State of California
AIR RESOURCES BOARD

# Advanced Clean Trucks Regulation

## Standardized Regulatory Impact Assessment (SRIA)

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**Air Resources Board**
**1001 I Street**
**Sacramento, California 95814**

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# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AB | Assembly Bill |
| ACC | Advanced Clean Car |
| ACT | Advanced Clean Truck |
| ASB | Airport Shuttle Bus |
| ATM | Advanced Technology Multiplier |
| BAU | Business-As-Usual |
| BEV | Battery-Electric Vehicle |
| CAAQS | California Ambient Air Quality Standards |
| CARB | California Air Resources Board |
| CEC | California Energy Commission |
| CEQA | California Environmental Quality Act |
| CNG | Compressed Natural Gas |
| $CO_2$ | Carbon Dioxide |
| CPI | Consumer Price Index |
| DMV | Department of Motor Vehicles |
| EER | Energy Efficiency Ratio |
| EIA | Energy Information Administration |
| EMFAC | Emission Factor Inventory Model |
| EPA | Environmental Protection Agency |
| ER | Emergency Room |
| EVSE | Electrical Vehicle Supply Equipment |
| FCEV | Fuel Cell Electric Vehicle |
| FY | Fiscal Year |
| GHG | Greenhouse Gas |
| GO-Biz | Governor’s Office of Business and Economic Development |
| GSP | Gross State Product |
| GVWR | Gross Vehicle Weight Rating |
| HVIP | Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project |
| ICCT | International Council on Clean Transportation |
| ICE | Internal Combustion Engine |
| ICT | Innovative Clean Transit |
| IPCC | Intergovernmental Panel on Climate Change |
| ISOR | Initial Statement of Reasons |
| IWG | Interagency Working Group |
| kWh | Kilowatt-Hour |
| LCFS | Low Carbon Fuel Standard |
| LHD | Light Heavy-Duty |
| LTL | Less-than-Truckload |
| MMT | Million Metric Tons |
| MY | Model Year |
| NHTSA | National Highway Traffic Safety Administration |
| NOx | Oxides of Nitrogen |
| PHEV | Plug-In Hybrid Electric Vehicle |
| PM | Particulate Matter |

| | |
|---|---|
| SB | Senate Bill |
| SC-$CO_2$ | Social Cost of Carbon |
| SRIA | Standardized Regulatory Impact Assessment |
| State SIP Strategy | State Strategy for the State Implementation Plan |
| TCO | Total Cost of Ownership |
| tpd | Tons per Day |
| TTW | Tank-to-Wheel |
| WTW | Well-to-Wheel |
| ZE | Zero-Emission |
| ZEB | Zero-Emission Bus |
| ZEP | Zero-Emission Powertrain |
| ZEV | Zero-Emission Vehicle |

## A. Introduction

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 upstream emissions are included. Zero-emission vehicles (ZEVs) have no tailpipe emissions and help protect public health, reduce petroleum use, meet sustainability objectives, and reduce direct exposure to diesel emissions in local communities.

The proposed Advanced Clean Trucks (ACT) regulation (Proposed ACT Regulation) aims to accelerate adoption of medium and heavy duty ZEVs with a gross vehicle weight rating (GVWR) greater than 8,500 lbs. as part of California's strategy to reduce emissions from transportation. The Proposed ACT Regulation has two main elements:

- Manufacturers would be required to produce and sell medium and heavy duty ZEVs at an increasing percentage of California sales, and
- Large employers like retailers, manufacturers, government agencies and fleet owners would be required to report information that can be used to develop future strategies to further accelerate the use of ZEVs.

The proposed manufacturer ZEV sales requirement will meet several objectives and recommendations included in the Sustainable Freight Action Plan, Mobile Source Strategy[1] and ZEV Action Plan. The Proposed ACT Regulation will also complement recently approved regulations that require transit agencies and airport shuttle service providers to begin purchasing zero-emission buses, and to meet the zero-emission (ZE) truck purchase requirements in Assembly Bill 769 (AB 769) for state government fleets. The proposed manufacturer ZEV sales requirement also complements the federally and California-adopted Phase 2 GHG (CA Phase 2 GHG) regulation, because ZEVs can be used to meet these existing requirements. Finally, the Proposed ACT Regulation, including the proposed reporting requirement, establishes a foundation for meeting executive orders, plans, and directives issued by the Governor as described in the next section.

### 1. Regulatory History

In March 2017, CARB adopted the Revised Proposed 2016 State Strategies document as part of the State Implementation Plan (SIP) which identified several sectors that are key to launching heavy-duty zero-emission technology in the on-road heavy-duty sector: transit buses, delivery trucks, and airport shuttles.[2] The Proposed ACT Regulation continues implementation of these strategies to increase the first wave of heavy-duty ZEV deployments. The SIP includes the "Last Mile Delivery" measure which focuses on deploying zero-emission vehicles and equipment in well-suited applications. Based on continued assessment of

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

[2] California Air Resources Board, Revised Proposed 2016 State Strategy for the State Implementation Plan, released on March 7, 2017 (web link: https://www.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf, last accessed June 2019).

technological readiness, the Proposed ACT Regulation includes last mile delivery vehicles and expands to include a wider range of vehicles in well-suited applications. The experience gained by operating these early ZEVs are expected to benefit other heavy-duty vehicle markets and increase the commercialization, and acceptance, of clean transportation technologies in a wide range of applications.

The Sustainable Freight Action Plan established the strategy of using zero-emission technology where feasible, and “near-zero” with renewable fuels everywhere else, to meet California’s long-term air quality goals.[3] The Proposed ACT Regulation requires ZEV production and sales, while allowing for partial compliance with “near-zero” plug-in hybrid electric vehicle (PHEV) technology, closely matches with the Sustainable Freight strategy.

Several California executive orders and policies provide additional background for the Proposed ACT Regulation. In March 2012, Governor Edmund G. Brown issued Executive Order B-16-2012[4] directing California agencies to establish benchmarks for key milestones to help support and facilitate the ZEV market in California. One of those milestones include deploying over 1.5 million ZEVs and PHEVs on the road by 2025. As a result of this order, multiple state agencies, including the California Air Resources Board (CARB), worked to develop and release the 2013 ZEV Action Plan (2013 Plan).[5] The 2013 Plan identified over 100 strategies to meet the milestones of the Executive Order and included four broad goals to advance the overall ZEV market:

- Complete needed ZEV infrastructure and planning;
- Expand consumer awareness and demand of ZEVs;
- Transform fleets; and
- Grow jobs and investment in the private sector.

In January 2018, Governor Brown issued Executive Order B-48-18 building on past efforts to increase ZEVs by increasing California’s goal to 5 million ZEVs on the road by 2030, and setting a target of 250,000 chargers by 2025.[6] Also in 2018, Governor Brown issued executive order B-55-18, which sets a target to achieve carbon neutrality in California no later than 2045, and achieve and maintain net negative emissions thereafter.[7] The Proposed ACT Regulation

[3] Governor’s Office, Sustainable Freight Action Plan, released on July 2016 (web link: http://dot.ca.gov/hq/tpp/offices/ogm/cs_freight_action_plan/Documents/CSFAP_Main%20Document_FINAL_07272016.pdf, last accessed June 2019).
[4] Executive Order B-16-2012. State of California Executive Order signed by Governor Edmund G. (Jerry) Brown Jr. March 23, 2012 (web link: https://www.gov.ca.gov/2012/02/15/news17445/, last accessed June 14, 2019).
[5] Governor’s Interagency Working Group on Zero-Emission Vehicles, 2013. 2013 ZEV Action Plan: A roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025 (web link: http://opr.ca.gov/docs/Governors_Office_ZEV_Action_Plan_(02-13).pdf, last accessed June, 2019).
[6] Executive Order B-48-18. State of California Executive Order signed by Governor Edmund G. (Jerry) Brown Jr. January 26, 2018 (web link: http://business.ca.gov/Portals/0/ZEV/2018-ZEV-Action-Plan-Priorities-Update.pdf, last accessed June 2019).
[7] Executive Order B-55-18. State of California Executive Order signed by Governor Edmund G. (Jerry) Brown Jr. To Achieve Carbon Neutrality, Executive Department: State of California, Office of the Governor, September 10, 2018. (web link: https://www.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf, last accessed June 2019).

will support these goals by ensuring large scale production by manufacturers and is estimated to place 56,000 medium- and heavy-duty ZEV's in California by 2030.

In August 2018, Governor Brown sent a letter to Chair Nichols of CARB directing CARB to pursue conversion of public and private fleets to zero-emission vehicles in categories including large employers, delivery vehicles, and transportation service fleets.[8] In response, staff proposed adding a reporting requirement to the Proposed ACT Regulation, to collect additional information from large employers, retailers, brokers and fleets. The information would inform future rules to require the use of ZEVs that would further expand the ZEV market, and to complement the proposed manufacturer ZEV sales requirements, and other policies.

The Proposed ACT Regulation would complement other regulations recently adopted by the Board that require zero-emission airport shuttle and transit bus purchases. It also supports AB 739 that requires state fleets to purchase ZE trucks. The Innovative Clean Transit (ICT) regulation applies to buses with a GVWR greater than 14,000 lbs. It requires transit agencies to begin purchasing zero-emission buses (ZEBs) in 2023, and is phased-in so that 100 percent of bus purchases must be ZEBs beginning in 2029. Similarly, the Airport Shuttle Bus (ASB) regulation requires the purchase of zero-emission shuttle buses with a GVWR greater than 8,500 lbs. with a complete transition to zero-emission shuttles by 2035. Finally, AB 739 requires California state owned fleets of vehicles at or over 19,000 lbs. GVWR to purchase 15 percent ZEVs [9] starting in 2026, ramping up to 30 percent by 2030. Manufacturers can earn credit in the Proposed ACT Regulation for ZEVs sold to fleets affected by these other requirements. However, staff are excluding the cost and benefits of the ZEV purchases that are already required by the ICT regulation, ASB regulation, and AB739 from the Proposed ACT Regulation as they are already expected and attributed to other regulations.

The Proposed ACT Regulation also complements other regulations approved by CARB and the United States Environmental Protection Agency (US EPA) to reduce GHG emissions from medium- and heavy-duty vehicles. The U.S. EPA Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles - Phase 2 (Federal Phase 2 GHG) is structured to provide a range of options to manufacturers to reduce the fuel consumption of medium- and heavy-duty vehicles through use of a range of technologies including aerodynamics, more efficient engines, ZEVs and other technologies.[10] California adopted this federal program with minor changes. The California Greenhouse Gas Emissions Standards for Medium- and Heavy-duty Engines and Vehicles, and the Amendments to the Tractor-Trailer GHG Regulation (CA Phase 2 GHG) were adopted by the Board in February 2018.[11] There are some synergies in costs and emissions benefits between CA Phase 2 GHG

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[8] Governor's letter to Chair Nichols. Signed by Edmund G. (Jerry) Brown Jr. August 1, 2018. (web link: https://www.arb.ca.gov/msprog/zero_emission_fleet_letter_080118.pdf, last accessed June 2019).
[9] California State Legislature, Assembly Bill 739, signed into law October 10, 2017 (web link: https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB739, last accessed June 2019).
[10] United States Environmental Protection Agency (U.S. EPA) (2016). Final Rule for Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles - Phase 2. Final Rule. October 25, 2016. (web link: https://www.gpo.gov/fdsys/pkg/FR-2016-10-25/pdf/2016-21203.pdf, last accessed June 2019).
[11] California Air Resources Board, Staff Report: Initial Statement of Reasons for Proposed Rulemaking Proposed California Greenhouse Gas Emission Standards for Medium- and Heavy-Duty Engines and Vehicles and

and the Proposed ACT Regulation, because ZEVs can be used to comply with both regulations. Since the Phase 2 GHG regulation is already in effect, no new GHG emissions reductions are attributed to the Proposed ACT Regulation unless the number of ZEVs sold exceeds what is required to comply with the Phase 2 GHG regulation. The impact on cost estimates is described in the baseline discussion in Section 5.

The Advanced Clean Cars (ACC) ZEV regulation requires manufacturers of Class 1 and 2A vehicles to produce and sell ZEVs in California as a percentage of total annual sales.[12] The ACC ZEV regulation does not require manufacturers to produce and sell Class 2B and 3 ZEVs, but it does provide an optional credit provision for Class 2B and 3 ZEVs. The Proposed ACT Regulation interacts with this optional credit provision for Class 2B and 3 ZEVs. However, the Proposed ACT Regulation avoids double counting with the ACC ZEV regulation by specifying that manufacturers may not use credits from the same Class 2B and 3 vehicles in both rules.

Zero-Emission Powertrain (ZEP) Certification was approved by the Board earlier this year as optional certification procedures for medium and heavy-duty electric and fuel-cell vehicles or zero-emission powertrains. ZEP certification supports future zero-emission measures by helping ensure fleet purchasers are provided with consistent and reliable information about zero-emission technology and the vehicles that use it, and that heavy-duty electric and fuel-cell vehicles are well supported once deployed.[13] ZEP certification will help ensure that zero-emission powertrains, along with the heavy-duty vehicles they are designed for, are reliable in their intended applications. The Proposed ACT Regulation will make ZEP certification required for manufacturers to earn credits needed to comply.

The cost analysis includes the value of Low Carbon Fuel Standard program (LCFS) credits as part of the analysis to show the potential impacts on the state economy. The LCFS is a regulation designed to reduce GHG emissions associated with the lifecycle of transportation fuels used in California.[14] A fleet owner that opts into the LCFS program can receive credits for consuming electricity or producing an alternative fuel (e.g., hydrogen) onsite. The credits can be sold to regulated parties in the LCFS credit market, thereby reducing operating costs for fleet owners. These credits will have a monetary value when sold to regulated parties who must offset deficits created by their supply of fuels with Carbon Indexing that exceed the LCFS standards. According to the LCFS staff report, regulations are needed to encourage the adoption of zero-emission vehicles, and the generation of LCFS credits can assist that effort.[15]

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Proposed Amendments to the Tractor-Trailer GHG Regulation, December 19, 2017 (web link: https://www.arb.ca.gov/regact/2018/phase2/isor.pdf, last accessed June 2019).

[12] Zero-Emission Vehicle Standards for 2018 and Subsequent Model Year Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles, California Code of Regulations Section 1962.2, January 1 2016, (web link: https://www.arb.ca.gov/msprog/zevprog/zevregs/1962.2_Clean.pdf, last accessed June 2019).

[13] Staff Report: Initial Statement of Reasons - Proposed Alternative Certification Requirements and Test Procedures for Heavy Duty Electric and Fuel-Cell Vehicles And Proposed Standards and Test Procedures For Zero Emission Powertrains (Zero-Emission Powertrain Certification Regulation), December 31, 2018 (web link: https://www.arb.ca.gov/regact/2019/zepcert/isor.pdf, last accessed June 2019).

[14] Subarticle 7: Low Carbon Fuel Standard, California Code of Regulations § 95480-95503, January 4, 2019 (web link: https://www.arb.ca.gov/fuels/lcfs/fro_oal_approved_clean_unofficial_010919.pdf, last accessed June 2019).

[15] California Air Resources Board, Public Hearing to Consider Proposed Amendments to the Low Carbon Fuel Standard Regulation and to the Regulation on Commercialization of Alternative Diesel Fuels. Staff Report: Initial Statement of Reasons (web link: https://www.arb.ca.gov/regact/2018/lcfs18/isor.pdf, last accessed June 2019).

To isolate the effects of switching to lower carbon fuels of the same type vs switching to new vehicle technologies the LCFS program does not count GHG benefits that are resultant from regulations that require switching to different vehicle technologies that influence carbon intensities of transportation fuels. Therefore, all of the GHG emissions benefits of deploying ZEVs will be counted as part of the Proposed ACT Regulation except if the ZEVs are already required to be purchased from existing regulations or legislation.

Additionally, Assembly Bill 2061 (AB 2061) is a complementary piece of legislation that mitigates vehicle weight concerns for ZEVs required by the Proposed ACT Regulation. AB 2061, to the extent expressly authorized by federal law, authorizes a near-zero-emission vehicle or a zero-emission vehicle, to exceed the weight limits on the power unit by up to 2,000 pounds.[16] AB 2061 factors into staff's assessment because it improves the suitability of ZEVs and reduces concerns about the potential for reduced payload and loss in revenue for vehicles that operate at their weight limits.

## 2. Proposed Advanced Clean Trucks (ACT) Regulation

The overall strategy of the Proposed ACT Regulation is to develop a self-sustaining ZE truck market through increasing sales of ZE trucks in California by truck manufacturers. The Proposed ACT Regulation includes two primary elements. First, it requires a percentage of truck and bus sales to be zero-emissions. Second, it requires large organizations including retailers, manufacturers, government agencies, and large truck fleets to report information about services they contract for that require the use of trucks and shuttles.

The primary objectives of the Proposed ACT Regulation include the following:

- Accelerate first wave of zero-emission truck deployments in best suited applications
- Enable a large-scale transition to zero-emission technology
- Maximize the total number of ZEVs deployed
- Provide environmental benefits, targeting disadvantaged communities
- Ensure requirements are technologically feasible and cost effective
- Foster a self-sustaining zero-emission truck market

### a. *ZEV Sales Requirement*

The proposed manufacturer ZEV sales requirement applies to all manufacturers that certify incomplete chassis or complete vehicles with combustion engines in weight Classes 2B through 8 (GVWR greater than 8,500 lbs.). Manufacturers with 500 or more total annual California sales would be required to sell zero-emission vehicles as a percentage of annual California vehicle sales including incomplete vehicles, and complete vehicles. Manufacturers with less than 500 annual California sales are exempt from staff's proposal because they will incur similar investment costs to comply with the rule as larger manufacturers, but would not be likely to recoup their investments over their smaller production volumes.

The sales percentage requirements would begin with the 2024 MY to give manufacturers lead time to develop product lines. The requirements increase annually until the 2030 MY, and are

[16] California State Legislature, Assembly Bill 2061, signed into law September 20, 2018 (web link: https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB2061, last accessed June 2019).

detailed in Table A-1. The proposed ZEV sales percentages were developed based on analysis of ZE technology suitability to date, and current market developments. Staff subdivided vehicles into three categories reflecting differences in available ZEV technologies, and vehicle characteristics. The Class 4 through 8 straight trucks and shuttles are highly suited to electrification due to low average range needs, lower weight and payload concerns, and typically return to a base of operations enabling centralized fueling, thereby justifying the significant ramp up of the vehicle category requirements sooner than the others categories.

**Table A-1. ZEV Sales Percentage Schedule**

| Model Year (MY) | Class 2B-3* | Class 4-8** | Class 7-8 Tractors |
|---|---|---|---|
| 2024 | 3% | 7% | 0% |
| 2025 | 5% | 9% | 0% |
| 2026 | 7% | 11% | 0% |
| 2027 | 9% | 13% | 9% |
| 2028 | 11% | 24% | 11% |
| 2029 | 13% | 37% | 13% |
| 2030 and beyond | 15% | 50% | 15% |

*Excludes pickups until 2027 MY
**Excludes Class 7-8 Tractors

Class 7 and 8 tractors would be excluded until the 2027 MY because many vehicles in this category are more challenging to electrify due to longer range needs and higher payload needs. Today, only one Class 8 tractor is available for purchase and there is no publicly accessible infrastructure network to charge or fuel ZE trucks. Pickup truck sales are excluded from Class 2B-3 ZEV sales requirement until the 2027 model year due to concerns raised by stakeholders about highly variable towing needs and associated impacts on range.

Transit buses, double-decker buses, 60-foot articulated buses, and motor coach buses are excluded from the annual sales requirement because ZE buses are already required to be purchased by the Innovative Clean Transit (ICT)[17] and Zero-Emission Airport Shuttle Bus (ASB)[18] regulations, bus manufacturers have less than 500 annual sales in California, and several buses are already commercially available. However, there are some vehicles that are typically manufactured as cutaway or cab-and-chassis incomplete vehicles with a transit or shuttle body added after initial manufacture and sale that may be sold as ZEVs needed to comply with the ICT and ASB regulations. Similarly, ZEVs that are sold to state agencies to meet the requirements of AB 739 are already expected to be purchased. To simplify reporting and compliance tracking, staff are proposing to give credit for the sale of all ZEVs that are subject to the regulation, but will exclude projected sales of ZEV cutaway and cab-and-chassis sales that are already required from the existing ICT and ASB regulations and ZEV trucks required by AB739 from the inventory when estimating the cost and benefits of the Proposed ACT Regulation, and in the alternatives analysis discussed later in this document.

[17] California Air Resources Board, Innovative Clean Transit (web link: https://ww2.arb.ca.gov/our-work/programs/innovative-clean-transit, Last accessed June, 2019)
[18] California Air Resources Board, Zero-Emission Airport Shuttle (web link: https://ww2.arb.ca.gov/our-work/programs/zero-emission-airport-shuttle, Last accessed June, 2019)

Staff are proposing that credits can begin being generated starting with the 2021 MY, to incentivize early deployments, early development of ZE technologies and supply chains, and early action to result in achieving economies of scale sooner than the Proposed ACT Regulation would require.

### b. ***ZEV Sales Flexibility***

The Proposed ACT Regulation, is structured to use a credit and deficit system for required ZEV sales to provide flexibility to the manufacturer. The method accounts for the fact that larger vehicles have higher emissions per mile than lighter vehicles and allows manufactures to exceed ZEV sales requirements in one category to offset required ZEV sales in another category without significantly impacting expected emissions benefits. For the cost analysis, staff assumed manufacturers would meet the specified ZEV requirement in each vehicle category and did not assume reduced costs from flexibility.

### c. ***Plug-in Hybrid Electric Vehicles***

Staff are proposing plug-in hybrid electric vehicles (PHEVs) be allowed to earn partial credits based on their battery size and to use PHEV credits to meet part of their compliance obligation. It is unclear whether manufacturers are likely to utilize this option. Most manufacturers have already announced plans for full ZEVs and have stated that they are not planning to make additional models available as PHEVS; therefore, staff did not model costs differently for PHEVs.

### d. ***ZEP Certification***

The Proposed ACT Regulation would make ZEP Certification mandatory starting with the 2024 model year for medium and heavy duty ZEVs, and includes the costs associated with mandatory ZEP certification requirements in the cost analysis.

### e. ***Manufacturer Reporting***

Manufacturers that are subject to the ZEV sales requirement and those who sell ZEVs and want to earn credits must report annually to CARB. Manufacturers of ICE and ZEV chassis and complete vehicles must report to CARB annually to demonstrate compliance. Any manufacturers that sell ZEVs in California and elect to earn ZEV credits must report vehicle or chassis sales annually to earn credits. Manufacturers must report details of credit trade transactions so CARB can determine and track compliance.

### f. ***Large Entity Reporting Requirement***

Under the Proposed ACT Regulation, a large entity would be required to report information about contracting practices for services that require the use of shuttles or trucks and these large entities would also be required to report information about how their existing trucks and buses are used. Reporting would be done once, in early 2021. This information is needed to build a knowledge base of typical fleet operations and contracting practices to help develop future rules that would increase the use of ZEVs in California starting in 2024, with a goal of complementing the Proposed ACT Regulation. A large entity is defined as a public or private organization that did business in California and met one of the following in calendar year 2019:

- Received more than $50M in total annual gross revenue
- Owned or dispatched 100 or more Class 2B and larger vehicles

Large entity reporting applies to a wide range of large businesses and government agencies whether or not they own trucks and buses. Large entities include, retailers, manufacturers, refiners, accounting firms, hotels, drayage terminal operators, utility providers, refuse companies, federal, state, and local government agencies and other types of large employers. The information that large entities would be required to submit about the type of service, frequency of deliveries, type of facility, approximate location, and other summary information about any of the following that might apply:

- Contracts to move freight/materials by truck or van
- Contract for regular pick-up or delivery services
- Contract for shuttle or bus service
- Contracts for vocational truck service
- Vehicle usage characteristics if they own/lease trucks vans or buses
- For-hire truck or bus transportation services they provide
- Characteristics of facilities they operate that receive deliveries.

Vehicle owners would need to provide individual vehicle characteristics, operation data and usage data, and location information. Many fleets already provide some vehicle characteristics to CARB in the TRUCRS reporting system, but more would need to report and would need to include additional information about vehicle usage characteristics and terminal or yard locations. These data would then be used to identify opportunities for ZEV adoption and to inform decisions on what regulatory mechanism is most appropriate to ensure ZEV purchases are made and that ZEVs would be placed in uses that are suitable to meet individual fleet needs. Staff believes that collecting this level of detailed information from large organizations will provide sufficient information about fleet types and businesses in California to support and focus future rulemaking efforts that would require the use of ZEVs in California. Affected entities would need to spend time to understand the data request, would take staff time to gather all relevant information or to export data to submit. The estimated staff time to collect and report the information is a cost associated with the Proposed ACT Regulation.

### 3. Statement of the Need of the Proposed ACT Regulation

The Proposed ACT Regulation will contribute to achieve the state's criteria pollutant and GHG reduction goals and cleaner technology targets. The California 2016 Mobile Source Strategy states that mobile sources and the fossil fuels that power them are the largest contributors to the formation of ozone, GHG emissions, fine particulate matter (PM2.5), and toxic diesel particulate matter[19]. In California, the transportation sector alone accounts for 41 percent of

[19] California Air Resources Board, 2016 Mobile Source Strategy (web link: https://ww3.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf, last accessed June 2019)

total GHG emissions (50% when upstream emissions from fuel is included)[20] and is a major contributor to oxides of nitrogen (NOx) and particulate matter (PM) emissions.

The Proposed ACT Regulation is needed to accelerate the transition to zero-emissions in the medium-and heavy- duty vehicle sector. The Proposed ACT Regulation is identified as the "Last Mile Delivery" measure in the SIP and 2017 Climate Change Scoping Plan[21] as a necessary component for California to achieve established near- and long-term air quality and climate mitigation targets. In addition, the deployment of ZEVs meets goals identified in the 2016 ZEV Action Plan that supports the governor's Executive Order B-16-12 and Executive Order B-48-18, which calls for 1.5 million ZEVs in California by 2025 and establishes several milestones on the pathway toward this target.

Currently, regulations including Phase 2 GHG provide an incentive to build more fuel efficient, lower GHG vehicles, but these regulations have no specific requirement for medium- and heavy-duty manufacturers to build ZEVs. Phase 2 GHG includes a temporary credit multiplier for ZEVs through 2027. The Proposed ACT Regulation is needed to provide certainty and to ensure that manufacturers will invest into ZEV technology.

## 4. Major Regulation Determination

The Proposed ACT Regulation has been determined to be a major regulation because the economic impact of the regulation in California is estimated to exceed $50 million in multiple years of the regulatory timeline extending from 2020 to 2040. The economic impact is estimated as a result of direct cost and cost-savings to the manufacturer as passed on to California businesses. Cost increases are associated with the higher cost of producing ZEVs and savings for the manufacturers are the result of reduced costs of compliance with the Phase 2 GHG regulation while the ZEV multiplier is in effect prior to 2028. The temporary ZEV multiplier results in making ZEVs a lower cost option for manufacturers to meet Phase 2 GHG requirements for a few years than if assuming compliance would be achieved without producing ZEVs as originally assumed in the Phase 2 GHG rulemakings. More detail on this is in the next section.

## 5. Baseline Information

For the SRIA, the economic and emissions impacts of the Proposed ACT Regulation are evaluated against the business-as-usual (BAU) scenario each year for the analysis period from 2020 to 2040. The BAU case for the economic and emissions analysis for the Proposed ACT Regulation is referred to as the "baseline" and uses the same vehicle inventory for both analyses. The baseline vehicle inventory includes the same vehicle sales and population growth assumptions reflected in CARB's EMFAC emissions inventory for weight Class 2B and

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[20] California Air Resources Board, California Greenhouse Gas Emission Inventory (web link: https://www.arb.ca.gov/cc/inventory/data/data.htm, last accessed June 2019)
[21] California Air Resources Board, California's 2017 Climate Change Scoping Plan, released in November 2017 (web link: https://www.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf, last accessed June 2019)

larger vehicles for all fuel types[22]. EMFAC emissions inventory includes assumptions reflecting Phase 2 GHG, and LCFS program compliance.

ZEVs required by the Proposed ACT Regulation can also be used to comply with the CA Phase 2 GHG regulation and the U.S. EPA Phase 2 GHG regulation, and results in potential overlapping emissions and costs. In the Federal Phase 2 GHG rulemaking, EPA stated that they "do not project fully electric vocational vehicles to be widely commercially available in the time frame of the final Phase 2 rules. For this reason, [EPA and NHTSA] have not based the Phase 2 standards on adoption of full-electric vocational vehicles."[23] California adopted the U.S. EPA Phase 2 GHG regulation and similarly did not model ZEV deployments due to the CA Phase 2 GHG regulation.

Even though Phase 2 GHG gives an Advanced Technology Multiplier (ATM) that may make ZEVs a temporarily more cost effective compliance option until the end of the 2027 MY, staff does not believe the Phase 2 GHG regulation incentivizes ZEVs enough to ensure their production. Manufacturers bear risks in building and selling ZEVs due to the large upfront investments and uncertainty in future growth and may not be the lower cost option to comply with the Phase 2 GHG regulation post 2027.

For purposes of evaluating GHG emissions staff assumes no new GHG emissions benefits as a result of the Proposed ACT Regulation up to the total benefits anticipated from the CA Phase 2 GHG requirements. Staff does count GHG emissions benefits after any CA Phase 2 GHG anticipated benefits are exceeded. The interactions between CA Phase 2 GHG and the Proposed ACT Regulation are also factored into the cost analysis later in this document.

The ZEVs that are already required to be purchased by the existing ICT and ASB regulations and AB 739 are also excluded from the from the costs and emissions analysis of the Proposed ACT Regulation and any alternatives analysis to avoid double counting.

This analysis of the Proposed ACT Regulation counts ZEVs sold starting with the 2021 model year, but will not include those sold in prior years because incentive funding programs are already offsetting most, if not all of the incremental costs. Staff does not assume ZEV sales will continue without incentive or other policies to promote them. For example, some industry market projections forecast ZEV adoption, but these include assumptions about availability of incentives and government policies to increase ZEV sales. ACT Research, a major freight movement analytics firm, released an August 2018 report titled "Commercial Vehicle Electrification: To Charge or Not To Charge[24]", which predicted that ZEVs will be adopted in increasing numbers due to incentives and government policies, among other factors. Another reason that ZEVs are not included in the baseline inventory is that medium and heavy duty ZEV deployments were assumed in the SIP and only actions that are enforceable can be included in the SIP. The Proposed ACT Regulation would make ZEV sales enforceable.

[22] California Air Resources Board, EMFAC 2017 Database (web link: https://www.arb.ca.gov/emfac/2017/, last accessed June 2019)
[23] United States Environmental Protection Agency, Final Rule for Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles - Phase 2: Regulatory Impact Analysis, 2016. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100P7NS.PDF?Dockey=P100P7NS.PDF. Last accessed June 17, 2019.
[24] Advanced Clean Transportation Research, Commercial Vehicle Electrification: To Charge or Not To Charge (https://www.actresearch.net/cv-electrification-study/, last accessed June 2019)

## 6. Public Outreach and Input

For the Proposed ACT Regulation, CARB created a technical workgroup that comprises interested stakeholders including manufacturers, fleets, environmental groups, utilities, technology providers, and fuel providers. In addition to public workgroup meetings, CARB staff has conducted more than 100 individual meetings with more than 50 stakeholders. Some of these key stakeholders include but are not limited to Truck and Engine Manufacturers Association members (EMA), the California Electric Transportation Coalition (CalETC) and electric vehicle manufacturers, several fleet representatives, and nonprofit organizations.

Since 2016, CARB staff held six workshops, and five workgroup meetings to provide information to the public and solicit feedback. CARB staff posted information regarding these events and any associated materials on the ACT website and distributed notice of these meetings through two public list serves; actruck and zevfleet that include 2,662 and 948 recipients. The majority of the meetings were available by webcast and teleconference. At the meetings, CARB staff solicited stakeholder feedback on the Proposed ACT Regulation and overall regulatory process.[25] In addition to continued efforts to solicit feedback from stakeholders about the Proposed ACT Regulation, CARB staff solicited for alternatives during the May 31, 2018 workshop.[26]

Staff has reached out to the proposed regulated parties throughout the regulatory development. In the April 2017 workshop, staff asked fleets to submit answers to a draft fleet survey questionnaire in an effort to gather detailed information about everyday operations of local fleets. Staff also mailed notice letters to the 11,000 large entities and fleets that would be required to report under the Proposed ACT Regulation. Further, staff has met with the proposed ten regulated manufacturers (Daimler, FCA, Ford, GM, Isuzu, Navistar, Nissan, PACCAR, Hino/Toyota, and Volvo) on a group and individual basis throughout the regulatory development process. CARB staff has held two joint meetings with California Governor's Office of Business and Economic Development (GO-Biz) in which fleets, manufacturers, and utilities discussed medium-and heavy-duty electrification. Additionally, staff has engaged in frequent discussions with ZEV technology providers, electric utilities, fuel providers, and non-governmental environmental organizations during various outreach events such as technology symposiums and expositions.

Staff has produced two discussion documents that were made available to the public for comment on the ACT website; Total Cost of Ownership (TCO) and Energy Efficiency Ratio (EER) papers.[27,28] The TCO paper assessed the costs of owning and operating zero-emission vehicles. The EER paper analyzed of the efficiency of heavy-duty electric vehicles compared to conventional ICE vehicles of the same type and use; this analysis supported LCFS

[25] California Air Resources Board, Advanced Clean Truck meetings and workshops (https://ww2.arb.ca.gov/our-work/programs/advanced-clean-truck/act-meetings-workshops, last accessed June 2019).
[26] California Air Resources Board, Meeting notice of public workshop to discuss the proposed Advanced Clean Truck rule (web link: https://www.arb.ca.gov/msprog/mailouts/msc1811/msc1811.pdf, last accessed June 2019).
[27] California Air Resources Board, Advanced Clean Trucks Total Cost of Ownership Discussion Document – Draft(web link: https://ww2.arb.ca.gov/sites/default/files/2019-02/190225tco_0.pdf, last accessed June 2019).
[28] California Air Resources Board, Battery Electric Truck and Bus Efficiency Compared to Diesel Vehicles (web link: https://ww2.arb.ca.gov/sites/default/files/2018-11/180124hdbevefficiency.pdf, last accessed June 2019).

regulation amendments which increased the EER for heavy-duty battery-electric vehicles, resulting in nearly doubling the amount of credits earned for using electricity as a transportation fuel. In addition, CARB staff posted an updated version of a TCO calculator, on the ACT website, which allows stakeholders to calculate and compare the TCO between diesel, battery-electric, and hydrogen fuel-cell vehicles.

## B. Benefits

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."[29] The Proposed ACT Regulation supports the goals of the SIP and reduces pollutants linked to multiple adverse health effects identified by the California Ambient Air Quality Standards (CAAQS).[30] These pollutants are nitrogen oxides (NOx), key ingredients in the formation of several airborne toxic substances[31], and particulate matter of diameter less than 2.5 microns ($PM_{2.5}$), which may deposit deep inside the lung. Long-term exposure to PM2.5 has been linked to premature death, particularly in people who have chronic heart or lung diseases, and reduced lung function growth in children.[32] The Proposed ACT Regulation also reduces GHG emissions, petroleum use, and provides the certainty needed to establish a long term medium- and heavy-duty ZEV market.

### 1. Benefits to Typical Businesses

#### *a. Truck and Bus Owners*

Individual businesses that have operations that are well suited for using ZEVs may be able to lower their total cost of ownership by taking advantage of the operational cost savings of battery-electric vehicles. ZE truck owners that own their charging or hydrogen fueling stations can lower fuel costs by taking advantage of Low Carbon Fuel Standard (LCFS) program.

