03%	0.34%	0.58%	0.76%
	Change (2020M$)	-183	-872	-1,392	-1,084	161	1,927	3,413	4,573

6 Alternatives

Alternatives were solicited from the staff and the public throughout the process for developing the proposal, and most explicitly at the August 2021 workshop, in regulation development. These alternatives are analyzed relative to the same baseline presented in Section 1.7 and the results are then compared to the proposed major regulation along with the reason(s) for rejection of the alternatives. Alternatives are required to consider one case that achieves benefits beyond those of the proposed regulation (more stringent), and one that achieves the same level of benefits but is less likely or more costly to achieve those benefits. The three alternatives considered change the ZEV sales percentages because this has the most impact on costs and emission impacts.

Table 65: ZEV Sales Percentage Requirements by Scenario

Model Year	Proposal	Alternative 1	Alternative 2	Alternative 3
2026	26%	18%	25%	46%
2027	34%	24%	38%	52%
2028	43%	30%	50%	58%
2029	51%	36%	63%	64%
2030	60%	42%	75%	70%
2031	76%	47%	88%	76%
2032	82%	53%	100%	82%
2033	88%	59%	100%	88%
2034	94%	64%	100%	94%
2035 and subsequent	100%	70%	100%	100%

6.1 Alternative 1

The first alternative considered proposes at minimum 70 percent ZEV and PHEV sales by 2035 instead of the preferred proposal of 100 percent ZEV sales by 2035. This alternative is based on survey data that shows 30 percent of survey respondents have rejected considering electric vehicle technology and show hesitation in purchasing ZEVs or PHEVs.[116] Although staff does think this will change over time as ZEVs become cheaper and the market broadens to become more familiar with this technology, costing and analyzing impacts for a lower bound of ZEVs and PHEVs with more gasoline vehicles meeting the proposed LEV standard is important for understanding the effect of transitioning the fleet to zero-emission technology.

6.1.1 Costs

6.1.1.1 Total Manufacturer Costs

The total Manufacturer costs associated with Alternative 1 are presented in the Table 66 below. For the purposes of simplification, only the costs associated with the ZEV sales requirements are summarized in the table. The ZEV assurance measures, and LEV regulations are not included.

[116] Kurani, Kenneth, Nicolette Caperello, and Jennifer TyreeHapegeman. 2016. "New Car Buyers' Valuation of Zero-Emission Vehicles: California" (web link: *https://ww2.arb.ca.gov/sites/default/files/2020-04/12_332_ac.pdf*, accessed on October 18, 2021)

Table 66: Alternative 1 Average Incremental Cost and Total Cumulative Costs

CY	Sales	Ave. Incremental Cost Per Vehicle ($)	Cumulative Total Cost ($)
2026	1,911,785	$355	$678,032,697
2027	1,921,865	$526	$1,688,816,738
2028	1,931,661	$648	$2,939,786,249
2029	1,941,144	$701	$4,300,463,779
2030	1,950,372	$735	$5,734,639,343
2031	1,959,247	$744	$7,191,525,765
2032	1,967,905	$762	$8,690,861,674
2033	1,976,253	$750	$10,173,573,941
2034	1,984,287	$699	$11,559,614,583
2035	1,992,017	$640	$12,835,313,436
2036	2,001,977	$640	$14,117,390,783
2037	2,011,987	$640	$15,405,878,517
2038	2,022,047	$640	$16,700,808,690
2039	2,032,157	$640	$18,002,213,514
2040	2,042,318	$640	$19,310,125,361

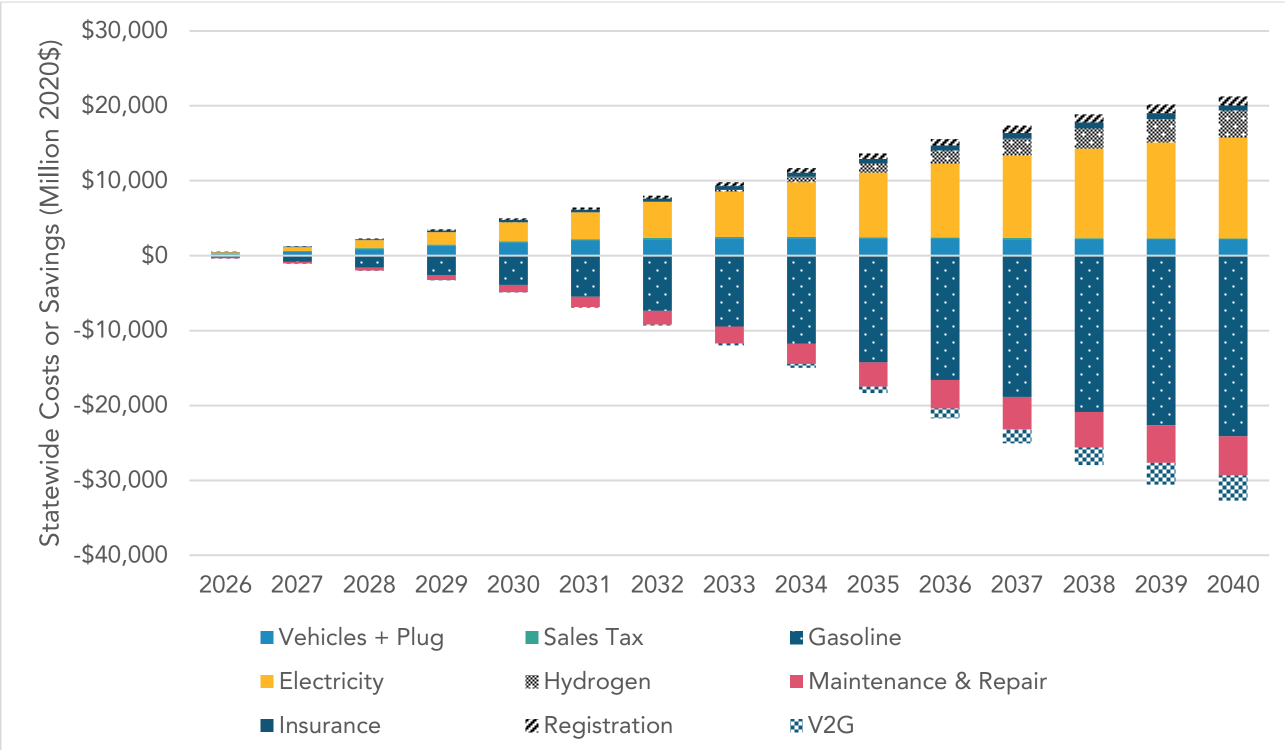
Compared to the Proposal, the incremental vehicle price, and total cumulative costs in 2035 for Alternative 1 is $640 and 19,310,125,361 in 2035 versus $1,732 and 51,887,558,040 in 2035 for the proposal.

6.1.1.2 Statewide Total Costs of Ownership

Table 67: Statewide TCO for Alternative 1

Year	Vehicle Price and PI	Sales Tax	Gasoline	Electricity	Hydrogen	Maintenance and Repair	Insurance	Registration	V2G	Total Cost	Total Savings	Net Cost
2026	$206	$70	-$293	$191	$0	-$76	$34	$18	$0	$518	-$369	$149
2027	$509	$103	-$817	$531	$0	-$213	$84	$50	-$1	$1,277	-$1,031	$246
2028	$889	$129	-$1,595	$1,037	$0	-$410	$147	$93	-$3	$2,295	-$2,009	$286
2029	$1,311	$143	-$2,611	$1,705	$0	-$668	$215	$149	-$8	$3,523	-$3,287	$236
2030	$1,762	$153	-$3,918	$2,556	$0	-$986	$287	$216	-$15	$4,974	-$4,919	$55
2031	$2,026	$159	-$5,510	$3,584	$0	-$1,367	$360	$294	-$65	$6,423	-$6,942	-$519
2032	$2,213	$166	-$7,389	$4,821	$0	-$1,811	$435	$385	-$134	$8,020	-$9,334	-$1,314
2033	$2,315	$164	-$9,457	$6,057	$258	-$2,270	$509	$487	-$271	$9,789	-$11,998	-$2,209
2034	$2,347	$154	-$11,729	$7,286	$725	-$2,743	$578	$600	-$500	$11,691	-$14,973	-$3,282
2035	$2,325	$146	-$14,244	$8,607	$1,227	-$3,261	$642	$723	-$850	$13,669	-$18,355	-$4,686
2036	$2,283	$145	-$16,602	$9,873	$1,734	-$3,780	$706	$848	-$1,356	$15,588	-$21,738	-$6,150
2037	$2,220	$145	-$18,877	$11,020	$2,226	-$4,303	$770	$973	-$1,862	$17,353	-$25,041	-$7,688
2038	$2,167	$146	-$20,865	$11,980	$2,699	-$4,751	$801	$1,080	-$2,367	$18,873	-$27,983	-$9,110
2039	$2,144	$146	-$22,620	$12,797	$3,157	-$5,065	$781	$1,156	-$2,872	$20,181	-$30,557	-$10,376
2040	$2,147	$147	-$24,137	$13,471	$3,597	-$5,184	$700	$1,190	-$3,375	$21,251	-$32,695	-$11,444
Total	**$26,864**	**$2,115**	**-$160,664**	**$95,516**	**$15,623**	**-$36,888**	**$7,048**	**$8,260**	**-$13,681**	**$155,425**	**-$211,232**	**-$55,807**

Figure 24: Statewide TCO for Alternative 1, 2026-2040



6.1.2 Benefit

6.1.2.1 Total Emission Benefits

The total well-to-wheel emission benefits associated with Alternative 1 are summarized in the table below:

Table 68: Alternative 1 WTW Emission Benefits

Calendar Year	NOx (tpd)	PM2.5 (tpd)	CO2 (MMT/year)
2026	0.5	0.01	0.49
2027	1.24	0.03	1.43
2028	2.18	0.07	2.81
2029	3.31	0.11	4.59
2030	4.62	0.18	6.76
2031	6.10	0.26	9.42
2032	7.75	0.35	12.48
2033	9.61	0.47	15.86

Calendar Year	NOx (tpd)	PM2.5 (tpd)	CO2 (MMT/year)
2034	11.65	0.6	19.53
2035	13.85	0.75	23.53
2036	16.04	0.90	27.42
2037	18.22	1.04	31.11
2038	20.37	1.19	34.60
2039	22.45	1.32	37.88
2040	24.46	1.46	40.97

The cumulative GHG emission reductions multiplied by the SC-C02 values shown in Section 2.4.2 gives a monetary estimate of the benefit of GHG emission reductions from Alternative 1. These benefits range from about $6.7 billion to $28.1 billion through 2040, depending on the chosen discount rate.

6.1.2.2 Health Benefits

Alternative 1 results in emissions reductions relative to the baseline leading to health benefits as shown in Table 69. The health benefits are less than those of the proposed regulation due to less emissions reductions estimated for this alternative. Totals may not add up due to rounding. All values are in millions of 2020 dollars.

Table 69: Health Benefits of Alternative 1

Year	Avoided Premature Mortality	Avoided Cardiovascular Hospitalizations	Avoided Acute Respiratory Hospitalizations	Avoided ER Visits	Total Health Benefit
2023	0	0	0	0	$0.0
2024	0	0	0	0	$0.0
2025	0	0	0	0	$0.0
2026	2	0	0	1	$23.6
2027	6	1	1	3	$60.1
2028	11	2	2	6	$109.7
2029	17	3	3	9	$171.1
2030	24	4	5	13	$245.3
2031	33	5	6	17	$332.8
2032	43	7	8	22	$433.5
2033	55	9	10	28	$549.0
2034	68	11	13	34	$678.7

Year	Avoided Premature Mortality	Avoided Cardiovascular Hospitalizations	Avoided Acute Respiratory Hospitalizations	Avoided ER Visits	Total Health Benefit
2035	82	13	16	41	$821.6
2036	96	16	19	48	$965.1
2037	110	18	22	55	$1,105.9
2038	124	21	24	62	$1,245.7
2039	137	23	27	68	$1,381.5
2040	151	25	30	74	$1,513.3
Total	**959**	**157**	**187**	**481**	**$9,637.0**

6.1.3 Economic Impacts

Alternative 1 imposes a less stringent ZEVs sales requirement compared to the Proposed Regulation. This results in lower incremental vehicle cost as passed-through to end-users, but also less operational and fuel savings. The macroeconomic impact analysis results are qualitatively similar to the results of the Proposed Regulation, but of a smaller magnitude as shown in Table 70: Summary of Economic Impacts of Alternative 1. Figure 25 and Figure 26 show the job and economic impact changes of Alternative 1, respectively.

