DRAFT: ASSESSMENT OF CARB'S ZERO-EMISSION VEHICLE PROGRAMS PER SENATE BILL 498

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ACRONYMS

AB – Assembly Bill

BEV – Battery electric vehicle

BEVx – Battery electric vehicle with range extender

CARB – California Air Resources Board or Board

CO_2 – Carbon dioxide

CO_2e – Carbon dioxide equivalent

CVRP – Clean Vehicle Rebate Project

DCFC – Direct current fast charger

DPM – Diesel particulate matter

ePTO – electric power takeoff

eVMT – electric vehicle miles traveled

EVSE – Electric vehicle supply equipment

EVSP – Electric vehicle service provider

FCEV – Fuel cell electric vehicle

FPL – Federal Poverty Level

FY – Fiscal year

GHG – greenhouse gas

HVIP – Hybrid and Zero-Emission Voucher Incentive Program

kWh – kilowatt hour

LCFS – Low Carbon Fuel Standard

NOx – Nitrogen oxides

PHEV – Plug-in hybrid electric vehicle

PM 2.5 – particulate matter smaller than 2.5 micrometers or fine particulate matter

ROG – Reactive organic gases

SB – Senate Bill

TRU – Transport refrigeration unit

TNC – Transportation network company

VMT – Vehicle miles traveled

ZEV – Zero-emission vehicle

EXECUTIVE SUMMARY

Senate Bill (SB) 498 (Skinner, Chapter 628, Statutes of 2017) directs the California Air Resources Board (CARB) to review its programs that affect the adoption of light-, medium-, and heavy-duty zero-emission vehicles (ZEVs), including identifying each program's goals and status in meeting those goals, performing a cost-benefit analysis, and comparing CARB's ZEV programs with those of other jurisdictions. SB 498 also directs CARB to make policy recommendations for increasing the use of ZEVs in the State, and recommendations for vehicle fleet operators to increase the use of ZEVs. This report responds to that legislative direction.

Transitioning the transportation sector to zero-emission technology is critical to achieving California's public health protection goals, minimizing air pollution exposure, and mitigating climate change impacts.[1] The transportation sector is responsible for the vast majority of the State's emissions of toxic diesel particulate matter and regional smog-forming oxides of nitrogen (NO_X),[1] and is the largest source of greenhouse gas (GHG) emissions.[2]

Over 12 million Californians breathe unhealthy air, and several areas of the State are still in non-attainment for ozone. Exposure to ozone and particulate matter leads to a range of respiratory and cardiovascular health impacts, including exacerbations of asthma and heart disease, and is estimated to contribute to approximately 7,500 premature deaths in California, and millions globally, each year.[3] While significant improvements have been made in both the South Coast Air Basin and the San Joaquin Valley, these areas still represent the greatest challenges to meeting our air quality goals.

California is already experiencing significant and widespread impacts on its economy and environment as a result of climate change, such as more severe and frequent heat waves, droughts, flooding, sea-level rise, and wildfires, and these are expected to worsen.[4] California has sensible and far reaching goals to mitigate these impacts– including a reduction of Statewide GHG emissions 40 percent below 1990 levels by

[1] CARB, 2016. Mobile Source Strategy, https://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf.
[2] CARB, 2019. 2019 Edition, California Greenhouse Gas Emission Inventory: 2000 – 2017, https://www.arb.ca.gov/cc/inventory/pubs/reports/2000_2016/ghg_inventory_trends_00-16.pdf.
[3] CARB, 2017. Revised Proposed 2016 State Strategy for the State Implementation Plan, https://ww3.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf.
[4] Bedsworth et al., 2018. California's Fourth Climate Change Assessment, Statewide Summary Report. http://www.climateassessment.ca.gov/.

2030[5] and carbon neutrality by 2045[6]–and meeting those goals will require that the transportation sector transforms to zero-emission technology rapidly.

California's Mobile Source Strategy,[1] State Strategy for the State Implementation Plan,[7] and Scoping Plan[8] lay out the measures needed to put California on track to attain the national ambient air quality standards, reduce air pollution-related health impacts, and meet our climate goals. These plans underscore the fact that penetration of ZEV technology throughout the transportation sector is critical. Currently, California's efforts to transition to a clean transportation system are under attack by federal backsliding on vehicle emissions, which threatens to undermine California's momentum on ZEVs. This report outlines areas of opportunity to grow California's ZEV market in spite of this federal threat. Future work, notably the carbon neutrality study being developed by the California Environmental Protection Agency, will identify additional strategies to achieve carbon neutrality for the transportation sector, and may identify additional strategies to accelerate the transition to zero-emission vehicles.[9]

Policy Recommendations

Governor Newsom recently issued Executive Order N-19-19[10] that outlines a number of actions that California State agencies must take to reduce GHG emissions. Implementation of that Executive Order is critical in order to keep California on the path to meet our ambitious climate goals. This report identifies eight policy areas to increase ZEV adoption and use, which support that Executive Order, and would either require or benefit from legislative action. These policy recommendations build on actions identified in ZEV Action Plans[11, 12, 13] and CARB staff's report that identified barriers that low-income Californians face in accessing zero-emission transportation options "*Low-Income Barriers Study, Part B: Overcoming barriers to Clean*

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[5] SB 32 (Pavley, Chapter 249, Statutes of 2016).
[6] Executive Order B-55-18. September 10, 2018. https://www.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf.
[7] CARB, 2017. Revised Proposed 2016 State Strategy for the State Implementation Plan, https://ww3.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf.
[8] CARB, 2017. November 2017. "California's 2017 Climate Change Scoping Plan." https://ww3.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf.
[9] California Environmental Protection Agency, 2019. Carbon Neutrality Studies: Vehicle Emissions and Fossil Fuel Demand and Supply. https://calepa.ca.gov/climate/carbon-neutrality-studies/
[10] Executive Order N-19-19. September 20, 2019. https://www.gov.ca.gov/wp-content/uploads/2019/09/9.20.19-Climate-EO-N-19-19.pdf.
[11] Governor's Interagency Working Group on Zero-Emission Vehicles, 2013. February 2013. "2013 ZEV Action Plan: A Roadmap Toward 1.5 Million Zero-Emission Vehicles." http://opr.ca.gov/docs/Governors_Office_ZEV_Action_Plan_(02-13).pdf.
[12] Governor's Interagency Working Group on Zero-Emission Vehicles, 2016. October 2016. "2016 ZEV Action Plan: An Updated Roadmap Toward 1.5 Million Zero-Emission Vehicles on California Roadways by 2025." https://www.ca.gov/archive/gov39/wp-content/uploads/2018/01/2016_ZEV_Action_Plan-1.pdf.
[13] Governor's Interagency Working Group on Zero-Emission Vehicles, 2018. September 2018. "2018 ZEV Action Plan: Priorities Update." http://business.ca.gov/Portals/0/ZEV/2018-ZEV-Action-Plan-Priorities-Update.pdf.

Transportation Access for Low-Income Residents,"[14] and are informed by the review of CARB programs and comparison with other jurisdictions. These policy recommendations are meant to grow the ZEV market through:

1) Incentives and pricing strategies,
2) Lower fuel costs,
3) ZEV refueling infrastructure,
4) Local policies,
5) Fleet adoption,
6) Outreach and education,
7) Workforce development, and
8) Program flexibility.

The policy recommendations are summarized here and elaborated on in Chapter 8:

1) Incentives and pricing strategies

ZEVs currently cost more than their conventional counterparts,[15] so a suite of complementary policies is needed to expand the ZEV market beyond early adopters and to ensure equitable access to zero-emission mobility.

a. Provide predictable and expanded funding for CARB's ZEV incentive programs that is sufficient to drive consumer demand.

Waitlists and unpredictable future incentive funding inhibit ZEV production and sales. Incentive certainty entices consumers and fleets to choose light-, medium-, and heavy-duty ZEVs, nudges manufacturers to invest and innovate to bring a wider array of ZEVs to market, and encourages dealers to promote ZEVs. Demand for incentives outstrips the available funding, leading to waitlists. However, beyond the waitlists, predictable future incentive funding would allow consumers, fleets, manufacturers, and administering program grantees to better plan future ZEV deployments.

b. Provide CARB with increased incentive funding to ensure priority populations[16] and school districts can access zero-emission transportation.

[14] CARB, 2018. "Low-Income Barriers Study, Part B: Overcoming Barriers to Clean Transportation Access for Low-Income Residents", https://ww2.arb.ca.gov/sites/default/files/2018-08/sb350_final_guidance_document_022118.pdf.

[15] Lutsey and Nicholas, 2019. International Council on Clean Transportation (ICCT) Working Paper. April, 2019. "Update on Electric Vehicle Costs in the United States through 2030." https://theicct.org/sites/default/files/publications/EV_cost_2020_2030_20190401.pdf.

[16] Priority populations include disadvantaged communities (DACs), low-income communities, and low-income households. DACs are defined as the top 25 percent of communities experiencing disproportionate amounts of pollution, environmental degradation, and socioeconomic and public health conditions according to the CalEnviroScreen tool (https://oehha.ca.gov/calenviroscreen). Low-income communities and households are those with incomes either at or below 80 percent of the Statewide median or below a threshold designated as low-income by the Department of Housing and Community Development.

Low-income and disadvantaged community residents need more help to afford ZEVs and benefit from having accessible zero-emission transportation in their communities, such zero-emission transit and reduced transportation emissions. CARB's school bus programs need increased funding since schools have limited budgets for expenditures for transporting children and many of the underfunded schools also have the oldest, dirtiest school buses. Replacing all polluting diesel school buses is an imperative societal responsibility to support healthy, thriving students.

c. Establish Statewide incentives that promote ZEVs through pricing strategies, such as usage- or emission-based fees, registration fee exemptions, and temporary sales tax exemptions for more vehicle types to provide relief to ZEVs, and zero-emission truck lanes along freight corridors.