#### *b. Utility Providers*

The Proposed ACT Regulation will increase the number of ZEVs deployed which in turn will increase the amount of electricity supplied by utility providers

The Proposed ACT Regulation also helps the state's investor-owned utilities meet the goals of SB350. SB350 requires the state's investor-owned utilities to develop programs "to accelerate widespread transportation electrification." Pacific Gas and Electric and Southern California Edison have both developed and been approved to set up programs to install electric

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29 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, last accessed June 2019).
30 California Air Resources Board, California Ambient Air Quality Standards (web link: https://ww2.arb.ca.gov/resources/california-ambient-air-quality-standards, last accessed June 2019).
31 California Air Resources Board, Nitrogen Dioxide and Health (web link: https://ww2.arb.ca.gov/resources/nitrogen-dioxide-and-health, last accessed June 2019).
32 California Air Resources Board, Inhalable Particulate Matter (PM 2.5 and PM10) (web link: https://ww3.arb.ca.gov/research/aaqs/common-pollutants/pm/pm.htm, last accessed June 2019).

infrastructure on the customer's site up to the charger and would offer a voucher for the charger itself. San Diego Gas and Electric has proposed a similar program that is currently awaiting CPUC decision. All three utilities are either developing or have been approved to establish new electricity rates for commercial ZEV deployments. By ensuring that vehicles will be available to make use of these utility investments and rates, the Proposed ACT Regulation supports the utilities' programs and the goals of SB350.

### *c. Other California Businesses*

The Proposed ACT Regulation may result in benefits to zero-emissions truck component suppliers, electrical vehicle supply equipment (EVSE) suppliers and installers, and hydrogen fuel station suppliers. Due to higher demand for ZEVs from the Proposed ACT Regulation, production of ZEVs in California would likely increase leading to increases in manufacturing and related jobs throughout the state. The increase in the production and usage of ZEVs could also benefit various businesses related to the ZEV component supply chain, including those involved in battery, fuel cell, and electric drivetrain businesses.

The Proposed ACT Regulation may also benefit EVSE suppliers who may see an increase in charging equipment installation as a result of increased medium and heavy duty ZEV purchases. Most of these installations are expected to be located in central depots or yards where trucks are parked overnight. Increased installation of charging infrastructure will benefit the EVSE suppliers, equipment installers, and electricians. All of the installations will be in California, and some of the EVSE equipment may be manufactured in California. Increased purchase of ZEVs under the Proposed ACT Regulation could also benefit various California businesses related to installing hydrogen fueling stations, supplying hydrogen and associated maintenance.

## 2. Benefits to Small Businesses

The Proposed ACT Regulation may result in benefits to small business due to higher demand for ZEVs, and would likely lead to increases in manufacturing, distribution, infrastructure installation and maintenance and other related jobs for small businesses throughout the state. Electricians, construction companies, including infrastructure installers, existing ZEV manufacturers, fuel cell and electric drivetrain parts and components businesses may fall into the small business category. Increased installation of charging infrastructure will benefit EVSE suppliers, equipment installers, and electricians that are small business. All of the installations will be in California, and some of the EVSE equipment may be manufactured in California. Increased purchase of ZEVs under the Proposed ACT Regulation could also benefit various California small businesses related to installing hydrogen fueling stations, supplying hydrogen and associated maintenance.

## 3. Benefits to Individuals

The Proposed ACT Regulation will benefit California residents mainly from reductions in NOx, PM, and from improvements in California air quality and reduced impact on adverse health impacts. The reduction of GHG emissions, while being a global pollutant, will also benefit California residents.

### a. ***Criteria Pollutant Emissions Benefits***

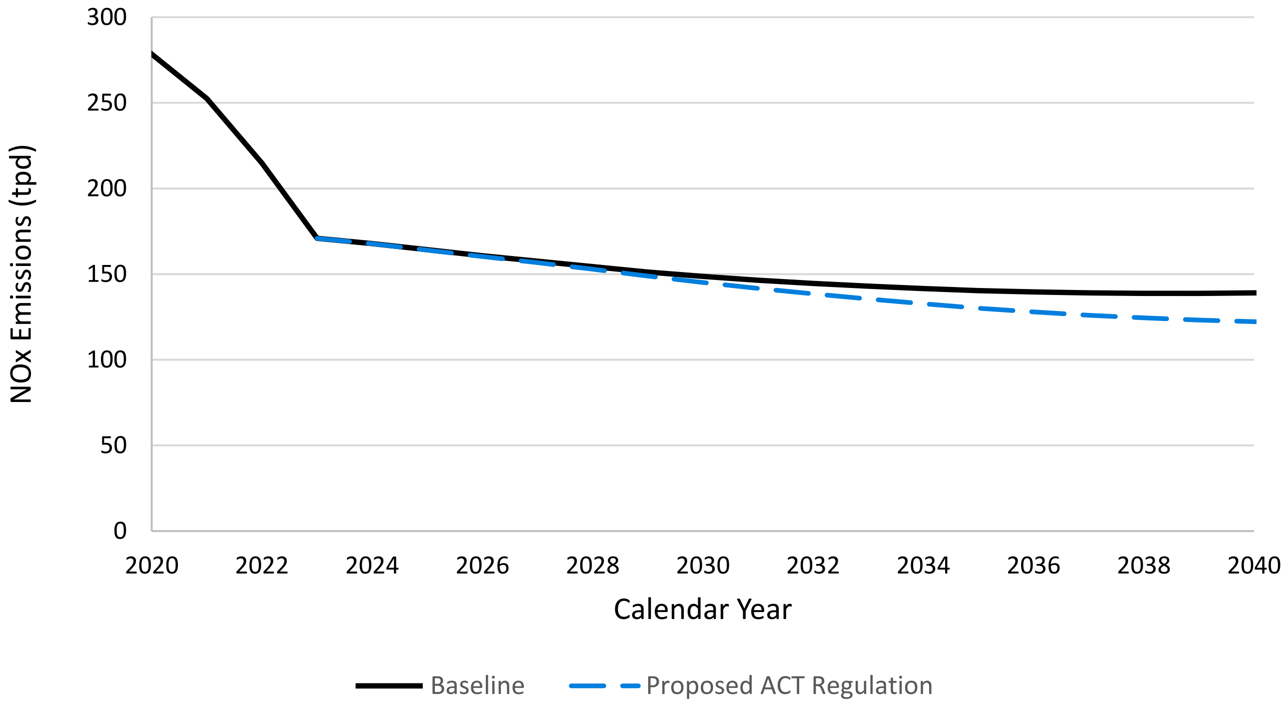
The projected benefits of the proposed Advanced Clean Trucks regulation are identified in Table B-1 with respect to NOx, $PM_{2.5}$, and GHG. Emissions benefits are projected by assuming zero tailpipe emissions for the forecasted number of ZEVS sold in California assuming no change in VMT and California sales compared to the baseline. In addition, staff is including an estimated 50% brake wear reduction for electric vehicles compared to conventional due to the effects of regenerative braking. These sales projections are further discussed in Section C. Emission benefits continue to grow as the ZEV sales requirement continues to be in effect past 2030 and the population of ZEV continue to grow. The cumulative total emission reductions from 2020 to 2040 is estimated to result in 125,830 tons reduction in NOx and a 3,382 tons reduction in $PM_{2.5}$ relative to baseline. The emissions presented below for GHG are solely tank-to-wheel (TTW) meaning upstream emission reductions are not included. Staff is in the process of developing and updating upstream emission factors and will include WTW emissions in the Initial Statement of Reasons. Once these are included, they are expected to show greater GHG emissions reductions due to the lower upstream emissions of electricity and hydrogen compared to gasoline and diesel. Table B-1 shows the benefits of the Proposed ACT Regulation in 2031 and 2040.

**Table B-1. Proposed ACT Regulation NOx, $PM_{2.5}$, and TTW GHG Benefits Relative to Baseline**

| Calendar Year | NOx (tpd) | $PM_{2.5}$ (tpd) | $CO_2$ (MMT/yr) |
|---|---|---|---|
| 2031 | 4.77 | 0.16 | 0.34 |
| 2040 | 16.84 | 0.46 | 1.27 |

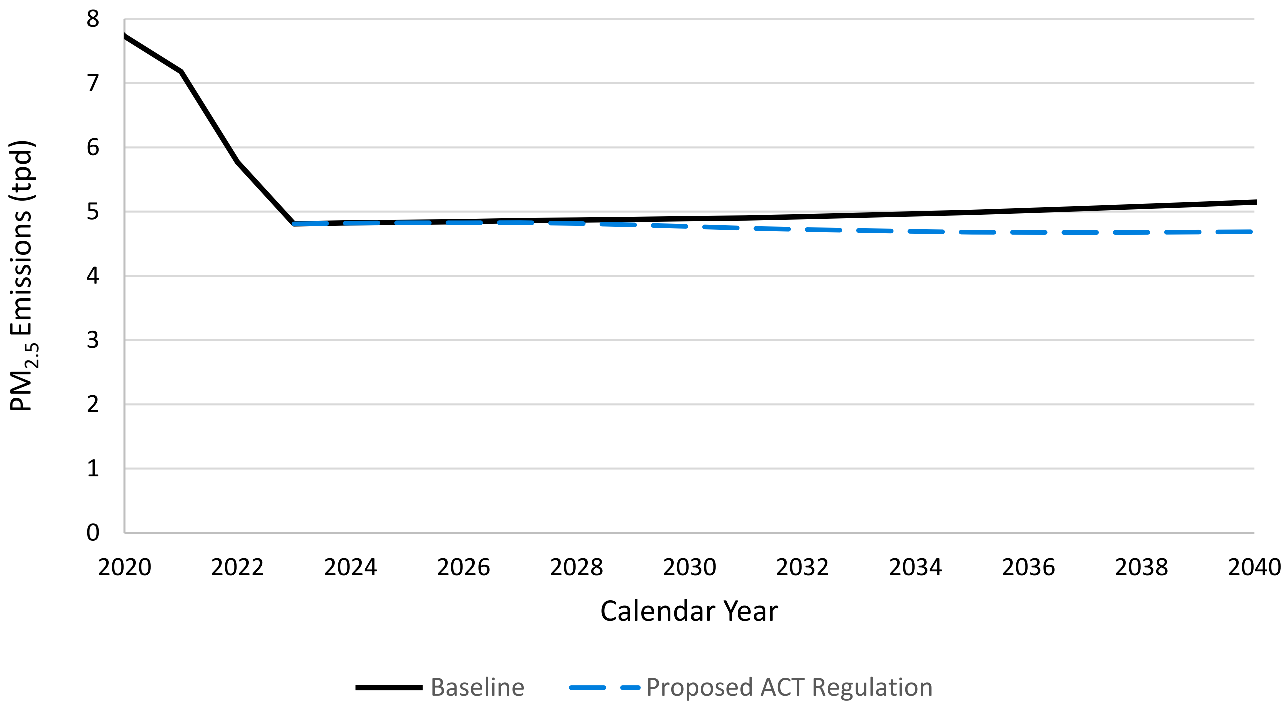
The $NO_x$ and $PM_{2.5}$ emissions impact of the Proposed ACT Regulation are presented relative to the baseline in Figure B-1 and Figure B-2 respectively and are shown in short tons per day (tpd). In the baseline, projected NOx emissions decrease sharply until 2023 when the Truck and Bus regulation achieves its goal of upgrading most diesel vehicles to 2010 MY and newer engines. The Truck and Bus regulation applies to trucks and buses with a GVWR greater than 14,000 lbs.

**Figure B-1. Projected TTW $NO_x$ Emissions, Baseline and Proposed ACT Regulation**




Past 2023, NOx emissions are expected to decrease in the baseline scenario in EMFAC even as miles travelled continues to grow. This occurs because of continued NOx reduction through natural attrition to cleaner engines for vehicles that are not subject to the Truck and Bus Regulation. Medium- and heavy-duty vehicles that are not subject to the Truck and Bus regulation include, public fleet vehicles, Solid Waste Collection Vehicles with pre-2007 MY engines, vehicles with a GVWR less than 14,001 lbs and other vehicles that do not use diesel fuel.

**Figure B-2. Projected $PM_{2.5}$ Emissions, Baseline and Proposed ACT Regulation**



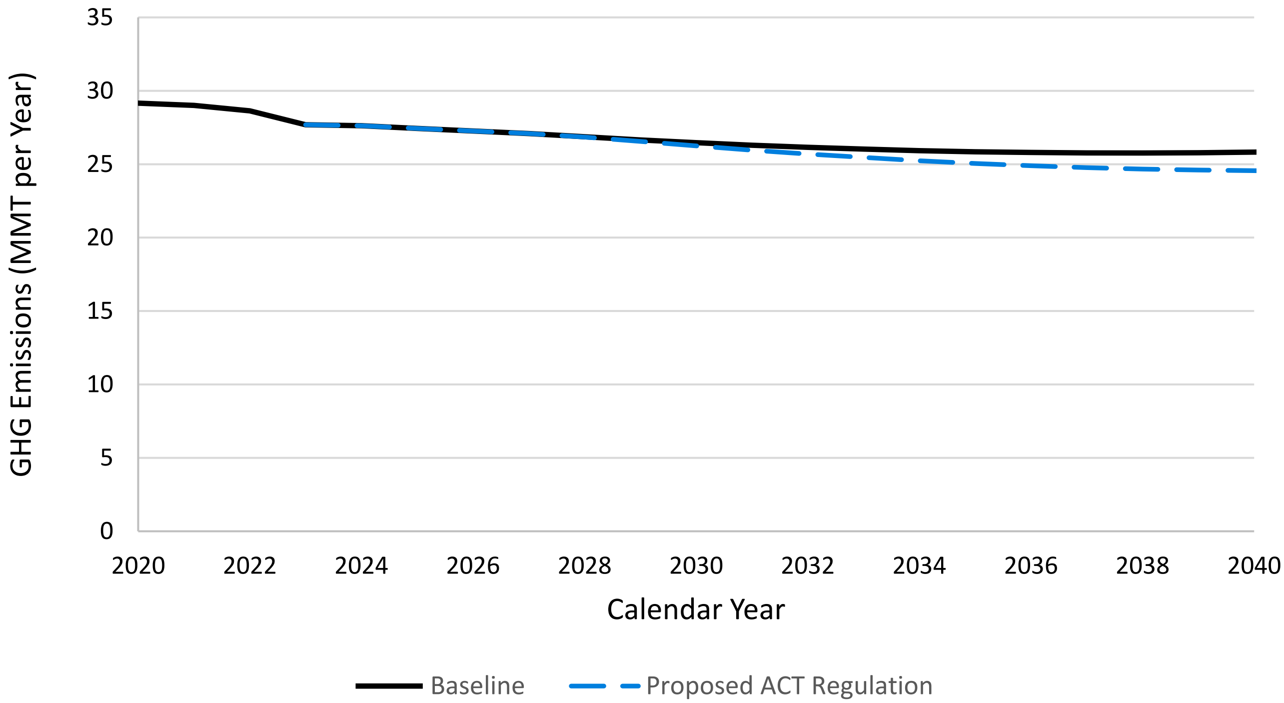

Similarly, $PM_{2.5}$ emissions decrease sharply in the baseline scenario until 2023 but level off for several years before beginning to rise in later years. By 2023, nearly all diesel trucks with a GVWR greater than 14,000 lbs will have PM filters due to the Truck and Bus Regulation. Beginning 2024, $PM_{2.5}$ emissions begin to increase slightly as vehicle miles travelled in EMFAC continue to grow, but the increase is partially offset from some $PM_{2.5}$ emissions reductions from lighter vehicles that continue to be replaced through normal attrition. These vehicles, with a GVWR less than 14,000 lbs, are not subject to in-use requirements to be retrofitted or replaced. For these lighter vehicles, when the pre-2007 diesel engines that do not have $PM_{2.5}$ are replaced, the PM emissions from this segment of the truck population continues to go down until all diesel vehicles have PM filters.

### b. ***GHG Emissions Benefits***

The Proposed ACT Regulation accounts for GHG benefits in terms of carbon dioxide ($CO_2$). Figure B-3 summarizes the estimated TTW GHG emissions reductions with the Proposed ACT Regulation compared to the baseline in million metric tons per year (MMT per Year). The emissions presented below for GHG are solely tank-to-wheel (TTW) meaning upstream emission reductions are not included. Staff is in the process of developing and updating upstream emission factors and will include WTW emissions in the Initial Statement of Reasons. Once these are included, they are expected to show greater GHG emissions reductions due to the lower upstream emissions of electricity and hydrogen compared to gasoline and diesel. Staff expects the Proposed ACT Regulation to reduce cumulative TTW GHG emissions by an estimated 10.1 Million Metric Tons (MMT) of $CO_2$ relative to the baseline from 2020 to 2040. The benefits for this rule do not include any ZEVs which may be used to comply with the California Phase 2 GHG regulation. Only ZEVs sold in excess of the

California Phase 2 GHG regulation's requirements are included in GHG calculations to avoid double-counting.

**Figure B-3. Projected TTW GHG Emissions under the Baseline and Proposed ACT Regulation**




The benefit of these GHG 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 this analysis, 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 [33] and is in line with Executive Orders including 12866 and the OMB Circular A-4 of September 17, 2003, and reflects the best available science in the estimation of the socio-economic impacts of carbon.[34]

The IWG describes the social costs of carbon as follows:

> *The social cost of carbon (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 carbon dioxide ($CO_2$) emissions into the atmosphere in that year, or equivalently, the*

[33] California Air Resources Board, California's 2017 Climate Change Scoping Plan, released in November 2017 (web link: https://www.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf, last accessed June 2019).
[34] Office of Management and Budgets, Circular A-4 (web link: https://www.transportation.gov/sites/dot.gov/files/docs/OMB%20Circular%20No.%20A-4.pdf, last accessed June 2019).

*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 $CO_2$.*

*These 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.*[35]

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 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 ACT Regulation 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 B-2 shows the range of IWG SC-$CO_2$ values used in California's regulatory assessments.[36]

**Table B-2. SC-$CO_2$, 2012-2050 (in 2007$ per Metric Ton)**

| Year | 5 Percent Discount Rate | 3 Percent Discount Rate | 2.5 Percent Discount Rate |
|---|---|---|---|
| 2020 | $12 | $42 | $62 |
| 2025 | $14 | $46 | $68 |
| 2030 | $16 | $50 | $73 |
| 2035 | $18 | $55 | $78 |
| 2040 | $21 | $60 | $84 |
| 2045 | $23 | $64 | $89 |
| 2050 | $26 | $69 | $95 |

If all TTW GHG reductions under the Proposed ACT Regulation are assumed to be carbon reductions, the avoided SC-CO2 from 2020 to 2040 is the sum of the annual TTW GHG emissions reductions multiplied by the SC-CO2 in each year. The cumulative TTW GHG emission reductions along with the estimated benefits from the Proposed ACT Regulation are shown in Table B-3. These benefits range from about $239 million to $1.01 billion through 2040, depending on the chosen discount rate.

[35] National Academies of Sciences, Engineering, Medicine, Valuing Climate Damages: Updating Estimation of Carbon Dioxide (web link: http://www.nap.edu/24651, last accessed June 2019).
[36] Interagency Working Group on the Social Cost of Carbon, Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis -Under Executive Order 12866 (web link: https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf, last accessed June 2019).

**Table B-3. Avoided Social Cost of $CO_2$**

| Year | GHG emission reductions (MMT) | Avoided SC-$CO_2$ (Million 2018$) | | |
|---|---|---|---|---|
| | | 5% discount rate | 3% discount rate | 2.5% discount rate |
| 2024 | 0.0 | $0.0 | $0.0 | $0.0 |
| 2025 | 0.0 | $0.0 | $0.0 | $0.0 |
| 2026 | 0.0 | $0.0 | $0.0 | $0.0 |
| 2027 | 0.0 | $0.0 | $0.1 | $0.1 |
| 2028 | 0.0 | $0.4 | $1.5 | $2.1 |
| 2029 | 0.1 | $2.0 | $6.6 | $9.7 |
| 2030 | 0.2 | $5.0 | $15.6 | $22.8 |
| 2031 | 0.4 | $7.8 | $25.0 | $36.3 |
| 2032 | 0.5 | $11.3 | $34.7 | $50.0 |
| 2033 | 0.7 | $14.3 | $44.5 | $63.8 |
| 2034 | 0.8 | $18.1 | $54.4 | $77.5 |
| 2035 | 0.9 | $21.0 | $64.2 | $91.0 |
| 2036 | 1.1 | $25.1 | $73.9 | $104.2 |
| 2037 | 1.2 | $27.8 | $83.5 | $118.6 |
| 2038 | 1.3 | $32.1 | $93.0 | $131.5 |
| 2039 | 1.4 | $34.7 | $102.4 | $144.0 |
| 2040 | 1.5 | $39.1 | $111.6 | $156.3 |
| **Total** | **10.1** | **$238.8** | **$710.8** | **$1,007.9** |

It is important to note that the SC-$CO_2$, while intended to be a comprehensive estimate of the damage caused by carbon globally, does not represent the cumulative cost of climate change and air pollution to society. There are additional costs to society outside of the SC-$CO_2$, including costs associated with changes in co-pollutants, the social cost of other GHGs including methane and nitrous oxide, and costs that cannot be included due to modeling and data limitations. The Intergovernmental Panel on Climate Change (IPCC) has stated that the IWG SC-$CO_2$ estimates are likely underestimated due to the omission of significant impacts that cannot be accurately monetized, including important physical, ecological, and economic impacts.

### c. *Health Benefits*

The Proposed ACT Regulation reduces NOx and $PM_{2.5}$ emissions, resulting in health benefits for individuals in California. The value of these health benefits are due to fewer instances of premature mortality, fewer hospital and emergency room visits, and fewer lost days of work. As part of setting the National Ambient Air Quality Standard for PM, the U.S. EPA quantifies the health risk from exposure to PM and CARB relies on the same health studies for this evaluation.[37] The evaluation method used in this analysis is the same as the one used for

[37] United States Environmental Protection Agency, Health and Environmental Effects of Particulate Matter (web link: https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm, last accessed June 2019)

CARB proposed Low Carbon Fuel Standard 2018 Amendments, and Heavy-Duty Vehicle Inspection Program and Periodic Smoke Inspection Program.

CARB analyzed the value associated with five health outcomes in the BAU, proposed amendments, and alternatives: Cardiopulmonary[38] mortality, hospitalizations for cardiovascular[39] illness, hospitalizations for respiratory[40] illness, emergency room (ER) visits for respiratory illness, and ER visits for asthma.

These health outcomes were selected because US EPA has identified these as having a *causal* or *likely causal* relationship with exposure to $PM_{2.5}$.[41] The US EPA examined other health endpoints such as cancer, reproductive and developmental effects, but determined there was only *suggestive* evidence for a relationship between these outcomes and PM exposure, and insufficient data to include these endpoints in the national health assessment analyses routinely performed by U.S. EPA.

The U.S. EPA has determined that both long-term and short-term exposure to $PM_{2.5}$ 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. This relationship persists when other risk factors such as smoking rates, poverty and other factors are taken into account.[42] While other mortality endpoints could be analyzed, the strongest evidence exists for cardiopulmonary mortality.[43] The greater scientific certainty for this effect, along with the greater specificity of the endpoint, leads to an effect estimate for cardiopulmonary deaths that is both higher and more precise than that for all-cause mortality.[44]

The US 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.[45] These outcomes lead to hospitalizations and ER visits, and are included in this analysis.

[38] Outcomes related to the heart or lungs
[39] Outcomes related to the heart or blood vessels
[40] Respiratory illness such as chronic obstructive pulmonary disease, and respiratory infections
[41] U.S. EPA, 2010. Quantitative Health Risk Assessment for Particulate Matter (Final Report). https://www3.epa.gov/ttn/naaqs/standards/pm/data/PM_RA_FINAL_June_2010.pdf
[42] U.S. EPA. Integrated Science Assessment (ISA) for Particulate Matter (Final Report, Dec 2009). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/139F, 2009. http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=494959
[43] U.S. EPA. Integrated Science Assessment (ISA) for Particulate Matter (Final Report, Dec 2009). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/139F, 2009. http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=494959
[44] Air Resources Board (ARB), 2010. Estimate of Premature Deaths Associated with Fine Particle Pollution (PM2.5) in California Using a U.S. Environmental Protection Agency Methodology. https://www.arb.ca.gov/research/health/pm-mort/pm-report_2010.pdf
[45] U.S. EPA. Integrated Science Assessment (ISA) for Particulate Matter (Final Report, Dec 2009). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/139F, 2009. http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=494959

In general, health studies have shown that populations with low socioeconomic standings are more susceptible to health problems from exposure to air pollution.[46,47] However, the models currently used by U.S. EPA and CARB do not have the granularity to account for this impact. The location and magnitude of projected emission reductions resulting from many proposed regulations are not known with sufficient accuracy to account for socioeconomic impacts, and an attempt to do so would produce uncertainty ranges so large as to make conclusions difficult. CARB acknowledges this limitation.

A detailed summary of the health modeling methodology is included in Health Benefits Appendix of this SRIA.

### i. Results

Table B-4 shows the estimated avoided premature mortality, hospitalizations, and emergency room visits because of the Proposed ACT Regulation for 2020 through 2040 by California air basin, relative to the baseline. Only the regions with values of one or higher are shown, and regions with zero or insignificant impacts are not shown. Values in parenthesis represent the 95 percent confidence intervals of the central estimate. As detailed in the previous section, the Proposed ACT Regulation is estimated to reduce overall emissions of $PM_{2.5}$ and NOx in most years, and lead to net reduction in adverse health outcomes statewide, relative to the baseline.

The Proposed ACT Regulation may decrease the occupational exposure to air pollution of California truck operators and other employees who work around truck traffic. CARB staff cannot quantify the potential effect on occupational exposure due to lack of data on the typical occupational exposure for these types of workers.

**Table B-4. Regional and Statewide Avoided Mortality and Morbidity Incidents from 2020 to 2040 under the Proposed ACT Regulation***

| Air Basin | Avoided Premature Deaths | Avoided Hospitalizations for cardiovascular illness | Avoided Hospitalizations for respiratory illness | Avoided ER visits |
|---|---|---|---|---|
| Great Basin Valleys | 0 (0 - 0) | 0 (0 - 0) | 0 (0 - 0) | 0 (0 - 0) |
| Lake County | 0 (0 - 0) | 0 (0 - 0) | 0 (0 - 0) | 0 (0 - 0) |
| Lake Tahoe | 0 (0 - 0) | 0 (0 - 0) | 0 (0 - 0) | 0 (0 - 0) |
| Mojave Desert | 4 (3 - 4) | 1 (0 - 1) | 1 (0 - 1) | 1 (1 - 2) |
| Mountain Counties | 4 (3 - 4) | 0 (0 - 1) | 0 (0 - 1) | 1 (1 - 2) |
| North Central Coast | 3 (2 - 3) | 0 (0 - 1) | 1 (0 - 1) | 2 (1 - 2) |
| North Coast | 1 (1 - 1) | 0 (0 - 0) | 0 (0 - 0) | 0 (0 - 0) |
| Northeast Plateau | 0 (0 - 0) | 0 (0 - 0) | 0 (0 - 0) | 0 (0 - 0) |
| Sacramento Valley | 24 (19 - 29) | 3 (0 - 6) | 3 (1 - 6) | 9 (6 - 12) |
| Salton Sea | 3 (2 - 4) | 0 (0 - 1) | 0 (0 - 1) | 1 (1 - 2) |

[46] Krewski et al. (2009) Extended Follow-Up and Spatial Analysis of the American Cancer Society Study Linking Particulate Air Pollution and Mortality. Health Effects Institute Research Report 140. https://ephtracking.cdc.gov/docs/RR140-Krewski.pdf.
[47] Gwynn RC, Thurston GD. (2001) The burden of air pollution: impacts among racial minorities. Environ Health Perspectives;109(4):501–6. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1240572/

| | | | | |
|---|---|---|---|---|
| San Diego County | 27 (21 - 33) | 4 (0 - 7) | 5 (1 - 8) | 11 (7 - 15) |
| San Francisco Bay | 54 (42 - 66) | 9 (0 - 17) | 10 (2 - 18) | 30 (19 - 41) |
| San Joaquin Valley | 70 (55 - 86) | 8 (0 - 17) | 10 (2 - 18) | 26 (16 - 35) |
| South Central Coast | 10 (8 - 12) | 2 (0 - 3) | 2 (0 - 3) | 4 (3 - 6) |
| South Coast | 387 (303 - 473) | 65 (0 - 128) | 78 (18 - 137) | 198 (124 - 271) |
| **Statewide** | 587 (459 - 718) | 92 (0 - 181) | 110 (26 - 194) | 283 (178 - 388) |

*Values in parenthesis represent the 95% confidence interval. Totals may not add due to rounding.

In accordance with U.S. EPA practice, health outcomes are monetized by multiplying each incident by a standard value derived from the economic studies.[48] The value per incident is shown in Table B-5. The value for avoided premature mortality is based on willingness to pay,[49] 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. 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 (Section E). As avoided hospitalizations and ER 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 ER 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, and lost earnings or 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).[50] These monetized benefits from avoided hospitalizations and ER visits are included in macroeconomic modeling (Section E).

**Table B-5. Valuation per Incident for Avoided Health Outcomes**

| Outcome | Value per incident (2018$) |
|---|---|
| Avoided Premature Mortality | $9,419,320 |
| Avoided Cardiovascular Hospitalizations | $56,588 |
| Avoided Acute Respiratory Hospitalizations | $49,359 |
| Avoided Emergency Room Visits | $810 |

Statewide valuation of health benefits were calculated by multiplying the value per incident by the statewide total number of incidents for 2020-2040 as shown in Table B-6. The estimated

[48] U.S. EPA, Appendix B: Mortality Risk Valuation Estimates, Guidelines for Preparing Economic Analyses (240-R-10-001, released December 2010) (web link: http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-22.pdf/$file/EE-0568-22.pdf
[49] U.S. EPA, An SAB Report on EPA's White Paper Valuing the Benefits of Fatal Cancer Risk Reduction (EPA-SAB-EEAC-00-013, released July 27, 2000) (web link: https://yosemite.epa.gov/sab%5CSABPRODUCT.NSF/41334524148BCCD6852571A700516498/$File/eeacf013.pdf
[50] Chestnut, L. G., Thayer, M. A., Lazo, J. K. and Van Den Eeden, S. K. (2006), The Economic Value Of Preventing Respiratory And Cardiovascular Hospitalizations, Contemporary Economic Policy, 24: 127– 143. doi: 10.1093/cep/byj007

total statewide health benefits derived from criteria emission reductions is estimated to be $5.5 billion, with $5.2 billion resulting from reduced premature mortality and $0.34 billion resulting from reduced hospitalizations and emergency room visits. The spatial distribution of these benefits across the state follows the distribution of the health impacts by air basin as described in Table B-4.

**Table B-6 Statewide Valuation from Avoided Health Outcomes**

| Outcome | Avoided Incidents | Valuation (Million 2018$) |
|---|---|---|
| Avoided Premature Mortality | 587 | $5,528.9 |
| Avoided Cardiovascular Hospitalizations | 92 | $5.2 |
| Avoided Acute Respiratory Hospitalizations | 110 | $5.4 |
| Avoided Emergency Room Visits | 283 | $0.2 |
| **Total** | | **$5,540** |

d. ***Other Benefits to Individuals***

In addition to emission reductions, ZEVs offer a number of other benefits to truck operators when compared to gasoline and diesel vehicles. ZEVs are quiet and have a smoother ride than ICE vehicles, and reduces noise at the worksite as well as in the community the vehicle is operating.

## C. Direct Costs

The Proposed ACT Regulation will require manufacturers to produce and sell vehicles that have a higher upfront cost than in the baseline. Manufacturers bear the risk associated with the incremental costs associated with producing and selling ZEVs, but producing and selling these ZEVs will simultaneously decrease the manufacturers' cost of comply with the Phase 2 GHG regulation. Staff assumes the costs to California includes the higher upfront capital costs, infrastructure upgrades and lower operating expenses. This approach shows the full estimated cost to California for deploying the same number of ZEVs required by the regulation.

### 1. Direct Cost Inputs

The estimated direct costs from the Proposed ACT Regulation and the baseline scenario include: upfront capital costs of the vehicles, infrastructure, and ongoing operating costs which include fueling and maintenance. Compared to gasoline or diesel vehicles, ZEVs generally have higher upfront capital costs but lower operating costs, which result in an overall savings in staff's analysis over the useful life of the vehicles. Currently there are a number of rebate and voucher programs in California that offset some or all of the incremental costs for ZEVs and supporting infrastructure; however, none of these incentives are included in the cost analysis. LCFS credits are a form of incentive, but it is a market-based mechanism that increases the use of low carbon transportation fuels in California that has been established by California regulations. The assumptions underlying the direct costs are detailed in the following sections.

### a. ***Vehicle Population and Annual Mileage***

Staff divided the affected vehicle population into five vehicle groups to match the requirements of the Proposed ACT Regulation. Note that Class 6-7 and Class 8 excludes Class 7-8 tractors because there is a separate category for those vehicles.

- Class 2B-3 – Vehicles with a GVWR from 8,501 to 14,000 lb.
- Class 4-5 – Vehicles with a GVWR from 14,001 to 19,500 lb.
- Class 6-7 – Vehicles with a GVWR from 19,500 to 33,000 lb. (excluding Class 7 tractors)
- Class 8 – Vehicles with a GVWR above 33,001 lb. (excluding Class 8 tractors)
- Class 7-8 Tractors – Tractors with a GVWR above 26,001 lb.

In this analysis, all estimates for annual California sales come from CARB's Emission Factor (EMFAC) inventory model.[51] The EMFAC model is developed and used by CARB to assess emissions from on-road vehicles including cars, trucks, and buses in California, and to support CARB's regulatory and air quality planning efforts to meet the Federal Highway Administration's transportation planning requirements. U.S. EPA approves EMFAC for use in State Implementation Plan and transportation conformity analyses. It includes vehicle population growth, mileage accrual rates over time, vehicle fuel usage and associated emission factors, and vehicle attrition over time. The vehicle categories in EMFAC were matched to the Proposed ACT Regulation's vehicle groups as shown in Table C-1:

**Table C-1. Vehicle Groups and EMFAC categories**

| Vehicle Group | EMFAC Categories |
|---|---|
| Class 2B-3 | Light Heavy-Duty 1 and Light Heavy-Duty 2 |
| Class 4-5 & Class 6-7 | T6 Small (Class 4-6 Vehicles), T6 Heavy (Class 7) excluding tractors, School Bus, All Other Buses |
| Class 8 | T7 (Class 8) excluding tractors |
| Class 7-8 Tractor | T6 Heavy Tractors, T7 Tractors |

EMFAC groups Class 4-5 and Class 6-7 into the same category called T6. However, because staff needed to match population categories with the proposed rule to more accurately model the resulting changes in vehicle populations for this analysis, the T6 category was split into Class 4-5 and Class 6-7. Staff assumes a 49% Class 4-5 to 51% Class 6-7 split based on DMV data.[52]

Because the Proposed ACT Regulation only affects vehicles sold into California, the total sales numbers were adjusted downward using California DMV data to remove out-of-state sales. The estimated number of California sales from 2024-2030 model years for each category are shown in Table C-2. Truck sales are forecasted by EMFAC to grow at about 1 percent per year.[53]

[51] California Air Resources Board, EMFAC2017 Web Database (web link: https://www.arb.ca.gov/emfac/2017/, last accessed June 2019).
[52] California Department of Motor Vehicles, DMV Data, 2018. (Last accessed June 2019).
[53] California Air Resources Board, EMFAC2017: Volume III – Technical Documentation (web link: https://ww3.arb.ca.gov/msei/downloads/emfac2017-volume-iii-technical-documentation.pdf, last accessed June 2019).

**Table C-2. Estimated Number of Annual Sales per Vehicle Group**

| Model Year | Class 2B-3 | Class 4-5 | Class 6-7 | Class 8 | Class 7-8 Tractor | Total Sales |
|---|---|---|---|---|---|---|
| 2024 | 53,761 | 6,856 | 7,136 | 1,119 | 4,686 | 73,559 |
| 2025 | 54,217 | 6,957 | 7,241 | 1,137 | 4,769 | 74,321 |
| 2026 | 54,753 | 7,083 | 7,372 | 1,177 | 4,918 | 75,302 |
| 2027 | 55,152 | 7,228 | 7,523 | 1,194 | 4,993 | 76,091 |
| 2028 | 55,765 | 7,354 | 7,654 | 1,216 | 5,075 | 77,064 |
| 2029 | 56,371 | 7,482 | 7,788 | 1,239 | 5,161 | 78,041 |
| 2030 | 56,968 | 7,613 | 7,924 | 1,264 | 5,263 | 79,032 |

Vehicle manufacturers sell trucks powered by a variety of fuels – most commonly gasoline or diesel, but also including compressed and liquid natural gas, propane, E85, and other fuels. In staff's assumed baseline conditions, for simplification, Class 2B-3 vehicles are split between gasoline- and diesel-powered assuming a 43 percent gasoline to 57 percent diesel ratio based on available EMFAC data.[54] Staff assumes Class 4-8 vehicles are solely diesel-powered to simplify the analysis. Based on EMFAC data, roughly 10 percent of Class 4-8 vehicles use a fuel other than diesel.