Table 70: Summary of Economic Impacts of Alternative 1

Indicator	Metric	2026	2028	2030	2032	2034	2036	2038	2040
GSP	% Change	-0.01%	-0.05%	-0.09%	-0.10%	-0.09%	-0.07%	-0.06%	-0.05%
	Change (2020M$)	-298	-1,707	-3,406	-3,816	-3,559	-2,936	-2,387	-2,063
Personal Income	% Change	-0.02%	-0.08%	-0.15%	-0.18%	-0.17%	-0.15%	-0.13%	-0.12%
	Change (2020M$)	-560	-2,598	-5,039	-5,971	-6,060	-5,533	-4,911	-4,555
Employment	% Change	-0.01%	-0.06%	-0.13%	-0.15%	-0.16%	-0.14%	-0.12%	-0.11%
	Change in Jobs	-3,003	-16,398	-32,663	-39,004	-40,071	-36,797	-32,454	-28,280
Output	% Change	-0.01%	-0.06%	-0.11%	-0.13%	-0.14%	-0.13%	-0.13%	-0.12%
	Change (2020M$)	-578	-3,303	-6,749	-8,318	-8,791	-8,711	-8,595	-8,651
Private Investment	% Change	-0.02%	-0.08%	-0.12%	0.00%	0.20%	0.41%	0.56%	0.63%
	Change (2020M$)	-87	-429	-620	-15	1,118	2,334	3,275	3,793

Figure 25: Employment Impacts by Major Sector for Alternative 1

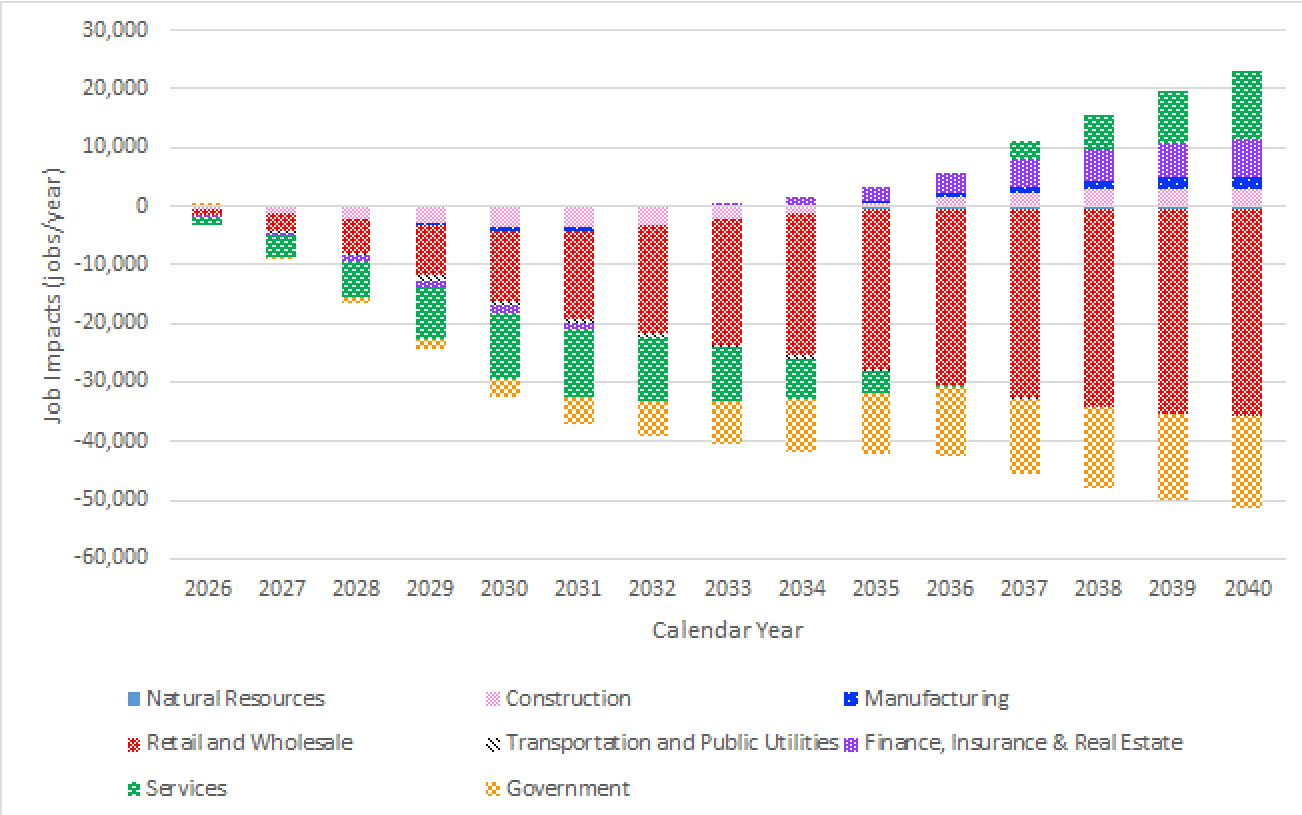
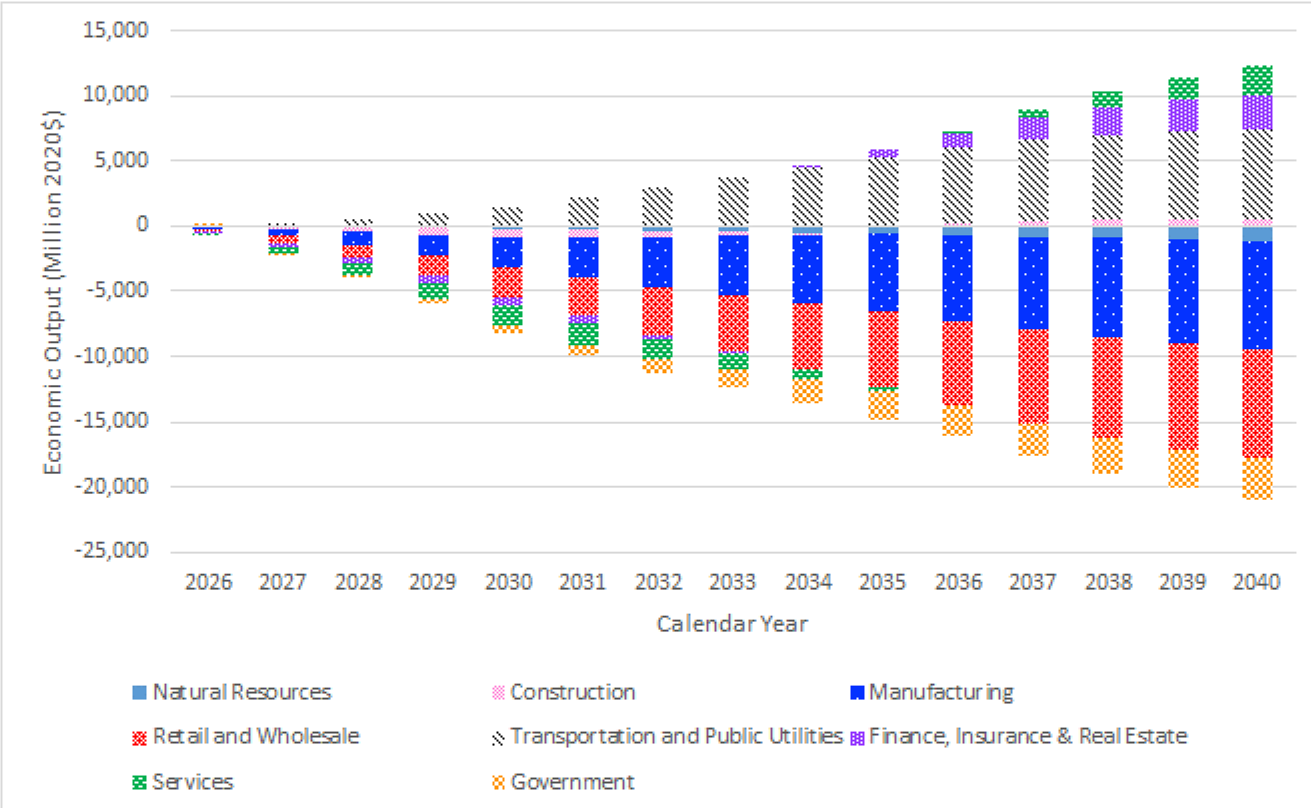


Figure 26: Change in Output in California by Major Sector for Alternative 1



6.1.4 Cost-Effectiveness

The metric to quantify cost-effectiveness of the proposed regulation and alternatives is the ratio of total monetized benefits divided by total monetized costs. A comparison of this type is an appropriate cost-effectiveness measure if the harm associated with increased emissions is fully captured in the estimates of monetized health impacts. Benefits to California include both health benefits and cost savings after subtracting tax impacts to State and local governments. Table 71 indicates that the Alternative 1 has a total cost of $155.4 billion and total benefit of $206.4 billion over the regulatory horizon. This results in a net benefit of $54.3 billion for the proposed regulation and a Benefit-Cost ratio of 1.35, indicating that the benefits are 35 percent greater than the costs.

Table 71: Benefit-Cost Ratio of Alternative 1 for 2026-2040

Scenario	Total Costs	Cost Savings (benefit)	Health Benefits	Tax and Fee Revenue	Total Benefit	Net Benefit	Benefit-Cost Ratio
Proposal	$288,970	$338,317	$14,553	-$15,867	$337,003	$48,033	1.17
Alternative 1	$155,425	$211,232	$9,637	-$11,142	$209,727	$54,302	1.35

When the social cost of carbon is included, the total benefits of the alternative are up to $237.82 billion with a benefit-cost ratio to 1.53, based on a 2.5 percent discount rate.

6.1.5 Reason for Rejecting

Alternative 1 is rejected because it fails to maximize the number of ZEVs deployed, and does not maximize NOx, $PM_{2.5}$, and GHG reductions. The benefit to cost ratio for this alternative is better, however, it gets less emission benefits than the proposal. The Proposed ACC II Regulation is identified as a measure in the State SIP Strategy as well as part of the Climate Change Scoping Plan as a necessary component needed to improve California's air quality consistent with federal and state legal requirements and achieve the state's climate protection goals. Alternative 1 does not maximize the number of ZEVs deployed in California as it requires a lower number of ZEVs to be produced. Because of the low number of vehicles deployed, Alternative 1 does not maximize NOx and $PM_{2.5}$ emission reductions which are necessary to meet SIP attainment goals. Alternative 1 does not reduce GHG emissions, failing to meet the goals of the Climate Change Scoping Plan.

6.2 Alternative 2

The second alternative considered proposes an accelerated 100 percent ZEV requirement by 2032 instead of 2035 as proposed for this rulemaking. This is based on a more aggressive ZEV stringency that could be possible with an aggressive ZEV uptake based on model turnover. For this alternative, staff took into account the most recent industry announcements for electrification, assuming best case market conditions, and most deployments would occur in California, as well as other global jurisdiction aggressive sales trajectories for a similar timeframe.

6.2.1 Costs

6.2.1.1 Total Manufacturer Costs

The total manufacturer costs associated with Alternative 2 are presented in the table below. For the purposes of simplification, only the costs associated with the ZEV sales requirements are summarized in the table. The ZEV assurance measures and LEV regulations are not included.

Table 72: Alternative 2 Average Incremental Cost and Total Cumulative Costs

CY	Sales	Ave. Incremental Cost Per Vehicle ($)	Cumulative Total Cost ($)
2026	2,389,731	$ 697	$1,666,004,396
2027	2,402,332	$ 1,199	$4,547,361,060
2028	2,414,577	$ 1,628	$ 8,477,923,385
2029	2,426,430	$ 2,028	$13,398,767,099
2030	2,437,965	$ 2,303	$19,014,399,836
2031	2,449,059	$ 2,797	$25,863,982,587
2032	2,459,882	$ 3,346	$34,094,348,440
2033	2,470,316	$ 2,937	$41,350,307,814
2034	2,480,359	$ 2,545	$47,663,235,479
2035	2,490,021	$ 2,169	$53,063,438,737
2036	2,502,471	$ 2,169	$58,490,643,012
2037	2,514,984	$ 2,169	$63,944,983,309
2038	2,527,559	$ 2,169	$69,426,595,306
2039	2,540,196	$ 2,169	$74,935,615,364
2040	2,552,897	$ 2,169	$80,472,180,522

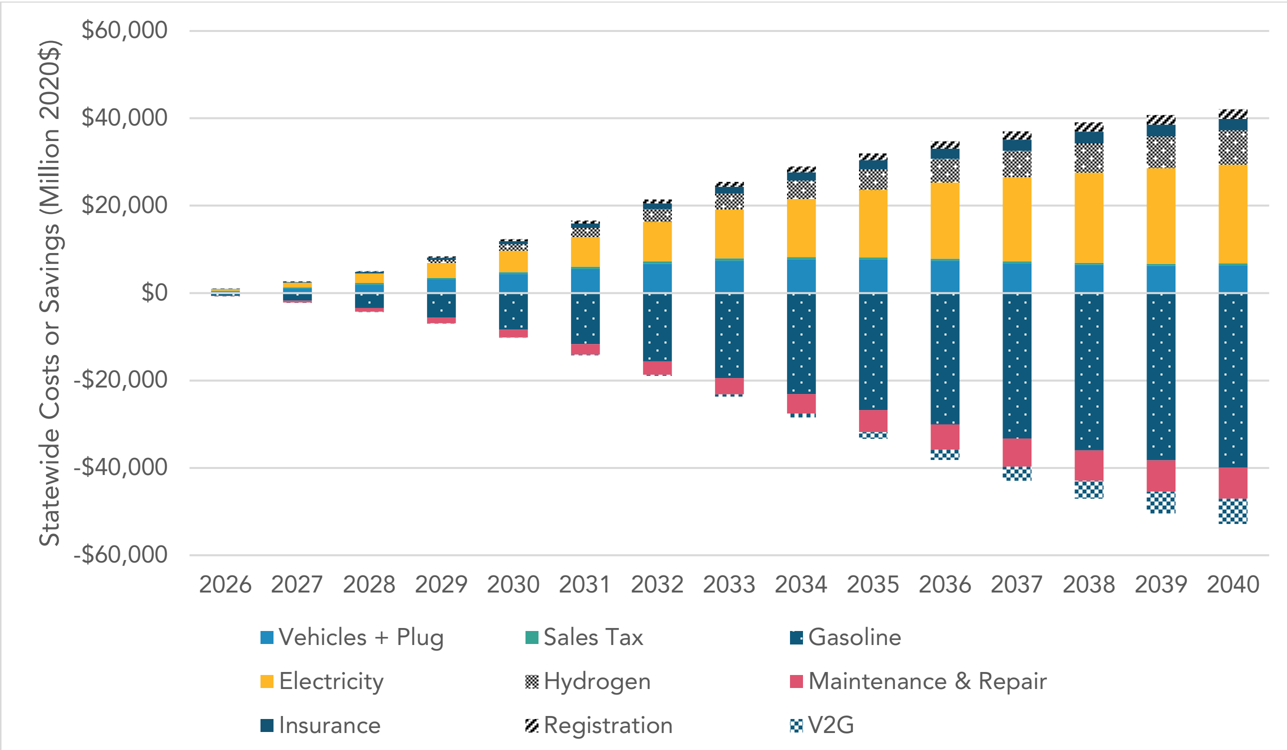
Compared to the Proposal, the incremental vehicle price, and total cumulative costs in 2035 for Alternative 1 is $2,169 and 80,472,180,552 in 2035 versus $1,732 and 51,887,558,040 in 2035 for the proposal.