Pricing strategies that favor ZEVs, for example, reduced or exempt road usage-based pricing (such as in high-occupancy toll lanes), parking rates at State facilities, or emissions-based pricing (such as fees on non-ZEVs in multi-vehicle households) are statutory changes that would send a strong signal to encourage the adoption of ZEVs and would be a new funding source for ZEV incentives. Because ZEV technologies are mostly more expensive than their conventional counterparts, sales taxes and registration fees, which are both based on the full purchase price not including any purchase incentives, also cost more. Recently passed AB 784[17] exempts transit buses from sales and use taxes. California would benefit from having zero-emission light-duty vehicles as well as medium- and heavy-duty trucks exempt from the State sales taxes as well. As the ZEV market matures, the price difference between zero-emission and conventional vehicles will decrease, and this tax and fee relief will no longer be needed. Finally, the time savings from dedicated zero-emission truck lanes along busy freight corridors would motivate truck operators to invest in these vehicles.

2) Fuel costs

Predictable, cost-competitive and stable electricity and hydrogen fuel costs are critical to encourage consumers and fleets to choose ZEVs.

a. Define SB 350[18] transportation electrification to be inclusive of renewable hydrogen.

Electricity rate structures that reduce the cost of renewable hydrogen production could attract private investments to deploy more hydrogen fueling stations, which are needed to support a growing fuel cell electric vehicle market. Electricity rates designed to reduce the cost of renewable hydrogen production can also encourage hydrogen production to occur when it is most beneficial to the electricity grid.

[17] Mullin, Chapter 684, Statutes of 2019.
[18] De León, Chapter 547, Statutes of 2015.

b. Set targets for technologies and strategies that integrate electric vehicles with the electricity grid to lower the cost of fueling.

Vehicle grid integration,[19] on-site renewable energy generation, energy storage, and other strategies requiring statutory changes can lower ZEV fuel costs, especially when they reduce or eliminate demand charges[20] that can result from the high power demand to charge electric vehicles quickly.

c. Require the Integrated Resource Plans submitted by publicly owned utilities (POUs) to the California Energy Commission (CEC) include details of electricity rate design for transportation electrification.

Although some POUs have already deployed electricity rates to support ZEVs,[21] more should do so.

3) ZEV refueling infrastructure

Current ZEV infrastructure cannot support the growing population of ZEVs, and long-term, holistic infrastructure planning and investment is critical to giving consumers confidence in ZEVs and to expand ZEVs to more market segments, including heavy-duty applications.

a. Extend CEC's Clean Transportation Program beyond 2023 and promote ZEV fuels.

Both electric vehicle and hydrogen refueling infrastructure investment will continue to be needed after 2023, when the funding sunsets, to continue closing the gap between needed ZEV refueling infrastructure and the State's ZEV deployment targets.[22,23] Support is critical to ensure that stations are distributed throughout the State to serve all markets and to allow the ZEV market to mature sufficiently for infrastructure to become a sustainable business model.

b. Convene a multi-agency working group with the goal of accelerating heavy-duty and off-road ZEV infrastructure (especially hydrogen) to be on par with light-duty ZEV infrastructure.

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[19] Which includes smart charging.

[20] Demand charges are fees for very high power demand that penalize short bursts of high power demanded from charging electric vehicles, especially with the faster chargers. https://www.cpuc.ca.gov/General.aspx?id=12188.

[21] These include Alameda Municipal Power (https://afdc.energy.gov/laws/12105), Azusa Light and Water (https://afdc.energy.gov/laws/12106), Burbank Water and Power (https://afdc.energy.gov/laws/12107), Los Angeles Department of Water and Power (https://afdc.energy.gov/laws/6142), and Sacramento Municipal Utility District (https://afdc.energy.gov/laws/4241).

[22] Bedir, et al., 2018. California Energy Commission Staff Report CEC-600-2018-001. March 2018. "California Plug-In Electric Vehicle Infrastructure Projections: 2017-2025." https://efiling.energy.ca.gov/GetDocument.aspx?tn=224521&DocumentContentId=55071.

[23] CARB, 2018. July 2018. "2018 Annual Evaluation of Fuel Cell Electric Vehicle Deployment & Hydrogen Fuel Station Network Development." https://ww3.arb.ca.gov/msprog/zevprog/ab8/ab8_report_2018_print.pdf.

ZEV infrastructure for heavy-duty and off-road sectors is crucial to serve the number of ZEVs anticipated by recent and upcoming regulations.[24] This group should ensure heavy-duty and off-road ZEV infrastructure is on par with light-duty ZEV infrastructure, create a level playing field between hydrogen and electricity, address broader infrastructure issues such as implications for electricity transmission and distribution, compare ZEV infrastructure costs across State agencies' ZEV programs, identify cost-effective investment strategies, maintain a database of heavy-duty and off-road ZEVs in California, and monitor progress.

c. Require that electric vehicle charging infrastructure provisions in California's Green Building Standards (CALGreen) Code include mandatory installation of level 2 charging in new construction, and require infrastructure installation at existing buildings undergoing major renovations.

Current electric vehicle charging requirements in CALGreen do not address the need for charging at existing residential and commercial buildings and school facilities, and do not require the installation of charging equipment, which would significantly increase Californians' access to charging.

d. Exempt sales tax on ZEV infrastructure.

There is a large gap in the ZEV infrastructure California needs to support the growing light-and heavy-duty ZEV market. A sales tax exemption on electric vehicle recharging or fuel cell refueling infrastructure would allow private and public funding for ZEV infrastructure to be maximized.

e. Require charging infrastructure at both new and existing State facilities where feasible.

California needs ZEV infrastructure to serve the public at State facilities and the State should provide charging for its own fleet and to encourage State employees to use ZEVs.

f. Provide CEC with additional funding for the deployment of light- and heavy-duty ZEV infrastructure within and near low-income and disadvantaged communities and schools.

By supporting cleaner trucks and buses operating in their communities, ZEV infrastructure for heavy-duty vehicles, including for transport refrigeration units, at warehouses, grocery stores, truck stops, ports, and rail, in disadvantaged communities would provide air quality benefits where they are needed most. Light-duty vehicle charging is also a barrier for households that cannot afford to install level 2 home charging, or face other barriers such as landlord resistance or lack of off-street parking. Schools have limited budgets for expenditures for

[24] The Innovative Clean Transit and the Zero-Emission Airport Shuttle regulations have been adopted. The Advanced Clean Trucks, ZEV Fleet Rule, Zero-Emission Transport Refrigeration Unit Regulation, and the Zero-Emission Drayage Truck Regulation, among others, are being developed.

transporting students and many of the underfunded schools also have the oldest, dirtiest school buses. Funding ZEV infrastructure for school buses will facilitate replacement of polluting diesel school buses with zero-emission technology.

g. Direct CEC and CPUC to identify investment priorities for ZEV infrastructure to serve high-mileage fleets and build the business case for ZEV infrastructure.

High-mileage fleets, such as ride-hailing services, transit, delivery vehicles, and heavy-duty applications have the potential to reduce more GHG and criteria air pollutants through ZEVs. Ongoing planning efforts should be leveraged to ensure that public funds for ZEV infrastructure support high-mileage applications and help build the business case for ZEV infrastructure (for example, lowering the cost of upstream transmission and distribution system upgrades [e.g., transformers] would reduce barriers to large-scale deployments of high-mileage or heavy-duty vehicles).[25]

h. Increase CEC and Caltrans funding for state-of-the-art ZEV regional readiness planning and implementation, including engagement with local jurisdictions.

Regional readiness plans enable communities to plan for and efficiently deploy ZEV infrastructure, permitting procedures, and other supportive policies that enable successful support of ZEVs within a region. These plans should take an integrated approach to light-duty, and heavy-duty infrastructure, and include upcoming regulations. These plans should also be rewarded with streamlined grant requirements for implementation funding.

i. Expand focus of transportation funding to reflect ZEV infrastructure needs at seaports and freight distribution facilities.

Statutory support for developing key ZEV infrastructure projects will help enable adoption and operation of zero-emission technologies along major freight corridors, at the ports of Los Angeles, Long Beach and Oakland, at freight distribution centers and hubs. For example, when improving a conventional roadway in these freight areas, should also install an adjacent zero-emission truck parking and refueling facility to support transportation electrification in freight.

j. Direct the Electric Program Investment Charge (EPIC) programs, implemented by the CEC and the investor-owned utilities, to include research, and development into next-generation ZEV infrastructure technologies and operational strategies, including a focus on growing ZEVs in disadvantaged communities.

[25] Nicholas and Hall, 2018. ICCT White Paper. July 2018. "Lessons Learned on Early Electric Vehicle Fast-Charging Deployments." https://theicct.org/sites/default/files/publications/ZEV_fast_charging_white_paper_final.pdf.

Newer technologies and strategies, such as wireless charging, ultrafast charging stations, smart-charging, and vehicle-to-grid integration, have potential to increase convenience of refueling ZEVs, helping to grow the ZEV market.

4) Local policies

Local governments currently do not have explicit authority or a uniform statutory framework to implement policies such as zero-emission zones, road-usage, or emissions-based pricing. These policies are likely to yield substantial local air quality benefits,[26] could create new local revenue, and would send a strong signal to encourage the use of light- and heavy-duty ZEVs. These policies should be developed in the context of the jurisdiction's general plan.

a. **Provide explicit authority to local jurisdictions to create zero-emission zones.**

   Statute allowing for the creation of zero-emission zones would support ZEV market growth. These should be designed with equity considerations, to minimize the exposure of sensitive populations to air pollution. These zones could be at the city-level involving all vehicles or focused on encouraging the adoption of zero-emission delivery trucks through localized green loading zones that preferentially allow zero-emission deliveries or green logistics zones that restrict internal combustion delivery trucks at certain times and locations such as those in effect in Shenzhen, China.[27] Furthermore, ports and other freight facilities could also establish fast green lanes for zero-emission trucks during peak hours that provide "front-of-the-line" access as a motivation for encouraging early ZEV adoption.

b. **Provide explicit authority to local governments to implement equitable pricing mechanisms that favor pooling and ZEVs in a way that meets the mobility needs of priority populations.**

   Pricing mechanisms support multiple State goals, including encouraging pooling and accelerating the ZEV market, but in order to ensure these policies serve mobility needs of priority populations, they must be designed with equity considerations and community needs in mind.

c. **Incentivize local governments to develop local ZEV readiness plans and implement policies to encourage the use of ZEVs, such as preferential or discounted parking programs and curbside charging.**

   Regional readiness plans enable communities to plan for and efficiently deploy ZEV infrastructure, permitting procedures, and other supportive policies that

[26] Simeonava, et al., 2018. National Bureau of Economic Research Working Paper Series. March 2018. "Congestion Pricing, Air Pollution and Children's Health." https://www.nber.org/papers/w24410.pdf.
[27] Crow, et al., 2019. Rocky Mountain Institute. July 2019. "A New EV Horizon: Insights from Shenzhen's Path to Global Leadership in Electric Logistics Vehicles." https://rmi.org/wp-content/uploads/2019/06/a-new-ev-horizon.pdf.

enable successful support of ZEVs within a region. Local governments also have the ability to implement other policies that favor ZEVs, for example by providing curbside charging and parking-related incentives such as free or discounted parking for ZEVs or by locating ZEV parking spaces in desirable locations.