Under the Proposed ACT Regulation, manufacturers can comply with a combination of battery-electric, fuel-cell electric, and plug-in hybrid electric technologies. It is difficult to predict manufacturers' future plans for complying with the Proposed ACT Regulation, especially as battery and fuel-cell technologies improve and costs continue to decline. Based on manufacturers' publicly announced plans, staff assumed manufacturers will comply with the Proposed ACT Regulation requirements for Class 2B-3 and Class 4-8 vocational trucks by building battery-electric vehicles. Staff assumed no FCEVs in these two categories because no manufacturers that would be regulated have announced plans to commercially produce FCEVs. Cummins is a powertrain manufacturer that has announced plans to offer a plug-in hybrid powertrain to vehicle manufacturers that allows for full-electric, series hybrid, and parallel hybrid functionality.[55] At this time it is unclear if PHEVs will result in lower costs for regulated manufacturers because the vehicles would have two propulsion systems, and would earn fewer PHEV credits than an equivalent ZEV meaning that more PHEVs would need to be sold to meet the same credit requirement. The reduced PHEV credit also ensures that total emission benefits remain about the same. Although PHEVs are expected to have lower cost per vehicle than full ZEVs, they still require charging infrastructure and will not have as significant operational cost savings as battery-electric vehicles. At workgroup meetings, multiple manufacturers have stated they would not produce both PHEVs and ZEV models if still required to produce ZEVs to comply. For all of these reasons, staff are not including PHEVs in the cost analysis.

For Class 7-8 tractors, staff assumes 90% of the required vehicles will be sold as battery-electric and 10% will be sold as fuel-cell electric. While there is interest from numerous manufacturers in fuel-cell tractor technology, most manufacturers are currently investing in

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[54] California Air Resources Board, EMFAC2017 Web Database (web link: https://www.arb.ca.gov/emfac/2017/, last accessed June 2019).
[55] Cummins, Powerdrive for Electric Trucks (web link: https://www.cummins.com/electrification/powerdrive-for-electric-trucks, last accessed June 2019).

battery-electric tractor technology. The proposed percentage requirements are not stringent enough to require electrification of the long haul sector meaning manufacturers can focus their deployments in short-haul tractor applications. Battery-electric technology is well suited for short-haul applications and offers potential fuel savings. Long-haul applications are where fuel cell electric trucks offer the greatest advantage over battery-electric tractors due to their rapid refueling and lower weight.

Table C-3 outlines the assumptions for each vehicle group in the baseline and proposal scenarios.

**Table C-3. Vehicle Groups and Technologies**

| Vehicle Group | Baseline Scenario | Proposal Scenario |
|---|---|---|
| Class 2B-3 | Gasoline (43%)<br>Diesel (57%) | Battery-electric<br>(All normal range) |
| Class 4-5 | Diesel | Battery-electric<br>(50% long range after 2030) |
| Class 6-7 | Diesel | Battery-electric<br>(50% long range after 2030) |
| Class 8 | Diesel | Battery-electric<br>(50% long range after 2030) |
| Class 7-8 Tractor | Diesel | Battery-electric (90%)<br>Fuel Cell Electric (10%) |

The percentage schedules shown below in Table C-4 are applied to the annual sales numbers to calculate the annual number of zero-emission trucks required by the regulation.

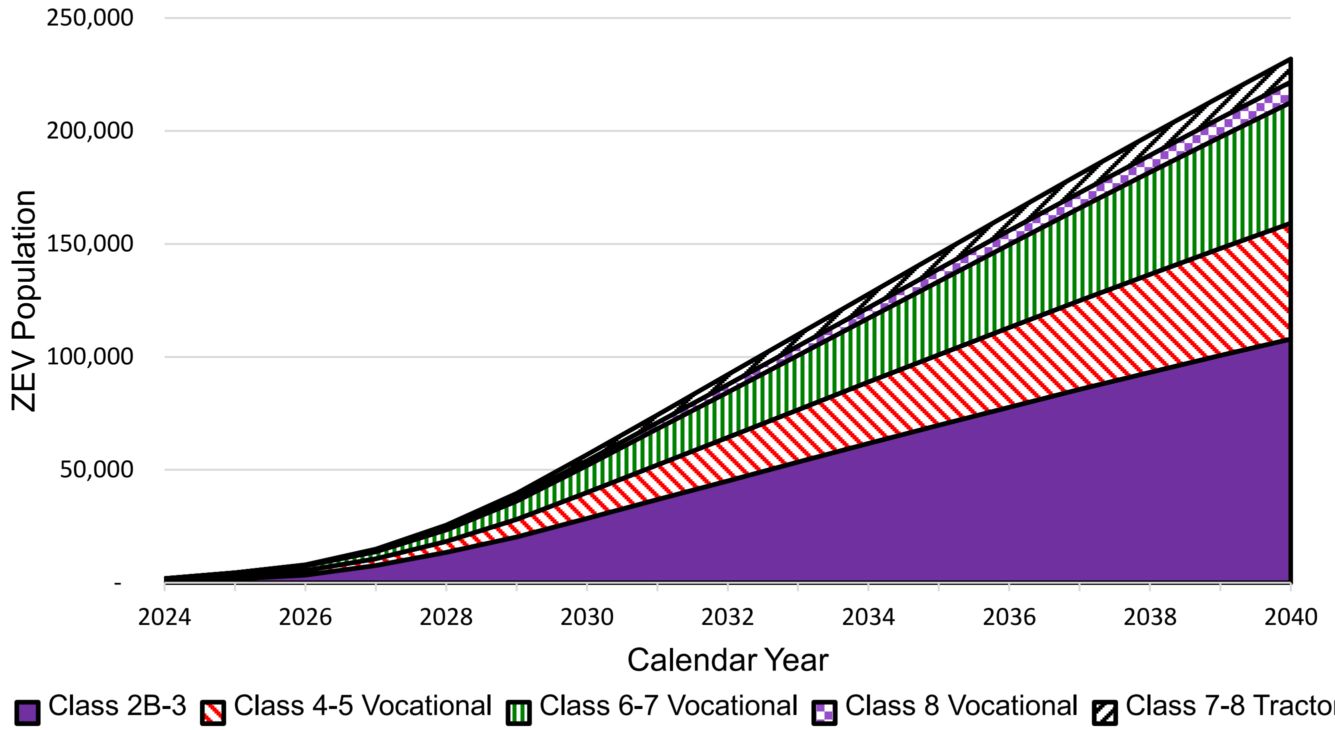
**Table C-4. Advanced Clean Trucks ZEV Sales Percentage Schedule**

| Model Year | Baseline | Class 2B-3* | Class 4-8** | Class 7-8 Tractor |
|---|---|---|---|---|
| 2024 | 0% | 3% | 7% | 0% |
| 2025 | 0% | 5% | 9% | 0% |
| 2026 | 0% | 7% | 11% | 0% |
| 2027 | 0% | 9% | 13% | 9% |
| 2028 | 0% | 11% | 24% | 11% |
| 2029 | 0% | 13% | 37% | 13% |
| 2030 and beyond | 0% | 15% | 50% | 15% |

*Pickup trucks are excluded from Class 2B-3 requirements until 2027
**Excluding Class 7-8 tractors

These percentages are applied to the annual California sales numbers to estimate the number of zero-emission trucks that will be sold in California as shown in Figure C-1. The population growth rate increases to 2030 as the ZEV sales percentage requirement ramps up, and starts to slow down afterwards as ZEV sales begin to replace ZEVs that retire out of the fleet.

**Figure C-1. ZEV Population Forecast over Time (>8,500 lb. GVWR)**




Staff are not anticipating any pre-buy situation where manufacturers increase sales of their vehicles before the Proposed ACT Regulation and decrease sales after implementation begins. Fleets, not manufacturers, decide when to purchase vehicles and this regulation would not encourage them to delay their purchases.

Annual mileage factors into a number of costs in this analysis including fuel costs, maintenance, and LCFS revenue. All annual mileage are based on EMFAC inventory estimates of mileage accrual rates over a vehicles life. For most vehicle categories, annual mileage is the highest early for low age vehicles and drops over time as the vehicle ages. EMFAC categories are matched to vehicle groupings as follows:

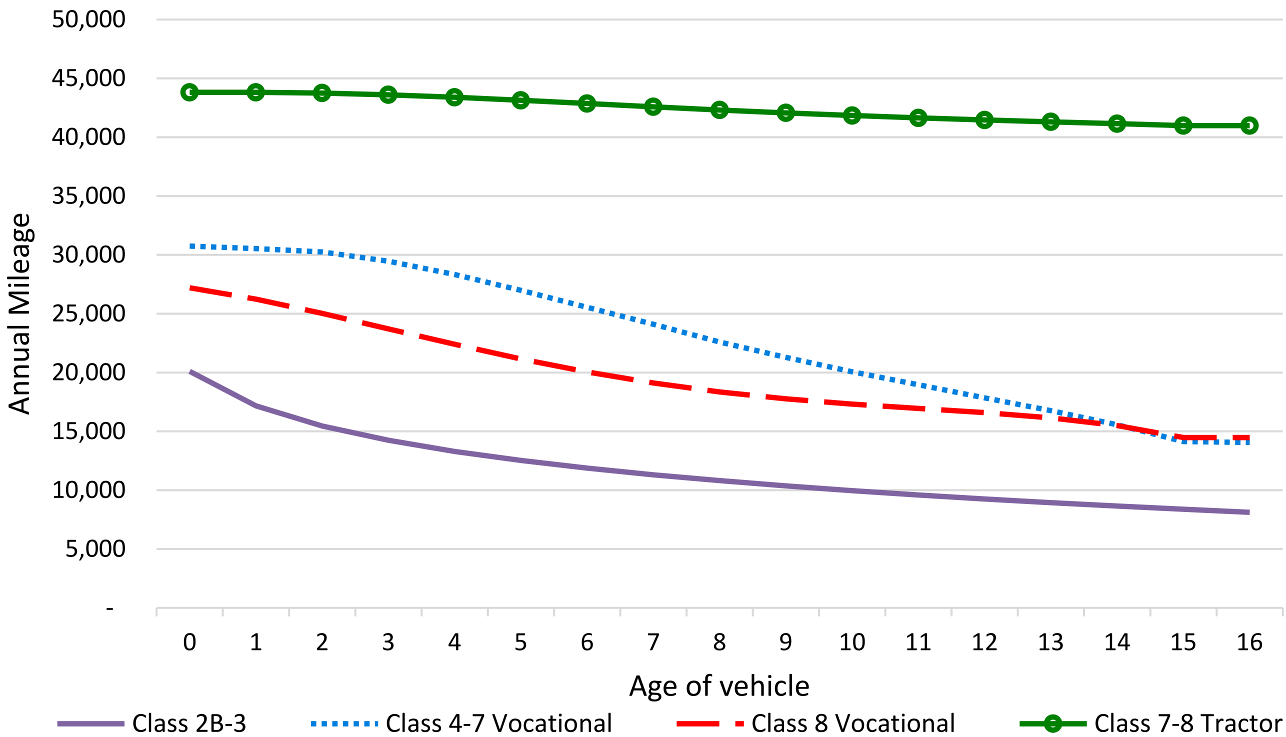
- Class 2B-3 annual mileage is the population weighted average of the following EMFAC categories: Light Heavy-Duty 1 and 2
- Class 4-5 and Class 6-7 vehicles are not separated in EMFAC and are lumped together into a Class 4-7 grouping. Based on data available from the 2002 US Vehicle Inventory and Use Survey and the 2018 California Vehicle Inventory and Use Survey, the annual miles for Class 4-5 and Class 6-7 trucks are fairly similar.[56, 57] The Class 4-7 vocational truck annual mileage is the population weighted average of the following EMFAC categories: T6 Public, T6 Instate, T6 Instate – Construction, T6 Utility, T6 gasoline powered trucks, School Buses, and All Other Buses.

[56] United States Census, 2002 Vehicle Inventory and Use Survey (web link: https://www.census.gov/library/publications/2002/econ/census/vehicle-inventory-and-use-survey.html , last accessed June 2019).
[57] California Department of Transportation, CalTrans Truck Survey, 2018. (Summarized data available here: http://www.scag.ca.gov/committees/CommitteeDocLibrary/mtf012319_CAVIUS.pdf, Last accessed June 2019).

- Class 8 truck annual mileage is the population weighted average of the following EMFAC categories:  T7 Public, T7 Single Unit, T7 Single Unit – Construction, T7 Solid Waste Collection Vehicle, and T7 Utility.
- Class 7-8 tractor annual mileage is the population weighted average on the three EMFAC drayage categories: Port of Los Angeles, Port of Oakland, and All Other Ports. We are currently assuming that all required sales zero-emission tractors will be used in drayage service or similar shorter-haul operation.

Figure C-2 illustrates the average mileage assumption for each vehicle group over the life of the vehicle from EMFAC.  Staff are assuming ZEVs will travel the same miles as conventional ICE vehicles in their typical operation.  Even today, commercially available ZEVs have the range to meet the majority of trucking needs and the lower operating cost of BEVs incentivizes higher mileage duty cycles.  Over time as technology advances and more models become available, range should become less of an issue.

**Figure C-2. Annual Mileage Accrual Rates by Vehicle and Age**




The California International Registration Plan and Out of State categories are not included in these calculations as these categories represent trucks that regularly travel in interstate operation.  Due to their high annual miles and variable infrastructure needs, these categories are not assumed to be representative of a zero-emission duty cycle.  In addition, many of these trucks are not sold into California despite operating within the state, so these sales would not be regulated under the proposed ACT rule.

### b. ***Costs to Manufacturers***

Manufacturers are the regulated party in the Proposed ACT Regulation and would be responsible for selling zero-emission vehicles in California.  The Proposed ACT Regulation requires that manufacturers must build and sell more expensive zero-emission trucks, certify their powertrain using the optional ZEP Certification procedure, and report information to CARB as part of their regulatory requirements. Manufacturers have the option to use the required zero-emission truck sales to help meet their Phase 2 GHG compliance obligation. Therefore, the incremental costs of producing ZEVs above the expected costs of compliance with the Phase 2 GHG without ZEVs are attributable to the Proposed ACT Regulation.

#### i. Vehicle Price

This section covers the cost to the manufacturer of building and selling a baseline ICE vehicle or a ZEV. Today and for the foreseeable future, battery-electric and fuel cell electric trucks will cost more than their diesel or gasoline counterparts. Declining battery and component costs in addition to economies of scale are expected to lower the incremental costs of zero-emission vehicles as the market expands. For this subsection, we are assuming the full incremental price of the vehicle when compared to the baseline is treated as a cost to the manufacturer. Vehicle prices are not amortized as the manufacturer would see the full cost in the year it is built and sold.

Gasoline and diesel vehicle prices are based on averages of prices taken from manufacturers' websites and other related websites. [58,59,60,61,62] For the Class 4-5, Class 6-7, and Class 8 vehicles, the cost is meant to represent a vehicle with a basic body such as a box or stake-bed and not a vehicle with an expensive specialty body such a boom truck or refuse truck.

Staff estimated the cost of zero-emission vehicles for battery-electric and fuel cell powered vehicles by adding electric components costs, fuel cell component costs, and energy storage costs to a conventional glider vehicle. The final retail price of the zero-emission vehicle is the sum of the total component costs adjusted by an additional 10 percent for other upfront costs such as research, development, retooling, and overhead. The calculated prices for battery electric vehicles are comparable to battery electric trucks and vans that are available through the HVIP program today

The cost of battery storage is the largest contributing factor associated with the price of battery-electric truck. Battery pack costs have dropped over 80 percent since 2010 and are projected to continue declining. The CARB discussion document "Battery Cost for Heavy-Duty Vehicles" was a literature review published in 2016 using data sources from 2013 and 2014 to assess battery costs for buses and heavy duty vehicles.[63] Battery pack cost for heavy duty applications are higher than for light cars due to smaller volumes and differing packaging requirements even though many use the same cells. However, this report is somewhat dated and does not reflect the current state of the battery market. At the December 4th, 2018

[58] Daimler, Mercedes-Benz Vans (web link: https://www.mbvans.com/sprinter/home , last accessed June 2019).
[59] FCA, Ram Commercial (web link: https://www.ramtrucks.com/ram-commercial/index.html, last accessed June 2019).
[60] Ford, Ford Fleet (web link: https://www.fleet.ford.com/ , last accessed June 2019).
[61] General Motors, General Motors Fleet (web link: https://www.gmfleet.com/, last accessed June 2019).
[62] TruckPaper, TruckPaper (web link: https://www.truckpaper.com/ , last accessed June 2019).
[63] California Air Resources Board, Battery Cost for Heavy-Duty Electric Vehicles (Discussion Draft) (web link: https://www.arb.ca.gov/msprog/bus/battery_cost.pdf, last access June 2019).

Advanced Clean Trucks workgroup meeting, a number of manufacturers suggested we use light-duty battery prices with a five-year delay to reflect battery-price projections that are applicable to heavy duty vehicles.

The battery-electric vehicle costs in this analysis are calculated using electric vehicle component costs from the International Council on Clean Transportation whitepaper (ICCT), "Transitioning to Zero-Emission Heavy-Duty Freight Vehicles" and battery costs will use the Bloomberg light-duty battery prices with a five-year delay.[64,65] Hydrogen fuel cell component costs are from a variety of sources. Electrical component costs and hydrogen tank costs are calculated using the same ICCT source and battery costs are estimated using the same Bloomberg light-duty battery prices with a five year delay. Hydrogen system component costs are calculated using a presentation from Strategic Analysis titled "Fuel Cell Systems Analysis" which estimated fuel cell system costs for medium- and heavy-duty trucks.[66] This presentation analyzed fuel cell system costs on a component level basis for multiple weight classes of vehicle and provided temporal and volume-based cost projections.

Staff are not forecasting that this rule will affect commercial battery prices and ZEV technology significantly. The Proposed ACT Regulation affects a portion of California's heavy-duty trucking fleet, which is very small compared to the worldwide market for batteries in consumer electronics, light-duty vehicles, battery-storage, and other applications. To the extent that this rule increases economies of scale for general ZEV components, infrastructure, and battery production, there may be lower component prices as a result of the rule, but these effects are less certain and are not modelled. The Proposed ACT Regulation may cause the cost for components specifically designed for medium- and heavy-duty ZEVs to decrease as economies of scale start to emerge in this new market.

The battery-electric vehicle is modelled using motors and electrical components in line with an existing diesel counterpart's power needs, and battery storage capacity based on the Age 0 daily mileage, the energy economy of the electric vehicle, and a 35% buffer to account for battery degradation and some operational variability. The hydrogen fuel cell tractor cost assumes the battery is 10 kWh, 40 kg. of hydrogen storage, and the fuel cell stack's power output is half the vehicle's peak power needs.

In the proposal and some alternatives, a long-range battery-electric vehicle is modelled, which assumes a 50% larger battery. For tractors, longer range needs are assumed to be met with fuel cell electric tractors. Table C-5 lists the specifications of the battery-electric vehicles.

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[64] International Council on Clean Transportation, Transitioning to Zero-Emission Heavy-Duty Freight Vehicles (web link: https://www.theicct.org/sites/default/files/publications/Zero-emission-freight-trucks_ICCT-white-paper_26092017_vF.pdf, last accessed June 2019).
[65] Bloomberg, Better Batteries (web link: https://www.bloomberg.com/quicktake/batteries, last accessed June 2019).
[66] Strategic Analysis, Fuel Cell Systems Analysis. (web link: https://www.hydrogen.energy.gov/pdfs/review18/fc163_james_2018_o.pdf, last accessed June 2019).

**Table C-5. Battery Size Calculation**

| Vehicle Group | Age 0 Daily Mileage | Efficiency (kWh/mi) | Normal Range Battery Size (kWh) | Long Range Battery Size (kWh) |
|---|---|---|---|---|
| Class 2B-3 | 65 | 0.6 | 55 | 80 |
| Class 4-5 Vocational | 100 | 1.0 | 135 | 200 |
| Class 6-7 Vocational | 100 | 1.5 | 200 | 300 |
| Class 8 Vocational | 90 | 2.0 | 240 | 360 |
| Class 7-8 Tractors | 140 | 2.1 | 400 | N/A |

The assumed vehicle prices for gasoline and diesel vehicles are shown in Table C-6, and the battery-electric and fuel cell electric price forecasts are shown Table C-7.

**Table C-6. Baseline Vehicle Prices**

| Vehicle Group | Vehicle Price |
|---|---|
| Class 2B-3 - Gasoline | $45,000 |
| Class 2B-3 - Diesel | $50,000 |
| Class 4-5 | $55,000 |
| Class 6-7 | $85,000 |
| Class 8 | $120,000 |
| Class 7-8 Tractors | $130,000 |

**Table C-7. ZEV Price Forecast**

| Vehicle Group | 2024 MY | 2025 MY | 2026 MY | 2027 MY | 2028 MY | 2029 MY | 2030+ MY |
|---|---|---|---|---|---|---|---|
| Class 2B-3 – Electric Normal Range | $64,896 | $63,635 | $62,599 | $61,684 | $60,829 | $60,035 | $59,241 |
| Class 2B-3 – Electric Long Range | $69,241 | $67,568 | $66,201 | $65,011 | $63,909 | $62,895 | $61,881 |
| Class 4-5– Electric Normal Range | $80,127 | $77,616 | $75,585 | $73,852 | $72,267 | $70,830 | $69,394 |
| Class 4-5– Electric Long Range | $91,424 | $87,841 | $84,952 | $82,503 | $80,275 | $78,266 | $76,258 |
| Class 6-7– Electric Normal Range | $116,174 | $112,591 | $109,702 | $107,253 | $105,025 | $103,016 | $101,008 |
| Class 6-7– Electric Long Range | $133,554 | $128,321 | $124,112 | $120,563 | $117,345 | $114,456 | $111,568 |
| Class 8– Electric Normal Range | $154,799 | $150,486 | $147,007 | $144,057 | $141,371 | $138,949 | $136,527 |
| Class 8– Electric Long Range | $175,655 | $169,362 | $164,299 | $160,029 | $156,155 | $152,677 | $149,199 |
| Class 7-8 Tractor - Electric | $201,351 | $194,134 | $188,312 | $183,371 | $178,870 | $174,809 | $170,748 |
| Class 7-8 Tractor - Fuel Cell | $216,931 | $212,353 | $207,885 | $203,439 | $199,004 | $194,579 | $190,155 |

Table G-8 outlines the incremental cost difference between a ZEV and its diesel equivalent.

**Table G-8. Incremental ZEV versus Diesel Price Forecast**

| Vehicle Group | 2024 MY | 2025 MY | 2026 MY | 2027 MY | 2028 MY | 2029 MY | 2030+ MY |
|---|---|---|---|---|---|---|---|
| Class 2B-3 – Electric Normal Range | $14,896 | $13,635 | $12,599 | $11,684 | $10,829 | $10,035 | $9,241 |
| Class 2B-3 – Electric Long Range | $19,241 | $17,568 | $16,201 | $15,011 | $13,909 | $12,895 | $11,881 |
| Class 4-5– Electric Normal Range | $25,127 | $22,616 | $20,585 | $18,852 | $17,267 | $15,830 | $14,394 |
| Class 4-5– Electric Long Range | $36,424 | $32,841 | $29,952 | $27,503 | $25,275 | $23,266 | $21,258 |
| Class 6-7– Electric Normal Range | $31,174 | $27,591 | $24,702 | $22,253 | $20,025 | $18,016 | $16,008 |
| Class 6-7– Electric Long Range | $48,554 | $43,321 | $39,112 | $35,563 | $32,345 | $29,456 | $26,568 |
| Class 8– Electric Normal Range | $34,799 | $30,486 | $27,007 | $24,057 | $21,371 | $18,949 | $16,527 |
| Class 8– Electric Long Range | $55,655 | $49,362 | $44,299 | $40,029 | $36,155 | $32,677 | $29,199 |
| Class 7-8 Tractor - Electric | $71,351 | $64,134 | $58,312 | $53,371 | $48,870 | $44,809 | $40,748 |
| Class 7-8 Tractor - Fuel Cell | $86,931 | $82,353 | $77,885 | $73,439 | $69,004 | $64,579 | $60,155 |

Though the cost for manufacturers to comply is estimated in detail as described above, it is not straightforward to predict how these costs and cost-savings would be passed on to consumers. Vehicle pricing is complex, and different manufacturers could use different strategies to pass on these costs. It is possible that manufacturers may pass on incremental ZEV costs through the ZEVs themselves, through the rest of their ICE fleet, or some combination thereof.

### ii. Zero-Emission Powertrain Certification Costs

The Proposed ACT Regulation requires manufacturers starting 2024 MY to certify their vehicles using the Zero-emission Powertrain (ZEP) Certification procedure in order to earn ZEV credits. This requirement would only apply to vehicles affected by ZEP certification – complete vehicles above 14,000 lb. GVWR and incomplete vehicles above 10,000 lb. GVWR. Based on our current knowledge, there are roughly ten manufacturers who are regulated by the Proposed ACT Regulation and would sell ZEVs that be required to follow the ZEP certification procedure.

The Initial Statement of Reasons (ISOR) for the ZEP Certification rulemaking estimated the cost of certification would be $9,200 per powertrain.[67] For this rulemaking and analysis, we are estimating that each regulated manufacturer affected would certify two powertrains in 2024 model year and afterwards would certify an additional two new powertrains every 5 years afterwards.

The ISOR for ZEP certification included a $25 cost per vehicle for labelling costs and a $100 cost per vehicle family for ZEP vehicle family certification. We are not modelling this cost in for the Proposed ACT Regulation because this assumption does not take into account for avoided costs from not having to meet more rigorous ICE labelling requirements or ICE vehicle family certifications for the same number of vehicles, nor does it assume any potential reductions in ICE certification costs as the ZEV sales percentage requirement ramps up.

Manufacturers who are not regulated under the Proposed ACT Regulation would need to follow the ZEP certification to generate credits in this proposal. Manufacturers who are not required to meet ZEP certification may still do so if 1) they wish to earn credits in this rule to be sold to other manufacturers, or 2) a different program such as HVIP requires it. Because neither of these are costs attributable to the Proposed ACT Regulation, we are not modelling any ZEP certification costs to unregulated manufacturers. This assumes regulated manufactures would only buy credits if the credits reduce their overall compliance costs which already included ZEP certification costs.

[67] California Air Resources Board, Proposed Alternative Certification Requirements and Test Procedures for Heavy-Duty Electric and Fuel Cell Electric Vehicles and Proposed Standards and Test Procedures for Zero-Emission Powertrains – Staff Report: Initial Statement of Reasons (web link: https://www.arb.ca.gov/regact/2019/zepcert/isor.pdf, last accessed June 2019).

### iii. Phase 2 GHG Compliance Costs

The federal and California Phase 2 GHG regulations require manufacturers to build trucks that are more fuel efficient and have lower GHG emissions. These requirements start in 2021 model year and ramp up through the 2027 model year. EPA estimated the cost per vehicle to comply with the regulation shown in Table C-9.[68]

**Table C-9. U.S. EPA Phase 2 GHG Incremental Compliance Costs**

| Phase 2 Category | 2021-2023 MY | 2024-2026 MY | 2027+ MY |
|---|---|---|---|
| Class 2B-3 Pickup/Van | $524 | $963 | $1,364 |
| Vocational Vehicles | $1,110 | $2,022 | $2,662 |
| Tractors | $6,484 | $10,101 | $12,442 |

Manufacturers can meet the Phase 2 standards through a variety of technologies including improved aerodynamics, low rolling resistance tires, engine and accessory optimization, weight reduction, idle reduction systems, hybridization, powertrain electrification, and more. The Proposed ACT Regulation requires the sale of zero-emission vehicles that can also be used to comply with Phase 2 GHG. The costs of producing ZEVs are assumed to be higher than other compliance options, but would also reduce the amount of upgrades the manufacturers would need to make for their remaining ICE sales. While it is possible for a manufacturer to meet their entire compliance obligation with electric trucks, the U.S. EPA assumed this compliance pathway is a higher cost option than building cleaner combustion vehicles. In the Federal Phase 2 GHG rulemaking, EPA stated that they "…do not project fully electric vocational vehicles to be widely commercially available in the time frame of the final Phase 2 rules. For this reason, [EPA and NHTSA] have not based the Phase 2 standards on adoption of full-electric vocational vehicles."[69]

The cost difference between Phase 2 GHG compliance costs in the baseline scenario and the Proposed ACT Regulation represents the potential cost savings to the manufacturer. Manufacturers can build ZEVs and comply with the Proposed ACT regulation and the Phase 2 GHG regulations simultaneously which will reduce the number of ICE vehicles that need to be upgraded to meet Phase 2 standards. In the baseline scenario, the cost to comply with the California Phase 2 GHG regulation is the number of vehicles sold multiplied by the cost per vehicle as outlined in Table C-9.

In the Proposed ACT Regulation scenario, as the ZEV sales percentage requirement ramps up, the number of ICE trucks that must be upgraded to the Phase 2 GHG standards decreases. This is because, per the Phase 2 GHG regulation, electric vehicles do not produce tailpipe GHG emissions and therefore can offset compliance requirements for the rest of the

[68] United States Environmental Protection Agency, Final Rule for Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles - Phase 2 (web link: https://www.govinfo.gov/content/pkg/FR-2016-10-25/pdf/2016-21203.pdf, last accessed June 2019).

[69] United States Environmental Protection Agency, Final Rule for Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles - Phase 2: Regulatory Impact Analysis, pg. 73704 (web link: https://nepis.epa.gov/Exe/ZyPDF.cgi/P100P7NS.PDF?Dockey=P100P7NS.PDF, last accessed June 2019).

manufacturer's fleet. The lower costs of complying with the Phase 2 GHG regulation in the Proposal ACT Regulation scenario are modelled using the following formula:

$$GHG\ Phase\ 2\ Annual\ Cost\ Savings\ to\ Manufacturer\ Due\ to\ Proposed\ ACT\ Regulation = \frac{Vehicles\ Sold}{Year} x \frac{Phase\ 2\ GHG\ Cost}{Vehicle\ Sold} x \frac{ZEV\ Sales\ \% * ATM}{Phase\ 2\ Reduction\ \%}$$

Where:

- "ZEV Sales %" is the annual ZEV Sales percentage requirement each year
- "ATM" is the Phase 2 GHG Advanced Technology Multiplier which gives extra credit to PHEV, BEV, and FCEV vehicles until the end of the 2027 MY. This multiplier is 3.5, 4.5, and 5.5, respectively.
- "Phase 2 Reduction %" is the percentage of GHG reduction that the Phase 2 GHG regulation requires per year. By 2027, the standards are roughly 17-20% more stringent than the 2018 Phase 2 GHG baseline.

This formula calculates the potential avoided costs to upgrade ICE vehicles to comply with the Phase 2 GHG regulation.

The Phase 2 GHG compliance costs offset by the Proposed ACT Regulation are derived primarily from the federal regulation. If these compliance cost savings are passed through to fleets it would likely be a nationwide effect. Therefore, staff make a conservative assumption that percent savings passed through to California fleets is proportional to California's share of the national truck population estimated at 10% as to not overestimate the cost-savings.[70] Table C-10 displays the nationwide and California portion of reduced Phase 2 GHG compliance costs relative to the compliance costs relative to the baseline.

**Table C-10. Cumulative Nationwide and California Phase 2 GHG Cost Savings Relative to the Baseline (million 2018$)**

| Calendar Year | Nationwide | California Portion |
|---|---|---|
| 2031 | -$1,539 | -$154 |
| 2040 | -$3,737 | -$375 |

### iv. Manufacturer Reporting Costs

The Proposed ACT Regulation will require information from manufacturers regarding their total sales of combustion powered vehicles, ZEV sales, and PHEV sales starting in the 2021 model year. This information will be used to determine which manufacturers are regulated and their annual credit and deficit generation.

Manufacturers are already required to report information to CARB as a requirement of the California Phase 2 GHG regulation including sales per model year of every powertrain and vehicle family. Because manufacturers are already collecting and reporting this information to CARB, we are not modelling any significant additional reporting costs to manufacturers as a result of the Proposed ACT Regulation. Similarly, no reporting costs are attributed to

[70] Energy Information Administration, Annual Energy Outlook 2018 (web link: https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2018&cases=ref2018&sourcekey=0, last accessed June 2019).

unregulated ZEV manufacturers that may optionally report information for purposes of earning and trading credits to other manufacturers because credits are assumed to be purchased if regulated manufacturers can reduce their overall compliance costs.

### c. *Costs to California Businesses*

The Proposed ACT Regulation regulates vehicle manufacturers that primarily manufacture vehicles outside of California. Most of regulatory requirements associated with the Proposed ACT Regulation applies to these manufacturers. The only requirement on California businesses in the Proposed ACT Regulation is the large entity reporting requirement which is proposed as a one-time requirement. However, for purposes of demonstrating the potential economic impacts on the state's overall economy, all of the costs from deploying the number of ZEVs required by the Proposed ACT Regulation are assumed to be borne in California. Therefore, in the statewide cost analysis, all costs including the incremental vehicle costs, infrastructure upgrades, fueling, maintenance, and other costs are assumed to be the direct costs of the regulation in California despite the lack of a specific fleet purchase requirement. For this analysis, vehicle and infrastructure costs are amortized over a five and twenty year period, respectively, to reflect typical purchasing patterns.

#### i. Large Entity Reporting

Under the Proposed ACT Regulation, large fleet owners and large companies that contract out for transportation related services will be required to report information to CARB regarding what vehicles they own and how they operate, as well as company-wide information about their California locations and how they and their contractors move freight and perform other services.

Staff are estimating that roughly 12,000 companies or entities will be affected by this reporting requirement consisting of 11,000 large companies or trucking fleets and 1,000 public entities, utility fleet, and refuse fleets. Companies that do not own trucks will need to report summary information about the types of product they move and services they hire. Most large companies that own trucks or buses will have fleet software or other data management systems to pull information about their fleet and company quickly. Staff are estimating it will take on average two hours to retrieve, review, and report company-specific information, and an additional two hours to retrieve, review, and report vehicle information resulting in four hours of reporting per company. This may be higher or lower from company to company. These averages assume that some large entities will not have information to report other than to respond that they do not contract directly for any transportation services. The hourly cost is assumed to be $50 per hour for staffing and lost revenue from the employee assigned to pull the information.[71]

[71] California Air Resources Board, Technical Support Document: Proposed Regulation for In-Use Road Diesel Vehicles (web link: https://www.arb.ca.gov/regact/2008/truckbus08/tsd.pdf, last accessed June 2019).

### ii. Sales Tax and Federal Excise Tax

Taxes are additional costs levied on the purchase of a vehicle. Because they are based on the purchase price of the vehicle, they are higher for zero-emission vehicles due to their higher upfront costs.

Vehicles purchased in California must pay a sales tax on top of the vehicle's purchase price. The sales tax varies across the state from a minimum of 7.25% up to 10.25% in some municipalities; a value of 8.5% was used for staff's analysis based on a statewide population weighted average.[72] This results in higher costs for fleets and higher revenue for state and local governments. Class 8 vehicles are subject to an additional Federal Excise Tax which adds 12% to their purchase price.