6.2.1.2 Statewide Total Costs of Ownership

Table 73: Statewide TCO for Alternative 2

Year	Vehicle Price and Plug	Sales Tax	Gasoline	Electricity	Hydrogen	Maintenance and Repair	Insurance	Registration	V2G	Total Cost	Total Savings	Net Cost
2026	$392	$133	-$574	$370	$0	-$149	$67	$36	$0	$997	-$724	$273
2027	$1,062	$227	-$1,695	$1,084	$0	-$432	$182	$102	-$2	$2,657	-$2,128	$529
2028	$1,978	$311	-$3,405	$2,213	$0	-$846	$339	$198	-$7	$5,038	-$4,258	$780
2029	$3,095	$379	-$5,637	$3,434	$653	-$1,307	$536	$323	-$16	$8,419	-$6,959	$1,460
2030	$4,370	$432	-$8,356	$4,927	$1,414	-$1,811	$761	$475	-$29	$12,379	-$10,196	$2,183
2031	$5,526	$525	-$11,671	$6,786	$2,080	-$2,425	$1,035	$659	-$120	$16,611	-$14,217	$2,394
2032	$6,697	$624	-$15,620	$8,981	$2,917	-$3,089	$1,364	$875	-$244	$21,459	-$18,954	$2,506
2033	$7,420	$556	-$19,423	$11,170	$3,576	-$3,754	$1,654	$1,087	-$489	$25,463	-$23,666	$1,797
2034	$7,745	$489	-$23,118	$13,348	$4,196	-$4,421	$1,907	$1,294	-$893	$28,979	-$28,433	$546
2035	$7,722	$425	-$26,731	$15,449	$4,753	-$5,090	$2,123	$1,497	-$1,504	$31,969	-$33,325	-$1,357
2036	$7,426	$425	-$30,076	$17,457	$5,413	-$5,761	$2,340	$1,702	-$2,375	$34,762	-$38,212	-$3,450
2037	$6,842	$426	-$33,300	$19,260	$6,049	-$6,436	$2,558	$1,907	-$3,245	$37,042	-$42,981	-$5,939
2038	$6,466	$428	-$36,005	$20,719	$6,661	-$6,965	$2,710	$2,077	-$4,116	$39,061	-$47,085	-$8,024
2039	$6,292	$430	-$38,233	$21,871	$7,250	-$7,214	$2,748	$2,183	-$4,984	$40,773	-$50,431	-$9,658
2040	$6,312	$432	-$39,969	$22,698	$7,816	-$7,052	$2,630	$2,193	-$5,848	$42,081	-$52,869	-$10,788
Total	**$79,344**	**$6,242**	**-$293,814**	**$169,769**	**$52,777**	**-$56,752**	**$22,950**	**$16,607**	**-$23,873**	**$347,690**	**-$374,439**	**-$26,750**

Figure 27: Statewide TCO for Alternative 2, 2026-2040



6.2.2 Benefits

6.2.2.1 Total Emission Benefits

The total well-to-wheel emission benefits associated with alternative 2 are summarized in the table below.

Table 74: Alternative 2 total WTW Emission Benefits

Calendar Year	NOx (tpd)	PM2.5 (tpd)	CO2 (MMT/year)
2026	0.64	0.03	0.96
2027	1.69	0.07	2.92
2028	3.16	0.15	5.90
2029	5.06	0.28	9.67
2030	7.28	0.42	14.05
2031	9.88	0.60	19.42
2032	12.84	0.82	25.78
2033	15.88	1.03	32.10

Calendar Year	NOx (tpd)	PM2.5 (tpd)	CO2 (MMT/year)
2034	18.97	1.24	38.18
2035	22.05	1.46	44.02
2036	25.12	1.67	49.60
2037	28.16	1.88	54.90
2038	31.13	2.09	59.90
2039	34.00	2.30	64.59
2040	36.76	2.49	68.97

The cumulative GHG emission reductions multiplied by the SC-C02 values shown in Section 2.4.2 gives a monetary estimate of the benefit of GHG emission reductions from Alternative 2. These benefits range from about $12.1 billion to $51.2 billion through 2040, depending on the chosen discount rate.

6.2.2.2 Health Benefits

Alternative 2 results in emissions reductions relative to the baseline leading to health benefits as shown in Table 75Table 69. The health benefits are greater than those of the proposed regulation due to greater emissions reductions estimated for this alternative. Totals may not add up due to rounding. All values are in millions of 2020 dollars.

Table 75: Health Benefits of Alternative 2

Year	Avoided Premature Mortality	Avoided Cardiovascular Hospitalizations	Avoided Acute Respiratory Hospitalizations	Avoided ER Visits	Total Health Benefit
2023	0	0	0	0	$0.0
2024	0	0	0	0	$0.0
2025	0	0	0	0	$0.0
2026	3	1	1	2	$34.5
2027	10	1	2	5	$95.7
2028	18	3	3	10	$184.4
2029	30	5	6	16	$303.4
2030	44	7	8	23	$444.5
2031	61	10	11	31	$612.7
2032	81	13	15	41	$809.1
2033	101	16	19	51	$1,010.5
2034	121	20	23	61	$1,213.3

Year	Avoided Premature Mortality	Avoided Cardiovascular Hospitalizations	Avoided Acute Respiratory Hospitalizations	Avoided ER Visits	Total Health Benefit
2035	141	23	28	71	$1,417.1
2036	161	27	32	81	$1,622.0
2037	181	30	36	91	$1,823.2
2038	201	33	40	100	$2,023.4
2039	221	37	44	109	$2,217.1
2040	239	40	48	118	$2,404.7
Total	**1613**	**264**	**315**	**811**	**$16,215.5**

6.2.3 Economic Impacts

Alternative 2 imposes a more stringent ZEVs sales requirement compared to the Proposed Regulation, pushing up the 100% sales requirement by 3 model years from 2035 to 2032. This results in greater incremental vehicle cost as passed-through to end-users, but also greater operational and fuel savings. The macroeconomic impact analysis results are qualitatively similar to the results of the Proposed Regulation, but of a greater magnitude as shown in Table 76. Figure 28 and Figure 29 show the job and economic impact changes of Alternative 2, respectively.

Table 76: Summary of Economic Impacts of Alternative 2

Indicator	Metric	2026	2028	2030	2032	2034	2036	2038	2040
GSP	% Change	-0.02%	-0.10%	-0.24%	-0.33%	-0.35%	-0.29%	-0.21%	-0.14%
	Change (2020M$)	-564	-3,628	-8,601	-12,284	-13,447	-11,629	-8,864	-6,040
Personal Income	% Change	-0.03%	-0.18%	-0.38%	-0.54%	-0.59%	-0.53%	-0.44%	-0.36%
	Change (2020M$)	-1,062	-5,625	-12,479	-18,216	-20,495	-19,094	-16,166	-13,980
Employment	% Change	-0.02%	-0.14%	-0.32%	-0.46%	-0.51%	-0.45%	-0.36%	-0.26%
	Change in Jobs	-5,710	-34,903	-81,499	-117,115	-130,382	-117,075	-94,265	-67,577
Output	% Change	-0.02%	-0.12%	-0.27%	-0.38%	-0.42%	-0.38%	-0.32%	-0.25%
	Change (2020M$)	-1,100	-6,980	-16,034	-23,315	-26,660	-25,097	-21,727	-17,715
Private Investment	% Change	-0.03%	-0.18%	-0.37%	-0.37%	-0.10%	0.35%	0.78%	0.99%
	Change (2020M$)	-164	-926	-1,950	-1,989	-539	1,999	4,539	5,968

Figure 28: Employment Impacts by Major Sector for Alternative 2

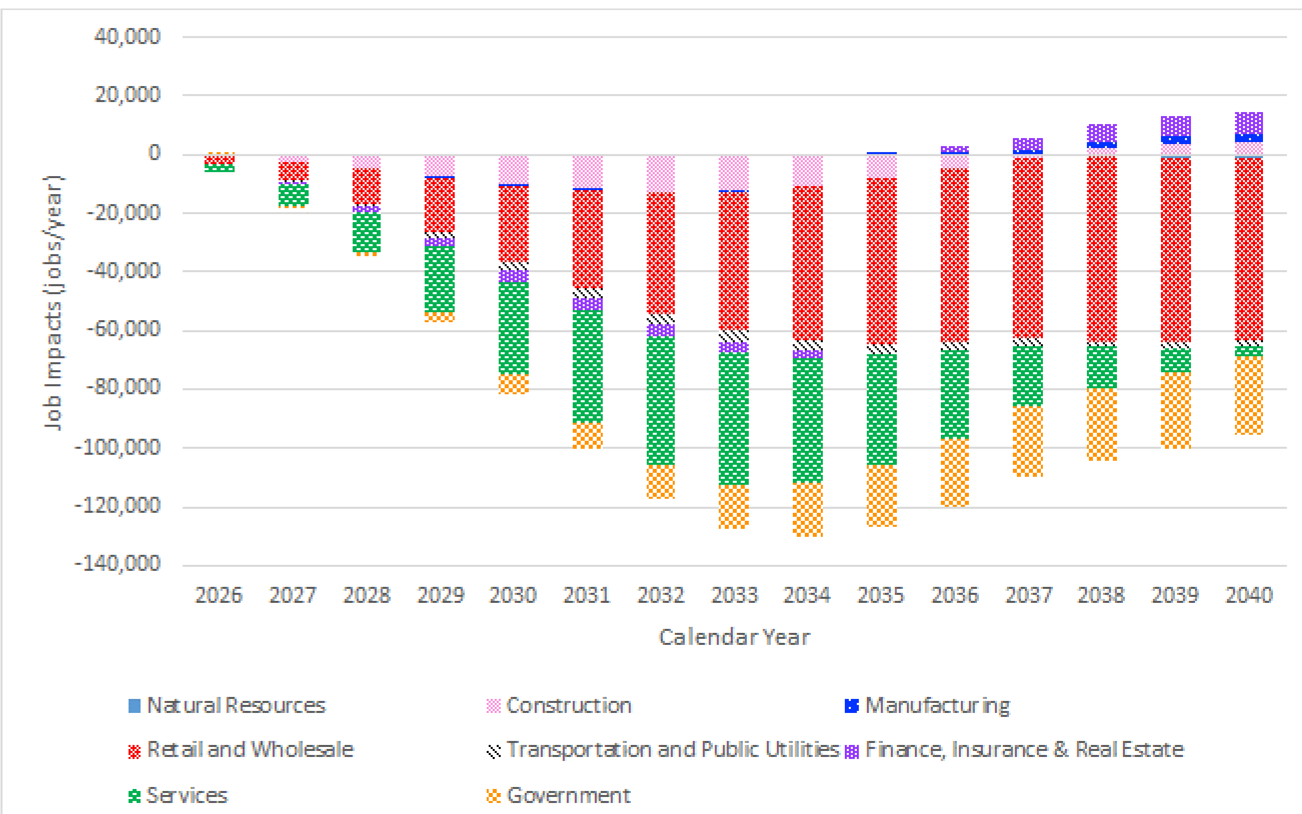
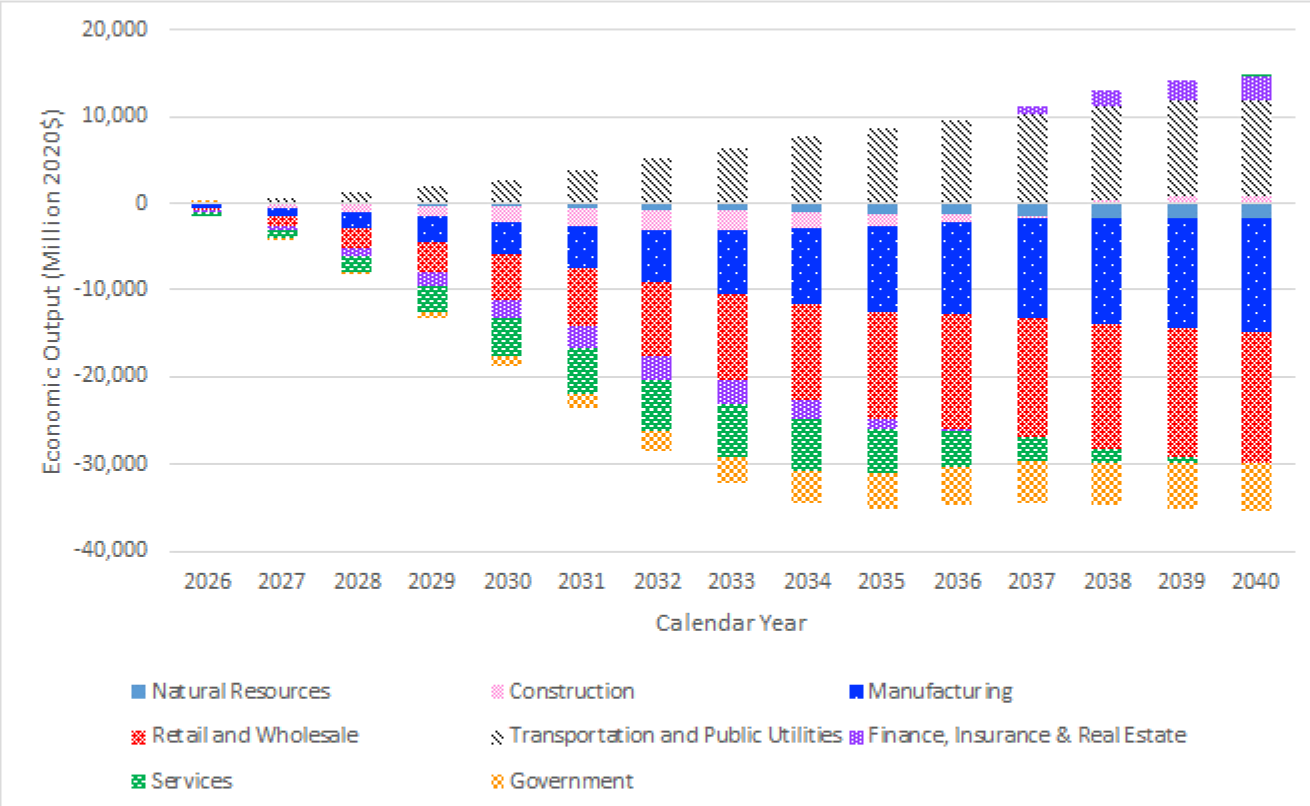


Figure 29: Change in Output in California by Major Sector for Alternative 2



6.2.4 Cost-Effectiveness

The metric to quantify cost-effectiveness of the proposed regulation and alternatives is the ratio of total monetized benefits divided by total monetized costs. A comparison of this type is an appropriate cost-effectiveness measure if the harm associated with increased emissions is fully captured in the estimates of monetized health impacts. Benefits to California include both health benefits and cost savings after subtracting tax impacts to State and local governments. Table 77 indicates that the Alternative 2 has a total cost of $347.69 billion and total benefit of $373.94 billion over the regulatory horizon. This results in a net benefit of $26.25 billion for the proposed regulation and a Benefit-Cost ratio of 1.08, indicating that the benefits are 8 percent greater than the costs.