5) Fleet adoption

As a wider array of ZEVs and plug-in hybrid electric vehicles (PHEVs) becomes available, light-, medium-, and heavy-duty fleets of all types will have more opportunities to adopt and use them, with the potential to rapidly expand both market growth and consumer awareness of ZEVs and zero-emission miles.

a. Direct CARB to adopt zero-emission mileage requirements in all high-mileage and new mobility fleets (such as carsharing), while ensuring that these requirements also aim to minimize vehicle miles traveled overall (e.g., by building connections to transit and active transportation wherever possible, similar to SB 1014).[28]

   High-mileage fleets (such as carsharing and delivery fleets) emit more GHGs and criteria air pollutants, therefore ZEVs should be in these fleets to further reduce emissions and accelerate ZEV market growth and awareness.

b. Direct the Department of General Services (DGS) to track vehicle usage and establish zero-emission VMT targets for the State's fleet, and set ZEV targets for other vehicles used by the State (e.g., rental cars and new mobility services used for State employee travel).

   Replacing gasoline and diesel miles with zero-emission miles supports the State's air quality and climate goals. California should lead by example and support light-, medium-, and heavy-duty ZEV market growth. In fact, California's DGS is leading by example by requiring all non-public safety sedans purchased by State agencies to be ZEVs, in response to EO N-19-19.[29] Setting zero-emission VMT targets ensures ZEVs in the State fleet are actually utilized.

c. Establish ZEV targets for other government fleets as ZEV models become available to meet their needs.

   Local governments should also lead by example, and prepare for the increasing number of ZEVs in their jurisdictions.

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[28] Skinner, Chapter 369, Statues of 2018.

[29] DGS, 2019. November 15, 2019. "State Announces New Purchasing Policies to Reduce Greenhouse Gas Emissions from the State's Vehicle Fleet." https://www.dgs.ca.gov/Press-Releases/Page-Content/News-List-Folder/State-Announces-New-Purchasing-Policies-to-Reduce-Greenhouse-Gas-Emissions.

6) Outreach and education

Awareness of light- and heavy-duty ZEVs remains low,[30, 31] affecting consumer acceptance and implementation of supporting policies like infrastructure.

a. **Create a State "Electricity Rate" Ombudsperson to provide expertise to fleets that are transitioning to ZEVs.**

   Electricity costs for transportation electrification are difficult to predict and can be higher than gasoline or diesel depending on the electricity rate a customer is enrolled in through their local utility and their charging behavior, especially for commercial entities.[32, 33] Individuals, fuel providers, and fleet operators have a difficult time estimating their electricity bill and optimizing their charging behavior to maximize ZEV fuel cost savings due to complex electricity rate structures and demand charges.[34]

b. **Increase funding for existing and new programs for ZEV consumer and fleet outreach and education campaigns to build awareness and dispel misconceptions about ZEVs, including for priority populations and heavy-duty fleet operators.**

   Ongoing efforts, such as Veloz's Statewide consumer campaign and the DriveClean website, lack sufficient resources to scale up and broaden beyond the light-duty sector. In addition to State funds, seek investments from the private sector to support these efforts. Additionally, support new efforts such as incentivizing light- and heavy-duty driver education facilities to train future drivers using ZEVs to increase awareness and familiarity with the technology, which could be a powerful outreach campaign.

c. **Fund training for local government inspection, building, and planning officials, and builders, about ZEVs and ZEV infrastructure to achieve ZEV infrastructure permit streamlining for light- and heavy-duty applications.**

   Installation of infrastructure is taking longer to build out in California than in other states due in part to slow permitting processes. ZEV infrastructure

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[30] Kurani, et al., 2016. Final Report. March, 2016. "New Car Buyers' Valuation of Zero-Emission Vehicles: California" https://ww3.arb.ca.gov/research/single-project.php?row_id=65166.

[31] Turrentine, et al., 2018. International EV Policy Council Policy Guide. March 2018, "Driving the Market for Plug-in Vehicles: Increasing Consumer Awareness and Knowledge." https://phev.ucdavis.edu/wp-content/uploads/Consumer-Education-Policy-Guide-March-2018.pdf.

[32] Nicholas, 2018. ICCT Briefing. February 2018. "Ensuring Driving on Electricity is Cheaper than Driving on Gasoline." https://theicct.org/sites/default/files/publications/Driving-on-electricity-versus-gasoline_ICCT-Briefing_26022018_vF.pdf.

[33] Lee and Clark, 2018. Harvard Faculty Research Working Paper Series RWP18-026. September 2018. "Charging the Future: Challenges and Opportunities for Electric Vehicle Adoption." https://projects.iq.harvard.edu/files/energyconsortium/files/rwp18-026_lee_1.pdf.

[34] Because demand charges are based on the maximum load, rather than the average, they penalize short bursts of high power demanded from charging electric vehicles, especially with the faster chargers. Demand charges favor consistent loads, even if high.

permitting timeliness and complexity is a barrier despite the requirement for local jurisdictions to streamline permitting pursuant to AB 1236.[35] *Outreach to permitting officials and builders regarding siting and permit review best practices would speed up and reduce the cost of ZEV infrastructure installations for both light-duty and heavy-duty applications.*[36]

d. Provide funding for CARB to establish partnerships with manufacturers and the academic community to foster experimentation and innovation.

Partnerships with industry and the academic community could accelerate commercialization and deployment of ZEVs. Research into sustainable business models for ZEV manufacturers and charging/fueling, ZEV opportunities in the freight sector, and strategies to ensure California's policies are exportable to other jurisdictions and will help California build a sustainable ZEV market and ensure that the State remains at the leading edge of the ZEV transition. These partnerships could create a public forum for sharing lessons learned from adopting zero-emission technology across the heavy-duty applications.

7) Workforce development

The ZEV transition will require a growing workforce that can manufacture, service, and operate zero-emission vehicles and infrastructure. With California leading the ZEV market, this can create opportunities for quality job creation and for increased access to quality employment for disadvantaged and under-represented workers.

a. Increase investment in existing California Workforce Development Board (CWDB) and Employment Training Panel (ETP) programs that target occupation and skill gaps and promote job preparation through partnerships between educational institutions and ZEV-related employers.

Growing a strong ZEV workforce requires that professional development, training, and apprenticeships match occupation gaps and lead to employment. This investment is critical for priority populations.

b. Fund CWDB to conduct research on the net job benefits from public investments in zero-emission vehicles and infrastructure and identify strategies to ensure the quality and accessibility of these jobs.

Transitioning the transportation sector to zero-emissions will create clean technology jobs, but more information is needed about the net benefits and impacts to jobs and to ensure that ZEV-related jobs are high-quality and that disadvantaged and under-represented workers have access to these career pathways.

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[35] Chiu, Chapter 598, Statutes of 2015.

[36] GO-Biz's Electric Vehicle Charging Station Permitting Guidebook provides a foundational outreach document: http://businessportal.ca.gov/wp-content/uploads/2019/07/GoBIZ-EVCharging-Guidebook.pdf.

8) Program flexibility

Agencies administering ZEV incentive and infrastructure programs need flexibility and longer expenditure deadlines for funding to respond to the rapidly evolving ZEV market, keep programs streamlined and easy to access and understand by consumers, support ZEV development especially in the earliest stages of commercialization, and respond to needs from priority populations.

a. Remove statutory barriers that inhibit consumers' ability to access ZEV incentives.

Point-of-sale incentives are the most effective type of vehicle purchase incentive.[37] However, income caps introduce complexity that make it nearly impossible to provide the rebates at the point-of-sale. These types of competing priorities often lead to program complexity.

b. Remove statutory barriers that limit ZEV program adaptability.

Additionally, many existing ZEV programs' specific requirements become outdated as the ZEV market matures, hindering their ability to respond to the emerging ZEV market. More flexibility in funding program requirements would allow investments to shift toward emerging technologies that will continue to accelerate the ZEV transition.

c. Continue to provide four years as the funding liquidation deadline especially for technology demonstration projects, pilots, and programs that include ZEV refueling infrastructure.

These projects are complex and need sufficient time for vehicle manufacturing, and the lengthy permitting and CEQA review processes. Two years to spend the funds, as was allowed in budgets prior to the FY 2019-20, is often inadequate to see a project through to completion, and leaves little or no time for data collection and reporting. Continuing to have four years to liquidate and two to encumber the funds, as was done in the 2019-2020 budget, is sufficient time.

These eight sets of policy recommendations will help further accelerate the adoption and use of ZEVs in California, and to continue to foster the environment of investment and innovation that the ZEV market still requires if California is to meet its air quality, climate, and community health goals. These policy recommendations have been refined and improved based on feedback from external stakeholders, including other State agencies, researchers at the University of California, Institute of Transportation Studies (UC-ITS), and the public. These policy recommendations are near-term measures. If California does not sufficiently accelerate the adoption of ZEVs, then

[37] Hardman, et al., 2018. International EV Policy Council Policy Guide. March 2018. "Driving the Market for Plug-in Vehicles: Understanding Financial Purchase Incentives." https://phev.ucdavis.edu/wp-content/uploads/Purchase-Incentives-Policy-Guide-March-2018.pdf.

more aggressive measures will be needed, such as a ban on internal combustion engine vehicles.