### iii. Gasoline, Diesel, Electricity, and Hydrogen Fuel Cost

Fuel costs are calculated using total fuel used per year and the cost of fuel per unit. The total fuel used per year is based on the vehicle population per calendar year, the annual mileage of these vehicles, and the fuel economy of the vehicles. Population and mileage assumptions are discussed on Vehicle Population and Annual Mileage subsection on page 24. In general, ZEVs are 2 to 5 times as efficient as similar vehicles with internal combustion engines technologies and significantly reduce petroleum and other fossil fuel use and use less total energy.[73]

Fuel economy is measured in miles per gallon for gasoline and diesel, miles per kilowatt-hour for battery-electric, and miles per kilogram for fuel cell electric trucks. Gasoline and diesel fuel economy is derived from EMFAC inventory projections for each gasoline and diesel vehicle group. These projections incorporate the effects of Phase 2 GHG which will increase gasoline and diesel fuel economies over the next decade. Battery-electric vehicle fuel economy is derived from in-use data collected from a variety of vehicles. For fuel cell efficiency, we are applying the LCFS program's Energy Efficiency Ratio (EER) of 1.9 to the diesel fuel economy to estimate the fuel cell fuel economy as we are not aware of any data available measuring the fuel efficiency of fuel cell electric tractors.

Staff modeled that for both battery-electric and fuel cell electric vehicles, the efficiency will improve at the same rate as for gasoline and diesel powered vehicles. This may be a conservative estimate as both of these technologies are less developed than ICE powertrains and reports have shown improvements in the technology recently.

Table C-11 outlines the fuel economy assumptions for each vehicle group and technology type over the course of the regulation.

[72] California's basic sales tax rate is 7.25 percent with 3.94 percent going to the State and the rest to local authorities. In addition to the basic sales tax, districts levy special taxes that differ amongst districts.
[73] California Air Resources Board, Battery Electric Truck and Bus Efficiency Compared to Diesel Vehicles (web link: https://ww2.arb.ca.gov/sites/default/files/2018-11/180124hdbevefficiency.pdf, last accessed June 2019).

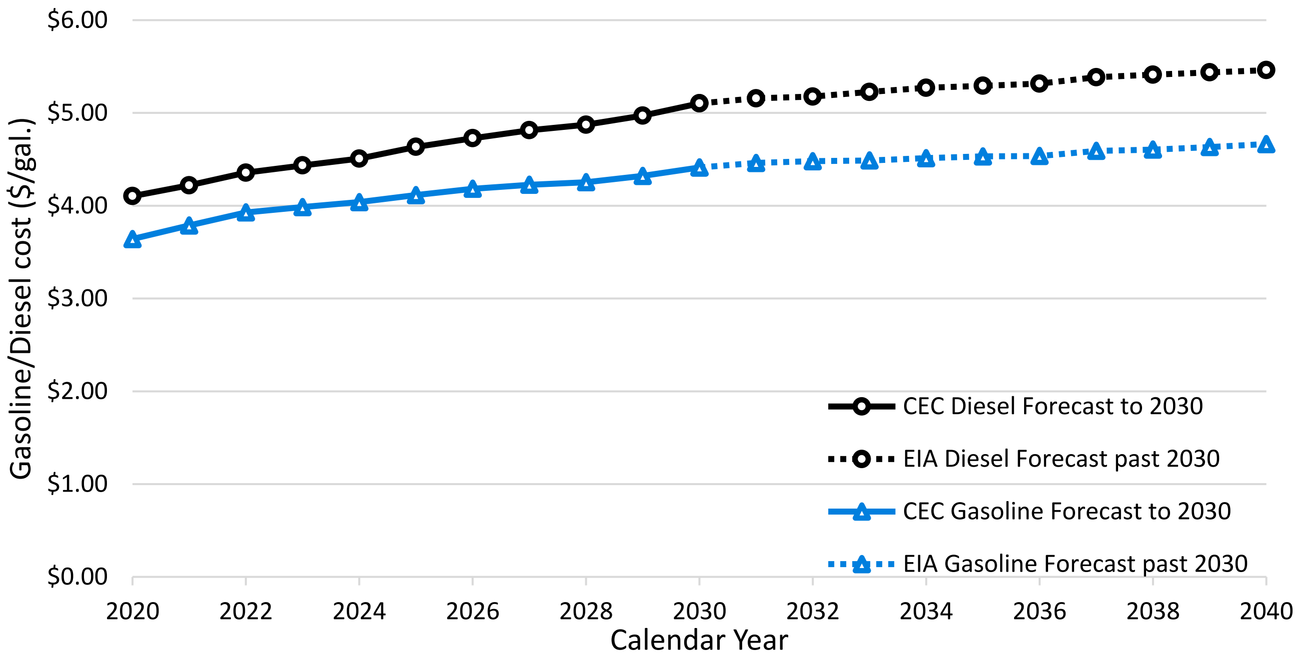
**Table C-11. Fuel Economy for Each Vehicle Group and Technology**

| Vehicle Group | Technology | Fuel Economy 2024-2026 MY | Fuel Economy 2027 MY and beyond | Units |
|---|---|---|---|---|
| Class 2B-3 | Gasoline | 10.89 | 11.74 | mpg |
| | Diesel | 23.03 | 24.83 | mpg |
| | Battery-Electric | 1.98 | 2.13 | mi./kWh |
| Class 4-5 | Diesel | 13.75 | 14.28 | mpg |
| | Battery-electric | 1.26 | 1.30 | mi./kWh |
| Class 6-7 | Diesel | 9.55 | 9.91 | mpg |
| | Battery-electric | 0.80 | 0.83 | mi./kWh |
| Class 8 | Diesel | 7.72 | 8.08 | mpg |
| | Battery-electric | 0.62 | 0.65 | mi./kWh |
| Class 7-8 Tractor | Diesel | 8.75 | 9.22 | mpg |
| | Battery-electric | 0.61 | 0.64 | mi./kWh |
| | Fuel Cell Electric | 16.63 | 17.53 | mi./kg |

Gasoline and diesel fuel prices to 2030 are taken from the California Energy Commission's (CEC) "Revised Transportation Energy Demand Forecast, 2018-2030", adjusted to 2018 dollars using California CPI.[74] Fuel prices past 2030 are calculated using the Energy Information Administration's (EIA) 2018 Annual Energy Outlook for the Pacific region.[75,76] The annual percentage change in EIA gasoline and diesel fuel prices past 2030 is applied to the 2030 CEC gasoline and diesel prices to estimate price changes past 2030. Figure C-3 shows the projected prices of gasoline and diesel out to 2040.

[74] California Department of Finance, Consumer Price Forecast (web link: http://www.dof.ca.gov/Forecasting/Economics/Eco_Forecasts_Us_Ca/index.html , last accessed June 2019)
[75] California Energy Commission, Revised Transportation Energy Demand Forecast 2018-2030 (web link: https://efiling.energy.ca.gov/getdocument.aspx?tn=223241, last accessed June 2019).
[76] Energy Information Administration, Annual Energy Outlook 2018 (web link: https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2018&cases=ref2018&sourcekey=0, last accessed June 2019).

Figure C-3. Gasoline and Diesel Price Forecasts




Battery-electric fuel prices depend on how they are charged and include energy costs, fixed fees and demand fees. Vehicles charged at high power or during peak periods will have higher electricity costs than if charging overnight over an extended period. Electricity prices are calculated using CARB's Battery-Electric Truck and Bus Charging Calculator and assumes a fleet of 20 vehicles will be depot charged overnight on a separate utility meter using a managed charging strategy with the applicable rate schedule. Additionally, charger efficiency losses and local electricity taxes are incorporated into these numbers. The energy, demand, fixed costs, efficiency losses and local taxes and fees are all calculated using the Charging Calculator.[77] The cost per kWh is calculated separately for each utility and a weighted average is used to determine the cost per kWh per vehicle in 2018. Table C-12 shows the electricity price per kWh for each vehicle group and major utility region as well as the weighted statewide average. In general, electricity costs are lower for larger vehicles because larger vehicles tend to use more electricity which decreases the fixed costs per kWh and allows the use of lower cost rate schedules for larger utility customers.

Table C-12. Electricity Cost Calculation for 2018 (2018$/kWh)

| Utility Area | Class 2B-3 | Class 4-5 | Class 6-7 | Class 8 | Class 7-8 Tractor |
|---|---|---|---|---|---|
| Los Angeles Department of Water and Power | $0.11 | $0.10 | $0.10 | $0.11 | $0.10 |
| Pacific Gas and Electric (PG&E)* | $0.23 | $0.20 | $0.20 | $0.20 | $0.18 |
| Sacramento Municipal Utility District | $0.15 | $0.14 | $0.11 | $0.11 | $0.10 |
| San Diego Gas and Electric | $0.24 | $0.19 | $0.19 | $0.22 | $0.19 |
| Southern California Edison (SCE)** | $0.19 | $0.15 | $0.15 | $0.14 | $0.13 |

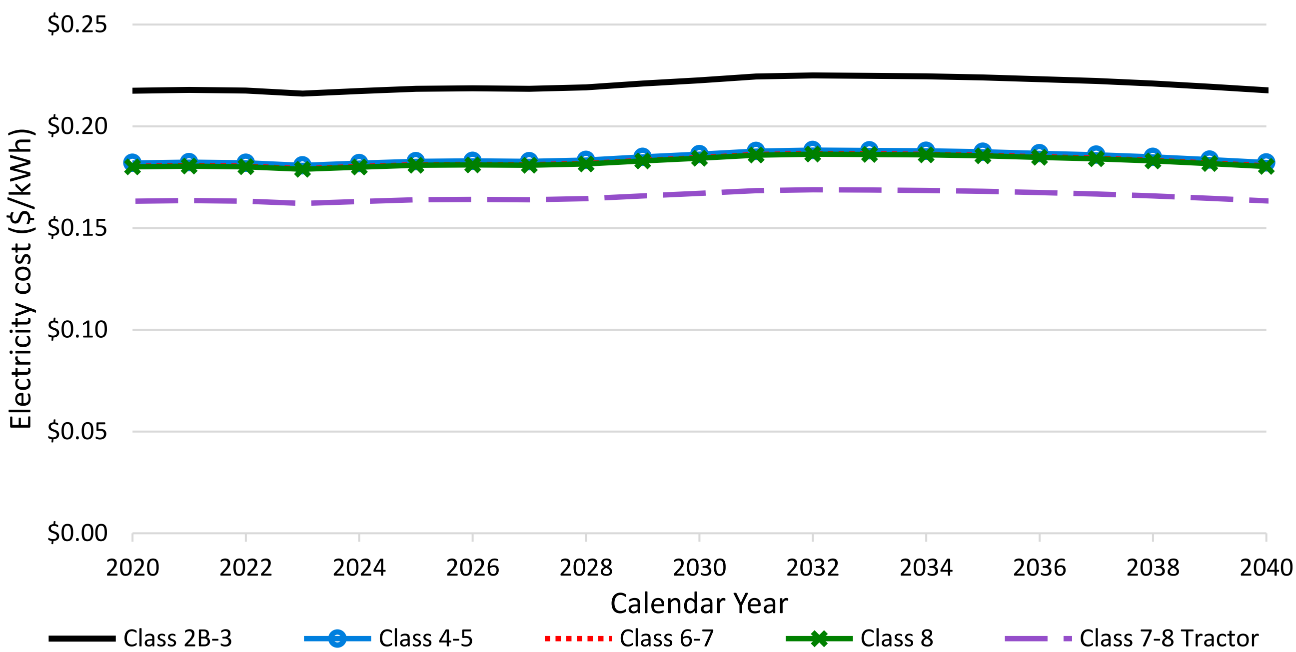
[77] California Air Resources Board, Battery-Electric Truck and Bus Charging Calculator (web link: https://ww2.arb.ca.gov/resources/documents/battery-electric-truck-and-bus-charging-cost-calculator, last accessed June 2019).

| Utility Area | Class 2B-3 | Class 4-5 | Class 6-7 | Class 8 | Class 7-8 Tractor |
|---|---|---|---|---|---|
| Weighted Statewide Average | $0.21 | $0.18 | $0.18 | $0.18 | $0.16 |

*PG&E has proposed two new electricity rates for commercial ZEVs, CEV-S and CEV-L, which are currently under CPUC review with a decision expected in August/September 2019. If approved, these rates will decrease electricity rates to commercial fleets to roughly $0.13-$0.15/kWh in PG&E territory.
**SCE's newly introduced electric vehicle rates, EV-8 and EV-9, have no demand fees from 2019 to 2023 and phase them back over the following five years, with demand fees being fully reintroduced in 2029. This analysis is based on an SCE estimate for what the electricity rate will look like in 2029 once demand fees are fully reintroduced.[78]

Electricity price changes over time are modelled using the CEC's "Revised Transportation Energy Demand Forecast, 2018-2030", adjusted to 2018 dollars using California CPI. Fuel prices past 2030 are calculated using the EIA 2018 Annual Energy Outlook for the Pacific region. The annual percentage change in EIA gasoline and diesel fuel prices past 2030 is applied to the 2030 CEC gasoline and diesel prices to estimate future price changes. Results per vehicle type are shown in Figure C-4. The electricity costs for Class 4-5, Class 6-7, and Class 8 are fairly similar resulting in them overlapping on the graph.

**Figure C-4. Electricity Price Forecasts**

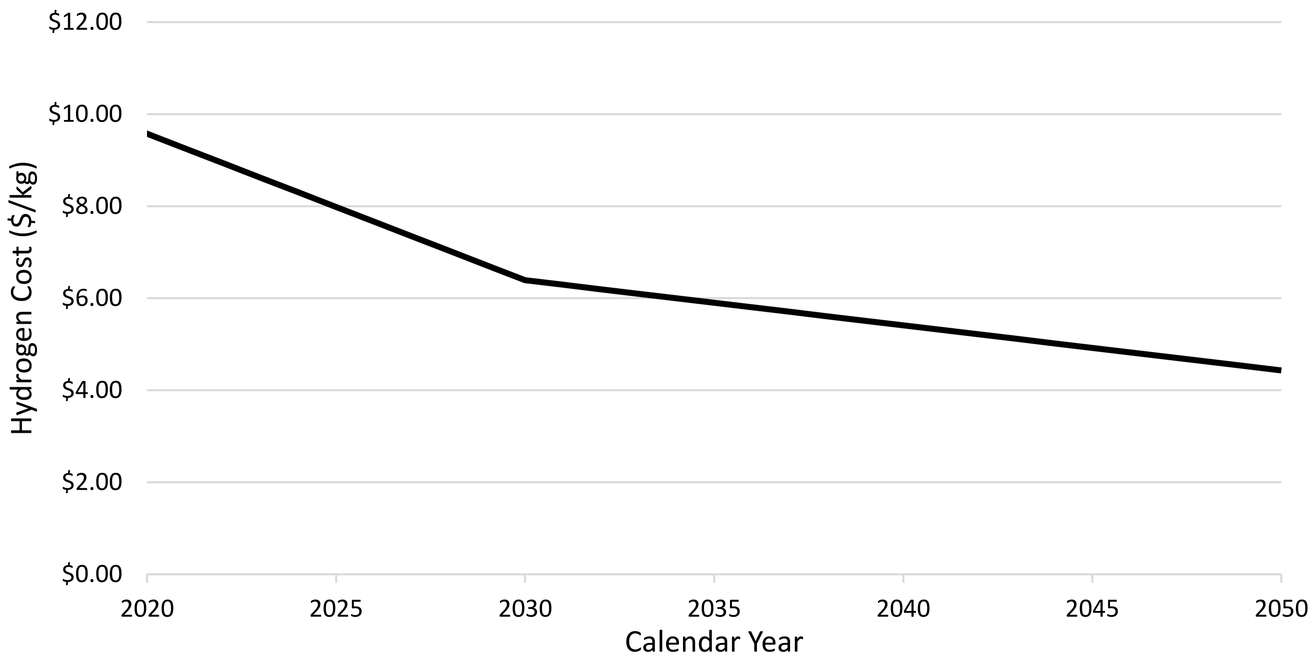



For this analysis, hydrogen stations were assumed to be available at strategic locations around ports or major distribution hubs where the infrastructure costs are included in the hydrogen fuel price rather than reflecting costs for stations installed in a depot. This model is currently used for light-duty hydrogen stations and heavy-duty diesel sales and based on stakeholder feedback appears most appropriate near term estimate for heavy-duty hydrogen fueling. Hydrogen fuel costs are based on communication with Trillium CNG who estimated the cost of

[78] Southern California Edison, Communication via email with Alexander Echele in April 2019.

hydrogen at low, intermediate, and high volumes using different production methods.[79] This report uses the liquid hydrogen delivery numbers based on what Trillium presented as being most feasible for production at scale. The low volume cost will be used in 2018, the intermediate volume in 2030, and the high volume in 2050 with intermediate years being interpolated. These assumptions are based on expecting low volume production today, intermediate volume by 2030 when we would see some moderate sized deployments but no complete conversions yet, and continuing price reductions out to 2050. Hydrogen costs over time are shown in Figure C-5.

**Figure C-5. Hydrogen Price Forecasts**




The cost of fuel displayed above includes fuel taxes. State and local taxes on fuel are listed below in Table C-13.

**Table C-13. Local and State Taxes on Fuel**

| Fuel Type | Local Tax | State Tax |
|---|---|---|
| Gasoline | 2.25% sales tax | $0.493/gal excise tax |
| Diesel | 4.5% sales tax | 8.5% sales tax + $0.38/gal excise tax |
| Electricity | 3.53% utility user tax* | $0.0003/kWh |
| Hydrogen | 0 | 0 |

*Statewide population-weighted average

### iv. Low Carbon Fuel Standard Revenue

The Low Carbon Fuel Standard (LCFS) is a California regulation that creates a market mechanism that incentivizes low carbon fuels. The LCFS regulation was amended in 2018. These amendments 1) increased the Energy Efficiency Ratio for Class 4-8 trucks from 2.7 to 5.0, 2) reduced the carbon intensity target to 20% reduction by 2030, and 3) clarified how

[79] Trillium CNG, Email communication with Ryan Erickson in November 2018.

hydrogen station operators can receive credits. The regulation now requires the carbon intensity of California's transportation fuels to decrease by 20% through the 2030 timeframe and maintains the standard afterwards. Electricity and hydrogen are eligible to earn LCFS credits which can be sold and used to offset the costs of these fuels. Fossil gasoline and diesel are generally not eligible for LCFS credits.

Fleets who own and operate their infrastructure generate credits based on the amount of fuel or energy they dispense. Credit values for different fuel types are calculated using the LCFS Credit Price Calculator.[80] The following credit values assume a credit price of $125 as estimated by LCFS program staff in the staff report for the 2018 rulemaking.[81] The average credit price for May 2019 was $185 has been above $180 since December 2018. Thus, the actual cost for fleets could be lower with higher LCFS credit value. An electric Class 2B-3 vehicle will earn $0.073/kWh in 2024 using grid electricity while an electric Class 4-8 vehicle will earn roughly $0.124/kWh in 2024. For hydrogen, we are assuming the hydrogen is produced from 33% renewable feedstock as required by SB 1505 (2006). This results in Class 4-8 vehicles earning $1.037/kg in 2024. LCFS credit revenue for a given fuel drops slightly over time as the program standards tighten and maintains upward pressure on the credit price.

#### v. Vehicle Maintenance Costs

Maintenance costs reflects the cost of labor and parts for routine maintenance, preventative maintenance, and repairing broken components. Maintenance costs for electric vehicles are generally assumed to be lower than for diesel in part due to their simpler design and fewer moving components. There is very little data available on hydrogen fuel cell vehicles currently, but available data appears to show maintenance costs that are comparable with diesel.

Maintenance costs for ICE Class 2B-3 vehicles are based on four sources from three reports.[82] [83] Maintenance costs for ICE vocational vehicles are based on the American Truck Research Institute study, "An Analysis of the Operational Costs of Trucking: 2017 Update" cost for straight truck maintenance per mile.[84] Maintenance costs for ICE tractors are based on the American Truck Research Institute study, "An Analysis of the Operational Costs of Trucking: 2018 Update" cost for less-than-truckload (LTL) maintenance cost per mile.[85] The LTL cost was used because the slower speed, frequent stops of LTL service match most closely to the

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[80] California Air Resources Board, LCFS Credit Price Calculator (web link: https://www.arb.ca.gov/fuels/lcfs/dashboard/creditpricecalculator.xlsx, last accessed June 2018).

[81] California Air Resources Board, Public Hearing to Consider Proposed Amendments to the Low Carbon Fuel Standard Regulation and to the Regulation on Commercialization of Alternative Diesel Fuels. Staff Report: Initial Statement of Reasons (web link: https://www.arb.ca.gov/regact/2018/lcfs18/isor.pdf, last accessed June 2019).

[82] Access LA, Access LA Fleet Design (web link: https://www.sacog.org/sites/main/files/file-attachments/access_la_life_cycle.pdf, last accessed June 2019).

[83] Utilimarc, Report: ½ Ton Pickup Truck Data (web link: https://utilimarc.com/report-12-ton-pickup-truck-data/, last accessed June 27, 2019).

[84] American Trucking Research Institute, An Analysis of the Operational Costs of Trucking: 2017 Update (web link: https://atri-online.org/wp-content/uploads/2017/10/ATRI-Operational-Costs-of-Trucking-2017-10-2017.pdf, last accessed June 2019).

[85] American Trucking Research Institute, An Analysis of the Operational Costs of Trucking: 2018 Update (web link: https://atri-online.org/wp-content/uploads/2018/10/ATRI-Operational-Costs-of-Trucking-2018.pdf, last accessed June 2019).

duty cycle of drayage or short-haul tractors that are more likely to become ZEVs prior to 2030. Table C-14 shows the maintenance cost assumptions used in this analysis. Battery-electric vehicles are assumed to have 25 percent lower vehicle maintenance costs compared to gasoline and diesel based on an aggregation of sources and data.[86, 87, 88, 89] Fuel cell electric vehicles are assumed to have similar maintenance costs to ICE vehicles; Ballard recommends estimating a fuel cell bus's maintenance costs as the same as a battery-electric bus plus $0.20/mi. for fuel cell maintenance. This adjustment will put a fuel cell bus's maintenance costs in line with a diesel or CNG bus.[90]

**Table C-14. Maintenance Cost per Mile per Vehicle Group**

| Vehicle Group | Gasoline/Diesel ($/mi.) | Battery-Electric ($/mi.) | Fuel Cell Electric ($/mi.) |
|---|---|---|---|
| Class 2B-3 | $0.17 | $0.128 | $0.17 |
| Class 4-5 Vocational | $0.31 | $0.233 | $0.31 |
| Class 6-7 Vocational | $0.31 | $0.233 | $0.31 |
| Class 8 Vocational | $0.31 | $0.233 | $0.31 |
| Class 7-8 Tractor | $0.19 | $0.142 | $0.19 |

### vi. Maintenance Bay Upgrades

Maintenance bays are facilities used to service vehicles. Services performed can include inspections, routine maintenance, preventative maintenance, repairs, overhauls and more. Servicing electric vehicles requires separate safety equipment, diagnostic tools, and equipment which will incur costs to the facility.

Based on transit agency data, upgrading a fifteen bus maintenance bay to handle battery-electric buses would cost $25,000, and upgrading to handle fuel cell electric buses would cost $750,000. For this analysis, we are assuming the cost per maintenance bay is the same and a fifteen bus maintenance bay could accommodate 25 trucks due to their smaller size. The amount of maintenance bay upgrades each year is based on the increase in ZEV population per year to avoid double-counting in situations where a ZEV is replaced by a ZEV.

### vii. Midlife Costs

Midlife costs are the cost of rebuilding or replacing major propulsion components due to wear or deterioration. For diesel vehicles, this would be a midlife rebuild, for battery-electric vehicles

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[86] California Air Resources Board, Literature Review on Transit Bus Maintenance Cost (web link: https://www.arb.ca.gov/msprog/bus/maintenance_cost.pdf, last accessed June 2019).

[87] Electrification Coalition, State of the Plug-in Electric Vehicle Market (web link: https://www.pwc.com/gx/en/automotive/industry-publications-and-thought-leadership/assets/pwc-ec-state-of-pev-market-final.pdf, last accessed June 2019).

[88] Propfe, B. et.al. Cost analysis of Plug-in Hybrid Electric Vehicles including Maintenance & Repair Costs and Resale Values (web link: http://www.mdpi.com/2032-6653/5/4/886, last accessed June 2019).

[89] Taefi, T. et.al. Comparative Analysis of European examples of Freight Electric Vehicle Schemes. http://nrl.northumbria.ac.uk/15185/1/Bremen_final_paperShoter.pdf, last accessed June 2019).

[90] Ballard, Fuel Cell Electric Buses: Proven Performance and the Way Forward (web link: https://info.ballard.com/fuel-cell-electric-buses-proven-performance-white-paper?hsCtaTracking=ab0058ba-1240-4ab6-a4e6-0032faf329b7%7Cd0616627-31ce-416a-bbe8-d036529a4d75, last accessed June 2019).

this would be a battery replacement, and for a hydrogen fuel-cell vehicle this would be a fuel cell stack refurbishment. The frequency and cost of a midlife rebuild vary from technology to technology.

The frequency of a diesel engine rebuild varies based on the vehicle's weight class. Table C-15 shows the anticipated diesel engine useful life based on years or miles. The cost of an engine rebuild is estimated to be one quarter of the total vehicle price.

**Table C-15. Useful life of diesel engines**

| Vehicle/Engine Category | Useful Life (Years/Miles) |
|---|---|
| Class 4-5 (Light-Heavy Duty) | 18/350,000 |
| Class 6-7 (Medium-Heavy Duty) | 18/450,000 |
| Class 8 (Heavy-Heavy Duty) | 18/850,000 |

Data is limited for battery-electric vehicles, but today zero-emission manufacturers are offering vehicles with warranties of eight or more years and up to 300,000 miles on their products. Information on battery degradation trends from light-duty Tesla vehicles was used to estimate when batteries for trucks would need to be replaced. [91,92,93,94] Staff estimate that the battery will be replaced every 300,000 miles. The cost of the battery replacement is assumed to be the size of the battery in kWh multiplied by the price per kWh at the time of the replacement.

For fuel cell electric vehicles, the consulting firm Ricardo has estimated that a fuel cell stack refurbishment is necessary every seven years and costs one third the cost of a new fuel cell stack at the time of refurbishment. [95]

Based on the above assumptions, Table C-16 shows when vehicles are assumed to incur midlife costs.

**Table C-16. Frequency of Midlife Rebuilds**

| Vehicle Group | Technology | Midlife Occurrence (yr) |
|---|---|---|
| Class 2B-3 | Gasoline | Not necessary |
| | Diesel | Not necessary |
| | Battery-Electric | Not necessary |
| Class 4-5 | Diesel | 13 |
| | Battery-electric | 10 |
| Class 6-7 | Diesel | 17 |
| | Battery-electric | 10 |

[91] BYD, The BYD K9 (web link: https://en.byd.com/wp-content/uploads/2019/07/4504-byd-transit-cut-sheets_k9-40_lr.pdf, last accessed June 2019).
[92] New Flyer, Xcelsior Charge (web link: https://www.newflyer.com/site-content/uploads/2019/06/Xcelsior-CHARGE-web.pdf, last accessed June 2019).
[93] Steinbuch, Tesla Model S Degradation Data (web link: https://steinbuch.wordpress.com/2015/01/24/tesla-model-s-battery-degradation-data/, last accessed June 2019).
[94] Proterra, Catalyst: 40 Foot Bus – Performance Specifications (web link: https://mk0proterra6iwx7rkkj.kinstacdn.com/wp-content/uploads/2019/06/Proterra-Catalyst-40-ft-Spec-Sheet.pdf, last accessed June 2019).
[95] Ricardo, Economics of Truck TCO and Hydrogen Refueling Stations, 2016.

| Vehicle Group | Technology | Midlife Occurrence (yr) |
|---|---|---|
| Class 8 | Diesel | 18 |
| | Battery-electric | 14 |
| Class 7-8 Tractor | Diesel | 18 |
| | Battery-electric | 5, 13, 20 |
| | Fuel Cell Electric | 7, 14, 21 |

### viii. Fueling Infrastructure Installation and Maintenance

Infrastructure is necessary to refuel or recharge vehicles. All vehicles need either dedicated refueling infrastructure onsite or publicly available retail stations in order to operate. There are numerous ways infrastructure expenses can be accounted for which will affect the cost to California businesses in different ways. Infrastructure expenses are generally an upfront capital investment needed prior to vehicles being deployed, but infrastructure can last multiple vehicle lifetimes and generally is amortized over its life.

In the baseline scenario, we are assuming that the fleet is either using existing gasoline or diesel infrastructure or publicly accessible stations and the infrastructure cost is already incorporated into the fuel cost. As a result, diesel infrastructure costs are not separately modeled.

In the proposal scenario, we are assuming that fleets using battery-electric will be setting up private, behind-the-fence infrastructure to recharge their vehicles and will not depend on publically available charging networks. There are two main cost components of installing charging infrastructure: the cost of the charger itself and the cost of upgrading the site to deliver power to the charger. The latter can include trenching, cabling, laying conduit, potential transformer upgrades and more.

Charger and infrastructure cost estimates for Class 2B-3 and Class 4-5 vocational vehicles are derived from Pacific Gas and Electric and Southern California Edison cost estimates as part of their SB 350 applications. Costs for Class 8 vocational and Class 7-8 tractors are taken from the ICT ISOR and comes from electric transit bus deployment data. Class 6-7 trucks are assumed to use the same infrastructure as a heavier truck but would be able to share the charger with another Class 6-7 truck; as a result, their infrastructure costs are half that of a Class 8 truck. Table C-17 outlines the assumptions for charger power, charger cost, and infrastructure upgrade costs.

**Table C-17. Charger Power Ratings and Infrastructure Costs**

| Vehicle Group | Charger Power (kW) | Charger Cost | Infrastructure Upgrade Cost |
|---|---|---|---|
| Class 2B-3 | 19 | $5,000 | $20,000 |
| Class 4-5 | 19 | $5,000 | $20,000 |
| Class 6-7 | 40 | $25,000 | $27,500 |
| Class 8 | 80 | $50,000 | $55,000 |
| Class 7-8 Tractor | 80 | $50,000 | $55,000 |

Fleets are assumed to amortize their infrastructure costs over a 20 year period with an interest rate of five percent.  The amount of chargers installations and infrastructure upgrades each year is based on the increase in ZEV population per year to avoid double-counting infrastructure costs in situations where a ZEV is replaced by a ZEV.

Hydrogen infrastructure costs are incorporated into the hydrogen fuel costs identified by Trillium and are not included here.

Depot and on-route chargers for zero-emission vehicles require regular maintenance.  The maintenance costs   of depot chargers are estimated by considering costs for replacing charger heads, connectors, and other components, as well as labor costs for regular inspections.[96]  The information about on-route chargers is based on data from Foothill Transit who has experience with Proterra on-route chargers.[97]  Charger maintenance costs are estimated at $500/yr/charger.  We assume that the maintenance cost for other fueling infrastructures are reflected in the fuel price.

### ix. Transitional Costs and Workforce Development

Transitioning to a new technology has inherent costs associated with its deployment, including shifts in operational and maintenance practices.  These recurring costs include operator and technician trainings, purchasing and upgrading of software, securing additional spare parts, and others.

Limited information is available for this type of transitional cost, but discussions occurred on this topic during the development of the Innovative Clean Transit rule.  Based on discussions with transit agencies, Staff assumed that these “other costs” associated with ZE bus deployments are equivalent to 2.5 percent of bus prices for all powertrains and discussed that the costs should go down over time for ZEBs as they become more common.  This method is based on the assumption that the Cost Subgroup used to reflect estimated soft costs for conventional internal combustion engine bus.[98]

In the cost analysis for the Proposed ACT Regulation, staff are making similar assumptions and that the workforce training and transitional costs are equal to 2.5% of the incremental cost difference between a baseline ICE vehicle and a ZEV.  These costs continue until 2030 at which point the technology will have developed to a point where these transitional costs become business as usual for trucking fleets.

### x. Registration Fees

Vehicles operating and registered in California must pay an annual registration fee.  The registration fee varies based on the vehicle’s cost, age, and weight.  These calculations are different for ICE vehicles and ZEVs.

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[96] Personal communications with Tesla and Clipper Creek in October 2016
[97] Foothill Transit, Email communication with Andrew Papson, Electric Bus Program Manager, in March 2017
[98] Transit Agency Subcommittee-Lifecycle Cost Modeling Subgroup (2017). Report of Findings, April 2017.

ICE and ZEV's are subject to the following fixed fees based on the DMV online calculator.[99] These are constant annual fees for every vehicle and are shown in Table C-18.

**Table C-18. Fixed Registration Fees for Diesel Vehicles and ZEVs**

| Diesel Fee Name | Amount | ZEV Fee Name | Amount |
|---|---|---|---|
| Current Registration | $58 | Current Registration | $58 |
| CVRA Registration Fee | $122 | Current California Highway Patrol | $25 |
| CVRA Service Authority for Freeway Emergencies Fee | $3 | CVRA Service Authority for Freeway Emergencies Fee | $1 |
| CVRA Fingerprint ID Fee | $3 | CVRA Fingerprint ID Fee | $1 |
| CVRA Abandoned Vehicle Fee | $3 | CVRA Abandoned Vehicle Fee | $1 |
| CVRA California Highway Patrol Fee | $41 | Current Air Quality Management District | $6 |
| Current Air Quality Management District | $6 | Alt Fuel/Tech Registration Fee | $3 |
| Current Cargo Theft Interdiction Program Fee | $3 | CVRA Auto Theft Deterrence/DUI Fee | $2 |
| CVRA Weight Decal Fee | $3 | Reflectorized License Plate Fee | $1 |
| Alt Fuel/Tech Registration Fee | $3 | Road Improvement Fee | $100 |
| CVRA Auto Theft Deterrence/DUI Fee | $4 | | |
| Reflectorized License Plate Fee | $1 | | |
| Total | $250 | Total | $198 |

All vehicles registered in California must pay a Transportation Improvement Fee based on the price of the vehicle. For vehicles priced between $35,000 and $60,000, the fee is $150, and for vehicles priced above $60,000, the fee is $175.

All registered vehicles are assessed a Vehicle License Fee which is equal to the vehicle price multiplied by 0.65% and a separate percentage schedule. This separate schedule is shown in Table C-19.

**Table C-19. Vehicle License Fee Decline over Time**

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Percentage | 100% | 90% | 80% | 70% | 60% | 50% | 40% | 30% | 25% | 20% | 15% |

For commercial ICE vehicles, vehicle owners are assessed an annual weight fee based on the vehicle's potential maximum loaded weight. For electric vehicles, the weight fee is based on its unladen weight. The estimated weight fees are shown in Table C-20.

**Table C-20. Weight Fees for ICE Vehicles and ZEVS**

| Diesel Fee Name | Diesel Weight Fee | ZEV Weight Fee |
|---|---|---|
| Class 2B-3 | $210 | $266 |
| Class 4-5 | $447 | $358 |
| Class 6-7 | $546 | $358 |
| Class 8 | $1,270 | $358 |
| Class 7-8 Tractor | $2,064 | $358 |

[99] California Department of Motor Vehicles, California New Vehicle Fees (web link: https://www.dmv.ca.gov/portal/dmv/detail/portal/feecalculatorweb, last accessed June 2019).

Overall, ZEV's pay lower registration fees over the vehicles life although it may be higher in the initial years of registration. This difference is greater for heavier vehicles due to the large difference in annual weight fees.

#### xi. Battery Recycling, Repurposing, and Disposal

The energy capacity of the batteries used in ZEVs will naturally degrade over their useful life and require battery replacements. When battery capacity is not sufficient for meeting daily range needs for a truck or bus, it is expected that there will be a second life for the batteries. The used battery at the end of its vehicle useful can be repurposed into other applications such as stationary storage, then at the end of the battery life it can be recycled and non-recyclable materials can be disposed.

The cost for battery recycling at the end of battery life is not included here, because this cost could be offset by the residual value of the battery at the end of its useful life in a truck or bus. The end of life may be a revenue source depending on whether the battery can be recycled and repurposed, or could become a cost if it must be disposed of. Today, light-duty vehicle batteries are already being repurposed for second life applications including stationary storage.[100,101] Even today, some lithium-ion battery manufacturers provide an attractive residual value to customers upon the retirement of a battery. Therefore, staff believes that the residual value will offset the recycling cost and become a revenue source, but does not include a residual battery value in the economic analysis.