Table 77: Benefit-Cost Ratio of Alternative 2 for 2026-2040

Scenario	Total Costs	Cost Savings (benefit)	Health Benefits	Tax and Fee Revenue	Total Benefit	Net Benefit	Benefit-Cost Ratio
Proposal	$288,970	$338,317	$14,553	-$15,867	$337,003	$48,033	1.17
Alternative 2	$347,690	$374,439	$16,215	-$16,716	$373,938	$26,248	1.08

When the social cost of carbon is included, the total benefits of the alternative are up to $425.14 billion with a benefit-cost ratio to 1.22, based on a 2.5 percent discount rate.

6.2.5 Reason for Rejecting

Alternative 2 is rejected as the more aggressive timeframe of transitioning the fleet 100% by 2032 model year requires a rate of change and progressive growth in sales that leaves little to no room for any setbacks along the way such as delays in the launch of a new product, design misses that sell poorly, or supply chain disruptions. The trajectory would effectively require every vehicle model to be completely switched to a ZEV platform on redesign and could place manufacturers in difficult competitive positions in market segments where they have a scheduled redesign earlier than their competitors in the same market segment. This could also lead to dramatic sales swings from one year to the next or force non-traditional more costly approaches that alter the normal product life cycles. This approach also puts more pressure on the build out of infrastructure to support the rapid sales growth and provides too little margin for error. Additionally, relative to the proposal, Alternative 2 increases cumulative upfront purchase price increases to consumers over 55% yielding overall disproportionally higher costs for the increased emission benefits and a worse benefit to cost ratio.

6.3 Alternative 3

Alternative 3 incorporates the ZEV sales fractions presented in the 2020 Mobile Source Strategy for calendar years 2026-2035, which would require higher electrification in 2026-2030 as compared to staff's proposal. The Mobile Source Strategy is a top-down analysis of potential ZEV penetrations that would aid in achieving state and federal clean air goals, not a regulatory feasibility analysis. Its trajectories are composed of multiple portfolios of policy changes, including public incentives and rules and private marketing strategies on behalf of companies, rather than individual feasibility-tested regulations. Accordingly, the Strategy itself does not determine the proper course of any particular regulatory proposal. However, the Strategy does provide a useful upper-bound scenario that could achieve important goals, and so serves as a useful alternative to test here as if it were contained in one single regulation. This Alternative would assume the most favorable market conditions, and that OEMs would be able to quickly redirect ZEV deployment to California to meet increased near-term requirements.

6.3.1 Costs

6.3.1.1 Total Manufacturer Costs

The total manufacturer costs associated with Alternative 3 are presented in the table below. For the purposes of simplification, only the costs associated with the ZEV sales requirements are summarized in the table. Proposal ZEV assurance measures and modifications to LEV regulations are not included.

Table 78: Alternative 3 Average Incremental Cost and Total Cumulative Costs

CY	Sales	Ave. Incremental Cost Per Vehicle ($)	Cumulative Total Cost ($)
2026	1,911,785	$ 2,020	$3,861,907,178
2027	1,921,865	$ 2,029	$7,761,863,496
2028	1,931,661	$ 2,091	$11,801,025,612
2029	1,941,144	$ 2,057	$15,793,662,372
2030	1,950,372	$ 1,976	$19,648,366,726
2031	1,959,247	$ 2,041	$23,646,240,979
2032	1,967,905	$ 2,059	$27,697,403,575
2033	1,976,253	$ 2,039	$31,727,016,003
2034	1,984,287	$ 2,035	$35,765,412,486
2035	1,992,017	$ 2,164	$40,075,877,072
2036	2,001,977	$ 2,164	$44,407,893,980
2037	2,011,987	$ 2,164	$48,761,570,974
2038	2,022,047	$ 2,164	$53,137,016,352
2039	2,032,157	$ 2,164	$57,534,338,957
2040	2,042,318	$ 2,164	$61,953,648,176

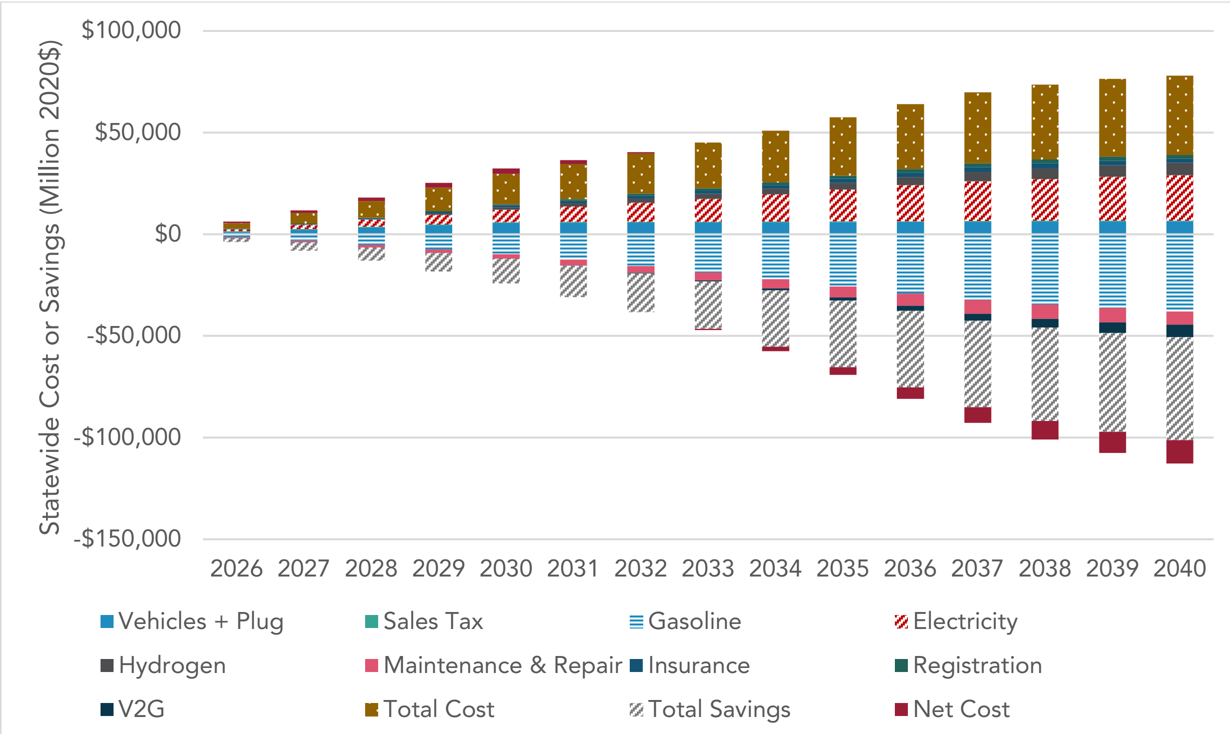
Compared to the Proposal, the incremental vehicle price, and total cumulative costs in 2035 for Alternative 3 is $2,164 and 61,953,648,176 in 2035 versus $1,732 and 51,887,558,040 in 2035 for the proposal.

6.3.1.2 Statewide Total Costs of Ownership

Table 79: Statewide TCO for Alternative 3

Year	Vehicle Price and Plug	Sales Tax	Gasoline	Electricity	Hydrogen	Maintenance and Repair	Insurance	Registration	V2G	Total Cost	Total Savings	Net Cost
2026	$1,092	$371	-$1,527	$975	$0	-$374	$193	$93	-$1	$2,723	-$1,902	$822
2027	$2,207	$378	-$3,240	$2,096	$0	-$788	$388	$197	-$3	$5,265	-$4,031	$1,234
2028	$3,363	$392	-$5,204	$3,378	$156	-$1,245	$590	$313	-$12	$8,193	-$6,461	$1,732
2029	$4,503	$387	-$7,391	$4,663	$671	-$1,716	$790	$441	-$24	$11,453	-$9,131	$2,323
2030	$5,612	$376	-$9,816	$6,040	$1,233	-$2,202	$982	$579	-$41	$14,822	-$12,059	$2,764
2031	$5,675	$392	-$12,532	$7,603	$1,694	-$2,745	$1,182	$730	-$146	$17,275	-$15,423	$1,851
2032	$5,737	$399	-$15,551	$9,337	$2,130	-$3,350	$1,385	$894	-$282	$19,882	-$19,183	$699
2033	$5,761	$400	-$18,705	$11,291	$2,468	-$3,974	$1,586	$1,070	-$543	$22,577	-$23,222	-$645
2034	$5,811	$404	-$22,051	$13,444	$2,798	-$4,640	$1,788	$1,259	-$970	$25,504	-$27,662	-$2,158
2035	$5,957	$426	-$25,704	$15,603	$3,347	-$5,339	$2,004	$1,462	-$1,614	$28,799	-$32,657	-$3,859
2036	$6,058	$426	-$29,095	$17,668	$3,958	-$6,041	$2,220	$1,667	-$2,531	$31,998	-$37,667	-$5,669
2037	$6,143	$428	-$32,365	$19,525	$4,548	-$6,745	$2,438	$1,872	-$3,448	$34,954	-$42,558	-$7,605
2038	$6,229	$429	-$34,449	$20,579	$5,116	-$7,079	$2,463	$1,985	-$4,364	$36,803	-$45,892	-$9,089
2039	$6,310	$431	-$36,321	$21,491	$5,664	-$7,003	$2,295	$1,996	-$5,277	$38,186	-$48,601	-$10,415
2040	$6,331	$433	-$37,942	$22,278	$6,125	-$6,472	$1,925	$1,890	-$6,183	$38,981	-$50,597	-$11,616
Total	**$76,788**	**$6,071**	**-$291,893**	**$175,970**	**$39,907**	**-$59,714**	**$22,230**	**$16,447**	**-$25,439**	**$337,413**	**-$377,046**	**-$39,632**

Figure 30: Statewide TCO for Alternative 3, 2026-2040



6.3.2 Benefits

6.3.2.1 Alternative 3 Total Emission Benefits

The total well-to-wheel emission benefits associated with alternative 3 are summarized in the table below.

Table 80: Alternative 3 WTW Emission Benefits

Calendar Year	NOx (tpd)	PM2.5 (tpd)	CO2 (MMT/year)
2026	0.98	0.08	2.58
2027	2.31	0.16	5.67
2028	3.91	0.26	9.07
2029	5.75	0.38	12.74
2030	7.82	0.51	16.57
2031	10.20	0.65	20.90
2032	12.76	0.81	25.63
2033	15.47	0.98	30.71
2034	18.33	1.18	36.11

Calendar Year	NOx (tpd)	PM2.5 (tpd)	CO2 (MMT/year)
2035	21.34	1.39	41.94
2036	24.35	1.61	47.57
2037	27.32	1.82	52.93
2038	30.24	2.02	57.97
2039	33.07	2.22	62.73
2040	35.81	2.42	67.19

The cumulative GHG emission reductions multiplied by the SC-C02 values shown in Section 2.4.2 gives a monetary estimate of the benefit of GHG emission reductions from Alternative 3. These benefits range from about $12.0 billion to $50.0 billion through 2040, depending on the chosen discount rate.

6.3.2.2 Health Benefits

Alternative 3 results in emissions reductions relative to the baseline leading to health benefits as shown in Table 81Table 69. The health benefits are greater than those of the proposed regulation due to greater emissions reductions estimated for this alternative. Totals may not add up due to rounding. All values are in millions of 2020 dollars.

Table 81: Health Benefits of Alternative 3

Year	Avoided Premature Mortality	Avoided Cardiovascular Hospitalizations	Avoided Acute Respiratory Hospitalizations	Avoided ER Visits	Total Health Benefit
2023	0	0	0	0	$0.0
2024	0	0	0	0	$0.0
2025	0	0	0	0	$0.0
2026	8	1	1	4	$75.6
2027	16	2	3	9	$165.6
2028	27	4	5	14	$268.9
2029	38	6	7	20	$386.8
2030	51	8	10	27	$515.9
2031	66	10	12	34	$660.0
2032	82	13	15	42	$819.2
2033	98	16	19	50	$989.8
2034	117	19	23	59	$1,173.3
2035	137	22	27	69	$1,374.2
2036	157	26	31	79	$1,576.2
2037	177	29	35	88	$1,774.4

Year	Avoided Premature Mortality	Avoided Cardiovascular Hospitalizations	Avoided Acute Respiratory Hospitalizations	Avoided ER Visits	Total Health Benefit
2038	196	33	39	98	$1,971.3
2039	215	36	43	107	$2,162.2
2040	234	39	46	116	$2,347.6
Total	**1618**	**264**	**315**	**814**	**$16,260.8**

6.3.3 Economic Impacts

Alternative 3 imposes a more stringent ZEVs sales requirement in the first 5 years compared to the Proposed Regulation. This results in greater incremental vehicle cost as passed-through to end-users, but also greater operational and fuel savings. The macroeconomic impact analysis results are qualitatively similar to the results of the Proposed Regulation, but of a greater magnitude as shown in Table 82. Figure 31 and Figure 32 show the job and economic impact changes of Alternative 3, respectively.