Review of CARB's ZEV Programs

SB 498 requires that CARB review its programs that affect the adoption of light-, medium-, and heavy-duty ZEVs, including identifying each program's goals and status in meeting those goals, and performing a cost-benefit analysis. The goal of all of California's on-road ZEV programs is to transform the transportation sector to zero-emission technology, in order to attain air quality, climate, and public health goals, and improve social equity to ensure that the benefits of technology advancement are shared by all Californians,[38, 39, 40, 41] and that all communities have access to clean transportation options.[42] CARB's portfolio of ZEV programs targets a broad range of vehicle technologies, including battery electric, plug-in hybrid, and fuel cell electric in light-, medium-, and heavy-duty applications, and a range of different stages of market development from pre-commercial demonstration to commercial deployment. In addition, some of the programs are focused exclusively on social equity.

At the time of publication of this draft report, CARB has 28 ZEV regulatory, incentive, and supporting programs either in place or under development, and CARB actively contributes to six programs managed by other agencies that affect the adoption of on-road ZEVs. These programs are introduced in Chapter 4. For ZEV programs currently in place, Chapter 5 of this report qualitatively assesses the programs' benefits, including benefits to climate, air quality, public health, market transformation, priority populations, jobs related to low carbon transportation, and energy and fuel savings. This chapter also quantifies the costs and emission benefits for the subset of programs that have sufficient data directly linked to the program. Collectively, these ZEV programs are encouraging manufacturers to produce ZEVs, helping to build a sustainable consumer market for ZEVs, and encouraging priority populations to access ZEVs. Through implementation of these programs, CARB has learned a number of lessons, enumerated in Chapter 7, which directly informed this report's policy recommendations.

Comparison with Other Jurisdictions

CARB continues to learn from implementation of our own ZEV programs, but many other jurisdictions in the United States and around the world are also pursuing policies and programs to accelerate ZEV adoption in order to meet their own public health, air quality, climate, and energy security goals. Additionally, some jurisdictions have also

[38] SB 535, De León, Chapter 830, Statutes of 2012.
[39] SB 1275, De León, Chapter 530, Statutes of 2014.
[40] AB 1550, Gomez, Chapter 369, Statutes of 2016.
[41] AB 617, C. Garcia, Chapter 136, Statutes of 2017.
[42] CARB, 2018a.

been motivated to support growth in their domestic ZEV industry.[43, 44] ZEV requirements are a key part of California's multi-pronged approach to grow the ZEV market, which also includes incentives for manufacturers to produce ZEVs and for consumers to help them surmount the upfront cost of early-market ZEVs, and many supporting programs to ensure adequate fueling infrastructure, raise consumer awareness, and more. California is at the leading edge of ZEV regulatory efforts and many other ZEV regulatory programs resemble California's program. California works directly with many other jurisdictions and exercises additional market power on vehicle manufacturers by doing so. There is a wide range of approaches to incentivizing ZEV purchases, with rebates, point-of-sale incentives, and tax-based approaches being the most common. The comparison to other jurisdictions in this report, Chapter 6, focuses on ZEV purchase incentive and regulatory programs because the majority of programs that CARB administers falls into one of these two categories. Results are summarized in Table ES - 1 and Table ES - 2. The details of the ZEV purchase incentive programs vary by jurisdiction. For example, some jurisdictions include increased incentives for low-income consumers, others incentivize the purchase or lease or used ZEVs and PHEVs, and others cap eligibility based on either the price of vehicles or the household income. Lastly, the amount of the incentive typically varies by vehicle technology and not every jurisdiction provides incentives for all technologies (e.g., Massachusetts does not incentivize PHEVs and Oregon excludes FCEVs).

[43] Bahree, 2019. March 9, 2019. Forbes. "India Offers $1.4 Billion in Subsidies to Support the Domestic Electric Vehicle Industry." https://www.forbes.com/sites/meghabahree/2019/03/09/india-offers-1-4-billion-in-subsidies-to-support-the-domestic-electric-vehicle-industry/#bc95a5b610a0. Accessed August 15, 2019.

[44] Huang, 2019. June 25, 2019. "China's Breaking up the EV Battery Monopoly it Carefully Created." https://qz.com/1651944/china-ends-policy-steering-ev-makers-to-local-battery-firms/. Accessed August 15, 2019.

Table ES - 1 Purchase Incentives for Light-Duty ZEVs and PHEVs Provided by Other Jurisdictions, Showing the Range of the Incentive Provided

Rebate	Income Tax Credit	Point-of-Sale Rebate	Other Tax Incentive	Feebate
California[45] ($1,500-$7,000) British Columbia ($1,125-$2,275) Connecticut[46] ($1,000-$5,000) Delaware ($1,500-$3,500) Massachusetts ($1,500) Oregon ($1,500-$5,000) Pennsylvania ($1,000-$2,500)	Colorado ($1,900-$5,000) United States (up to $7,500)	Canada ($1,900-$3,800) Connecticut[43] ($1,000-$5,000) New York ($500-$2,000) United Kingdom ($4,500)	China ($1,500-$3,700) Germany ($3,400-$4,600) Japan ($1,700-$3,500) Maryland (up to $3,000) Netherlands ($3,800-$8,000) New Jersey Norway ($10,000-$11,600) Portugal ($1,300-$3,400) South Korea ($6,700-$13,200) Spain ($6,400) Washington	France ($1,000-$9,100) Sweden ($2,400-$6,500)

[45] For California, showing the maximum incentive available for the CVRP, which incentivizes the purchase or lease of new ZEVs and PHEVs with an increased rebate for low-income consumers. However, California also has two incentive pilot projects for low-income and disadvantaged community residents: 1) the Clean Cars 4 All, which incentivizes the replacement of a high-polluting vehicle with the purchase or lease of used or new ZEVs, PHEVs, and other eligible vehicles by low-income consumers within certain air districts, and 2) the Financing Assistance for Lower-Income Consumers Project, which provides low interest loans and vehicle price buy-downs to these consumers for used or new ZEVs, PHEVs, and other eligible vehicles.

[46] Connecticut provides the option of a check mailed to consumer or point-of-sale rebate at the dealership.

Table ES - 2 Adopted and Proposed Light-, Medium-, and Heavy-Duty ZEV Regulations in Other Jurisdictions

Jurisdiction	ZEV Regulation	Type of Requirement
California	Light-duty ZEV regulation through model year (MY) 2025	Manufacturer vehicle production
	Innovative Clean Transit Regulation begins in 2020 with 100 percent zero-emission public transit bus fleet by 2040	Fleet requirement: transit agencies
	Zero-Emission Airport Shuttle Bus Regulation will be begin to be implemented in 2022	Fleet requirement: airport shuttles
	Advanced Clean Trucks Regulation in development; 2024-2030 period	Manufacturer vehicle production
	Clean Miles Standard, in development to begin in 2023	Fleet requirement: transportation network companies
Section 177 ZEV States[47]	Light-duty ZEV regulation same requirements as California's ZEV regulation	Manufacturer vehicle production
Québec, Canada	Light-duty ZEV regulation through MY 2025	Manufacturer vehicle production (new and used eligible vehicles)
British Columbia, Canada	Light-duty ZEV regulation for MY 2020 and beyond	Manufacturer vehicle production
China	Light-duty New Energy Vehicle (NEV) regulation 2019-2020 adopted; regulation for 2021-23 in development	Manufacturer vehicle production
European Union	Light-, medium-, and heavy-duty vehicles fleet-wide CO_2 emission targets for 2025, 2030 with voluntary ZEV quotas as a compliance flexibility	Manufacturer fleet-wide CO_2 emissions reduction

Recommendations for fleets

The final Chapter of this report focuses on recommendations for vehicle fleet operators to increase the number of ZEVs in vehicle fleet use.[48] California is part of the West Coast Electric Fleets[49] initiative that is helping private and public fleets expand the use

[47] Section 177 of the Clean Air Act (42 U.S.C. §7507) authorizes other states to choose to adopt California's standards in lieu of federal requirements. States are not required to seek U.S. EPA approval before adopting California's standards. Thirteen other states have adopted California's Low Emission Vehicle Regulations and nine of those have adopted California's ZEV Regulation. The Section 177 ZEV states are: Colorado, Connecticut, Maine, Maryland, Massachusetts, New York, New Jersey, Oregon, Rhode Island and Vermont.

[48] SB 498 defines fleets as ten or more vehicles under common ownership or operation.

[49] West Coast Electric Fleets, 2019. "West Coast Electric Fleets." http://www.westcoastelectricfleets.com/. Accessed August 15, 2019.

of ZEVs within their fleets through education and tools. CARB staff reviewed existing resources to identify these recommendations for fleet operators, which are summarized here and elaborated on in Chapter 9. CARB staff recommends fleets do the following:

1) Assess fleet needs

   Assess fleet applications or routes to find where zero-emission cars, trucks, and buses will meet vehicle performance characteristics needs. If choosing electric vehicles, need to consider the average and maximum daily driving range as well as the required recharging time. For both electric and hydrogen vehicles, you must consider how and where they will be refueled. Both ZEV technologies and the ZEV market are maturing rapidly as indicated by the introduction of increasing number of vehicle platforms that support usage in diverse vehicle vocations, increasing vehicle range, and decreasing purchase costs.

2) Research zero-emission options

   Compared to conventional cars, trucks, and buses, ZEVs typically have lower maintenance costs and can also have lower fuel cost per mile, especially when considering fuel incentives provided by the Low Carbon Fuel Standard. Today, ZEVs still have higher upfront purchase costs than comparable vehicles, but with purchase incentives this increased cost may be reduced. Therefore, your comparison between conventional vehicles and ZEVs should be done on a total cost of ownership basis, which will be increasingly favorable in many applications in the coming years.