### d. *Total Costs*

The Proposed ACT Regulation would increase the number of ZEVs sold in California relative to the baseline. These ZEVs have higher upfront capital costs for the vehicle and infrastructure investments, but lower operating costs over time resulting in lower overall costs for truck transportation in California. The cost to truck transportation in California assuming all vehicle manufacturer costs and 10 percent of the Phase 2 GHG savings are passed on is -$4.8 billion between 2020 and 2040 compared to the baseline scenario. Figure C-6 and Table C-22 illustrates the difference in cost between the Proposed ACT Regulation and the baseline scenario. In Figure C-6, the cost components are grouped as shown in Table C-21.

**Table C-21. Summarized Cost Items**

| Cost Category | Components |
|---|---|
| Manufacturer Cost | ZEV Price, ICE Phase 2 GHG (cost avoided), ZEP Certification |
| Fuel Cost | Gasoline, Diesel, Electricity, Hydrogen Fuel Cost |
| LCFS Revenue | LCFS Revenue |
| Infrastructure | Charger Costs, Infrastructure Upgrades, Charger Maintenance |
| Maintenance | Vehicle Maintenance Costs, Maintenance Bay Upgrades |

[100] Nissan Motor Corporation, Nissan LEAF batteries to light up Japanese town. (web link: https://newsroom.nissan-global.com/releases/180322-01-e?lang=en-US&la=1&downloadUrl=%2Freleases%2F180322-01-e%2Fdownload, last accessed June 2019).

[101] BMW Group, BMW Group, Northvolt and Umicore join forces to develop sustainable life cycle loop for batteries (web link: https://www.press.bmwgroup.com/global/article/detail/T0285924EN/bmw-group-northvolt-and-umicore-join-forces-to-develop-sustainable-life-cycle-loop-for-batteries, last accessed June 2019).

| Cost Category | Components |
|---|---|
| Midlife | Midlife Costs |
| Other | Sales Tax, Federal Excise Tax, Registration Fees, Large Entity Reporting, Transitional Costs and Workforce Development |

Based on the cost analysis, deploying ZEVs will decrease costs to the California economy primarily due to lower fuel costs. Manufacturers would see increased costs past 2024 MY in California as the cost to build ZEVs would be a higher cost pathway to comply with Phase 2 GHG than using other technologies. However, the Proposed ACT Regulation is estimated to reduce costs of compliance with the Phase 2 GHG regulation when factoring in nationwide savings due to the Advanced Technology Multiplier that expires at the end of 2027 MY.

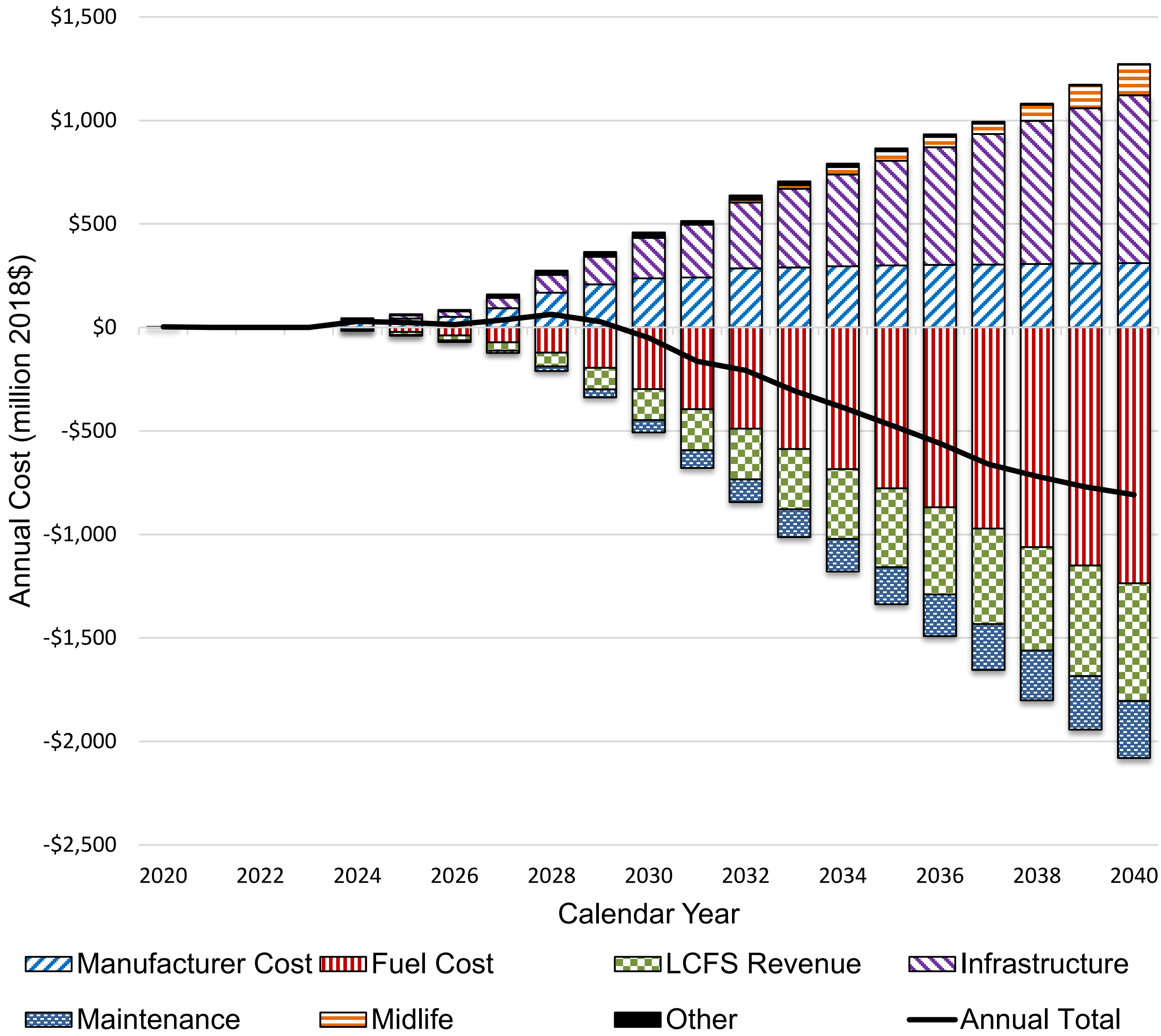
Despite these potential short term cost savings, large manufacturers have hesitated to invest significant amounts of capital into ZE products because of uncertainty in the longer term market and estimated higher costs after 2027. Transitioning from conventional ICE powertrains to battery-electric and fuel cell electric technology represents a major paradigm shift for both manufacturers and fleets, and it is difficult to forecast how the technology may grow without established government policy. There are other non-monetary risks associated with ZEV development that need to be managed such as infrastructure availability, range anxiety, weight concerns. Studies from University of California, Davis and the North American Council on Fuel Efficiency show some hesitancy from the trucking industry despite the potential for cost savings.[102, 103]

Additionally, manufacturers bear additional risks by building electric vehicles when compared to compliance strategies that depend on modest improvements in existing conventional truck technologies. Developing a ZE product line requires initial research and development expenses, new or heavily modified assembly lines, agreements with new suppliers, and more. While this analysis does show a cost saving while the Advanced Technology Multiplier is in effect, on a longer timeframe past 2027 MY, ZEVs are a more expensive vehicle to build. Demand for ZEVs is dependent on many factors outside the manufacturer's control including fuel price swings, battery and other component prices, shifting fleet behavior, and others. So while this cost analysis shows that ZEVs overall have potential to decrease costs to manufacturers for complying with Phase 2 GHG regulation prior to 2028, staff believe the manufacturers may not commercially produce ZEVs in a BAU scenario without certainty from a regulation.

102 Miller, Marshal; Wang, Qian; Fulton, Lew; Truck Choice Modeling: Understanding California's Transition to Zero-Emission Vehicle Trucks Taking into Account Truck Technologies, Costs, and Fleet Decision Behavior (web link: https://ncst.ucdavis.edu/wp-content/uploads/2016/10/NCST-TO-033.2-Fulton_Truck-Decision-Choice_Final-Report_Nov2017.pdf, last accessed June 2019).

103 North American Council for Fuel Efficiency, Electric Trucks: Where They Make Sense, 2018.

**Figure C-6. Total Estimated Direct Costs of Proposed ACT Regulation Relative to the Baseline (million 2018$)**



### Table C-22. Total Estimated Direct Incremental Costs Relative to the Baseline (million 2018$)

| | Cost to Manufacturers | | | Costs to Fleets | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Calendar Year** | ZEV Price | ICE Phase 2 GHG (Cost Avoided) | ZEP Cert. | Large Entity Reporting | Sales & Excise Tax | Fuel Cost | LCFS Revenue | Vehicle Maintenance Cost | Maintenance Bay Upgrades | Midlife Costs | EVSE & Infrastructure Installation & Maintenance | Transitional Costs & Workforce Development | Registration Fees | **Total Cost*** |
| 2020 | $0 | $0 | $0.00 | $2.4 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $2.4 |
| 2021 | $0 | $0 | $0.00 | $0.0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2022 | $0 | $0 | $0.00 | $0.0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2023 | $0 | $0 | $0.00 | $0.0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2024 | $43 | -$9 | $0.18 | $0.0 | $4 | -$9 | -$6 | -$3 | $0 | $0 | $6 | $1 | $0 | $28 |
| 2025 | $55 | -$12 | $0.04 | $0.0 | $5 | -$21 | -$14 | -$7 | $1 | $0 | $15 | $1 | $0 | $23 |
| 2026 | $66 | -$14 | $0.04 | $0.0 | $6 | -$39 | -$23 | -$12 | $2 | $0 | $26 | $2 | $0 | $13 |
| 2027 | $136 | -$43 | $0.04 | $0.0 | $14 | -$70 | -$40 | -$21 | $4 | $0 | $50 | $3 | -$1 | $34 |
| 2028 | $181 | -$13 | $0.04 | $0.0 | $19 | -$120 | -$66 | -$35 | $7 | $0 | $85 | $4 | -$1 | $60 |
| 2029 | $224 | -$18 | $0.04 | $0.0 | $23 | -$193 | -$103 | -$54 | $10 | $0 | $133 | $6 | -$3 | $25 |
| 2030 | $259 | -$23 | $0.04 | $0.0 | $27 | -$294 | -$150 | -$80 | $14 | $0 | $194 | $6 | -$6 | -$51 |
| 2031 | $263 | -$23 | $0.04 | $0.0 | $27 | -$390 | -$198 | -$105 | $18 | $0 | $256 | $0 | -$8 | -$161 |
| 2032 | $306 | -$23 | $0.04 | $0.0 | $31 | -$483 | -$245 | -$130 | $20 | $15 | $318 | $0 | -$10 | -$202 |
| 2033 | $311 | -$24 | $0.04 | $0.0 | $32 | -$580 | -$292 | -$154 | $22 | $18 | $380 | $0 | -$12 | -$299 |
| 2034 | $318 | -$24 | $0.04 | $0.0 | $33 | -$677 | -$337 | -$177 | $23 | $37 | $443 | $0 | -$15 | -$377 |
| 2035 | $322 | -$24 | $0.04 | $0.0 | $33 | -$770 | -$380 | -$199 | $23 | $46 | $506 | $0 | -$18 | -$462 |
| 2036 | $325 | -$25 | $0.04 | $0.0 | $33 | -$860 | -$422 | -$221 | $23 | $51 | $568 | $0 | -$20 | -$548 |
| 2037 | $327 | -$25 | $0.04 | $0.0 | $33 | -$962 | -$461 | -$241 | $23 | $51 | $630 | $0 | -$23 | -$648 |
| 2038 | $329 | -$25 | $0.04 | $0.0 | $34 | -$1,051 | -$499 | -$260 | $23 | $78 | $691 | $0 | -$26 | -$706 |
| 2039 | $332 | -$25 | $0.04 | $0.0 | $34 | -$1,138 | -$534 | -$278 | $23 | $109 | $751 | $0 | -$29 | -$757 |
| 2040 | $334 | -$25 | $0.04 | $0.0 | $34 | -$1,224 | -$568 | -$295 | $22 | $150 | $810 | $0 | -$32 | -$794 |
| Total* | $4,129 | -$375 | $1 | $2 | $423 | -$8,882 | -$4,337 | -$2,273 | $258 | $554 | $5,862 | $24 | -$203 | -$4,818 |

*Note: Totals may differ due to rounding

## 2. Direct Costs on Typical Businesses

### e. *Medium- and Heavy-duty Manufacturers*

Manufacturers are responsible for meeting the ZEV sales percentage requirement by either building and selling zero-emission trucks, or using flexibility provisions. While none of the regulated manufacturers build vehicles in California, this analysis is included to provide further information to stakeholders. Manufacturing ZEVs requires large upfront costs that go into research and development, prototyping, assembly line upgrades and tooling, and other categories. All these costs plus the actual component cost of the vehicle need to be recouped during the sale of the vehicle.

Manufacturers would have a requirement to sell ZEVs but most fleets do not currently have a requirement to purchase ZEVs. As a result, manufacturers bear risk in that they may have to sell vehicles below cost to fleets to meet the requirements of the regulation. Any ZEV costs that manufacturers cannot pass on through sale of their ZEVs may be added to the cost of the rest of their ICE fleet, or the manufacturer may not pass on the cost and must absorb the cost themselves.

The two extremes are either the manufacturer is able to fully pass on the cost of an electric vehicle to the purchaser, or they are not able to pass any cost on to the purchaser. One way to estimate what the purchaser would be willing to pay for would be to look at the payback of the ZEV. Studies and surveys have found that commercial fleets are willing to pay more for cost-saving technologies within a certain payback period that varies from fleet to fleet.[104,105] Two years is considered to be the time period where any cost-saving expense becomes an easy decision for a fleet. Table C-23 illustrates the percentage of incremental cost that the fleet will be willing to pay for based on a simple two-year payback analysis incorporating fuel costs, LCFS revenue, and amortized charger & infrastructure payments. These percentages should represent the floor for what portion of the incremental cost the fleet will pay for as most companies have longer horizons than two years with some looking at the full life of the vehicle.

**Table C-23. Percentage of Two-Year Simple Payback vs. Incremental Cost**

| Vehicle Group* | 2024 MY | 2025 MY | 2026 MY | 2027 MY | 2028 MY | 2029 MY | 2030 MY |
|---|---|---|---|---|---|---|---|
| Class 2B-3 | 24% | 26% | 28% | 29% | 31% | 34% | 38% |
| Class 4-5 | 54% | 61% | 69% | 73% | 81% | 89% | 101% |
| Class 6-7 | 54% | 63% | 72% | 77% | 86% | 98% | 113% |
| Class 8 | 28% | 34% | 40% | 41% | 47% | 55% | 67% |
| Class 7-8 Tractor - Electric | 33% | 38% | 42% | 44% | 48% | 53% | 60% |
| Class 7-8 Tractor - Fuel Cell | N/A | N/A | N/A | N/A | N/A | 3% | 8% |

*Class 2B-3 is using average of payback versus diesel and gasoline, all comparisons versus the normal range version of vehicle.

104 Volvo Technology of North America, Heavy-Duty Class 8 Electrification Roadmap: Regional Distribution and Short Haul Applications.

105 Environmental Protection Agency, Heavy-duty Trucking and the Energy Efficiency Paradox (web link: https://www.epa.gov/sites/production/files/2014-12/documents/heavy-duty_trucking_and_the_energy_efficiency_paradox.pdf, last accessed June 2019).

It is possible that manufacturers may shift sales for California-bound trucks out of state to avoid the requirements of the Proposed ACT Regulation which would consequentially reduce overall emissions reductions. Current California conditions include higher sales tax, registration fees and other factors that cause a portion of California tractors and trucks to be sold initially out of state despite operating within California. Generally, trucking companies make purchasing decisions based on a variety of reasons including the location of their headquarters, fleet facilities, expected duty cycles, and level of local delegation. Staff does not believe the Proposed ACT Regulation is likely to exacerbate these issues as fleet behavior determines where vehicles are purchased and operated, not manufacturer decisions.

While the proposed ACT regulation cannot ensure that sales will not affect decisions to shift sales out of state, future planned ZEV rules can require companies to incorporate zero-emission trucks into their fleets regardless of whether they were purchased in state or not. This issue can be avoided in how future regulations are structured to ensure real emissions reductions occur in California.

#### f. ***Trucking Fleets***

Manufacturers sell trucks to trucking fleets who operate the vehicles and incur costs after the point of sale including taxes, fueling, maintenance, midlife costs, and registration fees. Adding electric trucks to their fleet will also cause fleets to incur cost relating to EVSE, infrastructure, maintenance bay upgrades, workforce training, and other transitional costs.

The Proposed ACT Regulation will reduce costs to the overall state's trucking fleet as the operational cost savings of the ZEVs outweigh the potential infrastructure and vehicle prices. Amortizing the vehicle and infrastructure help with these company's cash-flow so they can have positive cash-flow shortly after purchase.

Table C-24 illustrates an example where an example fleet purchases 20 Class 4-5 trucks for usage in last mile delivery applications in 2024 for usage over twelve years. The costs for 20 diesel vehicles, 20 battery-electric vehicles and the difference between them is shown. All other mileage and cost assumptions are the same as described previously in this section. The costs over the twelve year period are lower for the battery-electric fleet as compared to the diesel fleet; however, the upfront capital expenses are significantly higher for the BEV fleet. Access to capital or financing will be critical for fleets to take advantage of the overall savings of BEVs. A more detailed discussion of fleet costs can be found in the "Draft Advanced Clean Trucks Total Cost of Ownership Discussion Document" released earlier this year.[106]

**Table C-24. Fleet Cost Example**

| Cost line items | Diesel | Battery Electric | Difference |
|---|---|---|---|
| Amortized Vehicle Price (including all mfr. expenses) | $1,270,361 | $1,747,840 | $477,479 |
| Sales Tax | $93,280 | $135,896 | $42,616 |
| Amortized EVSE Cost | $0 | $104,315 | $104,315 |
| Amortized Infrastructure Upgrades | $0 | $417,261 | $417,261 |
| Charger Maintenance | $0 | $120,000 | $120,000 |

[106] California Air Resources Board, Draft Advanced Clean Trucks Total Cost of Ownership Discussion Document (web link: https://ww2.arb.ca.gov/sites/default/files/2019-02/190225tco_0.pdf, last accessed June 2019).

| Cost line items | Diesel | Battery Electric | Difference |
|---|---|---|---|
| Fuel Costs | $2,220,329 | $947,961 | -$1,272,368 |
| LCFS Revenue | $0 | -$764,063 | -$764,063 |
| Maintenance Costs | $1,914,913 | $1,436,185 | -$478,728 |
| Midlife Costs | $0 | $259,200 | $259,200 |
| Maintenance Bay Upgrades | $0 | $20,000 | $20,000 |
| Transitional Costs and Workforce Development | $0 | $12,564 | $12,564 |
| Registration Fees | $245,823 | $232,840 | -$12,982 |
| Total | $5,744,706 | $4,669,999 | -$1,074,706 |

### 3. Direct Costs on Small Businesses

There is no expected direct cost on small businesses under the Proposed ACT Regulation. No manufacturers or fleets who are regulated under this rule are small businesses.

Small businesses who operate trucks will not be required to purchase zero-emission trucks, but may independently decide to do so. This may enable cost savings for small businesses due to electric trucks' lower cost of operation.

### 4. Direct Costs on Individuals

There are no direct costs onto individuals as a result of this regulation. Individuals may see health benefits as described in Section B.3 due to ZEVs displacing ICE vehicles and providing statewide, regional, and local emission benefits. Manufacturers and fleets will see increased and decreased costs as a result of this rule and will pass through to individuals in the state. Individuals may see macroeconomic benefits and costs; these costs are discussed further in Section E.

Some of the vehicles affected by this regulation, mainly Class 2B-3 pickup trucks, are purchased by individuals. Based on manufacturer estimates, this portion is roughly half of the overall Class 2B-3 population compared to the 15% sales requirement in the Class 2B-3 category in 2030.[107] Staff is assuming in this analysis that all ZEVs will be sold to businesses rather than individuals. Businesses are more likely to look at lifetime savings and the total cost of ownership compared to individuals, and the vehicles businesses purchase including vans are better suited for electrification as opposed to the pickups purchased by individuals.

## D. Fiscal Impacts

### 1. Local Government

[107] Truck and Engine Manufacturers Association, Advanced Clean Truck Market Segment Analysis (web link: https://ww2.arb.ca.gov/sites/default/files/2018-11/181204emaanalysis_0.xlsx , last accessed June 2019).

### a. Large Entity Reporting

Cities and counties are required to complete the Large Entity Reporting requirement in 2020. There are 58 counties and 482 cities in California and each would be required to report information about their fleets, and the transportation services they contract for.

### b. Utility User Taxes

Many cities and counties in California levy a Utility User Tax on electricity usage. This tax varies from city to city and ranges from no tax to 11%. A value of 3.53% was used in this analysis representing a population-weighted average.[108] By increasing the amount of electricity used, there will be an increase in the amount of the utility user tax revenue collected by cities and counties.

### c. Gasoline and Diesel Fuel Taxes

Fuel taxes on gasoline and diesel to fund transportation improvements at the state, county, and local levels. Displacing gasoline and diesel with electricity and hydrogen will decrease the total amount of gasoline and diesel dispensed in the state, resulting in a reduction in fuel tax revenue collected by local governments. The local tax on fuel is listed in Table C-13.

### d. Local Sales Taxes

Sales taxes are levied in California to fund a variety of programs at the state and local level. The Proposed ACT Regulation will require the sale of more expensive zero-emission trucks in California which will result in direct increase in sales tax revenue collected by local governments. Overall, local sales tax revenue may increase less than the direct increase from vehicle sales if overall business spending doesn't increase.

### e. Local Government Fleet Cost Pass-Through

The local government fleet is estimated to make up 2.9% of California's fleet based on information from manufacturers and the Department of General Services. A proportionate amount of the total costs outlined in Table C-22 are assumed to pass-through to local governments.

### f. Fiscal Impact on Local Government

Table D-1 shows the estimated fiscal cost to local governments due to the Proposed ACT Regulation relative to baseline conditions. The fiscal impact to local government is estimated to be -$0.1 million over the first three years of the regulation and $7 million over the regulatory lifetime.

[108] California State Controller's Office, User Utility Tax Revenue and Rates (web page: https://sco.ca.gov/Files-ARD-Local/LocRep/2016-17 Cities UUT.pdf, last accessed June 2019).

Table D-1. Estimated Fiscal Impacts to Local Government (million 2018$)

| Model Year | Large Entity Reporting | Utility User Tax Revenue | Local Gasoline and Diesel Fuel Taxes | Local Sales Tax | Local Government Fleet Cost Pass-Through | Fiscal Impact* |
|---|---|---|---|---|---|---|
| 2020 | -$0.1 | $0 | $0 | $0 | $0 | -$0.1 |
| 2021 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2022 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2023 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2024 | $0 | $0 | -$1 | $2 | -$1 | $0 |
| 2025 | $0 | $1 | -$1 | $2 | -$1 | $1 |
| 2026 | $0 | $1 | -$2 | $3 | $0 | $2 |
| 2027 | $0 | $2 | -$4 | $6 | -$1 | $3 |
| 2028 | $0 | $3 | -$7 | $8 | -$2 | $2 |
| 2029 | $0 | $5 | -$12 | $10 | -$1 | $2 |
| 2030 | $0 | $7 | -$18 | $12 | $1 | $2 |
| 2031 | $0 | $10 | -$23 | $12 | $5 | $4 |
| 2032 | $0 | $12 | -$29 | $14 | $6 | $3 |
| 2033 | $0 | $14 | -$35 | $14 | $9 | $2 |
| 2034 | $0 | $16 | -$41 | $14 | $11 | $0 |
| 2035 | $0 | $18 | -$46 | $15 | $13 | $0 |
| 2036 | $0 | $20 | -$51 | $15 | $16 | $0 |
| 2037 | $0 | $22 | -$57 | $15 | $19 | -$1 |
| 2038 | $0 | $24 | -$62 | $15 | $20 | -$3 |
| 2039 | $0 | $25 | -$66 | $15 | $22 | -$4 |
| 2040 | $0 | $26 | -$71 | $15 | $23 | -$7 |
| Total | -$0.1 | $206 | -$526 | $187 | $140 | $7 |

*Note: Totals may differ due to rounding

## 2. State Government

### *a. CARB Staffing and Resources*

The Proposed ACT Regulation would have a small impact on staffing resources and would require two additional Air Pollution Specialist (APS) positions responsible for administering contracts to set up the reporting systems, assisting stakeholders with inquiries, data analysis and auditing of information submitted by manufacturers and fleets, supporting ACT enforcement actions and other general implementation duties. Each position has a fully burdened cost to CARB of $180,000 in Fiscal Year (FY) 2020-2021 and $179,000 every year afterwards.

The manufacturer reporting requirement will require modifying an existing reporting system or developing a new system to handle the reporting. We are estimating a cost of $200,000 in FY2020-2021 in contracting costs to set up the manufacturer reporting system for the rule.

Similarly, the fleet and large entity reporting requirement will require modifying an existing reporting system or developing a new system to handle the reporting. We are estimating a cost of $200,000 in FY2020-2021 in contracting costs to set up the fleet reporting system for the rule.

### *b. Gasoline and Diesel Fuel Taxes*

Fuel taxes on gasoline and diesel to fund transportation improvements at the state, county, and local levels. Displacing gasoline and diesel with electricity and hydrogen will decrease the total amount of gasoline and diesel dispensed in the state. This will result in a reduction in revenue collected by the state for use in multiple levels of government. The state tax on fuel is listed in Table C-13.

### *c. Energy Resources Fee*

The Energy Resource 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 energy programs and projects deemed appropriate by the Legislature, including but not limited to, activities of the California Energy Commission.

### *d. Registration Fees*

The state collects registration fees to fund transportation improvements at the state, county, and local levels. The fee structure for zero-emission vehicles is different from diesel vehicles with some fees such as the Vehicle License Fee being higher and others such as weight fees being lower. These differences result in lower registration fees for the zero-emission vehicles. These lower fees result in reduced revenue collected by the state for use in transportation services.

### *e. State Sales Tax*

Sales taxes are levied in California to fund a variety of programs at the state and local level. This Proposed ACT Regulation will require the sale of more expensive zero-emission trucks in California which will result in higher sales tax collected by the state governments. Overall, state sales tax revenue may increase less than the direct increase from vehicle sales if overall business spending doesn’t increase.

### *f. State Fleet Cost Pass-Through*

The state government fleet is estimated to make up 2.1% of California’s fleet based on information from manufacturers and the Department of General Services. A proportionate amount of the total costs outlined in Table C-22 are assumed to pass-through to the state government.

### *g. Fiscal Impacts on State Government*

Table D-2 shows the estimated fiscal impacts to the state government due to the Proposed ACT Regulation relative to baseline conditions. The fiscal impact to local government is estimated to be -$1.4 million over the first three years of the regulation and -$2.01 billion over the regulatory lifetime.

**Table D-2. Estimated Fiscal Impacts on State Government (million 2018$)**

| Model Year | CARB Staffing and Resources | State Gasoline and Diesel Fuel Taxes | Energy Resources Fee | Registration Fee | State Sales Taxes | State Fleet Cost Pass-Through | Fiscal Impact* |
|---|---|---|---|---|---|---|---|
| 2020 | -$0.6 | $0 | $0 | $0 | $0 | $0 | -$1 |
| 2021 | -$0.4 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2022 | -$0.4 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2023 | -$0.4 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2024 | -$0.4 | -$2 | $0 | $0 | $2 | $1 | $1 |
| 2025 | -$0.4 | -$6 | $0 | $0 | $2 | $0 | -$4 |
| 2026 | -$0.4 | -$10 | $0 | $0 | $3 | $0 | -$7 |
| 2027 | -$0.4 | -$18 | $0 | -$1 | $5 | -$1 | -$15 |
| 2028 | -$0.4 | -$30 | $0 | -$1 | $7 | -$1 | -$25 |
| 2029 | -$0.4 | -$48 | $0 | -$3 | $9 | -$1 | -$43 |
| 2030 | -$0.4 | -$72 | $0 | -$6 | $10 | $1 | -$67 |
| 2031 | -$0.4 | -$95 | $0 | -$8 | $10 | $3 | -$90 |
| 2032 | -$0.4 | -$117 | $1 | -$10 | $12 | $4 | -$110 |
| 2033 | -$0.4 | -$139 | $1 | -$12 | $12 | $6 | -$132 |
| 2034 | -$0.4 | -$161 | $1 | -$15 | $13 | $8 | -$154 |
| 2035 | -$0.4 | -$182 | $1 | -$18 | $13 | $10 | -$176 |
| 2036 | -$0.4 | -$201 | $1 | -$20 | $13 | $12 | -$195 |
| 2037 | -$0.4 | -$221 | $1 | -$23 | $13 | $14 | -$216 |
| 2038 | -$0.4 | -$240 | $1 | -$26 | $13 | $15 | -$237 |
| 2039 | -$0.4 | -$257 | $1 | -$29 | $13 | $16 | -$256 |
| 2040 | -$0.4 | -$273 | $1 | -$32 | $13 | $17 | -$274 |
| Total | -$9 | -$2,072 | $10 | -$204 | $163 | $101 | -$2,011 |

*Note: Totals may differ due to rounding

## E. Macroeconomic Impacts

### 1. Methods for Determining Economic Impacts

This section describes the estimated total impact of the Proposed ACT Regulation on the California economy. The Proposed ACT Regulation will result in changes in expenditures by businesses in order to comply with its requirements. These changes in expenditures will affect employment, output, and investment in sectors that supply goods and services in support of the trucking industry and ZEVs.

These lead to additional induced effects, like changes in personal income that affect consumer expenditures across other spending categories. The incremental total economic impacts of the Proposed ACT Regulation are simulated relative to the baseline scenario using the cost data described in Section C. The analysis focuses on the incremental changes in major macroeconomic indicators from 2020 to 2040 including employment, growth, and gross state product (GSP). The years of the analysis are used to simulate the Proposed ACT Regulation through 12 months post full implementation.

Regional Economic Models, Inc. (REMI) Policy Insight Plus Version 2.2.8 is used to estimate the macroeconomic impacts of the Proposed ACT 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.[109] REMI Policy Insight Plus provides year-by-year estimates of the total impacts of the Proposed ACT Regulation, pursuant to the requirements of SB 617 and the California Department of Finance.[110,111] CARB uses the REMI single-region, 160-sector model with the model reference case adjusted to reflect the Department of Finance conforming forecasts. These forecasts include California population figures dated May 2019, U.S. real GDP forecast, and civilian employment growth numbers dated April 2019.

### 2. Inputs of the Assessment

The estimated economic impact of the Proposed ACT Regulation are 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 ACT Regulation. The direct costs estimated in Section C and the non-mortality health benefits estimated in Section B are translated into REMI policy variables and used as inputs for the macroeconomic analysis.[112]

The direct costs of the Proposed ACT Regulation, as described in Section C, include costs on manufacturers for producing the ZEVs as well as cost-savings that accrue for offsetting of a portion of Federal and California Phase 2 GHG compliance costs. While these costs are directly incurred by manufacturers, those manufacturers are not located in California; because this analysis focuses on the impacts to the California economy it is assumed here that these costs must be passed on from manufacturers to fleets in California through the price of vehicles. Additionally, the Phase 2 GHG compliance costs offset by the Proposed ACT Regulation is derived primarily from the federal regulation. If these compliance cost savings are passed through to fleets it would likely be a nationwide effect. Staff therefore make a conservative assumption, as to not overestimate the cost-savings, that the savings passed through to California fleets is proportional to California's share of the national truck population; estimated at 10%.[113] The net change in vehicle costs is input into the economic model as an increase in production costs in the truck transportation industry (NAICS 484) in California.

[109] For further information and model documentation see: https://www.remi.com/model/pi/

[110] California Legislature, Senate Bill 617, signed on October 5, 2011 (web link: http://dof.ca.gov/Forecasting/Economics/Major_Regulations/SB_617_Rulemaking_Documents/documents/Section%202000%20ISOR%201%20sb_617_bill_20111006_chaptered.pdf, last accessed June 2019)

[111] Department of Finance, Chapter 1: Standardized regulatory Impact Analysis For Major Regulations - Order of Adoption (web link http://dof.ca.gov/Forecasting/Economics/Major_Regulations/SB_617_Rulemaking_Documents/documents/Order_of_Adoption-1.pdf, last accessed June 2019)

[112] Refer to Section G: Macroeconomic Appendix for a full list of REMI inputs for this analysis.

[113] Energy Information Administration, Annual Energy Outlook 2018 (web link: https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2018&cases=ref2018&sourcekey=0, last accessed June 2019).

Fleets which use ZEVs will realize changes in production costs related to their change in fuel mix and operations and maintenance costs. Fleets will also need to make investments in infrastructure to support their use of the ZEVs, which will increase their production costs. Finally, fleets' changes in equipment, fuel, and activities will change the amount paid in federal, state, and local taxes. The total change in taxes businesses in the truck transportation industry are modeled as a reduction in production costs for the industry.

Costs and savings incurred by both manufacturers and fleets will result in corresponding changes in final demand for industries supplying those particular goods or services as shown in Table E-1. As the direct costs and cost-savings on vehicle manufacturers are incurred out of state, demand changes for the corresponding ZEV and ICE supply chain can't be directly modeled as a change in final demand in California. In order to account for this, staff estimates the share of demand which may be fulfilled be California businesses, based on California's share of national output for each industry (Electrical component mfg. and Motor vehicle parts mfg.).[114] All other changes in demand are included in this analysis. The infrastructure upgrades necessary for fleet use of ZEVs is assumed to be provided by businesses in the construction sector (NAICS 23). The electric vehicle supply equipment and maintenance is assumed to be supplied by businesses in the Other Electrical Equipment and Component Manufacturing industry (NAICS 3359). The change in demand for vehicle maintenance and midlife rebuild realized by the automotive repair and maintenance industry (NAICS 8111). The reduction in gasoline and diesel fuel demand is assumed to be incurred by the Petroleum and Coal Products manufacturing industry (NAICS 324). The increased demand for electricity and hydrogen fuel is assumed to be provided by the Electric power generation, transmission, and distribution industry (NAICS 2211) and Basic Chemical manufacturing industry (NAICS 3251), respectively. The large entity reporting and the transitional costs and workforce development are assumed to be provided by the Office administrative services (NAICS 5611, 5612) and private education services industries (NAICS 61), respectively.

**Table E-1: Sources of Changes in Production Cost and Final Demand by Industry**

| Source of Cost or Savings | Industry with changes in Production costs (NAICS) | Industries with Changes in Final Demand (NAICS) |
|---|---|---|
| Vehicle Prices | Truck Transportation (484) | *One-time cost: Electrical* component mfg.* (3353) |
| Phase 2 GHG Compliance (Costs Offset) | | *One-time cost:* Motor vehicle parts mfg.* (3363) |
| Infrastructure Upgrades | | *One-time cost:* Construction (23) |
| EVSE and maintenance | | *One-time and recurring cost:* Other electrical equipment and component mfg. (3359) |
| Vehicle maintenance and midlife rebuild | | *One-time and recurring cost:* Automotive repair and maintenance (8111) |

114 Based on REMI Policy Insight Plus (v 2.2.8), California's share of national output is 4.3% for electrical component mfg. (3353) and 2.0% for motor vehicle parts mfg. (3363) in 2018.

| | | |
|---|---|---|
| Gas and diesel fuel | | *Recurring cost:* Petroleum and Coal Products Mfg. (324) |
| Electricity | | *Recurring cost:* Electric power generation, transmission, and distribution (2211) |
| Hydrogen fuel | | *Recurring cost:* Basic Chemical manufacturing (3251) |
| Large Entity Reporting | | *One-time cost:* Office administrative services; Facilities support services (5611, 5612) |
| Transitional Costs and Workforce Training | | *Recurring costs:* Education services; private (61) |

*The Industry Sales policy variable is used here rather 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 D. The changes in fuel tax revenue change the production costs for the affected industry of truck transportation (484) and the corresponding change in government revenue is modeled as a change in state and local government spending, assuming this revenue reduction is not offset elsewhere. Additional CARB staff and resources in support of this regulation are modeled as changes in state government employment and spending. The change in federal excise tax revenue is outside the scope of the economic model and not evaluated here.