Table 82: Summary of Economic Impacts of Alternative 3

Indicator	Metric	2026	2028	2030	2032	2034	2036	2038	2040
GSP	% Change	-0.04%	-0.18%	-0.29%	-0.26%	-0.21%	-0.17%	-0.16%	-0.14%
	Change (2020M$)	-1,454	-6,212	-10,634	-9,835	-8,060	-6,911	-6,407	-5,861
Personal Income	% Change	-0.09%	-0.30%	-0.48%	-0.46%	-0.42%	-0.40%	-0.38%	-0.35%
	Change (2020M$)	-2,860	-9,480	-15,641	-15,417	-14,638	-14,296	-14,028	-13,579
Employment	% Change	-0.06%	-0.23%	-0.39%	-0.38%	-0.34%	-0.31%	-0.28%	-0.24%
	Change in Jobs	-14,746	-59,302	-100,454	-97,893	-87,894	-80,338	-73,653	-62,301
Output	% Change	-0.05%	-0.20%	-0.33%	-0.32%	-0.28%	-0.27%	-0.26%	-0.25%
	Change (2020M$)	-2,829	-11,678	-19,747	-19,566	-18,039	-17,526	-17,666	-17,466
Private Investment	% Change	-0.09%	-0.33%	-0.47%	-0.15%	0.31%	0.67%	0.86%	0.91%
	Change (2020M$)	-444	-1,704	-2,436	-809	1,718	3,807	5,022	5,495

Figure 31: Employment Impacts by Major Sector for Alternative 3

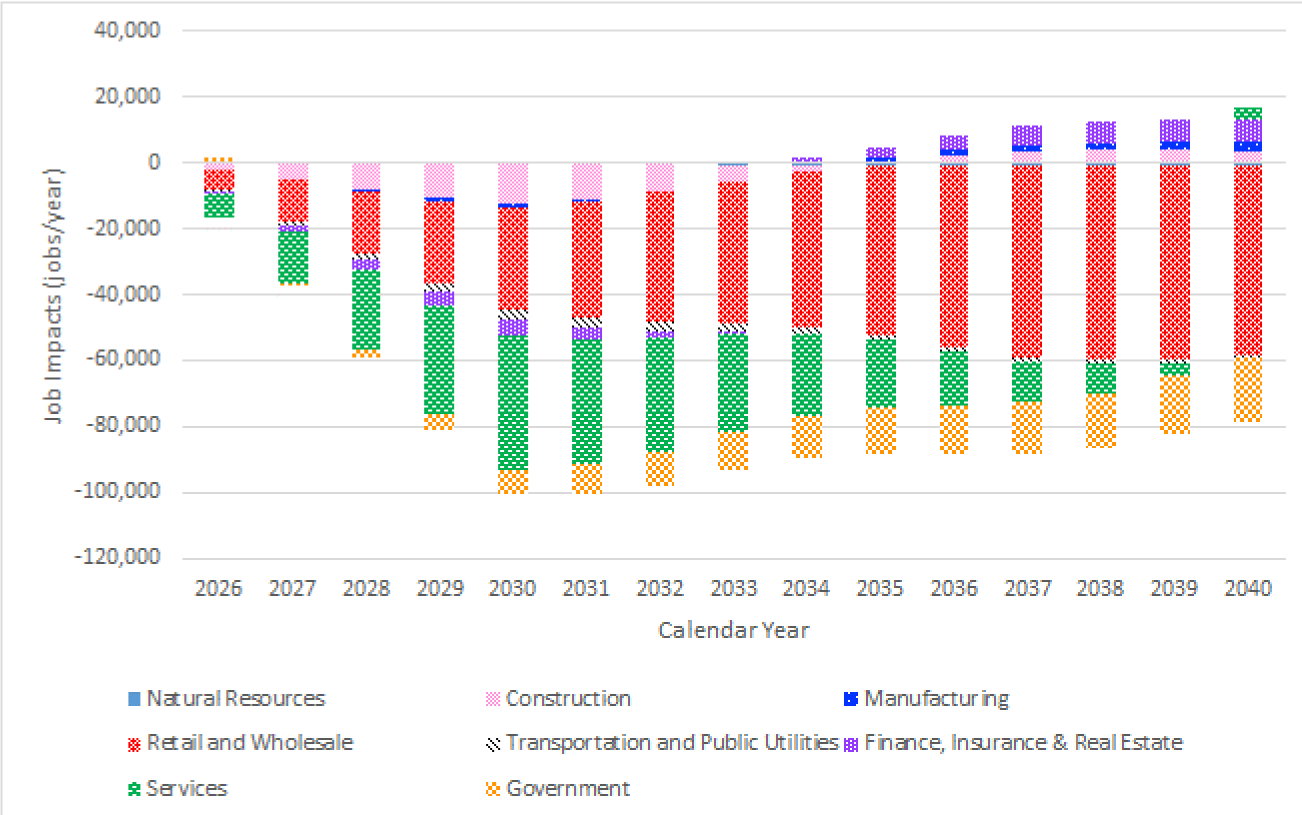
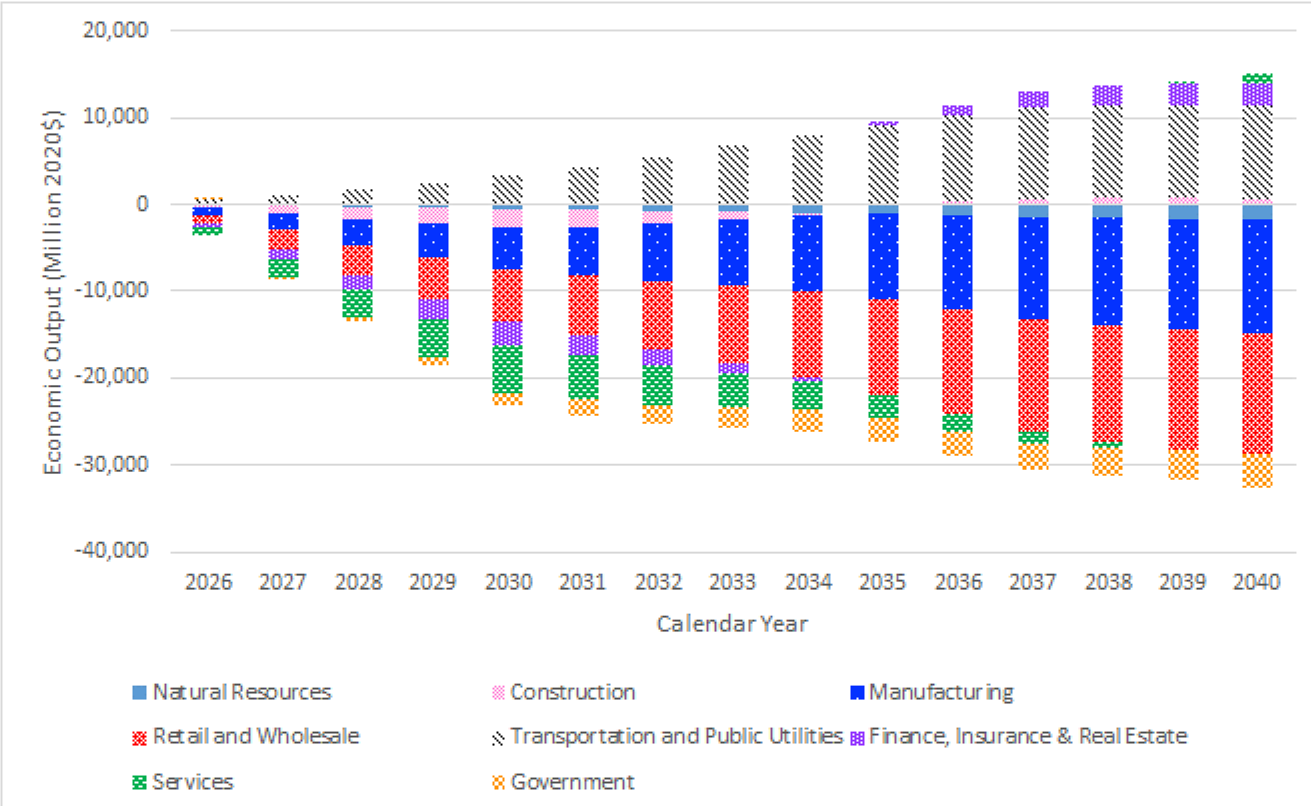


Figure 32: Change in Output in California by Major Sector for Alternative 3



6.3.4 Cost-Effectiveness

The metric to quantify cost-effectiveness of the proposed regulation and alternatives is the ratio of total monetized benefits divided by total monetized costs. A comparison of this type is an appropriate cost-effectiveness measure if the harm associated with increased emissions is fully captured in the estimates of monetized health impacts. Benefits to California include both health benefits and cost savings after subtracting tax impacts to State and local governments. Table 83 indicates that the Alternative 3 has a total cost of $337.41 billion and total benefit of $376.71 billion over the regulatory horizon. This results in a net benefit of $39.30 billion for the proposed regulation and a Benefit-Cost ratio of 1.12, indicating that the benefits are 12 percent greater than the costs.

Table 83: Benefit-Cost Ratio of Alternative 3 for 2026-2040

Scenario	Total Costs	Cost Savings (benefit)	Health Benefits	Tax and Fee Revenue	Total Benefit	Net Benefit	Benefit-Cost Ratio
Proposal	$288,970	$338,317	$14,553	-$15,867	$337,003	$48,033	1.17
Alternative 3	$337,413	$377,046	$16,260	-$16,598	$376,708	$39,294	1.12

When the social cost of carbon, quantified in Section 2.4, is included, the total benefits of the proposed regulation increase up to $426.71 billion and the benefit-cost ratio to 1.26, based on a 2.5 percent discount rate.

6.3.5 Reason for Rejecting

Alternative 3 is rejected as the more aggressive early requirements would require tripling of the ZEV market in California in the next 3 model years, as model year 2022 and 2023 are fully planned. This kind of market growth is unprecedented, and there is a lack of evidence as to how to prove a feasible path for manufacturers to comply even in the first model year of this alternative. Alternative 3 increases costs and emission benefits but has a lower benefit to cost ratio, similar to Alternative 2. Given the greater emissions benefits and similar cost effectiveness shown in this Alternative and in Alternative 2, however, staff continues to analyze the market to determine if additional stringency is warranted. As public processes to develop the regulation continue, staff will continue to evaluate stringency options, including those between the staff proposal and Alternatives 2 and 3.

Appendix A:

The following tables summarize the incremental cost incurred by manufacturers to convert gasoline vehicles to BEV300, BEV400, PHEV and FCEV vehicles, respectively.

Table A.1: BEV300 Incremental Cost by MY, Vehicle Class, Type, Drivetrain, and Towing Capability ($)

Vehicle Class	AWD / 4WD Present	Towing Capable	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Small Car	No	No	3,278	2,724	2,208	1,728	1,366	1,046	742	453	178	(83)
Small Car	Yes	No	4,276	3,711	3,186	2,696	2,324	1,995	1,681	1,383	1,099	828
Med Car	No	No	3,887	3,307	2,768	2,266	1,887	1,552	1,233	930	642	368
Med Car	Yes	No	4,978	4,387	3,837	3,324	2,934	2,589	2,260	1,947	1,648	1,364
Small SUV	No	No	3,841	3,252	2,704	2,194	1,810	1,471	1,149	842	550	273
Small SUV	Yes	No	4,862	4,262	3,704	3,185	2,791	2,442	2,109	1,793	1,492	1,206
Med SUV	No	No	4,512	3,800	3,137	2,521	2,057	1,648	1,259	889	537	203
Med SUV	No	Yes	12,932	11,591	10,347	9,193	8,334	7,581	6,867	6,191	5,549	4,940
Med SUV	Yes	No	5,722	4,997	4,323	3,695	3,219	2,798	2,398	2,017	1,654	1,308
Med SUV	Yes	Yes	14,142	12,789	11,533	10,367	9,496	8,732	8,006	7,318	6,665	6,045
Pickup	No	No	6,150	5,302	4,514	3,782	3,231	2,746	2,285	1,847	1,431	1,036

Vehicle Class	AWD / 4WD Present	Towing Capable	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Pickup	No	Yes	18,584	16,808	15,161	13,634	12,500	11,508	10,567	9,676	8,831	8,031
Pickup	Yes	No	7,439	6,578	5,777	5,032	4,469	3,972	3,499	3,049	2,621	2,213
Pickup	Yes	Yes	19,873	18,084	16,424	14,884	13,738	12,733	11,781	10,877	10,021	9,208

Table A.2: BEV400 Incremental Cost by MY, Vehicle Class, Type, Drivetrain, and Towing Capability ($)

Vehicle Class	AWD / 4WD Present	Towing Capable	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Small Car	No	No	6,135	5,391	4,699	4,056	3,573	3,148	2,745	2,361	1,997	1,650
Small Car	Yes	No	7,189	6,434	5,732	5,079	4,586	4,151	3,737	3,344	2,970	2,614
Med Car	No	No	7,260	6,461	5,718	5,027	4,508	4,051	3,617	3,204	2,812	2,440
Med Car	Yes	No	8,444	7,632	6,878	6,176	5,645	5,177	4,731	4,308	3,905	3,521
Small SUV	No	No	7,199	6,387	5,633	4,932	4,406	3,943	3,504	3,087	2,690	2,314
Small SUV	Yes	No	8,289	7,466	6,701	5,990	5,454	4,980	4,531	4,103	3,697	3,310
Med SUV	No	No	8,119	7,135	6,221	5,372	4,736	4,176	3,644	3,139	2,660	2,204

Vehicle Class	AWD / 4WD Present	Towing Capable	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Med SUV	No	Yes	14,686	13,212	11,844	10,575	9,631	8,803	8,018	7,273	6,567	5,898
Med SUV	Yes	No	9,419	8,422	7,496	6,634	5,985	5,412	4,868	4,351	3,859	3,392
Med SUV	Yes	Yes	15,986	14,499	13,118	11,837	10,880	10,039	9,242	8,485	7,767	7,086
Pickup	No	No	10,908	9,736	8,648	7,638	6,883	6,218	5,588	4,990	4,422	3,883
Pickup	No	Yes	21,118	19,184	17,391	15,728	14,493	13,412	12,388	11,418	10,498	9,626
Pickup	Yes	No	12,250	11,065	9,963	8,940	8,171	7,494	6,851	6,240	5,660	5,109
Pickup	Yes	Yes	22,459	20,512	18,705	17,029	15,782	14,688	13,651	12,668	11,736	10,852

Table A.3: PHEV Incremental Cost by MY, Vehicle Class, Type, Drivetrain, and Towing Capability ($)

Vehicle Class	AWD / 4WD Present	Towing Capable	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Small Car	No	No	3,639	3,446	3,266	3,098	2,968	2,853	2,743	2,639	2,538	2,443
Small Car	Yes	No	4,605	4,402	4,213	4,035	3,897	3,772	3,653	3,539	3,430	3,326
Med Car	No	No	3,961	3,754	3,561	3,381	3,242	3,119	3,001	2,889	2,782	2,679