3) Collaborate with internal and external stakeholders

   Engage with drivers, technicians, procurement staff, internal clients, and senior management to develop internal buy-in, define the motivation for electrifying the fleet, and identify barriers. Develop external relationships and partnerships with local utility representatives, zero-emission vehicle and infrastructure vendors, and others to help ensure success. Participating in external aggregate purchase agreements can also minimize the upfront costs of ZEVs.

4) Develop and implement a strategic plan to acquire and utilize ZEVs

   Because every fleet has different needs, budget constraints, different options for ZEV infrastructure, and unique internal, local, and state policies, it is important to develop a strategy specific to each fleet. This plan should include training internal stakeholders as necessary and researching the reliability of the supply chain.

5) Share your ZEV fleet experiences

   Let constituents and clients know if your fleet is an early ZEV adopter to gather support and good press coverage. Finally, help other fleets transitioning by sharing about your ZEV experience.

Next Steps

Per SB 498 requirements, CARB staff will present these policy recommendations to solicit input from CARB's Board and stakeholders at the January 23 and 24, 2020 CARB Board hearing. CARB staff will continue to incorporate stakeholder feedback into the final report, and will submit the final report to the Legislature at least 30 days after the Board hearing, as required by the bill.

CHAPTER 1: INTRODUCTION

In 2017, the California Legislature passed Senate Bill (SB) 498 (Skinner, Chapter 628, Statutes of 2017, Appendix A), that directs the California Air Resources Board (CARB) to review its programs that affect the adoption of light-, medium-, and heavy-duty zero-emission vehicles (ZEVs). This review includes identifying each program's goals and status with respect to meeting those goals, a cost-benefit analysis, and a comparison of CARB's ZEV programs with those of other jurisdictions. SB 498 also directs CARB to make policy recommendations for increasing the use of ZEVs in the State, and recommendations for vehicle fleet operators to increase the use of ZEVs. This report responds to SB 498. There is a companion report focused solely on the Clean Vehicle Rebate Project (CVRP) in response to Assembly Bill (AB) 615[50] (Cooper, Chapter 631, Statutes of 2017).

In developing this report, CARB staff consulted with stakeholders, including the Institutes of Transportation Studies of the University of California (UC-ITS), on the policy recommendations and quantification methodology used in this report, as required by SB 498. This report was also informed by the "Assessing Alternatives to California's Electric Vehicle Registration Fee"[51] report in response to SB 1,[52] and by CARB's staff's report that identified barriers that low-income Californians face in accessing zero-emission transportation options.[53] CARB staff also held a public workshop in May 2019 and will hold a Board hearing in October 2019 focused on the policy recommendations. Feedback received will be incorporated into the final version of this report. CARB staff also consulted with other State agencies that have complementary ZEV responsibilities that help accelerate the transition of on-road vehicles to zero-emission technologies through the Governor's Interagency Working Group on Zero-Emission Vehicles.

This report is focused on light-, medium-, and heavy-duty on-road vehicles, per the language in SB 498,[54] and is organized into eight main sections. After this introductory

[50] CARB, 2019. "Assembly Bill 615 Report to the Legislature on the Impact of the Clean Vehicle Rebate Project on California's Zero-Emission Vehicle Market" https://ww3.arb.ca.gov/research/apr/reports/AB%20615-Clean%20Vehicle%20Rebate.pdf.

[51] Jenn, 2018. Research Report from the University of California Institute of Transportation Studies. December 2018. "Assessing Alternatives to California's Electric Vehicle Registration Fee." https://doi.org/10.7922/G2PZ571D.

[52] Beall, Chapter 5, Statutes of 2017.

[53] CARB, 2018. "Low-Income Barriers Study, Part B: Overcoming Barriers to Clean Transportation Access for Low-Income Residents", https://ww2.arb.ca.gov/sites/default/files/2018-08/sb350_final_guidance_document_022118.pdf.

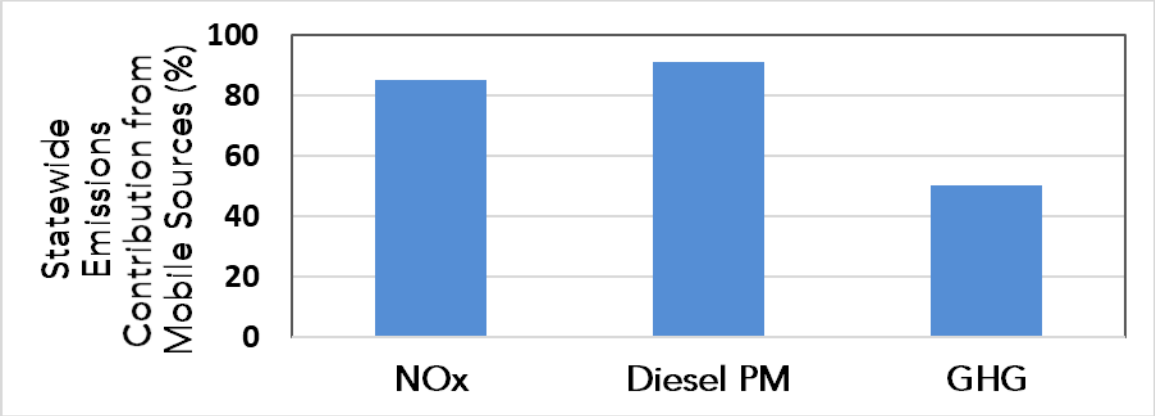
[54] There are a handful of programs discussed in this report that include both heavy-duty on-road vehicles as well as off-road vehicles and equipment. Medium-duty vehicles are not referenced specifically in this report because they are typically split into the light-duty or heavy-duty programs depending on the weight of the vehicle.

Chapter 1, Chapter 2 provides additional background on the importance of ZEVs and why they are crucial for meeting California's air quality and climate goals. Chapter 3 provides a status of the ZEV market. Chapter 4 and 5 comprise the review of CARB's ZEV programs, with Section 4 introducing all the programs, and Chapter 5 qualitatively assessing and quantitatively analyzing the ZEV programs' costs and benefits. Chapter 6 contains the comparison of CARB's ZEV programs with those of other jurisdictions, and Chapter 7 summarizes lessons learned. Chapter 8 describes policy recommendations to further accelerate ZEV adoption, and Chapter 9 outlines steps fleet operators can take to increase the share of ZEVs in their fleets. Appendices include the text of SB 498 (Appendix A), more detailed descriptions of CARB's ZEV programs (Appendix B), details of the cost-benefit methodologies (Appendix C), and an overview of ZEV programs that are administered by all California State agencies (Appendix D).

CHAPTER 2: WHY ZERO-EMISSION VEHICLES ARE IMPORTANT

In order to achieve California's public health protection goals, minimize air pollution exposure, and mitigate climate change impacts, California needs to reduce the total number of vehicles on the road and both the amount they are driven and idled.[55] Additionally, the remaining vehicles must be transitioned to zero-emission technology to help achieve these goals. California is the nation's largest vehicle market, with approximately 28 million total light-, medium-, and heavy-duty registered vehicles.[56] Each day these vehicles drive approximately 1 billion miles, consuming more than 40 million gallons of gasoline and 10 million gallons of diesel.[57] As a result, California's mobile sources[58] are responsible for the vast majority of the State's emissions of toxic diesel particulate matter and regional smog-forming NO_X[59]—posing a persistent challenge to meeting health-based National Ambient Air Quality Standards—and are the largest source of GHG emissions (comprising 50 percent of 2016 GHG emissions when including emissions from oil and gas extraction and fuel refineries).[60] (Figure 1)

Figure 1 Statewide Emissions Contribution from Mobile Sources



The health impacts of exposure to elevated levels of air pollution are

[55] CARB, 2016. Mobile Source Strategy, https://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf.
[56] CARB, 2015a. "EMFAC2017 Volume III – Technical Documentation" https://ww3.arb.ca.gov/msei/downloads/emfac2017-volume-iii-technical-documentation.pdf.
[57] Ibid.
[58] Mobile sources include on-road and off-road vehicles and equipment.
[59] CARB, 2016. Mobile Source Strategy, https://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf.
[60] CARB, 2019. 2019 Edition, California Greenhouse Gas Emission Inventory: 2000 – 2017, https://www.arb.ca.gov/cc/inventory/pubs/reports/2000_2016/ghg_inventory_trends_00-16.pdf.

considerable, and approximately 12 million Californians still breathe unhealthy air.[61] Exposure to regional ozone and particulate matter leads to a range of respiratory and cardiovascular health impacts, including exacerbations of asthma and heart disease, and is estimated to contribute to approximately 7,500 premature deaths in California, and millions globally, each year.[62] National Ambient Air Quality Standards for ozone and particulate matter seek to reduce those impacts; California's Mobile Source Strategy[63] and State Strategy for the State Implementation Plan[64] lay out the measures to achieve these standards in California.

California is already experiencing the impacts of climate change through increasingly severe and frequent heat waves, droughts, floods, sea-level rise, and wildfires, all of which pose direct and indirect risks to public health and the economy.[65] These impacts from climate change are expected to continue worsening as GHG emissions increase and disproportionately affect the State's most vulnerable populations. In order to mitigate these impacts, California has established Statewide GHG reduction goals of 40 percent below 1990 levels by 2030[66]—with a strategy to achieve this target outlined in the Scoping Plan[67]—and carbon neutrality by 2045.[68]

ZEV technology is critical to achieving these air quality and GHG goals because ZEVs eliminate tailpipe emissions while also drastically reducing GHGs and petroleum dependence; for example, Figure 2 illustrates the expected 2030 tailpipe and fuel production emissions for battery electric passenger cars compared to conventional gasoline cars. Meeting the National Ambient Air Quality Standards will pay substantial dividends in reducing the economic burdens associated with emergency room visits and hospitalization, lost work and school days, and premature mortality.