The health benefits resulting from the emission reductions of the Proposed ACT 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 $SC\text{-}CO_2$ represent the avoided damage from climate change worldwide per MT of CO2e. These benefits fall outside the scope of our economic model and are not evaluated here.

### 3. Results of the Assessment

The results from the REMI model provide estimates of the impact of the Proposed ACT Regulation on the California economy. These results represent the annual incremental change from the implementation of the Proposed ACT Regulation relative to the baseline scenario. The California economy is forecasted to grow through 2040, therefore, negative impacts reported here should be interpreted as a slowing of growth and positive impacts as an acceleration of growth resulting from the Proposed ACT Regulation. The results are reported here in tables for every five years from 2020 through 2040.

#### a. *California Employment Impacts*

Table E-2 present the impact of the Proposed ACT Regulation total employment in California across all industries. The employment impacts represent the net change in employment, which consist of positive impacts for some industries and negative impacts for others. The Proposed ACT Regulation is estimated to result in a slightly positive job impact from about

2025 to 2040. These changes in employment represent less than 0.04 percent of baseline California employment.

**Table E-2: Total California Employment Impacts**

| | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|
| **California Employment** | 24,368,647 | 25,267,147 | 26,206,546 | 27,105,799 | 27,920,649 |
| **% Change** | 0.00% | 0.00% | 0.02% | 0.02% | 0.03% |
| **Change in Total Jobs** | -2 | 725 | 4,587 | 5,607 | 8,065 |

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 E-1 and Table E-3 shows the changes in employment by industries that are directly impacted by the Proposed ACT Regulation. As the requirements of the Proposed ACT Regulation go into effect the industries generally realizing reductions in production cost or increases in final demand see an increase in employment growth. This includes the truck transportation, construction, and manufacturing sectors and upstream industries. The largest decrease in employment results from the public sector, which is estimated to realize a decrease in fuel and sales tax revenue and registration fees. The oil and gas extraction industry and automotive repair and maintenance industry see a decreased employment growth rate due to a reduction in final demand for their goods and services.

**Figure E-1: Job Impacts by Major Sector**

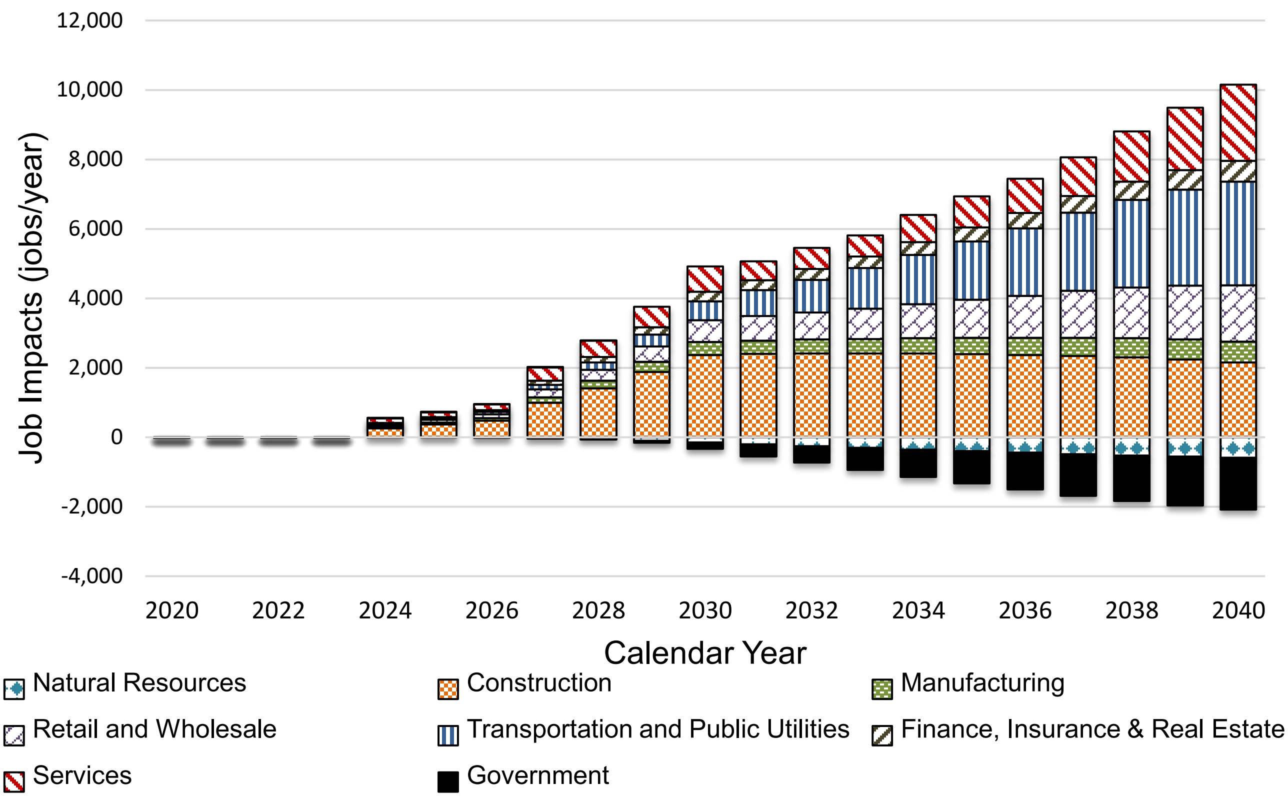


**Table E-3: Job Impacts by Primary and Secondary Industries**

| | | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| Truck transportation (484) | % Change | 0.00% | 0.00% | 0.10% | 0.42% | 0.82% |
| | Change in Jobs | -2 | 10 | 235 | 973 | 1,929 |
| Electric power generation, transmission and distribution (2211) | % Change | 0.00% | 0.04% | 0.42% | 0.96% | 1.28% |
| | Change in Jobs | 0 | 16 | 181 | 422 | 568 |
| Construction (23) | % Change | 0.00% | 0.03% | 0.21% | 0.21% | 0.18% |
| | Change in Jobs | -2 | 364 | 2,368 | 2,398 | 2,159 |
| Other electrical equipment and component manufacturing (3359) | % Change | 0.00% | 0.18% | 1.33% | 1.48% | 1.49% |
| | Change in Jobs | 0 | 28 | 196 | 213 | 211 |
| Petroleum and coal products manufacturing (324) | % Change | 0.00% | -0.04% | -0.46% | -1.07% | -1.42% |
| | Change in Jobs | 0 | -5 | -56 | -129 | -170 |
| Basic chemical manufacturing (3251) | % Change | 0.00% | 0.00% | 0.01% | 0.02% | 0.03% |
| | Change in Jobs | 0 | 0 | 1 | 1 | 2 |
| Office administrative services; Facilities support services (5611, 5612) | % Change | 0.02% | 0.00% | 0.01% | 0.01% | 0.02% |
| | Change in Jobs | 14 | 1 | 9 | 14 | 25 |
| Educational services; private (61) | % Change | 0.00% | 0.00% | 0.02% | 0.01% | 0.02% |
| | Change in Jobs | 0 | 22 | 119 | 86 | 131 |
| Automotive repair and maintenance (8111) | % Change | 0.00% | -0.03% | -0.30% | -0.56% | -0.49% |
| | Change in Jobs | 0 | -55 | -645 | -1,212 | -1,061 |
| State & Local Government | % Change | 0.00% | 0.00% | -0.01% | -0.04% | -0.06% |
| | Change in Jobs | -2 | 18 | -184 | -928 | -1,498 |

b. ***California Business Impacts***

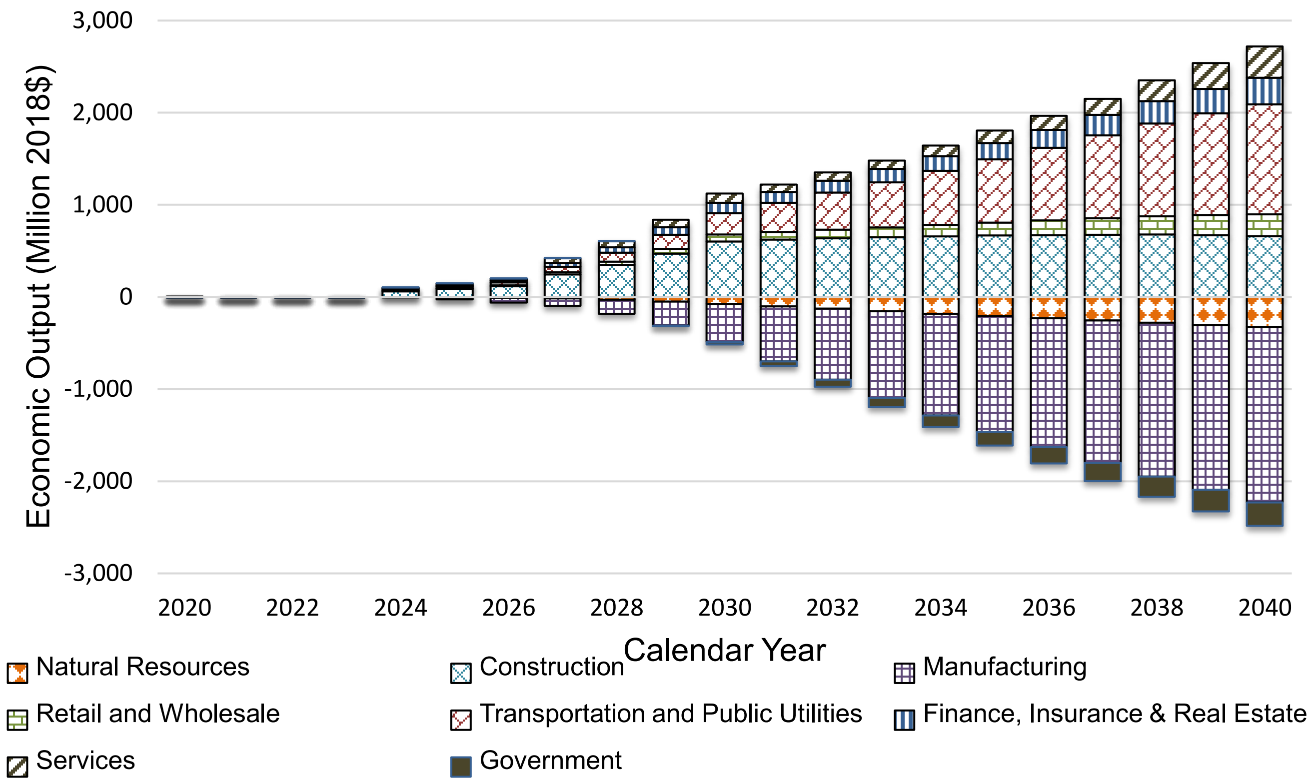
Gross output is used as a measure for business impacts because as it represents an industry's sales or receipts and tracks the quantity of goods or services produced in a given time period. Output growth is the sum of output in each private industry and State and local government as it contributes to 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 ACT Regulation show an increase in output of $639 million in 2030 and an increase of $785 million in 2040 as shown in Table E-4. The trend in output changes is illustrated by major sector in Figure E-2. Similar to the employment impacts, there are positive impacts on output for transportation, public utilities, and construction and negative impacts on oil and gas extraction, automotive repair and maintenance, and the public sector. The negative output impact on manufacturing is primarily driven by the petroleum and coal products manufacturing industry, which is estimated to see a relatively large decrease in final demand for gasoline and diesel.

## Table E-4: Change in California Output Growth by Industry

| | | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| California Economy | Output (2018M$) | 4,602,716 | 5,031,749 | 5,482,557 | 6,057,456 | 6,759,388 |
| | % Change | 0.00% | 0.00% | 0.01% | 0.01% | 0.01% |
| | Change (2018M$) | -1 | 114 | 639 | 496 | 785 |
| State & Local Government | % Change | 0.00% | 0.00% | -0.01% | -0.04% | -0.06% |
| | Change (2018M$) | 0 | 3 | -32 | -169 | -285 |
| Truck transportation (484) | % Change | 0.00% | 0.00% | 0.10% | 0.42% | 0.83% |
| | Change (2018M$) | 0 | 2 | 49 | 221 | 485 |
| Electric power generation, transmission and distribution (2211) | % Change | 0.00% | 0.04% | 0.42% | 0.97% | 1.29% |
| | Change (2018M$) | 0 | 12 | 140 | 347 | 501 |
| Construction (23) | % Change | 0.00% | 0.03% | 0.22% | 0.22% | 0.19% |
| | Change (2018M$) | 0 | 64 | 444 | 491 | 487 |
| Petroleum and coal products manufacturing (324) | % Change | 0.00% | -0.04% | -0.46% | -1.07% | -1.43% |
| | Change (2018M$) | 0 | -33 | -423 | -1,102 | -1,669 |
| Other electrical equipment and component manufacturing (3359) | % Change | 0.00% | 0.18% | 1.34% | 1.50% | 1.52% |
| | Change (2018M$) | 0 | 10 | 72 | 83 | 88 |
| Basic chemical manufacturing (3251) | % Change | 0.00% | 0.00% | 0.01% | 0.02% | 0.03% |
| | Change (2018M$) | 0 | 0 | 4 | 8 | 13 |
| Office administrative services; Facilities support services (5611, 5612) | % Change | 0.02% | 0.00% | 0.01% | 0.01% | 0.02% |
| | Change (2018M$) | 2 | 0 | 1 | 2 | 4 |
| Educational services; private (61) | % Change | 0.00% | 0.00% | 0.02% | 0.01% | 0.02% |
| | Change (2018M$) | 0 | 2 | 10 | 7 | 12 |
| Automotive repair and maintenance (8111) | % Change | 0.00% | -0.03% | -0.30% | -0.57% | -0.51% |
| | Change (2018M$) | 0 | -6 | -71 | -139 | -128 |

**Figure E-2: Change in California Economic Output by Major Sector**




### c. *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 ACT Regulation are shown in Table E-5 and show an increase of private investment of about $175 million in 2030 and $425 million in 2040, or less than 0.01 percent of baseline investment.

**Table E-5: Change in Gross Domestic Private Investment Growth**

| | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|
| Private Investment (2018M$) | 464,563 | 499,173 | 534,917 | 587,262 | 641,970 |
| % Change | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Change (2018M$) | -1 | 22 | 175 | 307 | 425 |

### d. *Impacts on Individuals in California*

The Proposed ACT Regulation will impose no direct costs on individuals in California. However, the costs incurred by affected businesses and the public sector will cascade through the economy and affect individuals.

One measure of this impact is the change in real personal income. Table E-6 shows annual change in real personal income across all individuals in California. Total personal income growth increases by about $470 million in 2030 and $1.40 billion in 2040 as a result of the Proposed ACT Regulation, representing about 0.01 percent of the baseline. 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 increase in personal income growth is estimated to be about $6 per person in 2030 and $11 per person in 2040.

**Table E-6: Change in Personal Income Growth**

| | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|
| Personal Income (2018M$) | 2,483,138 | 2,786,816 | 3,102,269 | 3,439,395 | 3,826,616 |
| % Change | 0.00% | 0.00% | 0.02% | 0.02% | 0.04% |
| Change (2018M$) | -2 | 54 | 470 | 859 | 1,397 |
| Personal Income per capita (2018$) | 61,362 | 66,247 | 71,102 | 76,213 | 82,320 |
| % Change | 0.00% | 0.00% | 0.01% | 0.01% | 0.01% |
| Change (2018$) | 0 | 1 | 6 | 8 | 11 |

e. ***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 used to gauge the health of an economy. Under the Proposed ACT Regulation, GSP growth is anticipated to increase by about $438 million in 2030 and decrease by $670 million in 2040 as shown in Table E-7. These changes do not exceed 0.01 percent of baseline GSP.

**Table E-7: Change in Gross State Product**

| | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|
| GSP (2018M$) | 2,787,689 | 2,905 | 3,160 | 3,459 | 3,797 |
| % Change | 0.00% | 0.00% | 0.01% | 0.01% | 0.02% |
| Change (2018M$) | 0 | 72 | 438 | 451 | 670 |

f. ***Creation or Elimination of Businesses***

The REMI model cannot directly estimate the creation or elimination of businesses. 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 ACT Regulation are very small relative to the total California economy, representing changes of less than 0.01 percent. However, impacts to specific industries are larger as described in previous sections. The trend of in decreasing production costs for the truck transportation industry has the potential to result in an expansion or increases in businesses in this industry if sustained over time. While, the decreasing trend in demand for gasoline and diesel fuel following from this Proposed ACT Regulation has the potential to result in a decrease in businesses in this industry if sustained over time.

g. ***Incentives for Innovation***

Staff are proposing incentives for early ZEV sales by allowing credits to be generated from ZEV sales starting in 2021 MY, 3 years prior to the beginning requirements in 2024 MY. Staff anticipates growth in industries that manufacture ZEV technologies, including first and second tier suppliers for manufacturers of ZEVs, which will strengthen the supply chain, and promote technology improvements earlier than they would have otherwise occurred. This growth will help foster and support a self-sustaining medium- and heavy-duty ZEV market.

h. ***Competitive Advantage or Disadvantage***

The Proposed ACT Regulation imposes a sales mandate on large truck manufacturers. These truck manufacturers are headquartered and produce vehicles entirely out-of-state for a national and international market. There are small manufacturing entities in- and out-of-state that would not be required to sell ZEVs in California. Any risk of creating a competitive advantage is mitigated by the 500 vehicle sales threshold. Any small manufacturer that is able to increase sales would become subject to the same ZEV requirements as other large manufacturers.

Early credit generation incentives are proposed to benefit all manufacturing entities, and therefore would not give an explicit competitive advantage or disadvantage to competing manufacturers.

## 4. Summary and Agency Interpretation of the Assessment Results

The results of the macroeconomic analysis of the Proposed ACT Regulation are summarized in Table E-8. As analyzed here, CARB estimates the Proposed ACT 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 0.03 percent of the baseline. The Proposed ACT Regulation results in increased growth in the truck transportation industry in California as fuel savings and LCFS credit generation from the use of ZEVs grow over time. The fuel savings for the truck transportation industry represent decreased demand for gasoline and diesel from the industry, implying a decrease in growth for the industry. This analysis also shows the negative impact estimated for state and local government output and employment due to tax revenue decreases, without any offsetting revenues.

**Table E-8: Summary of Macroeconomic Impacts of Proposed ACT Regulation**

| | | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| **GSP** | % Change | 0.00% | 0.00% | 0.01% | 0.01% | 0.02% |
| | Change (2018M$) | 0 | 72 | 438 | 451 | 670 |
| **Personal Income** | % Change | 0.00% | 0.00% | 0.02% | 0.02% | 0.04% |
| | Change (2018M$) | -2 | 54 | 470 | 859 | 1,397 |
| **Employment** | % Change | 0.00% | 0.00% | 0.02% | 0.02% | 0.03% |
| | Change in Jobs | -2 | 725 | 4,587 | 5,607 | 8,065 |
| **Output** | % Change | 0.00% | 0.00% | 0.01% | 0.01% | 0.01% |
| | Change (2018M$) | -1 | 114 | 639 | 496 | 785 |
| **Private Investment** | % Change | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |

| | Change (2018M$) | -1 | 22 | 175 | 307 | 425 |
|---|---|---|---|---|---|---|

## F. Alternatives

### 1. Alternative 1

Alternative 1 is a less stringent ZEV sales requirement than the Proposed ACT Regulation and would apply to the same manufacturers. Under this alternative, three percent of regulated manufacturer sales would need to be ZEVs in Class 2B-7 ramping up to 15 percent in 2030. Class 2B-3 pickup trucks and all Class 8 vehicles would be excluded from the ZEV sales requirement. This alternative would result in fewer ZEV sales compared to the Proposed ACT Regulation, but more ZEVs compared to the baseline scenario. Alternative 1 is based on the original ACT rule proposal presented in April 2017.[115] Table F-1 summarizes the ZEV sales percentage requirements of Alternative 1.

**Table F-1. Alternative 1 ZEV Sales Requirement**

| Model Year | Class 2B-3* | Class 4-7 | Class 8 |
|---|---|---|---|
| 2024 | 3% | 3% | 0% |
| 2025 | 5% | 5% | 0% |
| 2026 | 7% | 7% | 0% |
| 2027 | 9% | 9% | 0% |
| 2028 | 11% | 11% | 0% |
| 2029 | 13% | 13% | 0% |
| 2030 and beyond | 15% | 15% | 0% |

*Pickups excluded

Table F-2 shows the assumptions for vehicle groups in the baseline scenario and Alternative 1. The main difference between the assumptions for Alternative 1 and the Proposed ACT Regulation is Alternative 1 does not assume any long range BEVs need to be sold in Class 4-5 and Class 6-7 during the analysis period. Due to the reduced ZEV sales percentage requirements on the manufacturer, they would not need to sell more expensive long range vehicles to meet their requirement.

**Table F-2. Alternative 1 Vehicle Groups and Technologies**

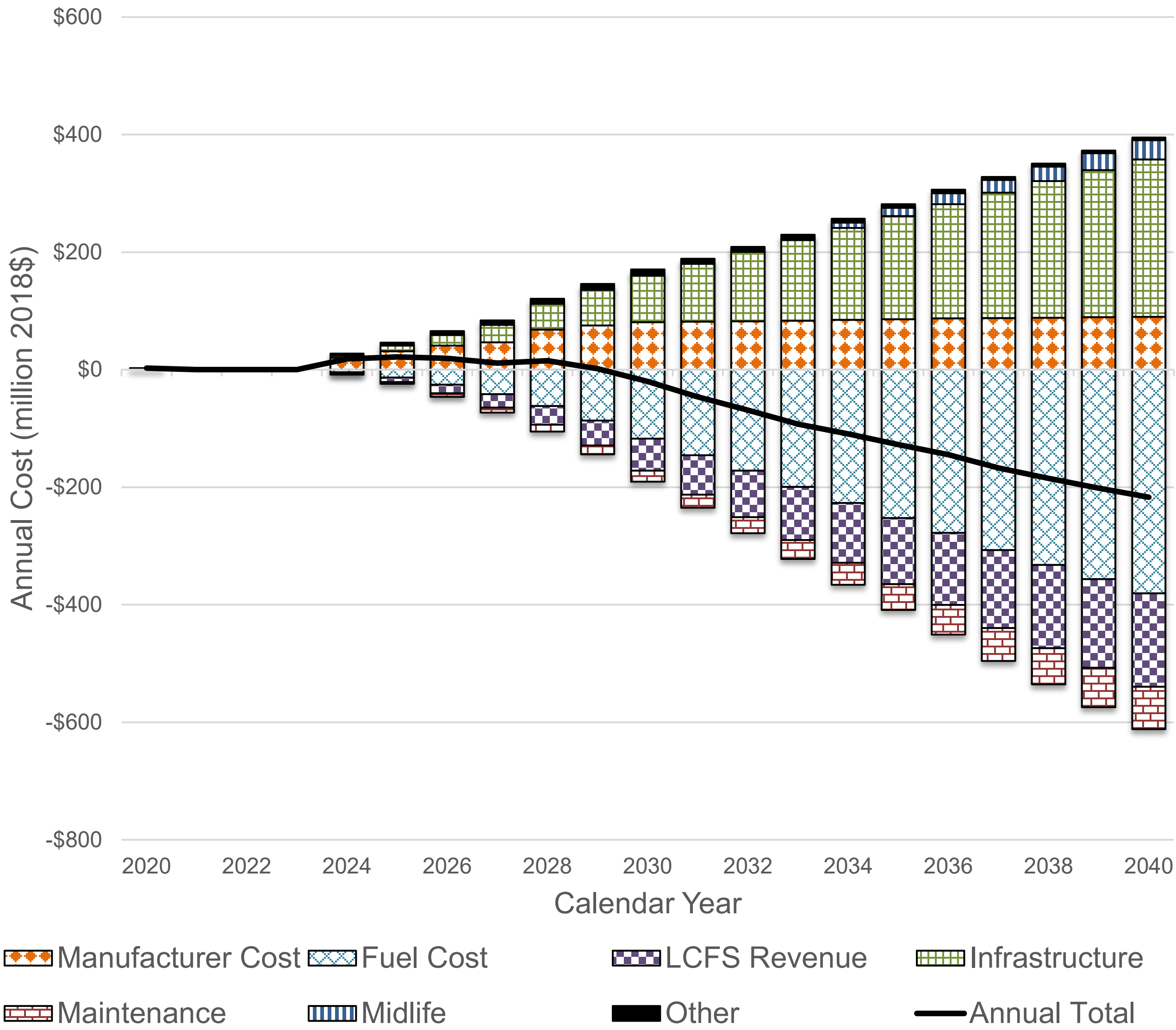
| Vehicle Group | Baseline Scenario | Proposal Scenario |
|---|---|---|
| Class 2B-3 | Gasoline (43%)<br>Diesel (57%) | Battery-electric<br>(All normal range) |
| Class 4-5 | Diesel | Battery-electric<br>(All normal range) |
| Class 6-7 | Diesel | Battery-electric<br>(All normal range) |
| Class 7 Tractor | Diesel | Battery-electric (90%)<br>Fuel Cell Electric (10%) |

[115] California Air Resources Board, Advanced Clean Trucks Workshop (web link: https://ww2.arb.ca.gov/sites/default/files/2018-10/170425workshoppresentation.pdf, last accessed June 2019).

a. ***Costs***

Alternative 1 would increase the number of ZEVs sold in California relative to the baseline, but would not deploy as many ZEVs as the Proposed ACT Regulation. This will result in lower costs to California compared to the baseline but increased costs compared to the Proposed ACT Regulation. The cost to the California economy when assuming all costs occur in California would be -$1.3 billion between 2020 and 2040 in Alternative 1 versus the baseline scenario, versus a cost of -$4.8 billion between 2020 and 2040 in the Proposed ACT Regulation versus the baseline. Figure F-1 illustrates the difference in cost between Alternative 1 and the baseline scenario.

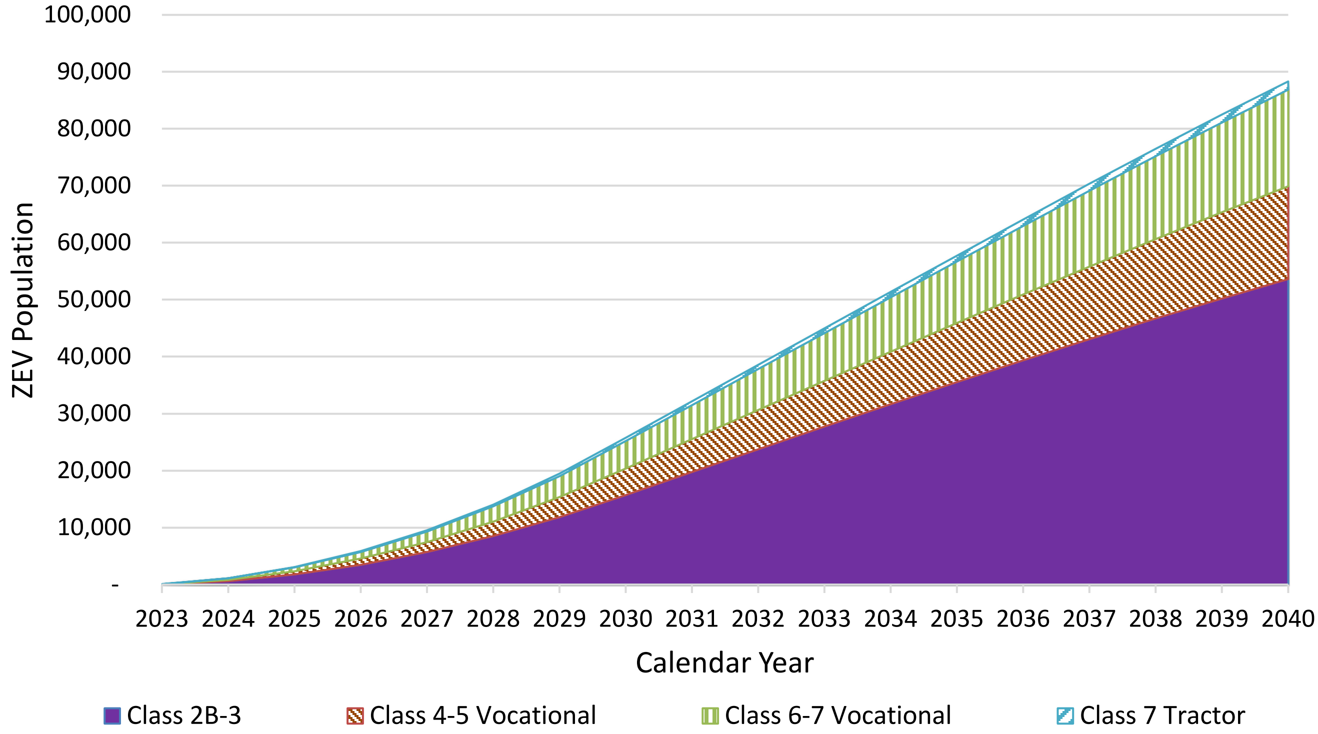
**Figure F-1. Alternative 1 Costs Compared to Baseline**



b. ***Benefits***

Alternative 1 results in more ZEVs deployed than the baseline scenario providing NOx and $PM_{2.5}$ emission reductions, but less total ZEVs than the Proposed ACT Regulation. Figure F-2 illustrates the ZEV population over time under Alternative 1.

**Figure F-2. Alternative 1 ZEV Population Forecast over Time (>8,500 lb. GVWR)**




i. **Emission Benefits**

The ZEVs deployed as a result of Alternative 1 provides NOx and $PM_{2.5}$ benefits compared to the baseline scenario, but results in fewer NOx, $PM_{2.5}$, and GHG benefits compared to the Proposed ACT Regulation. This alternative does not provide any additional GHG emission reductions compared to the baseline because all the required ZEV sales are assumed to be counted towards Phase 2 GHG compliance meaning this alternative does not achieve any additional GHG emissions benefits. Table F-3 summarizes the expected annual NOx, $PM_{2.5}$, and $CO_2$ reductions in Alternative 1 in 2031 and 2040when compared to the baseline.

**Table F-3. Alternative 1 NOx, GHG, and $PM_{2.5}$ Benefits Relative to Baseline**

| Calendar Year | NOx (tpd) | $PM_{2.5}$ (tpd) | $CO_2$ (MMT/yr) |
|---|---|---|---|
| 2031 | 1.3 | 0.05 | 0 |
| 2040 | 3.5 | 0.14 | 0 |

Figure F-3, Figure F-4, and Figure F-5 show the difference in GHG, NOx, and $PM_{2.5}$ emissions between baseline, Alternative 1, and the Proposed ACT Regulation.

**Figure F-3. Projected GHG Emissions under Baseline, Proposed ACT Regulation, and Alternative 1**

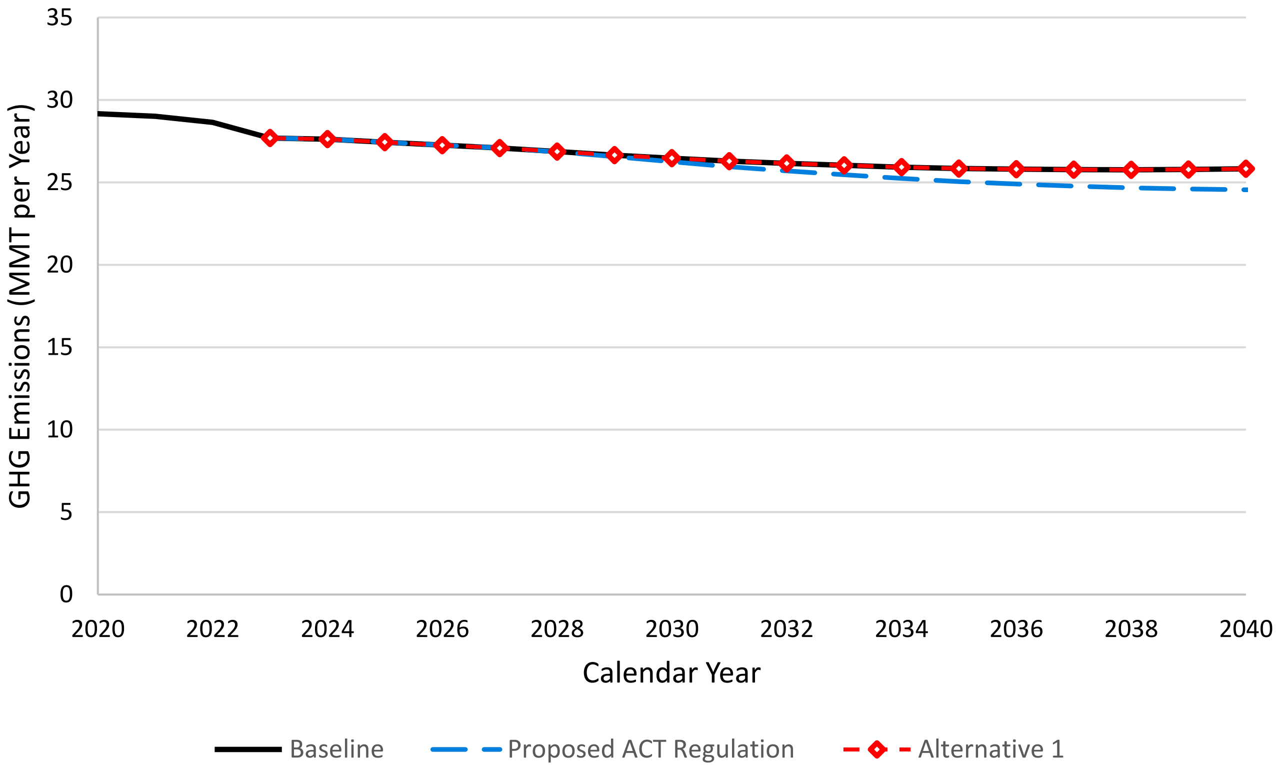



**Figure F-4. Projected NOx Emissions under Baseline, Proposed ACT Regulation, and Alternative 1**

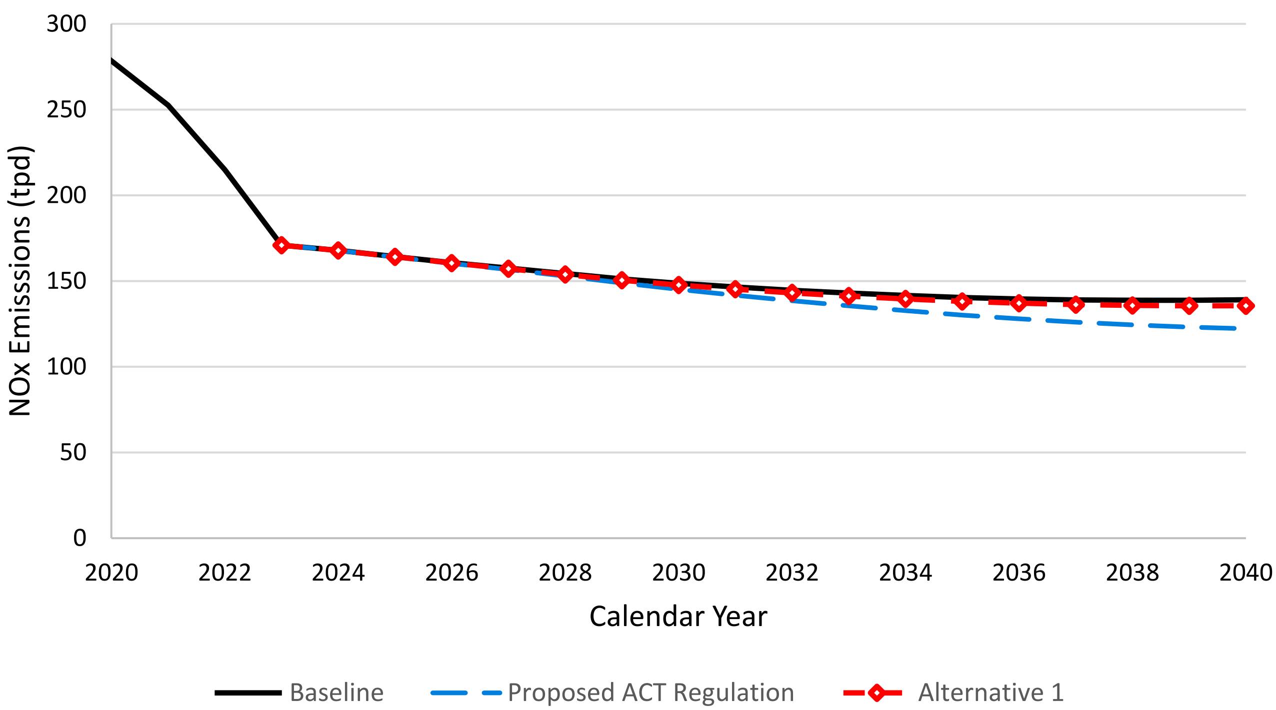
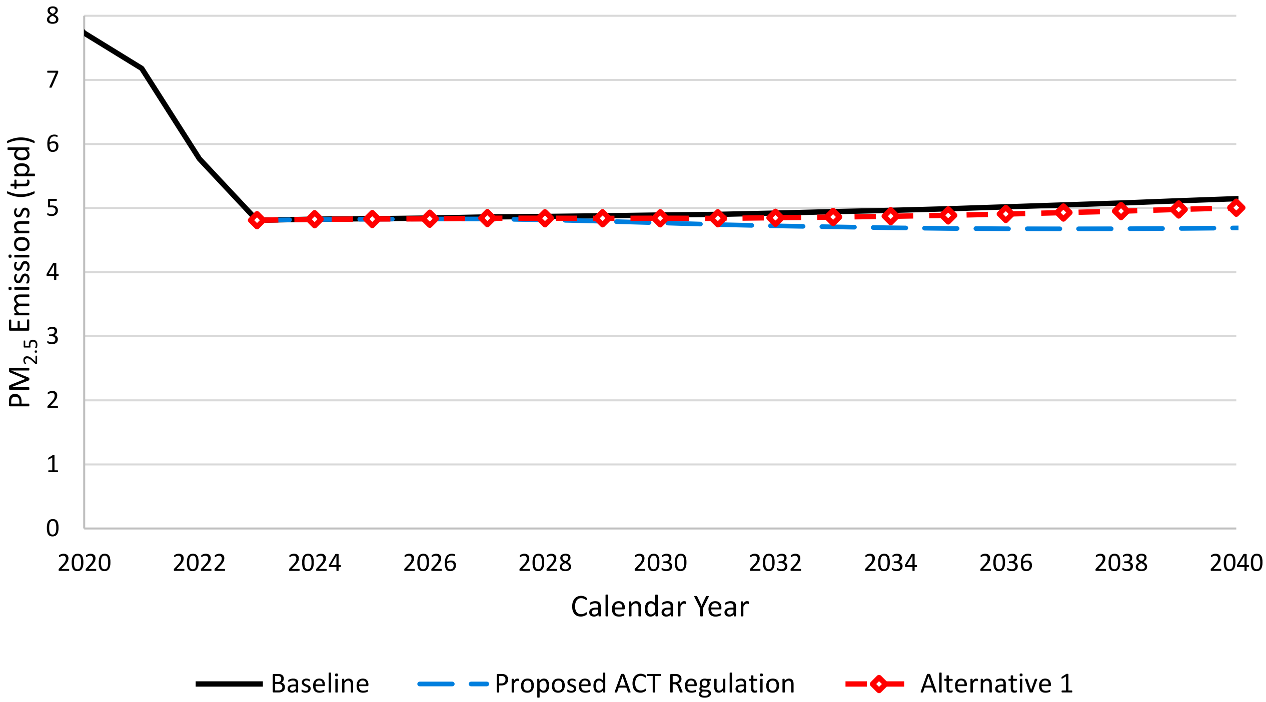


**Figure F-5. Projected $PM_{2.5}$ Emissions under Baseline, Proposed ACT Regulation, and Alternative 1**




### ii. Health Benefits

Alternative 1 results in emission reductions relative to the baseline leading to health benefits as shown in Table F-4. The health benefits are less than those of the Proposed ACT Regulation (Table B-6) due to less emission reductions estimated for this alternative.