Vehicle Class	AWD / 4WD Present	Towing Capable	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Med Car	Yes	No	5,012	4,795	4,592	4,401	4,252	4,119	3,991	3,869	3,752	3,640
Small SUV	No	No	4,356	4,122	3,903	3,700	3,544	3,406	3,274	3,148	3,028	2,914
Small SUV	Yes	No	5,417	5,173	4,944	4,730	4,564	4,416	4,274	4,138	4,008	3,884
Med SUV	No	No	4,706	4,454	4,220	4,001	3,834	3,685	3,544	3,409	3,280	3,157
Med SUV	No	Yes	4,706	4,454	4,220	4,001	3,834	3,685	3,544	3,409	3,280	3,157
Med SUV	Yes	No	5,271	5,014	4,774	4,550	4,377	4,223	4,076	3,936	3,802	3,674
Med SUV	Yes	Yes	5,271	5,014	4,774	4,550	4,377	4,223	4,076	3,936	3,802	3,674
Pickup	No	No	5,555	5,256	4,978	4,718	4,520	4,345	4,178	4,019	3,867	3,722
Pickup	No	Yes	5,555	5,256	4,978	4,718	4,520	4,345	4,178	4,019	3,867	3,722
Pickup	Yes	No	5,555	5,256	4,978	4,718	4,520	4,345	4,178	4,019	3,867	3,722
Pickup	Yes	Yes	5,555	5,256	4,978	4,718	4,520	4,345	4,178	4,019	3,867	3,722

Table A.4: FCEV Incremental Cost by MY, Vehicle Class, Type, Drivetrain, and Towing Capability ($)

Vehicle Class	AWD / 4WD Present	Towing Capable	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Small Car	No	No	6,256	5,442	4,640	3,850	3,072	2,776	2,483	2,194	1,907	1,624
Small Car	Yes	No	7,223	6,399	5,588	4,788	4,001	3,696	3,394	3,095	2,800	2,507
Med Car	No	No	9,735	8,557	7,406	6,281	5,183	4,810	4,441	4,079	3,721	3,369
Med Car	Yes	No	10,827	9,638	8,476	7,341	6,232	5,848	5,470	5,097	4,729	4,366
Small SUV	No	No	9,147	8,062	6,994	5,943	4,908	4,584	4,264	3,948	3,636	3,327
Small SUV	Yes	No	10,226	9,130	8,051	6,989	5,944	5,610	5,280	4,953	4,631	4,312
Med SUV	No	No	9,598	8,358	7,140	5,943	4,769	4,353	3,942	3,537	3,137	2,743
Med SUV	No	Yes	9,598	8,358	7,140	5,943	4,769	4,353	3,942	3,537	3,137	2,743
Med SUV	Yes	No	10,723	9,472	8,242	7,035	5,850	5,423	5,001	4,586	4,175	3,771
Med SUV	Yes	Yes	10,723	9,472	8,242	7,035	5,850	5,423	5,001	4,586	4,175	3,771
Pickup	No	No	13,650	12,132	10,645	9,188	7,763	7,199	6,643	6,096	5,556	5,025
Pickup	No	Yes	13,650	12,132	10,645	9,188	7,763	7,199	6,643	6,096	5,556	5,025
Pickup	Yes	No	14,849	13,318	11,819	10,351	8,914	8,339	7,772	7,213	6,662	6,120
Pickup	Yes	Yes	14,849	13,318	11,819	10,351	8,914	8,339	7,772	7,213	6,662	6,120

Description of Vehicle Operating Cost Assumptions

Annual mileage by age of vehicle

The following tables show the projected annual vehicle mileage in the fleet analysis. This is data from CARB's EMFAC2021 vehicle inventory model. The tables below show annual mileage for 2026 to 2035 model year vehicles, revealing how the annual mileage declines as vehicles age over the course of5 years. Three tables are presented each for a different vehicle classification.

Table A.5: Annual Milage by Age of Vehicle for Passenger Vehicles (PC)

	Model Year									
AGE	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
0	19,048	19,032	19,011	18,990	18,966	18,941	18,916	18,891	18,866	18,839
1	18,474	18,460	18,444	18,426	18,406	18,385	18,364	18,341	18,318	18,293
2	17,878	17,866	17,851	17,834	17,816	17,798	17,778	17,757	17,734	17,708
3	17,251	17,238	17,223	17,206	17,189	17,171	17,151	17,129	17,105	17,078
4	16,616	16,601	16,586	16,570	16,552	16,533	16,512	16,489	16,463	16,435
5	15,988	15,973	15,958	15,941	15,923	15,902	15,880	15,855	15,828	15,799
6	15,375	15,360	15,344	15,326	15,307	15,285	15,261	15,235	15,207	15,179
7	14,772	14,756	14,739	14,720	14,700	14,676	14,651	14,625	14,597	14,570
8	14,185	14,169	14,151	14,131	14,108	14,084	14,059	14,032	14,006	13,980
9	13,612	13,595	13,576	13,554	13,531	13,506	13,481	13,456	13,430	13,405
10	13,054	13,036	13,015	12,993	12,969	12,944	12,920	12,896	12,872	12,848
11	12,509	12,489	12,468	12,445	12,422	12,398	12,375	12,352	12,329	12,307
12	11,977	11,956	11,935	11,912	11,890	11,867	11,845	11,823	11,802	11,781
13	11,458	11,437	11,415	11,394	11,373	11,351	11,331	11,310	11,290	11,270
14	10,953	10,932	10,912	10,891	10,871	10,851	10,831	10,811	10,792	10,773
15	10,461	10,442	10,422	10,402	10,384	10,365	10,346	10,327	10,309	10,291

Table A.6: Annual Milage by Vehicle Age for Light Truck 1 (LDT1) Vehicles

	Model Year									
AGE	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
0	18,559	18,544	18,525	18,505	18,483	18,458	18,432	18,407	18,381	18,354
1	17,887	17,869	17,850	17,829	17,807	17,783	17,759	17,734	17,708	17,681
2	17,228	17,209	17,189	17,168	17,148	17,124	17,101	17,076	17,050	17,022
3	16,585	16,566	16,546	16,526	16,506	16,483	16,459	16,434	16,407	16,378

	Model Year									
AGE	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
4	15,963	15,943	15,923	15,904	15,884	15,862	15,838	15,812	15,783	15,754
5	15,363	15,344	15,325	15,306	15,286	15,263	15,238	15,211	15,182	15,153
6	14,786	14,768	14,749	14,730	14,709	14,685	14,659	14,632	14,603	14,573
7	14,231	14,213	14,194	14,174	14,153	14,127	14,101	14,073	14,045	14,017
8	13,697	13,679	13,659	13,638	13,616	13,590	13,564	13,536	13,509	13,482
9	13,183	13,164	13,143	13,121	13,098	13,072	13,045	13,019	12,993	12,968
10	12,691	12,671	12,650	12,627	12,603	12,577	12,552	12,527	12,503	12,479
11	12,218	12,197	12,175	12,151	12,128	12,103	12,079	12,055	12,032	12,010
12	11,767	11,745	11,722	11,699	11,676	11,652	11,629	11,607	11,585	11,563
13	11,334	11,312	11,289	11,267	11,244	11,222	11,200	11,179	11,158	11,137
14	10,924	10,901	10,879	10,857	10,835	10,815	10,794	10,773	10,753	10,734
15	10,534	10,512	10,490	10,469	10,448	10,428	10,408	10,389	10,370	10,350

Table A.7: Annual Mileage by Vehicle Age for light truck 2 (LDT2) vehicles

	Model Year									
AGE	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
0	18,401	18,369	18,332	18,295	18,253	18,228	18,203	18,178	18,152	18,126
1	17,737	17,701	17,666	17,628	17,588	17,564	17,540	17,516	17,490	17,464
2	17,081	17,046	17,010	16,974	16,934	16,912	16,888	16,864	16,838	16,811
3	16,443	16,408	16,373	16,337	16,299	16,277	16,254	16,229	16,203	16,174
4	15,828	15,794	15,759	15,725	15,689	15,666	15,643	15,617	15,589	15,560
5	15,233	15,199	15,166	15,133	15,097	15,074	15,049	15,023	14,995	14,965
6	14,659	14,627	14,594	14,561	14,525	14,502	14,476	14,449	14,421	14,392
7	14,107	14,075	14,043	14,010	13,974	13,949	13,923	13,896	13,868	13,841
8	13,578	13,546	13,514	13,481	13,444	13,419	13,393	13,365	13,339	13,313
9	13,067	13,036	13,003	12,969	12,932	12,907	12,881	12,856	12,830	12,805
10	12,579	12,548	12,514	12,480	12,444	12,418	12,394	12,369	12,345	12,322
11	12,110	12,077	12,044	12,010	11,973	11,950	11,926	11,903	11,880	11,858
12	11,659	11,627	11,594	11,560	11,526	11,502	11,480	11,458	11,437	11,415
13	11,229	11,197	11,164	11,132	11,098	11,076	11,055	11,034	11,014	10,994
14	10,819	10,787	10,755	10,724	10,692	10,672	10,651	10,631	10,612	10,593
15	10,429	10,398	10,367	10,337	10,307	10,287	10,268	10,249	10,230	10,211

Fuel/Electricity Costs

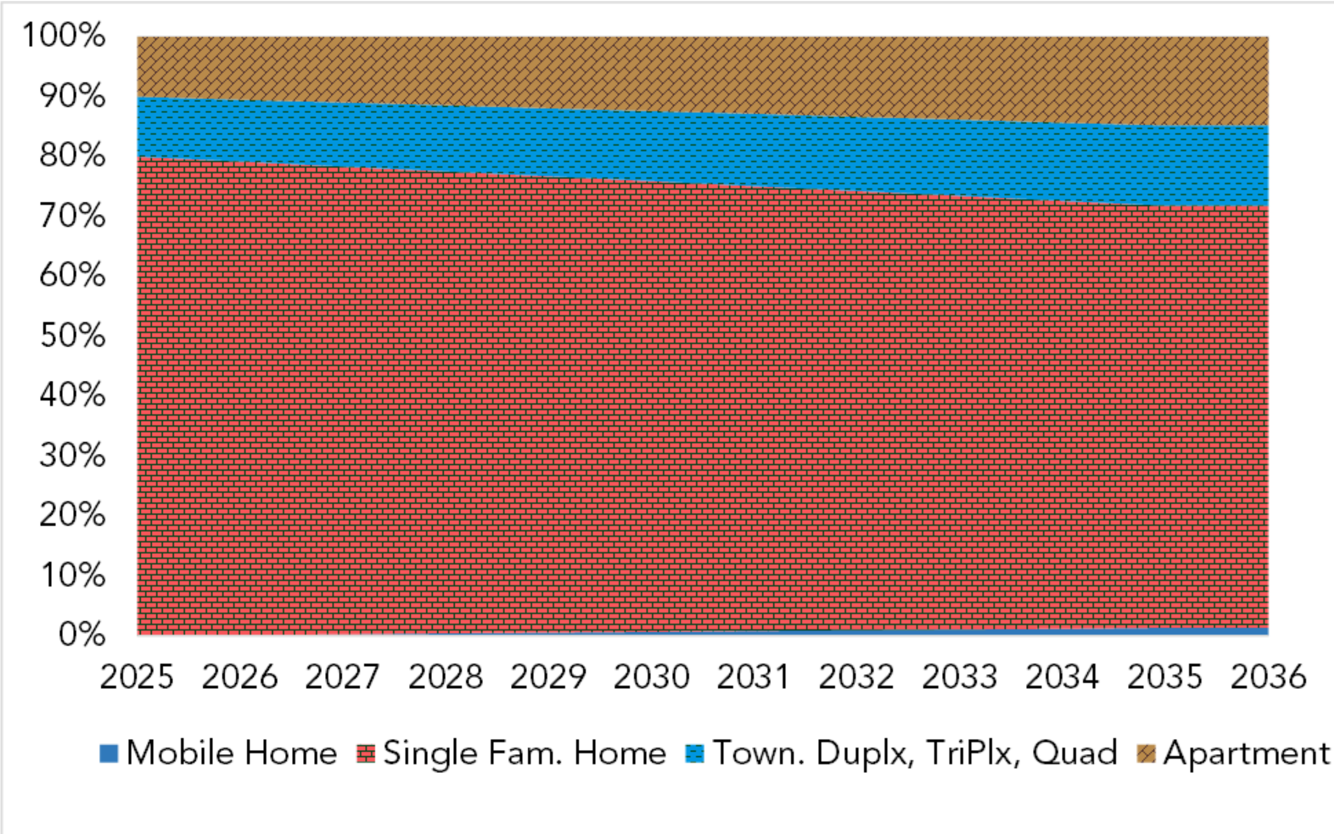
Electricity Prices:

New car buyer housing stock distribution: To estimate the distribution of housing stock among new ZEV buyers in California, a recent UC Davis study that surveys ZEV new car buyers provided the 2026 distribution and separate UC Davis study that surveys all new car buyers provided the 2035 distribution.117,118 As current ZEV buyers are early adopters and therefore self-selecting for those who have access to home charging, current ZEV buyers represent the distribution in the beginning of the regulation. However, once the proposed regulation progresses to all new car buyers by 2035, the housing stock representing all of California new car buyers becomes the appropriate distribution. A linear extrapolation was used between the two end-points. Figure A.1 shows the resulting trend.