Besides improving public health and stabilizing the climate, transitioning the transportation sector to zero-emission bolsters the California and U.S. economies by supporting clean technology jobs and associated economic activity. Increased

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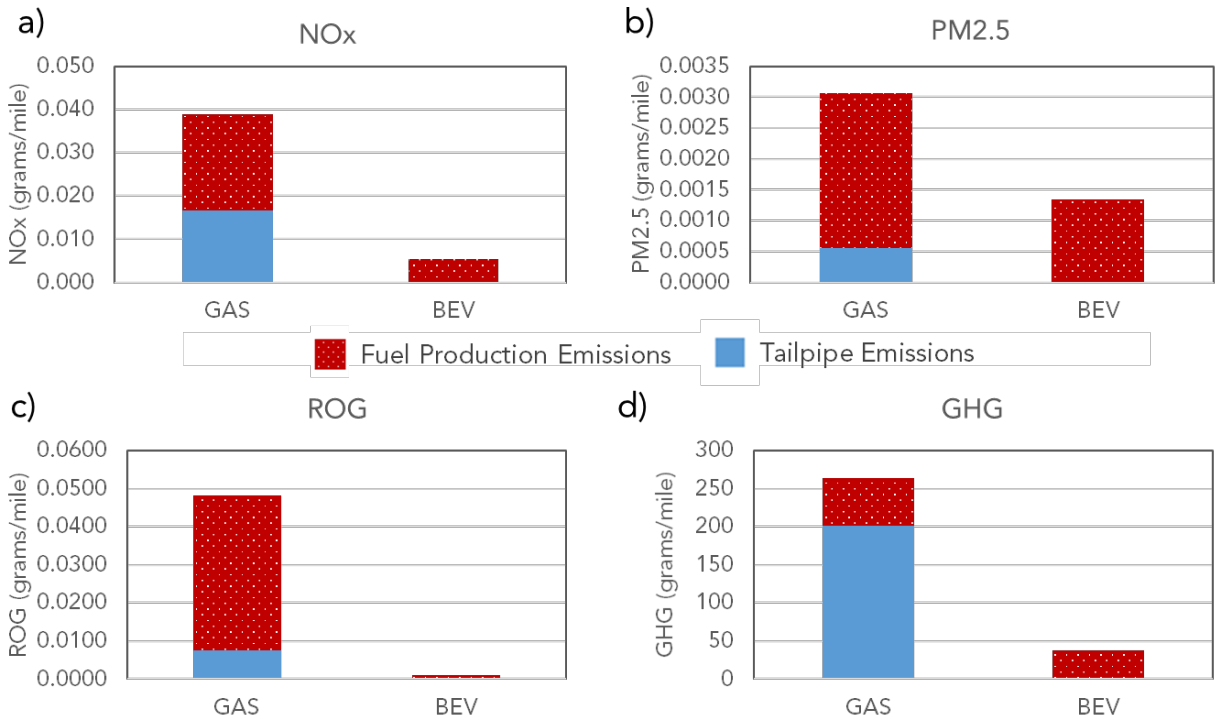
[61] CARB, 2016. Mobile Source Strategy, https://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf.
[62] CARB, 2017. Revised Proposed 2016 State Strategy for the State Implementation Plan, https://ww3.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf.
[63] CARB, 2016. Mobile Source Strategy, https://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf.
[64] CARB, 2017. Revised Proposed 2016 State Strategy for the State Implementation Plan, https://ww3.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf.
[65] Bedsworth, et al., 2018.
[66] SB 32, Pavley, Chapter 249, Statutes of 2016.
[67] CARB, 2017. November 2017. "California's 2017 Climate Change Scoping Plan." https://ww3.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf.
[68] Executive Order B-55-18. September 10, 2018. https://www.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf.

demand for zero-emission vehicles and infrastructure will affect employment, output, and investment in sectors that supply goods and services to support ZEVs, such as innovative technology developers, vehicle and grid software developers, utility providers, and many others. In addition, the growing need for ZEV infrastructure is expected to result in increases in construction jobs, including for electrical contractors and other wiring installation contractors.

Figure 2 Estimated Fuel Production and Tailpipe Emissions from New 2030 Gasoline and Battery Electric Passenger Vehicles in Grams per Mile[69]



Unfortunately, federal backsliding on vehicle emissions and fuel economy threatens to undermine California's momentum on ZEVs. In August 2018, the U.S. Environmental Protection Agency (U.S. EPA) and the National Highway Traffic Safety Administration (NHTSA) issued a proposal to significantly roll back existing federal greenhouse gas emissions and fuel economy standards for passenger cars and light trucks.[70] The proposal (which is premised on faulty analyses and modeling[71]) also sought to preempt California's passenger car and light truck greenhouse gas emission standards and ZEV requirements and withdraw California's waiver of federal preemption under the Clean

[69] Calculated based on vehicle and fuel regulations in place today that become more stringent by 2030 making both the vehicle and fuels cleaner. Source: CARB Vision Program 2019.

[70] 83 Fed. Reg. 42,986 (Aug. 24, 2018).

[71] *See* CARB, *Analysis in Support of Comments of the California Air Resources Board on the Safer Affordable and Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light-Duty Trucks* (Oct. 26, 2018), Docket No. EPA-HQ-OAR-2018-0283-5054, pp. 122, et seq.

Air Act for these regulations.[72] California's existing ZEV requirement would have continued increasing ZEV sales through model year 2025, but U.S. EPA and NHTSA finalized the preemption and waiver revocation pieces of the proposal on September 27, 2019,[73] effectively suspending California's ZEV sales requirement. California, with many other states, cities, and environmental organizations, has filed litigation challenging the finalized preemption and waiver revocation, and expects to similarly challenge the rolled back standards if or when U.S. EPA and NHTSA finalize them.[74] If California does not prevail against the federal proposal, it must rely to a much greater degree on other strategies to reduce transportation-related emissions, including land use strategies that reduce vehicle miles traveled, in-use regulations promoting zero-emission technologies, incentives, and continued cooperation from manufacturers.

[72] Section 209 of the Clean Air Act, 42 U.S.C. § 7543, authorizes California to regulate motor vehicle emission standards.

[73] 84 Fed. Reg. 51,310.

[74] If or when the federal government will finalize its unwise rolled back standards remains unclear. The proposal has been losing support. Several automobile manufacturers have agreed to a set of framework terms for light-duty vehicle greenhouse gas emission standards that would maintain a national program more rigorous than that the Trump Administration has proposed. Discussions with these automakers, the federal government, and CARB continue. CARB is focused on ways to ensure auto programs continue to protect public health, promote ZEVs, and reduce air pollution. *See* Eilperin, J., Dennis, B., *"Major automakers strike climate deal with California, rebuffing Trump on proposed mileage freeze,"* Washington Post, July 25, 2019, https://www.washingtonpost.com/climate-environment/2019/07/25/major-automakers-strike-climate-deal-with-california-rebuffing-trump-proposed-mileage-freeze/?utm_term=.6b2ceb5ac773.

CHAPTER 3: STATE OF THE ZEV MARKET

California's ZEV market continues to build momentum. In a span of ten years, the market has grown exponentially from a minimal number of total ZEVs in 2009 to over half 600,000 light-duty ZEVs on the roads in California in mid-2019.[75] ZEVs accounted for nearly eight percent of new light-duty vehicle sales in 2018[76] (Figure 3), which represents a growth in market share of almost 40 percent compared to 2017.[77] Additionally, there are 47 zero-emission light-duty cars and trucks offered for sale or lease in California[78] (Figure 4) with more planned in the coming years. While the majority of the ZEVs sold have been PHEVs and BEVs, the younger light-duty fuel cell electric vehicle (FCEV) market is gaining momentum growing from fewer than 100 a decade ago to approximately 6,000 on California's roads by mid-2019.[79] The heavy-duty ZEV market is also growing rapidly as ZEV technology transfers from light-duty and smaller heavy-duty ZEV applications,[80] with over 100 models commercially available today[81] (Figure 5) and many major manufacturers announcing plans for future commercialization of battery-electric and hydrogen fuel cell electric trucks and buses.

Refueling infrastructure is needed to power the vehicles and support the ZEV market. As of December 2019, California has 22,233 electric vehicle charging outlets, including 3,355 direct current fast chargers (DCFCs), at over 5,674 public stations throughout the State and 41 public retail hydrogen stations located in the major metropolitan areas compared to virtually none a decade ago.[82] The State's goal is to have 1.5 million ZEVs on the road, 250,000 charging outlets, including 10,000 DCFC, and 200

[75] Veloz, 2019. "Sales Dashboard." Last updated: August 6, 2019. https://www.veloz.org/sales-dashboard/. Accessed August 15, 2019.
[76] When adding up the electric vehicles, plug in hybrid vehicles and fuel cell vehicles from: California New Car Dealers Association (CNCDA), 2019a. "California's New Car Dealers Lead the Nation in Selling ZEVs." https://www.cncda.org/wp-content/uploads/CNCDA-ZEV-Handout_031119-3.pdf.
[77] CNCDA, 2019b. February 2019. "California Green Vehicle Report" https://www.cncda.org/wp-content/uploads/Cal-Alt-Powertrain-Report-1Q-19-Release.pdf.
[78] Veloz, 2019.
[79] CARB, 2019. July 2019. "2019 Annual Evaluation of Fuel Cell Electric Vehicle Deployment & Hydrogen Fuel Station Network Development." https://ww2.arb.ca.gov/sites/default/files/2019-07/AB8_report_2019_Final.pdf.
[80] CARB, 2017. November 9, 2017. "Part II: Three-year Investment Strategy for Heavy-duty Vehicles and Off-road Equipment from Low Carbon Transportation Investments and AQIP." https://ww3.arb.ca.gov/msprog/aqip/fundplan/proposed_1718_funding_plan_final.pdf.
[81] CALSTART, 2019. "Eligible Vehicle Catalog." https://www.californiahvip.org/how-to-participate/#vehicle-catalog.
[82] This number includes level 2 chargers along with DCFCs and excludes level 1 chargers from https://afdc.energy.gov/stations/#/analyze?region=US-CA&fuel=ELEC. Accessed August 15, 2019.

hydrogen stations by 2025 as well as 5 million ZEVs by 2030.[83] The magninute and speed of effort needed to achieve these goals is unprecedented.