**Table F-4. Statewide Valuation from Avoided Health Outcomes for Alternative 1**

| Outcome | Avoided Incidents | Valuation (Million 2018$) |
|---|---|---|
| Avoided Premature Mortality | 157 | $1,483.1 |
| Avoided Cardiovascular Hospitalizations | 25 | $1.4 |
| Avoided Acute Respiratory Hospitalizations | 30 | $1.5 |
| Avoided Emergency Room Visits | 77 | $0.1 |
| **Total** | | **$1,486** |

### c. *Economic Impacts*

Alternative 1 imposes a less stringent ZEVs sales requirement compared to the Proposed ACT Regulation. This results in lower incremental vehicle cost as passed-through to fleets, but also less Phase 2 GHG cost offsets and lower fuel savings. The macroeconomic impact analysis results are qualitatively similar to the results of the Proposed ACT Regulation, but of a smaller magnitude as shown in Table F-5. Figure F-6 and Figure F-7 show the job and economic impact changes of Alternative 1, respectively.

**Table F-5: Change in Growth of Economic Indicators for Alternative 1 Relative to Baseline**

| | | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| **GSP** | % Change | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% |
| | Change (2018M$) | 0 | 51 | 137 | 152 | 195 |
| **Personal Income** | % Change | 0.00% | 0.00% | 0.01% | 0.01% | 0.01% |
| | Change (2018M$) | -2 | 36 | 158 | 274 | 412 |
| **Employment** | % Change | 0.00% | 0.00% | 0.01% | 0.01% | 0.01% |
| | Change in Jobs | -2 | 513 | 1,498 | 1,842 | 2,317 |
| **Output** | % Change | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| | Change (2018M$) | -1 | 83 | 190 | 171 | 221 |
| **Private Investment** | % Change | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| | Change (2018M$) | -1 | 14 | 60 | 96 | 122 |

**Figure F-6: Job Impacts of Alternative 1 by Major Sector**

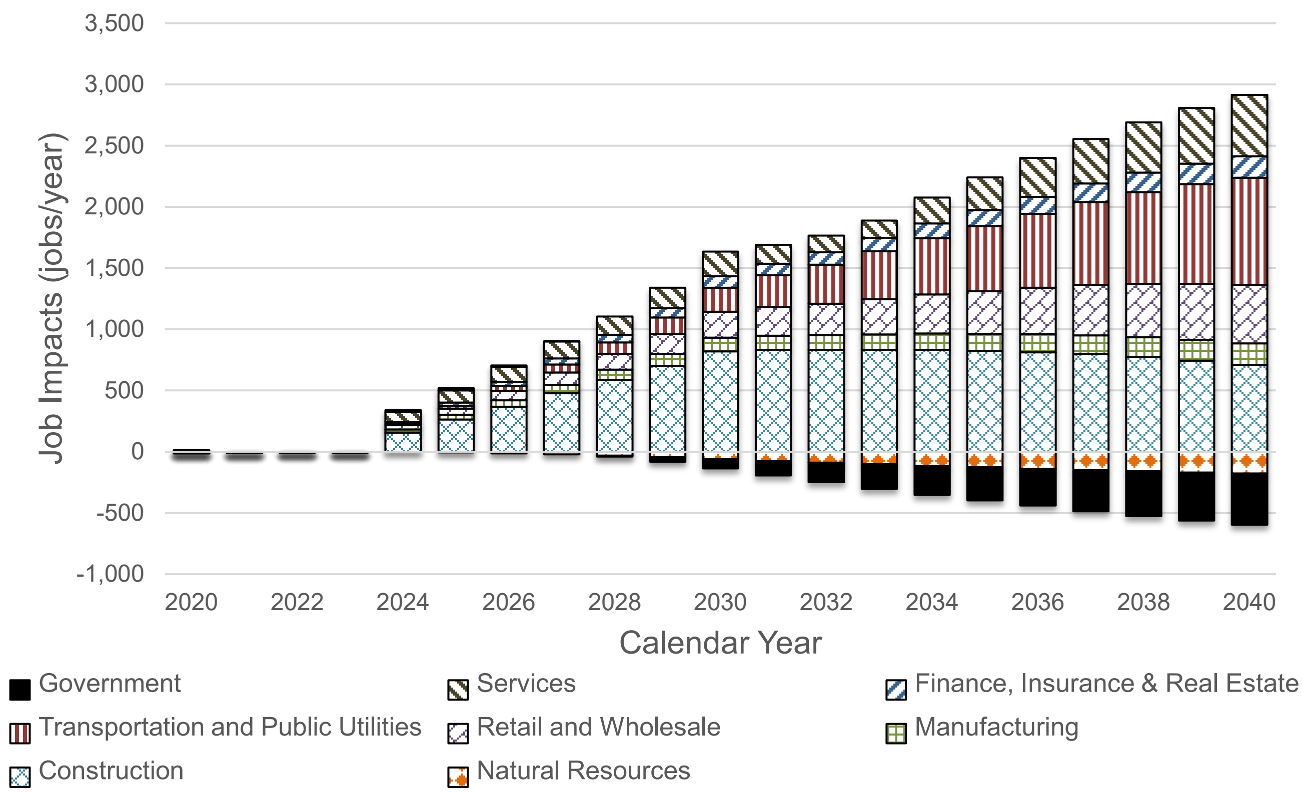
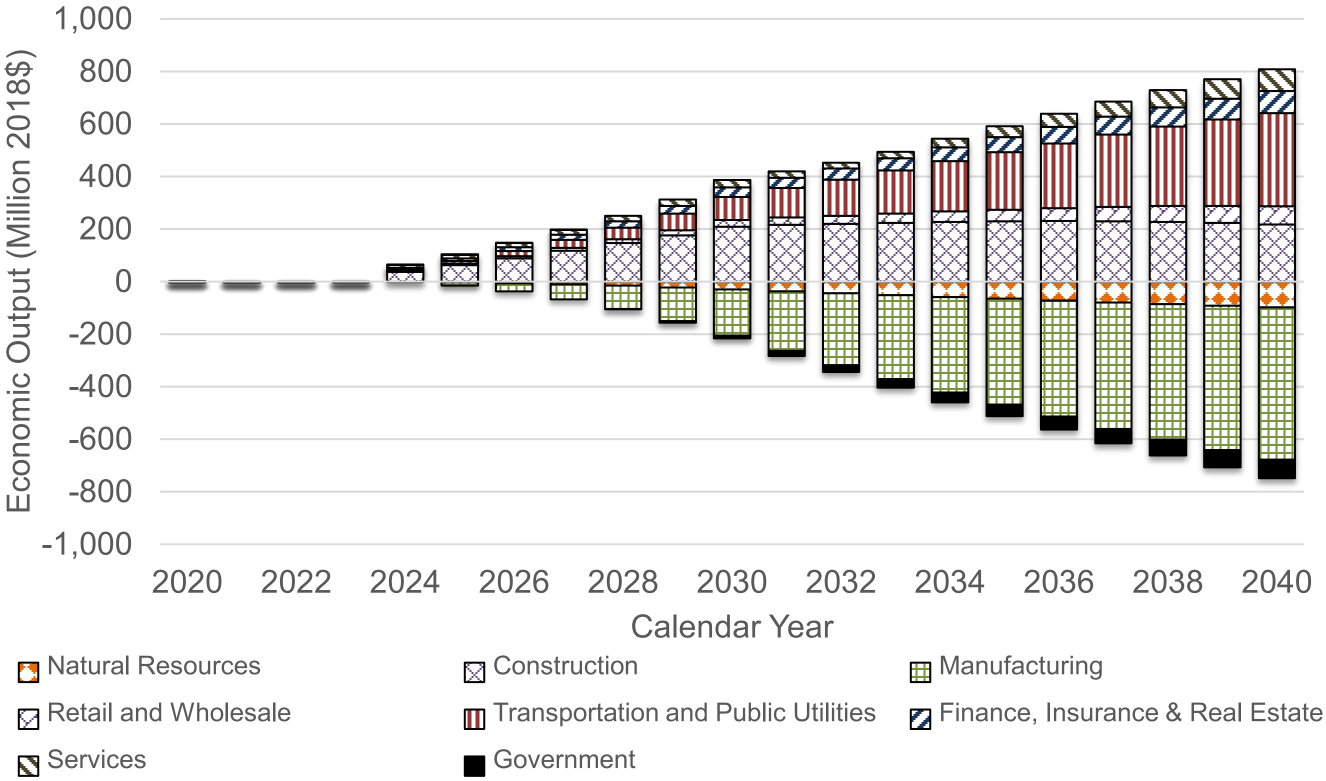


**Figure F-7: Changes in Economic Output from Alternative 1 by Major Sector**




### d. ***Cost-Effectiveness***

Cost-effectiveness is defined as the cost to achieve a ton of emission reduction. In the case of Alternative 1, the total cost from 2024 to 2040 is higher (lower net savings) than the proposed ACT regulation and would achieve less emission reductions. Alternative 1 is a less cost-effective alternative compared to the proposed ACT regulation.

### e. ***Reason for Rejecting***

Alternative 1 is rejected because it fails to maximize the number of ZEVs deployed, does not maximize NOx, $PM_{2.5}$, and GHG reductions, and does not adequately foster ZEV market development in California. The Proposed ACT Regulation is identified as a technology-forcing 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 and achieve the state's climate protection goals.

Alternative 1 does not maximize the number of ZEVs deployed in California as it requires a low amount of ZEVs to be produced and excludes both Class 2B-3 pickup trucks and all Class 8 vehicles. 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 as its requirements do not exceed the standards already set by Phase 2 GHG, failing to meet the goals of the Climate Change Scoping Plan.

## 2. Alternative 2

Alternative 2 is a more stringent ZEV sales requirement than the Proposed ACT Regulation and would apply to the same manufacturers. Under this alternative, 15 percent of regulated manufacturer sales would need to be ZEVs in Class 2B-8 ramping up to 40 percent in 2030. Unlike the proposal and Alternative 1, no vehicle types are excluded from the ZEV sales requirement in this scenario. This alternative was proposed by Earthjustice, Union of Concerned Scientists, and Sierra Club in a letter to CARB on March 25th, 2019.[116] Alternative 2 would result in greater zero-emission vehicle sales compared to the baseline and Proposed ACT Regulation.

Table F-6 summarizes the ZEV sales percentage requirements of Alternative 1.

**Table F-6. Alternative 2 ZEV Sales Requirement**

| Model Year | Class 2B-8 |
|---|---|
| 2024 | 15% |
| 2025 | 20% |
| 2026 | 24% |
| 2027 | 28% |
| 2028 | 32% |
| 2029 | 36% |
| 2030 and beyond | 40% |

Table F-7 shows the assumptions for vehicle groups in the baseline scenario and Alternative 2. The main difference between the assumptions for Alternative 2 and the Proposed ACT Regulation is Alternative 2 assumes long range BEVs need to be sold in Class 2B-3 and more fuel cell vehicles would need to be sold in Class 7-8 tractors. Due to the increased ZEV sales percentage requirements on the manufacturer, they would need to sell more capable and expensive longer range vehicles to meet their requirement.

**Table F-7. Vehicle Groups and Technologies**

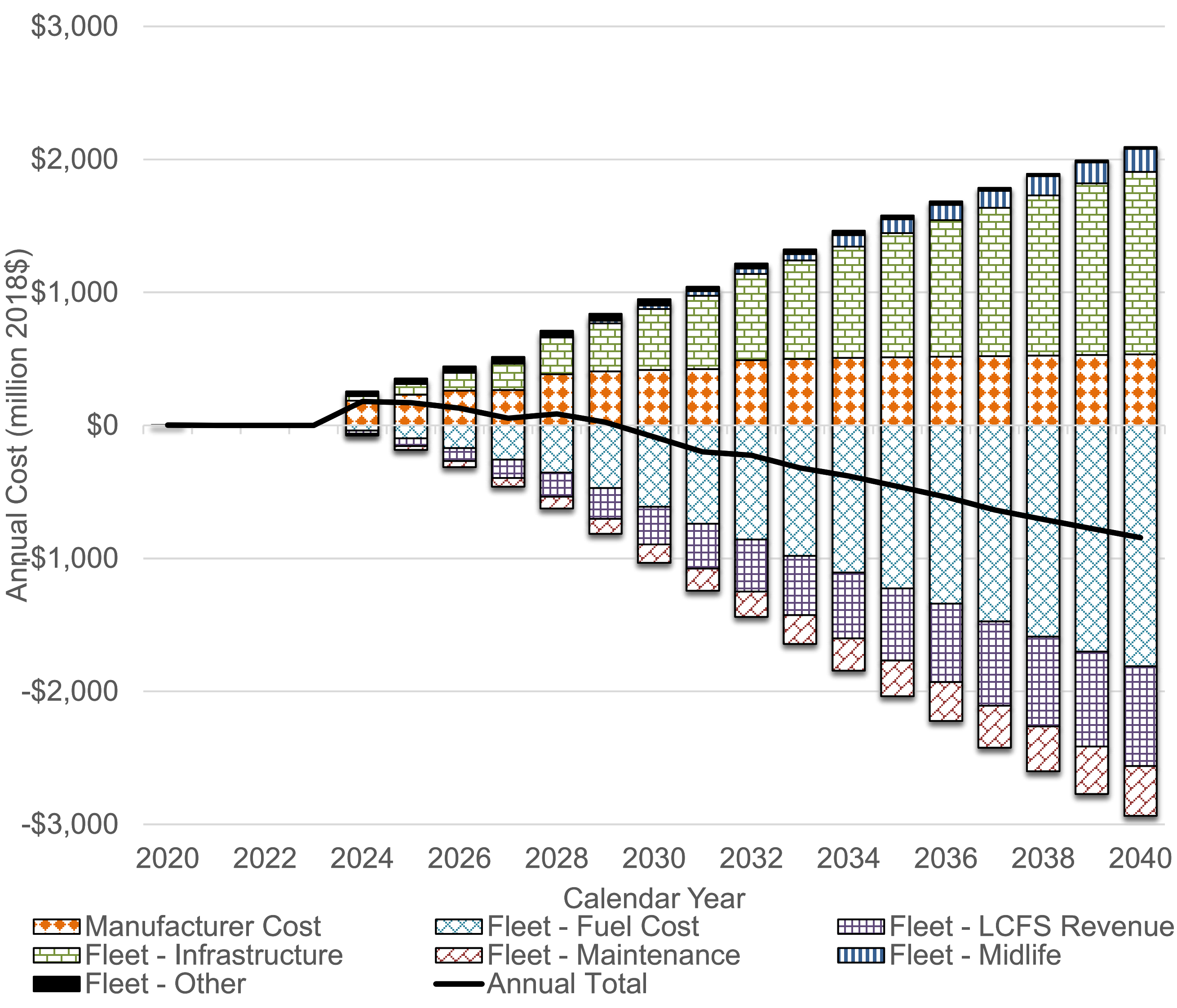
| Vehicle Group | Baseline Scenario | Proposal Scenario |
|---|---|---|
| Class 2B-3 | Gasoline (43%)<br>Diesel (57%) | Battery-electric<br>(50% long range after 2030) |
| Class 4-5 | Diesel | Battery-electric<br>(50% long range after 2030) |
| Class 6-7 | Diesel | Battery-electric<br>(50% long range after 2030) |
| Class 8 | Diesel | Battery-electric<br>(50% long range after 2030) |
| Class 7-8 Tractor | Diesel | Battery-electric (75%)<br>Fuel Cell Electric (25%) |

[116] Cort, Paul; O'Dea, Jimmy; Pingle, Ray, Advanced Clean Truck Rulemaking, 2019.

### a. ***Costs***

Alternative 2 would increase the number of ZEVs sold in California relative to the baseline and the Proposed ACT Regulation. This will result in lower costs to California compared to the baseline and the Proposed ACT Regulation. The cost to the California economy when assuming all costs occur in California would be -$4.5 billion between 2020 and 2040 in Alternative 2 versus the baseline scenario, versus a cost of -$4.8 billion between 2020 and 2040 in the Proposed ACT Regulation versus the baseline. Figure F-8 illustrates the difference in cost between Alternative 2 and the baseline scenario.

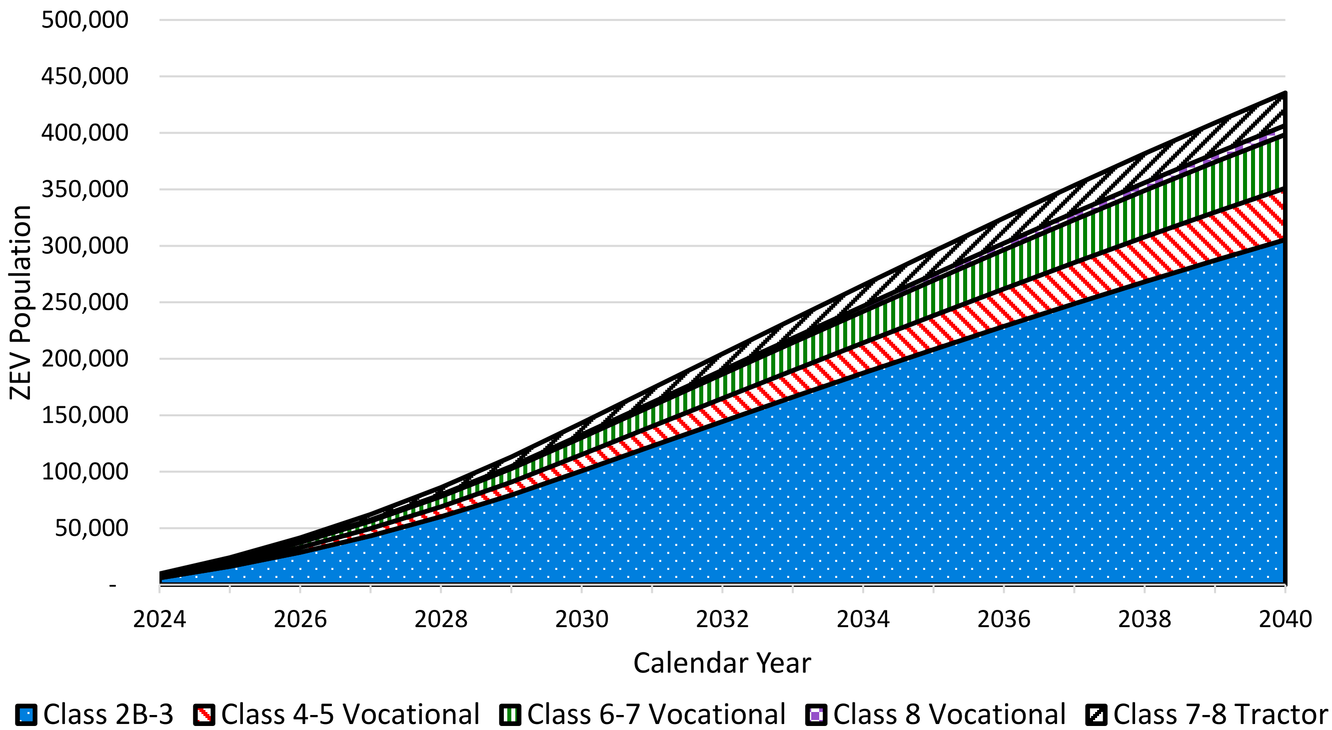
**Figure F-8. Alternative 2 Costs Compared to Baseline**



### b. ***Benefits***

Alternative 2 results in more ZEVs deployed than the baseline scenario and the Proposed ACT Regulation providing NOx, $PM_{2.5}$ and GHG emission reductions. Figure F-9 illustrates the ZEV population over time under Alternative 2.

**Figure F-9. Alternative 2 ZEV Population Forecast over Time (>8,500 lb. GVWR)**




#### i. Emission Benefits

Alternative 2 results in greater ZEV deployments compared to the baseline scenario and the Proposed ACT Regulation. These ZEVs will provide NOx, $PM_{2.5}$ and $CO_2$ benefits compared to both the baseline scenario and the Proposed ACT Regulation. Table F-8 summarizes the expected annual NOx, $PM_{2.5}$, and $CO_2$ benefits in Alternative 2 in 2031 and 2040.

**Table F-8. Alternative 2 NOx, GHG, and $PM_{2.5}$ Benefits Relative to Baseline**

| Calendar Year | NOx (tpd) | $PM_{2.5}$ (tpd) | $CO_2$ (MMT/yr) |
|---|---|---|---|
| 2031 | 8.7 | 0.32 | 1.16 |
| 2040 | 22.6 | 0.70 | 2.78 |

Figure F-10, Figure F-11, and Figure F-12 represent the difference in GHG, NOx, and $PM_{2.5}$ emissions between baseline and Alternative 2.

**Figure F-10. Projected GHG Emissions under Baseline, Proposed ACT Regulation, and Alternative 2**

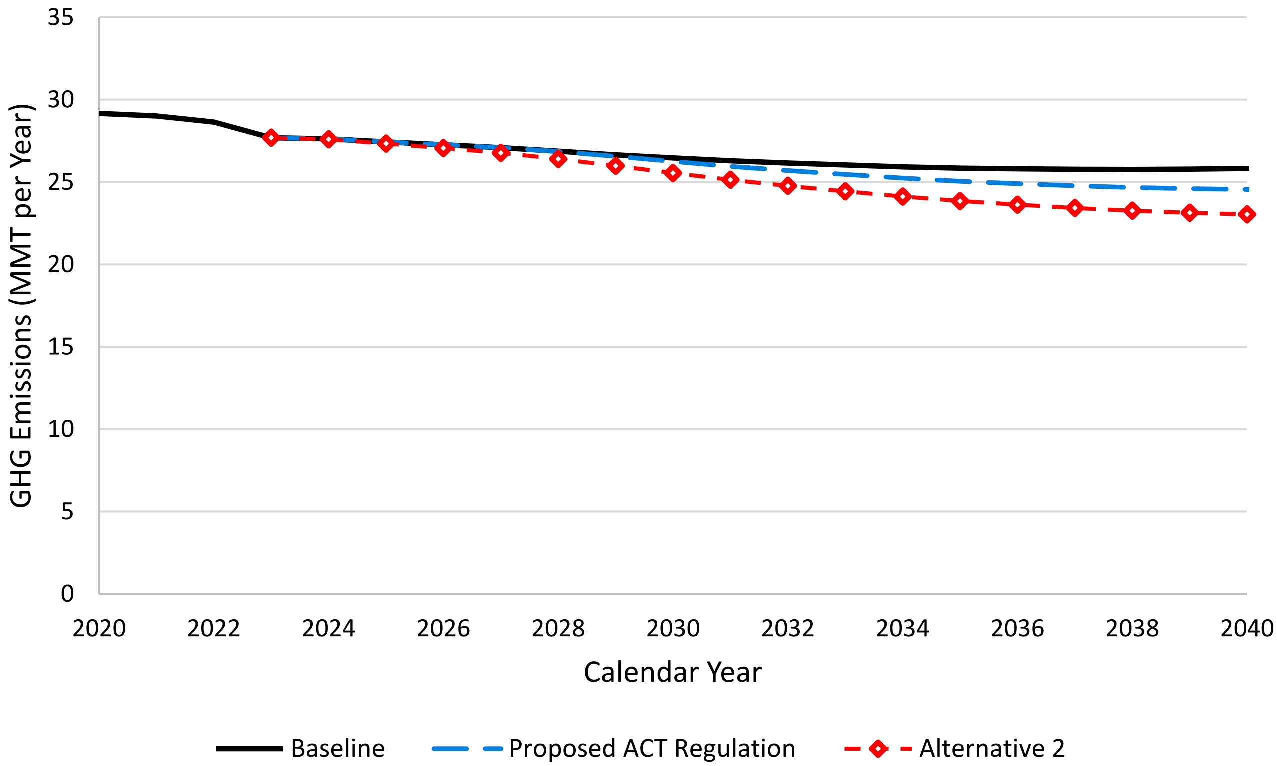



**Figure F-11. Projected NOx Emissions under Baseline, Proposed ACT Regulation, and Alternative 2**

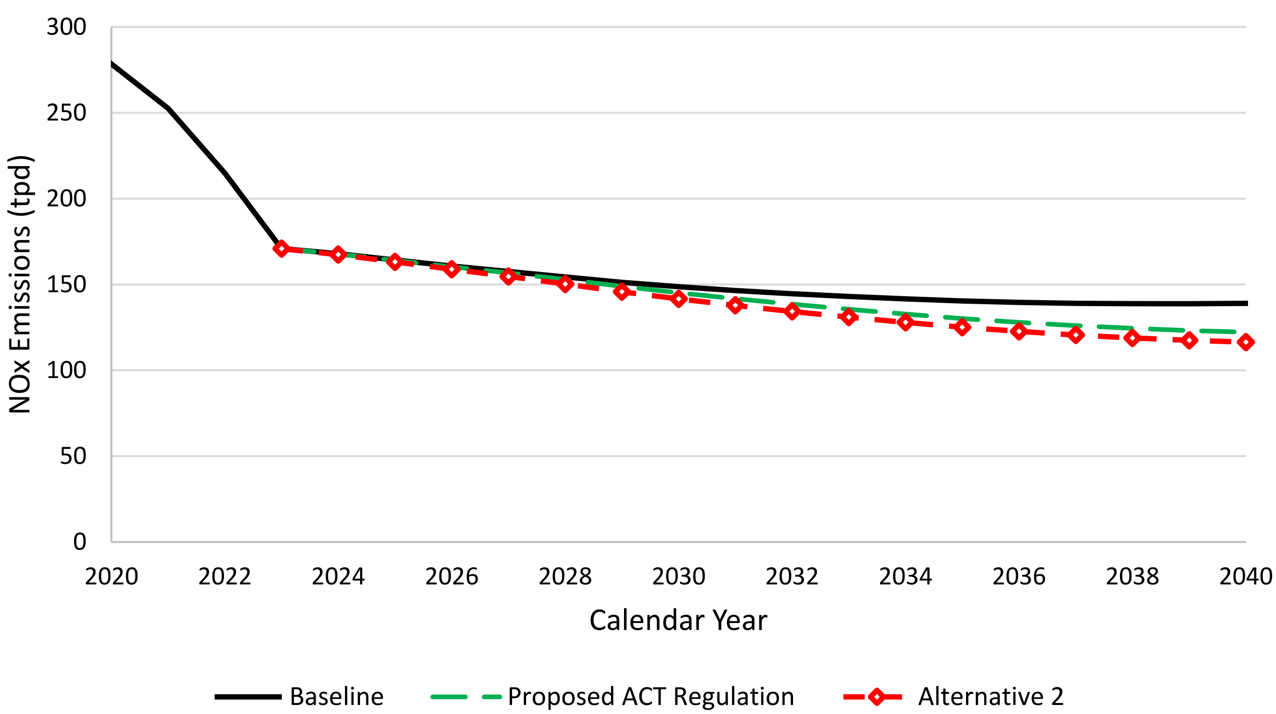
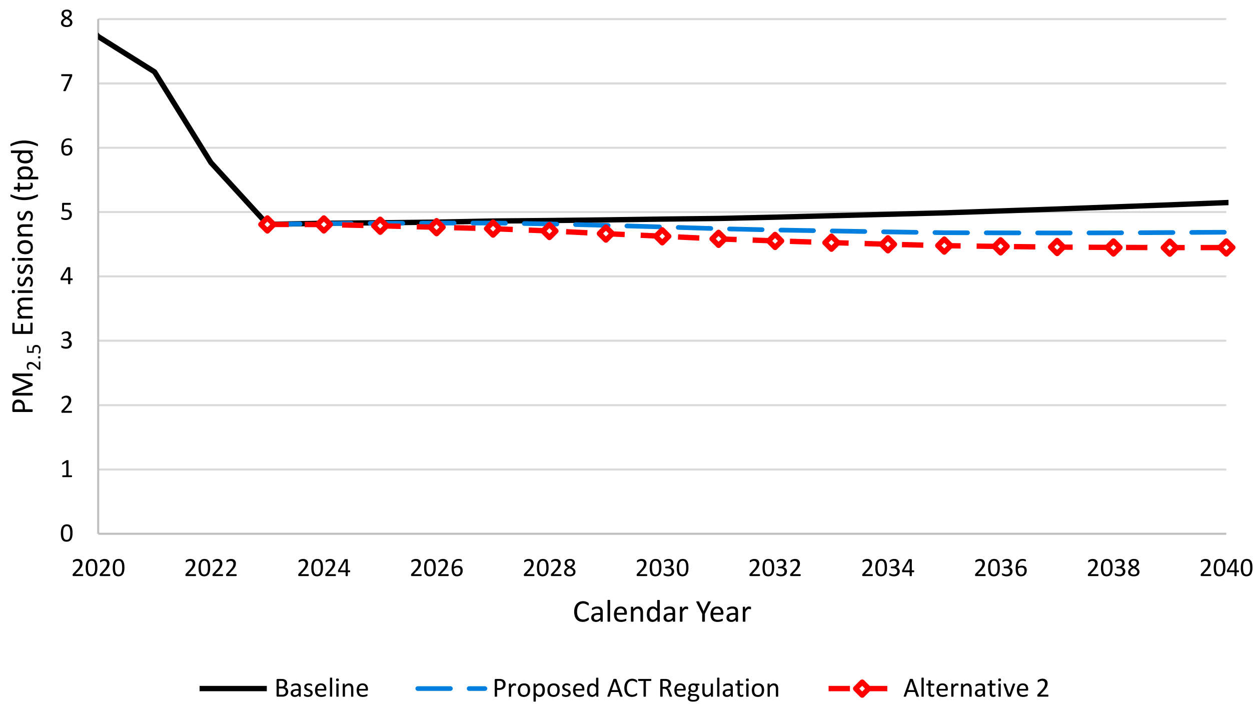


**Figure F-12. Projected $PM_{2.5}$ Emissions under Baseline, Proposed ACT Regulation, and Alternative 2**




The cumulative GHG emission reductions multiplied by the SC-CO2 values shown in Table B-2 gives a monetary estimate of the benefit of GHG emission reductions from Alternative 2. These benefits range from about $624 million to $2.67 billion through 2040, depending on the chosen discount rate.

### ii. Health Benefits

Alternative 2 results in emission reductions relative to the baseline leading to health benefits as shown in Table F-9. The health benefits are greater than those of the Proposed ACT Regulation (Table B-6) due to greater emission reductions estimated for this alternative.

**Table F-9. Statewide Valuation from Avoided Health Outcomes for Alternative 2**

| Outcome | Avoided Incidents | Valuation (Million 2018$) |
|---|---|---|
| Avoided Premature Mortality | 920 | $8,663.7 |
| Avoided Cardiovascular Hospitalizations | 143 | $8.1 |
| Avoided Acute Respiratory Hospitalizations | 171 | $8.4 |
| Avoided Emergency Room Visits | 442 | $0.4 |
| **Total** | | **$8,681** |

### c. ***Economic Impacts***

Alternative 2 would impose a more stringent ZEVs sales requirement compared to the Proposed ACT Regulation. This results in a greater incremental vehicle cost as passed-through to fleets, but also more Phase 2 GHG cost offsets and more fuel savings. The macroeconomic impacts analysis results shows that this alternative would result in similar impacts to the proposal on employment and output but of a smaller magnitude as displayed in Table F-10. These smaller positive impact appears to result primarily from the greater reduction in gasoline in diesel fuel demand. This reduces output more substantially in the petroleum and coal products manufacturing industry, shown in Figure F-14, and reduces employment more substantially in the public sector as the result of lower tax revenues, shown in Figure F-13.