[117] UC Davis (2021) "Emerging Technology Zero Emission Vehicle Household Travel and Refueling Behavior," UC Davis Plug-in Hybrid and Electric Vehicle Research Center, CARB Contract 16RD009, April 2021. (web link: *https://escholarship.org/uc/item/2v0853tp*)

[118] UC Davis (2016) "New Car Buyers' Valuation of Zero Emission Vehicles: California," UC Davis Plug-in Hybrid and Electric Vehicle Research Center, CARB Agreement No. 12-332, March 2016. (web link: *https://escholarship.org/uc/item/28v320rq*)

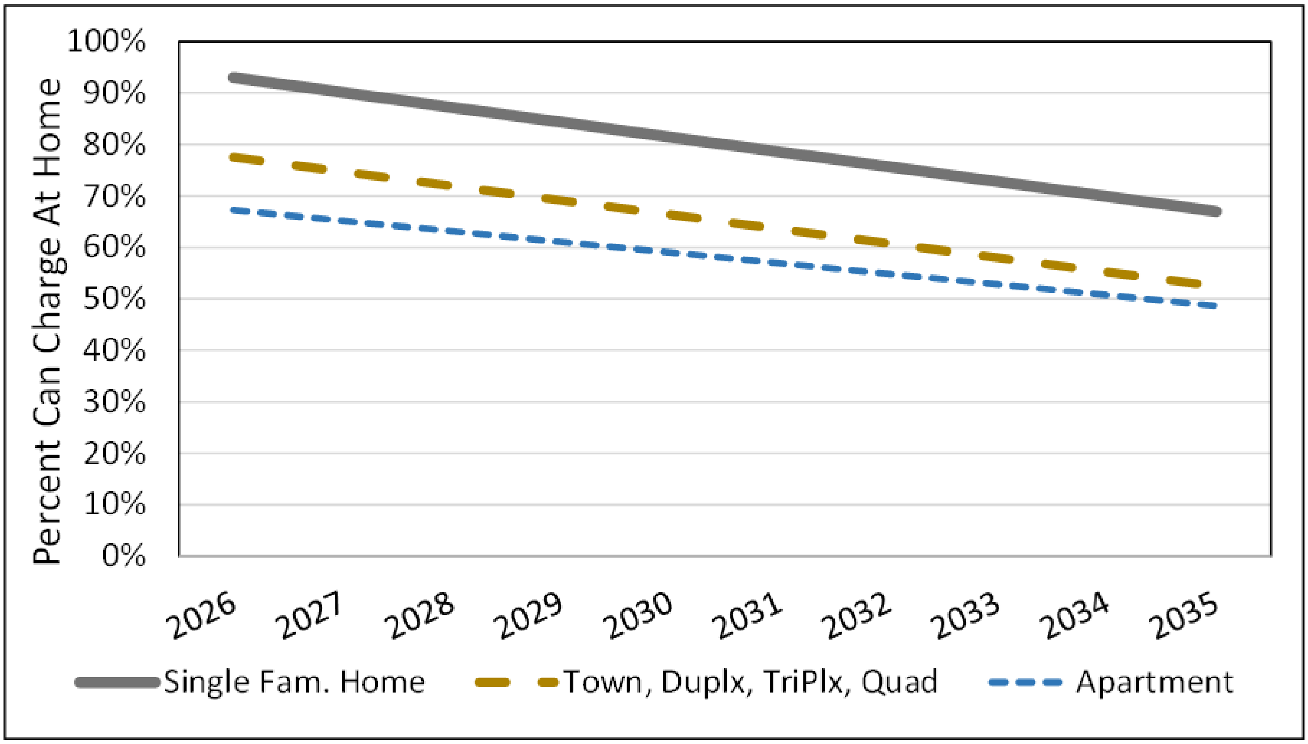
Figure A.1: Estimated Housing Stock Distribution for New Car Buyers in California



Percent can charge at home: The CEC, in partnership with NREL, conducted a survey of California residents, and relied on 1,286 respondents.[119] From the survey data, they built a model that predicts the percent of PEVs that have access to charging at home, by housing stock, as a function of the percent of the California vehicle fleet that is a PEV. A likely compliance scenario of ZEV adoption for the proposed regulation provides the estimated PEV penetration rate in the California on-road fleet. For each housing type, the proportion who can charge at home is deduced for each year of the regulation using the 'Potential Access' scenario from the methodology. The estimated values of 'percent of vehicles that can charge at home' are shown in Figure A.2 by housing type.

[119] *https://www.energy.ca.gov/publications/2022/home-charging-access-california*

Figure A.2: Estimated Percent of PEVs That Can Charge at Home in California by Housing Type



Percent use of each charging type (Home, Public L2, DCFC): To estimate how the average Californian charges their PEV, the CEC separately produced estimates by housing type, and for each year of the regulation. These estimates were extracted from its EVI-Pro model, which predicts the infrastructure needs of the State out to 2035.120 The model estimates, for each of the cases listed above, what percent of a vehicle's kWh's come from charging at home (if an option), the percent that come from Public L2's, and the percent that come from DCFCs. The model includes retail locations and workplace charging. DCFC are locations where 50kW or faster chargers are available to the public. The values provided by the EVI-Pro model are shown in Table A.8.

[120] Alexander, Matt, Noel Crisostomo, Wendell Krell, Jeffrey Lu, and Raja Ramesh. July 2021. Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment: Analyzing Charging Needs to Support Zero-Emission Vehicles in 2030 – Commission Report. California Energy Commission. Publication Number: CEC-600-2021-001-CMR.

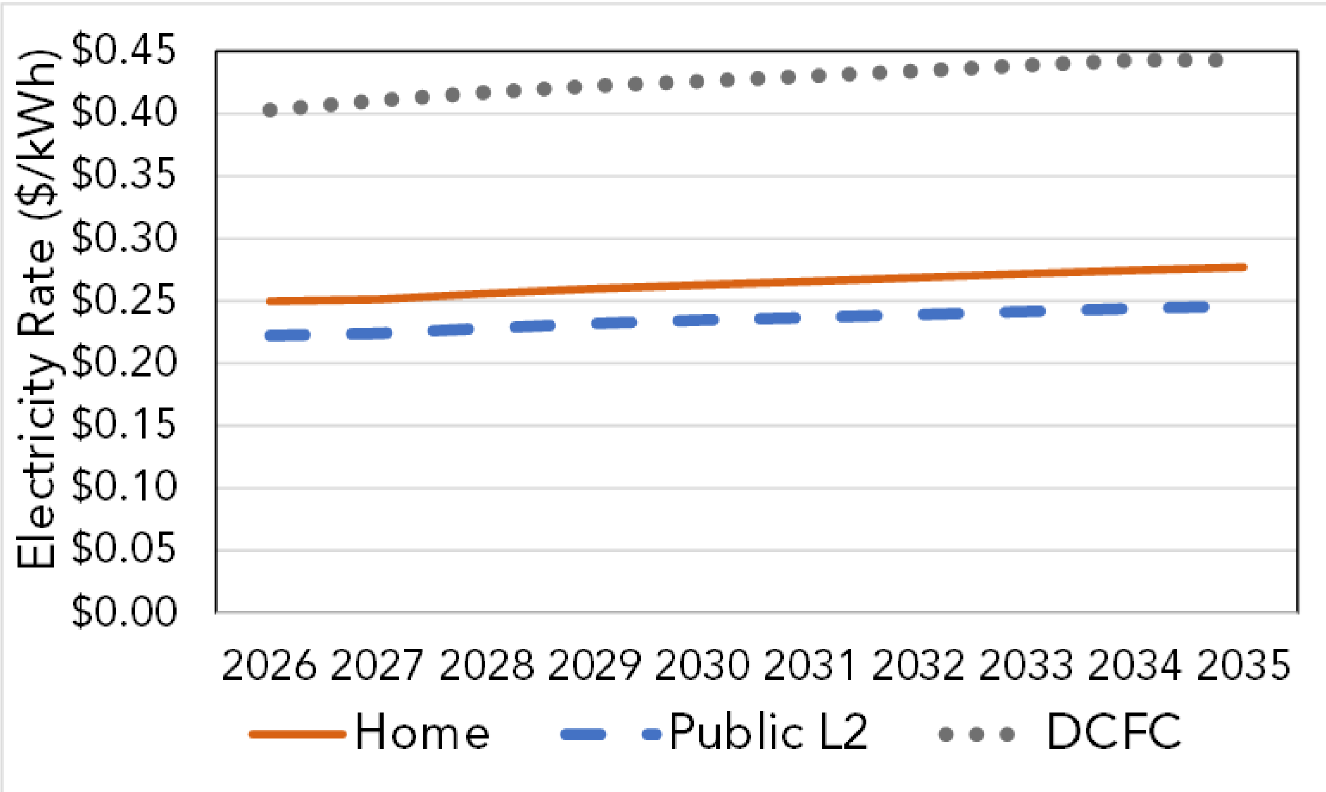
Table A.8: Percent Charge at Home, at Public L2, or at DCFC

Resident Type	Charging Type	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Average SFH Resident with Home Charging	Home	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%	78%
	Public L2	10%	10%	9%	9%	9%	9%	8%	8%	8%	8%	8%	8%	8%	7%	7%	7%
	Work L2	5%	5%	5%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
	Public DCFC	7%	8%	8%	8%	9%	9%	9%	9%	9%	10%	10%	10%	10%	10%	10%	11%
Average SFH Resident without Home Charging	Home	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Public L2	18%	17%	16%	16%	15%	15%	14%	14%	14%	13%	13%	13%	12%	12%	12%	11%
	Work L2	34%	33%	33%	32%	32%	32%	32%	32%	32%	32%	32%	31%	31%	31%	31%	31%
	Public DCFC	48%	50%	51%	52%	53%	53%	54%	54%	55%	55%	55%	56%	56%	57%	57%	57%
Average MFH Resident with Home Charging	Home	77%	77%	77%	77%	77%	77%	77%	77%	77%	77%	77%	77%	77%	77%	77%	77%
	Public L2	10%	9%	9%	9%	9%	9%	8%	8%	8%	8%	8%	8%	8%	7%	7%	7%
	Work L2	5%	5%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
	Public DCFC	9%	9%	10%	10%	10%	10%	11%	11%	11%	11%	11%	11%	12%	12%	12%	12%
Average MFH Resident without Home Charging	Home	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Public L2	17%	16%	15%	15%	15%	14%	14%	13%	13%	13%	13%	12%	12%	12%	11%	11%
	Work L2	34%	34%	34%	33%	33%	33%	33%	33%	33%	33%	33%	33%	32%	32%	32%	32%
	Public DCFC	48%	50%	51%	52%	52%	53%	53%	54%	54%	54%	55%	55%	56%	56%	56%	57%

Home electricity rate: The rates for those individuals living in single-family homes, both attached and detached, as well as for all types of multiunit dwellings are projected by CEC.121 Beyond this date, the electricity rates are flatlined at their value in 2035. The projected values account for time of use (TOU) EV rates and assume a growing participation in off-peak charging for future years. The projected electricity rates are shown in Figure A.3.

[121] CEC (2021) "Transportation Energy Demand Forecast," 2021 IEPR Workshop on Electricity and Natural Gas Demand Forecast, California Energy Commission, 21-IEPR-03, December 2021. (web link: https://www.energy.ca.gov/event/workshop/2021-12/session-2-iepr-commissioner-workshop-electricity-and-natural-gas-demand)

Figure A.3: Projected Home, Public L2, and DCFC Electricity Rates in California



Public L2 electricity rate: Shown in the figure above, the estimated Public L2 electricity rate of $0.20/kWh for 2020 was derived from a database of actual public L2 chargers hosted by NREL.122 CARB staff then projected this rate would grow at the same pace as the CEC commercial electricity rate forecasts.123

DCFC electricity rate: The estimated DCFC electricity cost is partly based on EVgo and Electrify America actual rates for 2021.124, 125 The EVgo rate was found to approximate $0.36/kWh for 2021 and landed in the central area of the Electrify America member and nonmember prices. As the membership cost is $4/month, the EVgo price was used as an approximation of both companies. The price was then increased at the rate of the CEC

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[122] L2 Public is from NREL Link below based on reported data (Levelized Cost of Charging EVs 2019) + 0% CA Bump up as compared to nation (CEC Commercial Growth Rate). Borlaug, et al. (2020) (web link: *https://www.osti.gov/dataexplorer/biblio/dataset/1637673*)

[123] Insert same CEC reference for 2021 IEPR Transportation Energy Demand Forecasts

[124] EVgo DCFC rates collected for California 7/6/21 and converted from $/min to $/kWh assuming an average charge rate of 50kW. See PDF of screen shot saved in ACC II References Folder

[125] Electrify America DCFC electricity rates for California as captured 9/29/21. See PDF saved in ACC II References Folder. *https://www.electrifyamerica.com/pricing/*

commercial electricity forecasts.126 The projected DCFC electricity costs for California are shown in Figure X4.

Note the capital cost of public charging infrastructure is assumed to be passed through to the consumer via refueling rates. Capital costs for home charging is discussed in a later section. While the impact in California of the Infrastructure Investment and Jobs Act (IIJA) (Public Law 117-58, also known as the "Bipartisan Infrastructure Law")[127] is uncertain, the large investment of $7.5 billion to build out a national network of EV chargers in the United States will help provide access to more infrastructure and may help keep retail refueling rates down.128 This infrastructure deal will provide funding for the deployment of EV chargers along highway corridors and within communities. The federal funding will have a particular focus on rural, disadvantaged, and hard-to-reach communities, further enabling more access and accelerating the adoption of EVs in overburdened areas.

Home solar impacts on cost: The reduced cost of residential electricity from on-site photovoltaic (PV) solar systems is beyond the scope of this analysis. CARB staff recognize that residential solar energy can reduce electricity costs for the residents, and residential vehicle charging costs can be lower than the rates provided by the electric utility if on-site production is used. However, the proportion of homes that have both rooftop solar and PEVs is small today, there is insufficient data available about residential renewable energy production and consumption to know what percentage of residential electricity production is used to charge vehicles, and reliable forecasts of residential solar deployment are not available. Staff do not have a reasonable method to project the growth of this in the housing stock, considering the uncertainty in PV costs and utility hook-up fees.

Vehicle to Grid (VGI) impacts on electricity cost:

Electricity cost savings associated with vehicle to grid integration (VGI) have been estimated for this analysis, though the benefits are only attributed to a small fraction of the BEV drivers. As described below, with V1G services there are clear benefits as all PEV drivers can time their charging sessions to maximize off-peak rates and thereby lower their overall cost of electricity. This component of VGI is incorporated in the TCO calculations as it is assumed all residential electricity rates will be on a time of use rate.

However, V2G service long term benefits and cost savings for drivers are harder to predict, due to developing technology and access limitations to chargers that can accommodate this service. V2G involves two-way power transfer, with a PEV providing energy to an entity such as a home during peak electricity rate periods then replenishing the energy used from the grid during periods of lower electricity rates. In this way, the BEV owner is bringing down

[126] CEC 2021 IEPR Transportation Energy Demand Forecasts

[127] Available at: *BILLS-117hr3684enr.pdf (congress.gov)*

[128] *https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/08/fact-sheet-the-bipartisan-infrastructure-deal-boosts-clean-energy-jobs-strengthens-resilience-and-advances-environmental-justice/*

their overall cost of electricity purchased. The benefit of this capability is that a portion of the home or business electricity bill becomes off grid (vehicle service) in order to save some money. Below is a more detailed discussion of the VGI data sources and assumptions used to estimate their electricity price benefits.