Figure 3 California Light-Duty ZEV Market Growing[84]

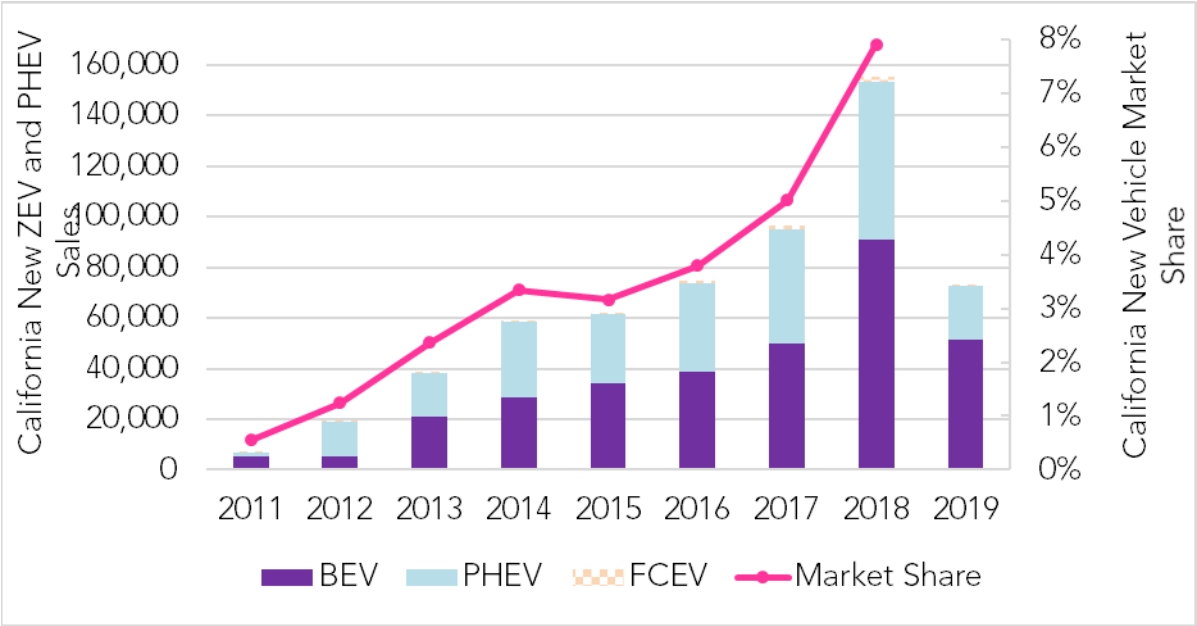
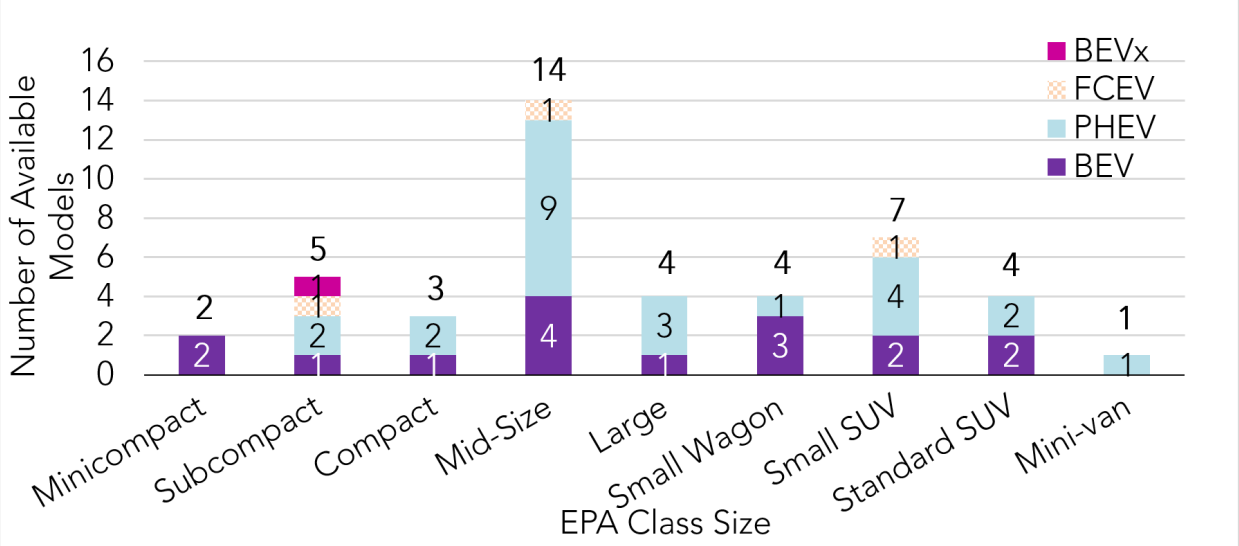


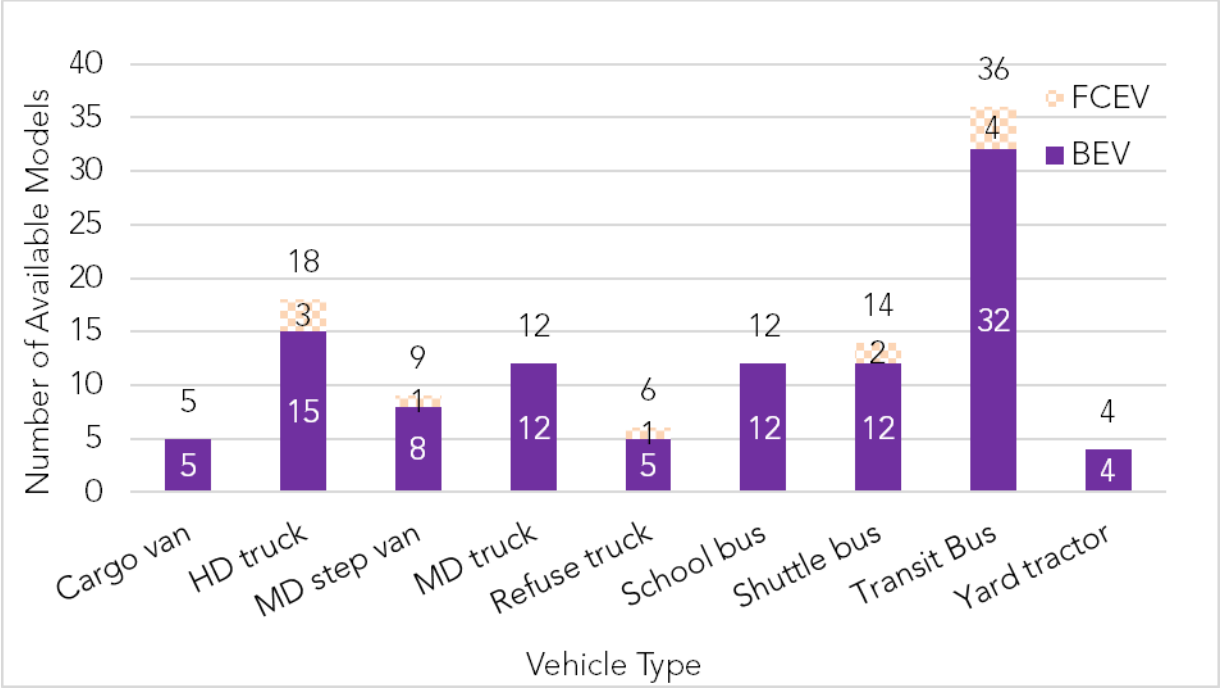
Figure 4 Light-Duty ZEV Model Availability Expanding



[83] Executive Order B-48-18. January 26, 2018. https://www.ca.gov/archive/gov39/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/index.html.

[84] Source: Auto Alliance Sales Dashboard, InsideEVs, and CA Auto Outlook.

Figure 5 Medium- and Heavy-Duty ZEV Model Availability Expanding



CHAPTER 4: OVERVIEW OF CARB'S ZERO-EMISSION VEHICLE PROGRAMS

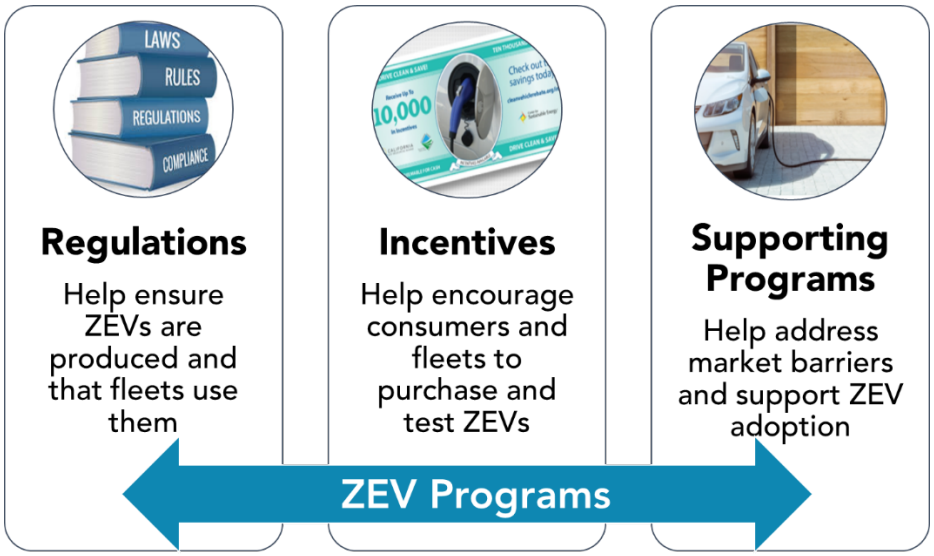
This chapter is the first of two chapters that comprise the review of CARB's ZEV programs. This chapter provides an overview of CARB's ZEV programs to introduce the variety of ZEV programs that CARB oversees and provides an overview of each program's goals and status with respect to meeting its goals, as required by SB 498. Before the programs are presented, the overarching program goals and program types are described. Chapter 5 reviews the costs and benefits of CARB's ZEV programs.