**Table F-10: Change in Growth of Economic Indicators for Alternative 2 Relative to Baseline**

| | | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| **GSP** | % Change | 0.00% | 0.01% | 0.01% | 0.01% | 0.01% |
| | Change (2018M$) | 0 | 349 | 464 | 294 | 308 |
| **Personal Income** | % Change | 0.00% | 0.01% | 0.02% | 0.03% | 0.03% |
| | Change (2018M$) | -2 | 226 | 598 | 868 | 1,334 |
| **Employment** | % Change | 0.00% | 0.01% | 0.02% | 0.02% | 0.02% |
| | Change in Jobs | -2 | 3,529 | 5,774 | 5,594 | 6,615 |
| **Output** | % Change | 0.00% | 0.01% | 0.01% | 0.00% | 0.00% |
| | Change (2018M$) | -1 | 562 | 562 | 62 | -43 |
| **Private Investment** | % Change | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| | Change (2018M$) | -1 | 94 | 237 | 331 | 430 |

**Figure F-13: Job Impacts from Alternative 2 by Major Sector**

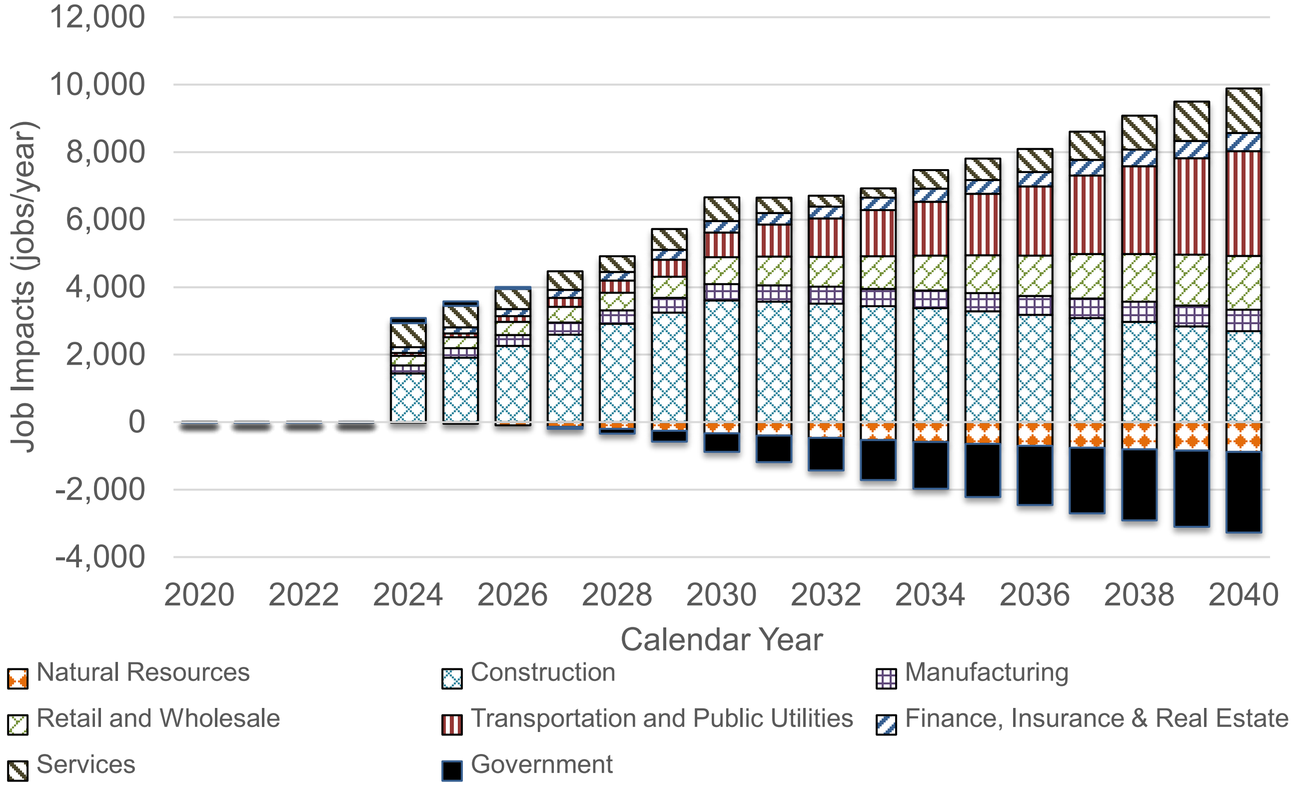
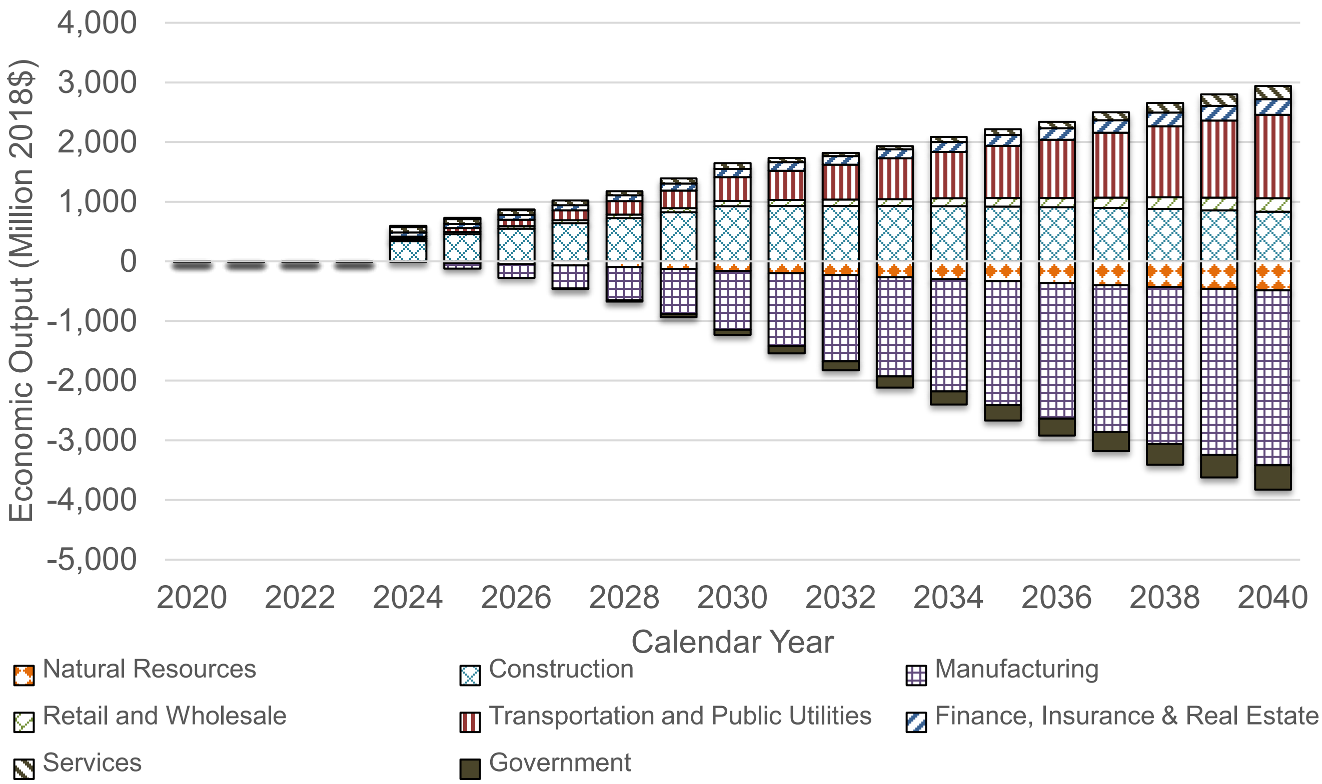



**Figure F-14: Change in Economic Output from Alternative 2 by Major Sector**



d. ***Cost-Effectiveness***

Cost-effectiveness is defined as the cost to achieve a ton of emission reduction. As Alternative 2 is modeled, the total cost from 2020 to 2040 is slightly higher (lower net savings) than the proposed ACT regulation and would achieve greater emission reductions. Alternative 2 is a more cost-effective alternative compared to the proposed ACT regulation.

e. ***Reason for Rejecting***

Alternative 2 is rejected as the more aggressive timeframe raises questions about feasibility for manufacturers to comply with its requirements. Alternative 2 nearly doubles the cumulative number of ZEVs to be sold between 2020 and 2040 with all of the increased sales occurring in the Class 2B-3 and Class 7-8 tractor categories. The current scarcity of commercial vehicle deployments in these categories present uncertainty in setting future requirements. Both Class 2B-3 and Class 7-8 tractors have increased concerns about payload, range, towing, charging/refueling infrastructure availability which may present barriers to their deployment. Given the greater emissions benefits and greater cost-effectiveness of Alternative 2, staff continues to analyze the rapidly evolving technical progress of these categories to determine if additional stringency is warranted.

## G. Health Benefits Methodology Appendix

**DRAFT (8/1/2019): Estimating Health Benefits Associated with Reductions in PM and NOx Emissions: Detailed Description**

### *1. Introduction*

CARB uses two different methods to estimate the number of adverse health outcomes, including premature death, related to exposure to particulate matter less than or equal to 2.5 μm in diameter (PM2.5). In most cases, CARB uses the *incidence-per-ton* (IPT) methodology to estimate health outcomes from emissions data. The IPT methodology is a simplified procedure that uses pre-calculated results, obtained by running a mathematical health model on a baseline scenario, to compute estimates of the number of cases of adverse health outcomes. In cases where measured or modeled PM2.5 concentrations are available at a high spatial resolution, CARB staff may input them directly into the health model to obtain estimates of health outcomes. This is referred to as *direct estimation*.

### *2. Overview of the IPT methodology*

CARB uses the IPT methodology to quantify the health benefits of regulations and programs that reduce PM2.5 and precursor emissions. It is based on an approach developed by the U.S. Environmental Protection Agency (EPA), as described by Fann et al. (2009, 2012, 2018). The mathematical relationship between changes in emissions and changes in health outcomes is approximately linear. The IPT methodology is based upon this relationship, and makes the following assumptions:

*(1) Changes in health outcomes are proportional to changes in PM concentration;*
*(2) Changes in primary pollutant concentrations are proportional to changes in emissions; and*
*(3) Changes in secondary pollutant concentrations are approximately proportional to changes in emissions. It should be noted that there may be cases where the relationship between emission of oxides of nitrogen (NOx) and ammonium nitrate aerosol is not linear.*

Due to the approximately linear relationship between premature deaths (or other health outcomes) and emission concentrations, the number of premature deaths can be estimated by multiplying emissions by a scaling factor: the *IPT factor*. IPT factors are developed by a applying a health model to measured air pollution concentrations for a baseline period to estimate the number of health outcomes associated with PM2.5 exposure, then dividing by emissions of PM2.5 or a precursor.

Measured or modeled air pollution concentrations, baseline incidence rates, projections of future population size, and a concentration-response function relating changes in PM2.5 exposure to changes in mortality incidence are used to perform calculations.
Current IPT factors were developed from a baseline scenario using air quality data, incidence data and emission inventories for 2014-2016, and age-stratified population projections for 2010 through 2060. IPT factors are calculated separately for each air basin.

IPT factors are currently available for two types of PM: diesel particulate matter (DPM) primarily from on-road sources, and secondary ammonium nitrate formed from NOx. Health effects of primary PM2.5 from sources other than on-road diesel engines are estimated by using IPT factors developed for DPM and multiplied by a relative potency factor, as described below.

In addition to premature mortality from cardiopulmonary causes, CARB currently uses IPT factors to estimate hospitalizations due to cardiovascular and respiratory causes and emergency room visits due to asthma.

Since the total incidence of health effects is proportional to population, results for future years are adjusted by the ratio of the projected population in the target year to the average population in the base years 2014-2016.

### *3. CARB's health model*

CARB's health model is based on the methodology used by US EPA's BenMAP benefits mapping and analysis software [US EPA BenMAP]. CARB developed its own health model in order to overcome limitations of BenMAP, primarily to provide the capacity to handle very large data sets, enable automation of repetitive tasks, and facilitate the incorporation of California-specific data. The health model uses a multi-step process to estimate health impacts from measured or modeled PM2.5 concentrations. These steps are described below.

**Estimating exposure from measured concentrations**
CARB's health model estimates population-weighed exposure to primary and secondary PM2.5 is from annual concentrations measured at monitors located throughout California. The mortality quantification method requires estimation of exposure between monitors across a geographic area, not only at points where monitors are located. The model uses a well established spatial interpolation method known as inverse distance-squared weighting. Since PM2.5 is emitted directly from sources (primary PM2.5) and also formed from gases that convert to PM2.5 through atmospheric chemical processes (secondary PM2.5), separate exposure estimates are made for each:

- ***Estimating Diesel particulate matter concentrations***

*Annual diesel particulate matter (DPM) concentrations are not measured directly. Rather, they are estimated indirectly from annual average NOx concentrations by multiplying them by air basin and year-specific DPM/NOx emission ratios computed from CARB emission inventories.*

The emissions and air quality used to perform this calculation are tabulated in the appendix. The methodology and its rationale is described in greater detail in CARB 2010a and Propper et al., 2015. DPM concentrations were estimated at 106 monitors located throughout the state. In order for an annual NOx average to be considered valid, the data were required to be at least 75% complete.

- ***Estimating secondary ammonium nitrate concentrations***

*In addition to DPM, CARB computes health impacts for secondary ammonium nitrates PM2.5 formed in the atmosphere from NOx by chemical processes. To estimate ammonium nitrate PM2.5 exposure, CARB staff use speciated PM2.5 nitrate ion ($NO_3^-$) concentration data from two sources: the air quality monitoring network maintained by CARB and local air quality districts, and the IMPROVE visibility network (IMPROVE Visibility Network).*

*CARB and air pollution control districts operate a network of PM2.5 monitors around the state, mostly in urban areas (ARB AQMN). PM2.5 samples are collected as 24-hour filter samples, once every 3-6 days. Samples from some monitors are further analyzed to determine the concentration of nitrate ion and other constituents. During 2014-2016, nitrate data were available from 18 urban monitors. Data for these monitors are retrieved from ARB's ADAM air quality database (ARB ADAM).*

In addition to the urban monitors, the national IMPROVE visibility network operated 20 PM2.5 nitrate ion monitor during 2014-2016, mainly in national parks and other remote locations (IMPROVE Visibility Network). These instruments collect one sample every three days. IMPROVE data are retrieved from the project web site (IMPROVE Visibility Network).

Daily samples were aggregated by monitor to obtain annual averages. In order for an annual average to be considered valid, the data were required to be at least 75% complete. To convert from nitrate ion concentration to ammonium nitrate ($NH_4NO_3$) concentration, the annual averages were multiplied by the ratio of the molecular weight of ammonium nitrate to that of the nitrate ion.

Prior to May, 2019 CARB used PM10 nitrate data instead of more accurate PM2.5 nitrate data to estimate ammonium nitrate aerosol concentrations to compute health impacts. This is because speciated PM10 data was available for more locations than speciated PM2.5, and better reflected the spatial variability in ammonium concentrations across California. However, the number of monitors in the speciated PM10 network has shrunk and is now comparable in size and coverage to the speciated PM2.5 network. Therefore, as of May, 2019 CARB uses PM2.5 nitrate data to compute impacts instead. The PM2.5 nitrate monitors are more accurate because they store the filters in a refrigerated compartment, and less of the sample is lost to volatilization. Consequently, the estimated PM2.5 nitrate concentrations and associated IPT factors for NOx emissions are approximately 50% higher than those used prior to May, 2019.

**Estimating exposure using from modeled concentrations**

The health model can also be run with concentrations derived from an air quality model as input. Air quality models include dispersion models, which model how pollutants are dispersed by the wind, and photochemical models, which are more elaborate and capture the effects of sunlight, temperature, chemical reactions and other physical processes on pollutants. Dispersion models are only used for primary pollutants, as they are not capable of modeling formation of secondary pollutants. Air quality models generate gridded results, with grid cells typically in the range of 500-2,000m square.

**Population projections at the census tract level**

CARB's health model uses age-resolved population data at the census tract level, for the 2010 Census, obtained from the U.S. Census Bureau (U.S. Census Bureau). These were projected to 2011-2060 using age-resolved county population projections from the California Department of Finance (CDOF).

Age-specific growth factors for each county, for each year, were computed from the CDOF projections by dividing each county population for the target year by the average county population for the base years 2014-2016. These growth factors were applied to each census tract in the county, for each age group separately. Population was projected for five-year age groups 0-4 through 80-84, and for age 85 and older.

This method of projection reflects growth in overall county population, but does not model changes in population distribution within counties, such as expansion of urban areas into surrounding rural land.

**Estimating baseline incidence**

CARB's health model uses incidence data for cardiopulmonary mortality extracted from the Center of Disease Control (CDC) Wonder database. Incidence data for hospitalizations for cardiovascular and respiratory causes, and emergency room visits for asthma are taken from US EPA BenMAP benefits mapping software (US EPA BenMAP).

Baseline incidence rates vary by age bracket. Incidence was estimated separately for five-year age groups 0-4 through 80-84, and for age 85 and older.

Mortality incidence data are county-specific. Incidence data for other health outcomes is uniform throughout California.

Baseline incidence of mortality, hospitalizations and emergency room visits is tabulated in the appendix.

**Estimating health outcomes using a concentration-response function**

CARB's health model estimates the incidence of premature death and other health outcomes at each census tract or modeling grid cell by an equation

$$\text{Incidence} = [\text{population}]_i \times [\text{baseline incidence}]_i \times [\ 1 - \exp(\ -\ \beta \times \text{PM2.5}\ )\ ]$$

where the subscript *i* indexes the age groups. The incidence is summed over age groups to obtain the total incidence for the census tract. The coefficient β is taken from one of the health studies discussed below.

The specific form of this equation is determined by the type of statistical model used by the health studies to model the relationship between PM2.5 exposure and health risk. All the studies selected by CARB use a so-called log-linear relationship, so all the equation for the incidence takes the form shown above.

CARB draws upon health studies used by the U.S. EPA for its risk assessments (US EPA 2010). CARB uses a subset of the endpoints used by U.S. EPA, chosen on the basis of their strength and robustness. For premature mortality, CARB uses the cardiopulmonary mortality risk coefficient for the 1999-2000 time period from Krewski et al., 2009, among the largest studies of its kind, with 360,000 participants. For cardiovascular and respiratory hospitalizations, CARB used Bell et al., 2008, and for emergency room visits for asthma CARB used Ito et al., 2007.

The process for selecting these studies was described in detail in CARB's 2010 PM2.5 mortality report (CARB 2010b).

**Aggregating health outcomes by air basin**

To aggregate results from census tracts to larger geographical subdivisions such as counties or air basins, CARB's health model uses a geospatial technique called areal interpolation. Areal interpolation is a procedure for translating spatial data from one set of geographical subdivisions to another when the boundaries do not exactly overlap. Numerous variants of the technique exist, but for the purpose of this analysis the simplest form, which uses area of polygon intersection, was employed (Goodchild and Lam, 1980, Flowerdew and Green, 1994). The precision of this method depends on the size of the geographical subdivisions and the spatial homogeneity of the quantity being apportioned. In urban areas, where census tracts are small and population is distributed more evenly, areal interpolation to larger subdivisions such as air basins yields relatively precise estimates. In rural areas where the population is distributed unevenly over large census tracts, estimates are less precise.

### *4. Computing IPT factors From health outcomes and emissions*

IPT factors are computed separately for each air basin. To compute IPT factors for DPM, the estimates incidence of premature death or other health outcomes associated with DPM exposure for the baseline years is divided by DPM emissions for each air basin. To compute IPT factors for secondary ammonium nitrate, incidence is divided by emissions of the precursor, NOx.

### Health benefit calculations using IPT factors

To estimate the reduction in health outcomes associated with reductions in DPM and NOx from a regulation, the change in emissions is multiplied by IPT factor. This value is then multiplied by the ratio of the projected target year population with the 2014-2016 average population to adjust for population growth.

## *5. Uncertainty in health impact estimates*

This methodology is well-established and includes up-to-date information. However, there are uncertainties in the underlying data and assumptions:

- *Air quality data is subject to natural variability from meteorological conditions, local activity, etc.*
- *The assumption that changes in concentrations of pollutants are proportional to changes in emissions of those pollutants or their precursors is an approximation. There may be cases where actual changes in concentrations are higher or lower than predicted.*
- *The estimation of DPM concentrations and DPM/NOx emission ratios is subject to uncertainty. Emissions are reported at an air basin resolution, and do not capture local variations.*
- *Inverse distance-squared weighting, the spatial interpolation method is used to estimate concentrations each census tract. Compared with other geospatial estimation methods such as Kriging, inverse distance-squared interpolation has the virtue of simplicity, and does not require selection of parameters. When data are abundant, most simple interpolation techniques give similar results (Jarvis et al., 2001). All geospatial estimation techniques exhibit greater uncertainty when data points are sparser, and uncertainty increases with distance from the nearest data points.*
- *Future population estimates are subject to increasing uncertainty as they are projected further into the future. For reasons of computational efficiency, the spatial resolution of population estimates is limited to census tract resolution.*
- *Observed baseline incidence rates change over time, and are subject to random year-to-year variation and systematic shifts as population characteristics and medical treatments evolve. Sample size requirements necessitate estimating baseline incidence rates at large geographic scales, state or county.*
- *Relative risks in the concentration response function are estimated with uncertainty and reported as confidence ranges.*

## *6. Relative potency factors for non on-road diesel sources*

To quantify the health benefits of reductions in primary PM2.5 from sources other than on-road diesel vehicles, CARB uses IPT factors developed for DPM and multiplies the results by a relative potency factor specific to the source and location of the emissions.

Relative potency may be determined in several ways, including but not limited to

- *The ratio of the Intake Fraction of the source to the Intake Fraction for DPM. The Intake Fraction is a measure of the fraction of the emissions from a given source that is inhaled by the receptor population. It is specific to a source and a location; e.g., a particular type of facility in a given air basin.*
- *Comparison of IPT results with direct estimation results for the same scenario. The ratio of the results obtained by the two methods may then be used to adjust the results obtained by IPT factors in a larger setting. For example, the ratio of results obtained by IPT and direct estimation for one air basin may be used to adjust results for other air basins.*
- *General consideration of conditions under which emissions take place. For example, if an on-road vehicle delivers goods from a facility in a remote location to a facility located in an urban area, half of idling emissions may be considered to occur far from receptor populations. Hence an adjustment factor of 0.5 may be appropriate for computing the health benefits of reducing idling emissions.*

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## H. Macroeconomic Appendix

### Table H-1 REMI Inputs for the Proposed ACT Regulation (Million 2016$)

| REMI Policy Variable | REMI Industry /Spending Category | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production Costs | Truck transportation | 2.1 | - | - | 0.0 | (0.1) | (4.7) | (12.1) | (17.9) | (30.6) | (65.1) | (126.4) | (184.6) | (216.3) | (276.0) | (329.5) | (395.5) | (460.9) | (548.1) | (598.7) | (642.9) | (675.8) |
| Exogenous Final Demand | Electric power generation, transmission and distribution | - | - | - | - | 6.6 | 15.8 | 27.5 | 48.9 | 82.6 | 130.5 | 192.6 | 255.1 | 315.3 | 372.9 | 428.6 | 481.5 | 530.9 | 577.3 | 619.7 | 658.1 | 693.3 |
| Exogenous Final Demand | Construction | - | - | - | - | 40.1 | 58.1 | 77.4 | 166.6 | 240.4 | 324.4 | 411.2 | 417.6 | 423.0 | 426.6 | 430.1 | 430.1 | 427.9 | 423.2 | 417.8 | 411.1 | 403.5 |
| Exogenous Final Demand | Other electrical equipment and component manufacturing | - | - | - | - | 21.6 | 30.4 | 40.3 | 83.0 | 128.2 | 181.7 | 238.4 | 248.8 | 259.4 | 269.5 | 280.1 | 289.2 | 296.7 | 302.8 | 308.6 | 313.5 | 318.0 |
| Exogenous Final Demand | Petroleum and coal products manufacturing | - | - | - | - | (17.8) | (43.0) | (75.3) | (134.8) | (228.1) | (361.4) | (538.3) | (713.8) | (883.4) | (1,053.1) | (1,220.3) | (1,379.4) | (1,532.4) | (1,690.6) | (1,832.9) | (1,968.6) | (2,098.5) |
| Exogenous Final Demand | Basic chemical manufacturing | - | - | - | - | - | - | - | 0.8 | 1.7 | 2.6 | 3.7 | 4.8 | 5.9 | 6.9 | 7.9 | 8.8 | 9.6 | 10.4 | 11.1 | 11.7 | 12.3 |
| Exogenous Final Demand | Office administrative services; Facilities support services | 2.6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Exogenous Final Demand | Educational services; private | - | - | - | - | 1.0 | 1.3 | 1.5 | 3.2 | 4.2 | 5.2 | 6.0 | - | - | - | - | - | - | - | - | - | - |
| Exogenous Final Demand | Automotive repair and maintenance | - | - | - | - | (2.7) | (6.5) | (11.3) | (19.4) | (32.5) | (51.0) | (75.0) | (98.7) | (107. | (126. | (131. | (144. | (159. | (178. | (171. | (158. | (136. |
| Industry Sales | Electrical equipment manufacturing | - | - | - | - | 1.6 | 2.0 | 2.5 | 5.1 | 6.8 | 8.4 | 9.7 | 9.8 | 11.5 | 11.7 | 11.9 | 12.1 | 12.2 | 12.2 | 12.3 | 12.4 | 12.5 |

| REMI Policy Variable | REMI Industry /Spending Category | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Industry Sales | Motor vehicle parts manufacturing | - | - | - | - | (0.2) | (0.2) | (0.3) | (0.8) | (0.3) | (0.3) | (0.4) | (0.4) | (0.4) | (0.4) | (0.5) | (0.5) | (0.5) | (0.5) | (0.5) | (0.5) | (0.5) |
| Consumer Spending | Hospitals | - | - | - | - | (0.0) | (0.0) | (0.0) | (0.1) | (0.1) | (0.2) | (0.3) | (0.4) | (0.5) | (0.6) | (0.8) | (0.9) | (1.0) | (1.1) | (1.3) | (1.4) | (1.5) |
| Government Spending | State | (0.5) | (0.3) | (0.3) | (0.3) | (1.0) | (3.6) | (7.0) | (12.5) | (21.4) | (36.9) | (59.6) | (82.2) | (102. | (124. | (146. | (167. | (188. | (209. | (229. | (247. | (265. |
| Government Spending | Local | 0.1 | - | - | 0.0 | 1.2 | 1.1 | 0.7 | 1.6 | 2.7 | 0.9 | (3.2) | (8.1) | (10.6) | (15.6) | (20.3) | (25.3) | (30.3) | (36.4) | (40.9) | (45.2) | (49.0) |
| Government Employment (jobs) | State | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |

## Table H-2 REMI Inputs for the Alternative 1 (Million 2016$)

| REMI Policy Variable | REMI Industry /Spending Category | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production Costs | Truck transportation | 2.1 | - | - | 0.0 | 1.4 | 0.0 | (3.5) | (9.8) | (15.0) | (25.7) | (43.4) | (58.9) | (71.2) | (89.2) | (103.1) | (118.9) | (134.1) | (153.9) | (169.1) | (183.4) | (196.8) |
| Exogenous Final Demand | Electric power generation, transmission and distribution | - | - | - | - | 3.5 | 9.7 | 18.1 | 28.6 | 41.6 | 57.1 | 75.1 | 92.9 | 109.5 | 125.1 | 140.1 | 154.2 | 167.4 | 179.9 | 191.3 | 201.4 | 210.6 |
| Exogenous Final Demand | Construction | - | - | - | - | 25.2 | 42.7 | 60.8 | 80.6 | 101.4 | 122.5 | 144.6 | 148.2 | 150.1 | 151.6 | 152.6 | 152.1 | 151.8 | 150.1 | 147.8 | 144.7 | 140.9 |
| Exogenous Final Demand | Other electrical equipment and component manufacturing | - | - | - | - | 11.0 | 19.1 | 27.8 | 37.3 | 47.3 | 57.6 | 68.4 | 71.4 | 74.1 | 77.1 | 80.5 | 83.4 | 86.6 | 89.1 | 91.3 | 93.0 | 94.3 |
| Exogenous Final Demand | Petroleum and coal products manufacturing | - | - | - | - | (9.4) | (26.0) | (49.4) | (78.6) | (114.2) | (157.3) | (208.4) | (257.9) | (304.4) | (350.4) | (395.4) | (437.9) | (479.0) | (522.3) | (560.7) | (597.3) | (632.0) |
| Exogenous Final Demand | Basic chemical manufacturing | - | - | - | - | 0.1 | 0.1 | 0.2 | 0.4 | 0.5 | 0.6 | 0.8 | 0.9 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.5 | 1.6 | 1.7 | 1.8 |
| Exogenous Final Demand | Office administrative services; Facilities support services | 2.6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Exogenous Final Demand | Educational services; private | - | - | - | - | 0.6 | 1.0 | 1.2 | 1.5 | 1.7 | 1.9 | 2.0 | - | - | - | - | - | - | - | - | - | - |
| Exogenous Final Demand | Automotive repair and maintenance | - | - | - | - | (1.4) | (3.8) | (7.3) | (11.7) | (17.0) | (22.7) | (29.6) | (36.2) | (42.5) | (48.4) | (48.3) | (49.7) | (51.2) | (54.1) | (56.0) | (57.3) | (58.1) |
| Industry Sales | Electrical equipment manufacturing | - | - | - | - | 1.0 | 1.5 | 2.0 | 2.4 | 2.8 | 3.1 | 3.3 | 3.3 | 3.4 | 3.4 | 3.5 | 3.5 | 3.6 | 3.6 | 3.6 | 3.6 | 3.7 |
| Industry Sales | Motor vehicle parts manufacturing | - | - | - | - | (0.1) | (0.2) | (0.2) | (0.3) | (0.1) | (0.1) | (0.1) | (0.1) | (0.1) | (0.1) | (0.1) | (0.1) | (0.1) | (0.1) | (0.1) | (0.1) | (0.1) |

| REMI Policy Variable | REMI Industry /Spending Category | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Consumer Spending | Hospitals | - | - | - | - | (0.0) | (0.0) | (0.0) | (0.0) | (0.1) | (0.1) | (0.1) | (0.1) | (0.1) | (0.2) | (0.2) | (0.2) | (0.3) | (0.3) | (0.3) | (0.3) | (0.4) |
| Government Spending | State | 1.6 | (0.3) | (0.3) | (0.3) | (0.6) | (2.0) | (4.2) | (7.4) | (10.6) | (15.3) | (21.4) | (27.0) | (32.4) | (37.8) | (43.0) | (48.0) | (52.9) | (57.9) | (62.5) | (66.9) | (71.0) |
| Government Spending | Local | - | - | - | - | 0.7 | 0.9 | 0.9 | 0.7 | 1.0 | 0.5 | (0.2) | (1.1) | (1.9) | (2.7) | (3.5) | (4.3) | (5.1) | (6.0) | (6.8) | (7.5) | (8.3) |
| Government Employment (jobs) | State | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |

# Table H-3 REMI Inputs for the Alternative 2 (Million 2016$)

| REMI Policy Variable | REMI Industry /Spending Category | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production Costs | Truck transportation | 2.1 | - | - | 0.1 | 24.2 | 20.7 | 6.6 | (19.5) | (30.1) | (61.0) | (134.8) | (188.5) | (211.2) | (267.9) | (302.6) | (355.4) | (411.4) | (496.7) | (559.2) | (621.6) | (682.3) |
| Exogenous Final Demand | Electric power generation, transmission and distribution | - | - | - | - | 29.9 | 72.2 | 121.8 | 176.5 | 239.0 | 310.2 | 389.2 | 467.5 | 541.2 | 610.5 | 677.4 | 740.3 | 798.7 | 853.5 | 902.8 | 946.6 | 986.0 |
| Exogenous Final Demand | Construction | - | - | - | - | 232.9 | 315.4 | 383.7 | 452.4 | 522.9 | 593.9 | 666.9 | 669.8 | 672.1 | 671.2 | 670.0 | 663.7 | 654.0 | 640.7 | 625.1 | 606.7 | 586.9 |
| Exogenous Final Demand | Other electrical equipment and component manufacturing | - | - | - | - | 104.5 | 146.8 | 184.9 | 224.3 | 265.6 | 308.1 | 353.1 | 367.0 | 382.4 | 396.1 | 411.2 | 423.0 | 432.7 | 440.3 | 446.5 | 450.7 | 454.1 |
| Exogenous Final Demand | Petroleum and coal products manufacturing | - | - | - | - | (81.9) | (199.4) | (339.8) | (497.4) | (674.5) | (878.3) | (1,112.0) | (1,337.1) | (1,550.0) | (1,762.2) | (1,971.4) | (2,168.9) | (2,357.9) | (2,557.2) | (2,732.2) | (2,898.5) | (3,056.6) |
| Exogenous Final Demand | Basic chemical manufacturing | - | - | - | - | 3.6 | 8.2 | 13.4 | 18.8 | 24.6 | 30.6 | 36.7 | 43.4 | 49.8 | 55.9 | 61.8 | 67.2 | 72.1 | 76.5 | 80.4 | 83.8 | 86.7 |
| Exogenous Final Demand | Office administrative services; Facilities support services | 2.6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Exogenous Final Demand | Educational services; private | - | - | - | - | 5.9 | 7.4 | 8.3 | 9.0 | 9.6 | 10.1 | 10.4 | - | - | - | - | - | - | - | - | - | - |
| Exogenous Final Demand | Automotive repair and maintenance | - | - | - | - | (10.8) | (26.2) | (44.5) | (65.4) | (89.0) | (95.4) | (119. | (139. | (160. | (179. | (168. | (174. | (186. | (197. | (202. | (207. | (212. |
| Industry Sales | Electrical equipment manufacturing | - | - | - | - | 9.5 | 11.8 | 13.3 | 14.5 | 15.6 | 16.5 | 17.2 | 17.4 | 20.0 | 20.2 | 20.6 | 20.8 | 21.0 | 21.2 | 21.3 | 21.5 | 21.7 |
| Industry Sales | Motor vehicle parts manufacturing | - | - | - | - | (1.3) | (1.5) | (1.7) | (2.3) | (0.6) | (0.7) | (0.7) | (0.8) | (0.8) | (0.8) | (0.8) | (0.8) | (0.8) | (0.8) | (0.8) | (0.8) | (0.8) |

| **REMI Policy Variable** | **REMI Industry /Spending Category** | **2020** | **2021** | **2022** | **2023** | **2024** | **2025** | **2026** | **2027** | **2028** | **2029** | **2030** | **2031** | **2032** | **2033** | **2034** | **2035** | **2036** | **2037** | **2038** | **2039** | **2040** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Consumer Spending | Hospitals | - | - | - | - | (0.0) | (0.1) | (0.1) | (0.2) | (0.3) | (0.4) | (0.6) | (0.7) | (0.9) | (1.0) | (1.2) | (1.3) | (1.5) | (1.6) | (1.8) | (1.9) | (2.1) |
| Government Spending | State | (0.5) | (0.3) | (0.3) | (0.3) | (2.1) | (13.8) | (29.5) | (48.6) | (66.5) | (92.1) | (125. | (154. | (179. | (206. | (233. | (259. | (284. | (311. | (334. | (357. | (378. |
| Government Spending | Local | 0.1 | - | - | 0.0 | 7.8 | 8.2 | 7.1 | 4.4 | 6.1 | 1.9 | (4.7) | (10.7) | (13.0) | (18.6) | (23.4) | (28.7) | (34.0) | (40.9) | (46.3) | (51.7) | (56.9) |
| Government Employment (jobs) | State | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |

**Errata to Advanced Clean Trucks Standardized Regulatory Impact Analysis**

1) The cumulative NOx and PM2.5 emission reductions shown on page 14 are erroneous because they are based on benefits from 2020 to 2050, not 2020 to 2040 as written in the text. The correct emission benefit numbers for 2020 to 2040 cumulative emissions are 36,770 tons of NOx and 1,092 tons of $PM_{2.5}$.

2) The cumulative GHG emission reductions shown on page 17 are erroneous because they do not account for the difference between short tons and metric tons. The correct emission benefit numbers for 2020 to 2040 cumulative emissions is 9.6 MMT $CO_2e$

3) To better follow CARB guidelines on references, Reference 52 is replaced with the following: California Air Resources Board, Class 4-5/6-7 Population Analysis, 2019.

4) To better follow CARB guidelines on references, References 58-62 are replaced with the following: California Air Resources Board, New Vehicle Prices, 2019.

5) Figures have been graphically edited to better comply with the American with Disabilities Act of 1990, the Rehabilitation Act of 1973, and Assembly Bill 434 (2017). The content contained within figures has not changed from what was originally submitted to Department of Finance on August 8, 2019.