V1G:

Vehicle to grid integration can take on several different forms. The two primary forms considered for the total cost of ownership calculation V1G and V2G. V1G only relies on one-way power flow (grid to vehicle), but allows for the charging power level to modulate to take advantage of price signals from the grid provider (commonly called smart charging). This can be a set time-of-use (TOU) rate at a single-family home electricity bill. It can also be a dynamic price signal which can be changed on a given time interval such as 5 or 15 minutes.

Staff took a weighted average of the known customers on a TOU rate from the state's Investor-Owned Utilities (IOUs) to set the percentage of people currently using TOU rates at home and assumed these drivers will be price sensitive enough to charge their vehicle on the cheaper rates as well. Starting in 2025 staff assumed 60% of drivers will be charging their vehicle on their home TOU rate at the cheapest time block. That number of drivers using this rate was grown to 80% in 2036. Many more drivers will be switched over to TOU rates, and drivers will be more aware of the cost savings benefits for charging on the cheaper rate to take advantage of it.

V2G:

The second of the two most common forms of VGI is called Vehicle-2-Grid (V2G), which is defined as the vehicle exporting electricity to the home, an energy storage device, or the grid. Staff focused on drivers exporting electricity to their homes to avoid using grid electricity during peak hours. Staff assumed drivers with vehicles that have a bi-directional inverter would invest in the hardware to power their homes during these times. While there have been many announcements of vehicles that will have bi-directional inverters129, it will still be a small segment of the market. Staff assumed 1% of drivers in a single family home will be able to partake in this use case, and that it scales up to 25% by 2035. Staff assumed drivers export 6kWh per day to power the home during peak times, then recharge the 6 kWh along with their normal driving needs during off-peak times. Staff assume this to grow over time to 10.4 kWh per day by 2035 due to batteries becoming more efficient and larger and increased driver confidence in the technology. See Table A.9 (below) for the details of peak electricity rates used and the cost savings per session. The cost savings the driver will see for powering their homes during peak times from their vehicle is 30%-31% for MY2025-MY2035. See section 3.5 for specific cost savings in the discussion of case studies.

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[129] Halverson, 2021. "Ford F-150 Lightening will be a home backup power brokder: What Tesla Powerwall?" May 21, 20221.

Table A.9: VGI Electricity Price Assumptions

V2G	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
kWs used in session	6	6.4	6.8	7.2	7.6	8	8.4	8.8	9.2	9.6	10	10.4
peak electricity rate	$ 0.44	$ 0.45	$ 0.47	$ 0.48	$ 0.49	$ 0.51	$ 0.52	$ 0.53	$ 0.56	$ 0.57	$ 0.59	$ 0.60
$/kWh avoided @ PEAK RATE	$ 2.64	$ 2.90	$ 3.17	$ 3.45	$ 3.75	$ 4.05	$ 4.37	$ 4.69	$ 5.15	$ 5.50	$ 5.87	$ 6.24
% of driver ability home	1%	1%	1%	2%	2%	2%	10%	10%	15%	20%	25%	30%
% of driver ability AC public	0%	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
Total charging electricity cost	$ 0.32	$ 0.33	$ 0.34	$ 0.35	$ 0.36	$ 0.37	$ 0.38	$ 0.39	$ 0.41	$ 0.42	$ 0.43	$ 0.44
kWh used per session	6	6.4	6.8	7.2	7.6	8	8.4	8.8	9.2	9.6	10	10.4
Cost to replenish V2G session	$ 1.92	$ 2.11	$ 2.31	$ 2.52	$ 2.74	$ 2.96	$ 3.19	$ 3.43	$ 3.77	$ 4.03	$ 4.30	$ 4.58
% Savings on VGI used kW	32%	31%	31%	31%	31%	31%	31%	31%	31%	31%	31%	31%

While V2G does provide a greater cost savings to drivers than V1G use cases, there several barriers that need to be removed prior to full utilization by all BEV drivers. One barrier is addressing the communications between the grid operator, the utility and the location where V2G services will take place. In September 2020 the Federal Energy Regulatory Commission (FERC) released FERC order 2222 which enables small scale power generation to happen through distributed energy resources (DERs) such as vehicles. The grid operations in the nation now have to become compliant with the order to set up these use cases, though the California Independent Service Operator (CAISO) is already in compliance. A second barrier to seeing full utilization of V2G involves establishing communication between the utilities and site equipment with the CAISO. Vehicles that have bi-directional on-board chargers and inverters are slow to arrive on the market. While many vehicles with these technologies have been announced, they are typically in the higher priced models.130 The slow growth of drivers being able to use the V2G technology is due to the delay in standardizing the communications between the home, grid and utility.

Hydrogen prices

Prices paid by FCEV drivers for hydrogen fuel were modeled according to data developed by the National Renewable Energy Laboratory (NREL) for the California Energy Commission's 2021 Integrated Energy Policy Report.131 the NREL analysis considered three cases of energy demand and corresponding impacts on fuel prices. For this analysis, CARB has

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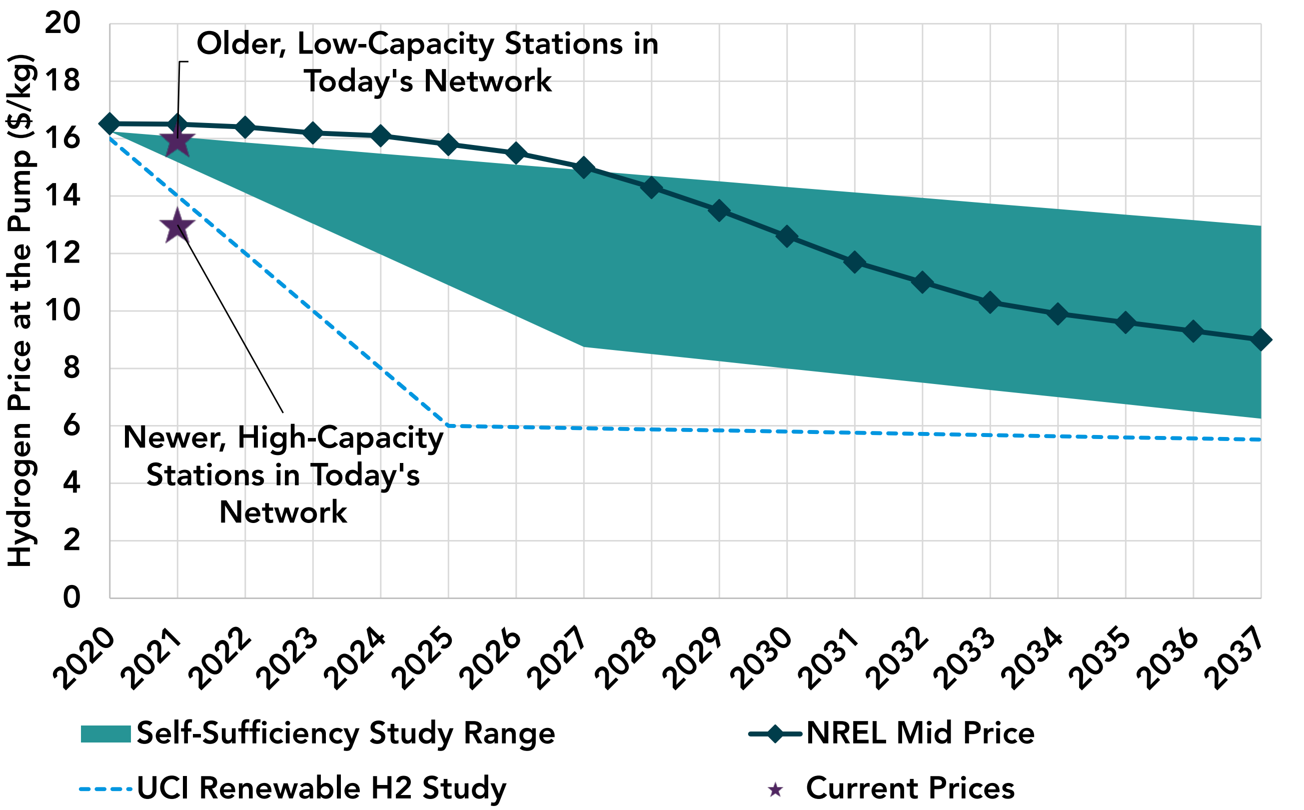
[130] *Vehicle-to-grid charging - E-Mobility (emobility-engineering.com)*

[131] See staff presentation here: https://www.energy.ca.gov/event/workshop/2021-12/session-2-iepr-commissioner-workshop-electricity-and-natural-gas-demand

adopted the Mid-demand case. The forecast provided by NREL is projected only through 2035; CARB extrapolated the trend for decreasing hydrogen price to 2037 along a linear best-fit curve.

Figure A.4: Hydrogen Fuel Price Forecast and Comparison to Reference Data



The forecast for hydrogen price is shown in Figure A.4, alongside additional reference data for context. Prices in the forecast decrease slowly through 2027 before decreasing at a more rapid pace. Prices decrease from a high of $16.52/kg in 2020 to $9.60/kg in 2035. The prices for 2020 match well with prices observed in today's hydrogen fueling network, as shown by the star symbols. Older, low-capacity stations in today's network sell hydrogen at around $16.00/kg; newer, high-capacity stations sell hydrogen at approximately 20% less, near $13/kg. Once prices in the NREL projection start decreasing more rapidly, they also lie within the range of potential prices investigated in CARB's recently published *Hydrogen Station Network Self-Sufficiency Analysis.*132 Finally, hydrogen prices assumed in all years are higher

[132] *https://ww2.arb.ca.gov/sites/default/files/2021-10/hydrogen_self_sufficiency_report.pdf*

than projections made in a recent study of potential renewable hydrogen price completed by researchers at the University of California, Irvine (UCI).133

[133] *http://www.apep.uci.edu/PDF_White_Papers/Roadmap_Renewable_Hydrogen_Production-UCI_APEP-CEC.pdf*

6.4 Macroeconomic Appendix

Table 84: REMI Inputs for the Proposed Regulation (Million 2020$)

	REMI Policy Variable	REMI Industry /Spending Category		2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2040
Consumer Price	New motor vehicles	375.2	893.4	1517.4	2225.8	3001.4	3693.3	4251.9	4695.4	5052.4	5339.2	5334.7	5324.6	5327.9	5337.6	5354.5	
Consumer Spending (w/ reallocation)	Motor vehicle fuels, lubricants, and fluids	(550.4)	(1427.8)	(2644.5)	(4213.2)	(6136.7)	(8776.1)	(11667.0)	(14699.1)	(17919.2)	(21338.0)	(24528.6)	(27605.7)	(30187.1)	(32447.1)	(34388.3)	
Consumer Spending (w/ reallocation)	Electricity	352.9	909.4	1706.2	2747.7	3842.4	5140.1	6562.6	8088.6	9674.6	11270.5	12563.0	13677.1	14459.3	15039.2	15412.6	
Consumer Spending (w/ reallocation)	Motor vehicle maintenance and repair	(142.2)	(364.1)	(666.3)	(1049.3)	(1463.0)	(1982.6)	(2557.8)	(3150.5)	(3787.5)	(4444.2)	(5104.0)	(5766.8)	(6290.4)	(6595.1)	(6600.8)	
Consumer Spending (w/ reallocation)	Net motor vehicle insurance	64.0	152.6	258.2	376.8	508.9	695.5	882.5	1065.9	1247.5	1427.2	1607.7	1789.0	1907.2	1937.6	1863.2	
Exogenous Final Demand	Basic chemical mfg.	0.0	0.0	(0.0)	0.0	418.7	1191.5	1891.4	2453.7	2973.0	3439.0	3975.3	4492.1	4989.5	5468.2	5928.6	
Reallocate Consumer Spending	n/a	(34.1)	(85.7)	(154.2)	(239.1)	(690.1)	(1473.6)	(2207.4)	(2837.4)	(3442.6)	(4014.4)	(4645.8)	(5261.7)	(5828.3)	(6328.4)	(6745.6)	
Production Cost	All industries (excluding 5321)	10.3	19.2	25.0	25.2	34.1	18.8	(24.7)	(89.4)	(176.1)	(287.0)	(421.7)	(563.1)	(688.8)	(800.0)	(893.3)	
Production Cost	Automotive equipment rental and leasing	1.5	2.7	3.6	3.6	4.9	2.7	(3.5)	(12.8)	(25.2)	(41.0)	(60.2)	(80.4)	(98.4)	(114.3)	(127.6)	
Consumer Spending	Motor vehicle fuels, lubricants, and fluids	(54.4)	(141.2)	(261.5)	(416.7)	(606.9)	(868.0)	(1153.9)	(1453.8)	(1772.2)	(2110.3)	(2425.9)	(2730.2)	(2985.5)	(3209.1)	(3401.0)	
Consumer Spending	Electricity	34.9	89.9	168.7	271.8	380.0	508.4	649.0	800.0	956.8	1114.7	1242.5	1352.7	1430.0	1487.4	1524.3	

	REMI Policy Variable	REMI Industry /Spending Category		2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2040
Consumer Spending	Motor vehicle maintenance and repair	(14.1)	(36.0)	(65.9)	(103.8)	(144.7)	(196.1)	(253.0)	(311.6)	(374.6)	(439.5)	(504.8)	(570.3)	(622.1)	(652.3)	(652.8)	
Consumer Spending	Net motor vehicle insurance	6.3	15.1	25.5	37.3	50.3	68.8	87.3	105.4	123.4	141.2	159.0	176.9	188.6	191.6	184.3	
Consumer Spending	Hospitals	(0.1)	(0.2)	(0.3)	(0.5)	(0.7)	(1.0)	(1.3)	(1.6)	(2.0)	(2.4)	(2.9)	(3.3)	(3.7)	(4.1)	(4.5)	
Government Spending	State government	57.9	69.9	68.6	56.2	37.0	47.8	8.6	(33.5)	(74.6)	(115.1)	(145.8)	(166.5)	(187.7)	(241.4)	(346.1)	
Government Spending	Local government	32.4	(6.3)	(76.2)	(174.6)	(305.2)	(447.6)	(661.2)	(885.5)	(1118.3)	(1361.1)	(1590.6)	(1815.3)	(2005.0)	(2171.7)	(2315.8)	