CARB's ZEV programs are designed to meet one or more of five overarching primary goals. As described in Chapter 2, the objectives of ZEVs programs include meeting California's GHG, air quality, and public health goals. However, these three goals can only be met in time by accelerating the ZEV market transformation, which is the fourth overarching goal. Additionally, a subset of programs are focused on benefiting priority populations, the fifth overarching goal, in order to ensure zero-emission transportation benefits all Californians.

CARB has three different types of ZEV programs: regulatory, incentive, and supporting programs. As of July 2019, CARB had 28 ZEV programs either in place or under development.[85] The regulatory programs help ensure that vehicles are manufactured and supplied to the market (e.g., the ZEV regulation) or procured for a certain usage (e.g., transit buses through the Innovative Clean Transit). Incentive programs help spur demand for these vehicles by encouraging consumers and fleet operators to purchase or lease ZEVs by offsetting some of the additional upfront costs of ZEVs compared to conventional vehicles (e.g., purchase rebates through the Clean Vehicle Rebate Project), or by developing and testing new technologies through demonstrations and pilots (e.g., the Advanced Technology Demonstration Project). The supporting programs also play a critical role in facilitating ZEV market growth by providing ZEV fuels and refueling infrastructure, building ZEV awareness, and sharing best practices among different jurisdictions through collaboration. Figure 6 depicts how these three types of programs work together to accelerate the ZEV market by fostering the supply and demand across all phases of ZEV technology commercialization and market development.

[85] CARB also actively contributes to seven supporting programs managed by other entities that affect the adoption of ZEVs, (e.g., the California Green Building Standards Code, Assembly Bill 8 Hydrogen Fueling Infrastructure, Volkswagen Zero-Emission Vehicle Investment Commitment, Veloz, the California Fuel Cell Partnership, the Multi-State ZEV Task Force, and the International ZEV Alliance. Information on these programs can be found in Appendix B.

Figure 6 Synergy between ZEV Program Types



CARB's incentive programs portfolio seeks to strike a balance of investment across technologies, stages of market development, and vehicle applications that provide cost-effective, near-term emission benefits and long-term, transformative zero-emission technologies to ensure that ZEV technology expands to new segments of the transportation sector. Both near-term and long-term emission reduction incentive programs are needed to foster continued ZEV market growth to meet national ambient air quality standards and California's climate goals.

There is a continuum in the stages of market development beginning with demonstration and ending with commercialization of high value of vehicles. In the demonstration phase, manufacturers are typically focused on producing single vehicle prototypes or small volume vehicle demonstration and testing projects. While per-vehicle incentives are larger for demonstration projects, these investments are crucial because they lay the foundation for the commercialization of advanced technology vehicles. Next, is the pilot phase, where projects are typically focused on larger scale deployments where issues around manufacturing design, user acceptance, and support can be assessed. During this phase, per-vehicle incentives are high because engineering designs are still evolving, manufacturing is not standardized and is focused on smaller batches of vehicles. Higher levels of incentives per-vehicle are needed to help entrepreneurs cover the costs of technology development. In the commercialization phase, incentives are provided to encourage user adoption of advanced technologies. The commercialization phase can be broadly separated into lower-volume and higher-volume production phases. In the lower-volume commercialization phase, sales volumes generally start low but grow over time as user acceptance increases and manufacturing costs decrease with engineering improvements, supply chain competition and economies of scale. In higher-volume production, incentives can help support the transition of the technology to wide-scale adoption.

Tables 1-4 summarize all of CARB's ZEV programs that affect the adoption of ZEVs, their primary goals, program type, targeted party, targeted or eligible vehicles, and status. The programs are organized into four groups: light-duty, heavy-duty, programs spanning both light- and heavy-duty programs, and supporting programs. Following the tables, each of the ZEV programs is introduced with short descriptions. More details on each program can be found in Appendix B.

Table 1 CARB's Light-Duty ZEV Programs

Program Name	Primary Goal(s)	Program Type	Targeted Party	Targeted or Eligible Vehicles	Status
ZEV regulation: requires vehicle manufacturers to produce and sell light-duty zero-emission vehicles	Air quality, GHG, market acceleration	Regulation	Vehicle manufacturers	New passenger vehicles and light-duty trucks	First adopted in 1990, amendments in development to include vehicle model years post-2025
Clean Miles Standard: will require TNCs to decrease GHG per passenger mile and meet zero-emission mile targets	GHG	Regulation	Transportation network companies	Vehicles driven for TNC operation	In development
On-Road Motorcycle Regulation: will require motorcycle manufacturers to produce and sell zero-emission motorcycles	Air quality, market acceleration	Regulation	Motorcycle manufacturers	New on-road motorcycles	In development
Clean Vehicle Rebate Project (CVRP): provides incentives for the purchase or lease of an eligible new vehicles with an increased rebate for lower-income consumers and public fleets located in disadvantaged communities	Air quality, GHG, market acceleration	Incentive	Consumers, including priority populations and fleets	New BEVs, PHEVs, FCEV, and zero-emission motorcycles	Launched in 2010; major changes in 2016 to place additional focus on lower-income consumers
Clean Cars 4 All: provides incentives for scrapping older, higher polluting vehicles and replacing with eligible used or new vehicles; program available in select air districts for low-income consumers and disadvantaged communities	Benefiting priority populations, air quality	Incentive	Consumers - priority populations	New and used BEVs, PHEVs, FCEV, and conventional hybrid vehicles	Launched starting in 2015, currently operating in four air districts and is expanding into more

Program Name	Primary Goal(s)	Program Type	Targeted Party	Targeted or Eligible Vehicles	Status
Clean Mobility Options: provides grants to projects designed to address the barriers and transportation needs of low-income residents and those living in disadvantaged communities	Benefiting priority populations	Incentive	Consumers - priority populations	ZEV car-sharing, bike-sharing, vanpools and carpooling, innovative transit services, and other clean mobility options	First two pilots launched in 2017 and 2018, four more launching in 2019
Financing Assistance for Lower-Income Consumers: helps lower-income Californians overcome the barrier of obtaining financing for new and used vehicles by providing low interest loans and vehicle price buy-downs to consumers for eligible vehicles	Benefiting priority populations	Incentive	Consumers - priority populations	New and used BEVs, PHEVs, FCEVs, and conventional hybrid vehicles	Regional pilot launched in 2016 and Statewide pilot launched in 2018
One-Stop-Shop Pilot Project: will provide coordinated community-based outreach and education, including a single application to maximize participation in CARB's Low Carbon Transportation Equity Projects to promote advanced technology vehicle adoption in disadvantaged communities, low-income communities, and low-income households	Benefiting priority populations	Supporting: outreach and education	Low-income and disadvantaged community members		Launching in early 2020

Program Name	Primary Goal(s)	Program Type	Targeted Party	Targeted or Eligible Vehicles	Status
Zero-Emission Assurance Project (ZAP): will help lower-income Californians reduce the risk of buying a used ZEV by providing a rebate for the purchase of a replacement battery or fuel cell component	Benefiting priority populations	Incentive	Low-income consumers of used ZEVs	Used BEVs, PHEVs, and FCEVs	In development

Table 2 CARB's Heavy-Duty ZEV Programs

Program Name	Primary Goal(s)	Program Type	Targeted Party	Targeted or Eligible Vehicles	Status
Carl Moyer Program: provides scrap and replace incentives for eligible technologies, including zero-emission, that reduce air pollution beyond what is required	Air quality, health	Incentive	Fleets and operators	New zero-emission medium- and heavy-duty trucks, buses, and off-road equipment	Adopted in 1998
Proposition 1B: Good Movement Emission Reduction Program (Prop. 1B): incentivizes eligible technologies that reduce emissions beyond what is required in California's four main trade corridors	Air quality, health, benefiting priority populations	Incentive	Priority trade corridors	New zero-emission medium- and heavy-duty trucks and buses	Adopted in 2007
Advanced Technology Demonstration Projects: provides funding for demonstration of pre-commercial zero-emission technology that reduces emissions and encourages market acceleration	Air quality, GHG, accelerating market growth, benefiting priority populations	Incentive	Fleets, freight facilities, and others	Pre-commercial zero and near-zero emission medium- and heavy-duty trucks and buses and off-road equipment	First projects selected in 2010, last set of projects funded from FY 2016-17, and another round of projects funded in FY 2019-20
Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP): incentivizes eligible commercially available zero-emission, hybrid or low NOx technologies	Air quality, GHG, accelerating market growth	Incentive	Fleets / independent operators	Commercial zero-emission medium- and heavy-duty trucks and buses	Launched in 2010; ZEVs first eligible starting in FY 2012-13

Program Name	Primary Goal(s)	Program Type	Targeted Party	Targeted or Eligible Vehicles	Status
Zero-Emission Truck and Bus Pilot Project: provides grants to pilot significant number of zero-emission truck and buses in fleet hubs to overcome early deployment challenges	Air quality, GHG, accelerating market growth, benefiting priority populations	Incentive	Fleets	Early commercial zero-emission medium- and heavy-duty trucks and buses	Projects were selected in 2016 with funding from FY 2014-15 and FY 2016-17. Some projects launched in 2016 and others in 2017
Rural School Bus Pilot Project: incentivizes turnover of school buses with newer vehicles in rural school districts	Air quality, GHG, health, accelerating market growth, benefiting priority populations	Incentive	School districts in rural areas	New zero-emission and new conventionally fueled school buses	First grantees selected in 2016
Clean Off-Road Equipment Voucher Incentive Project (CORE): incentivizes eligible commercially available transport refrigeration units and off-road zero-emission equipment	Air quality, GHG, accelerating market growth	Incentive	Freight facilities	Commercial new zero-emission transport refrigeration units and off-road equipment	Grantee selected in July 2019 and program launch expected in early 2020
Zero and Near-Zero Emission Freight Facilities (ZANZEFF): provides grant funding for deployment of emission-reducing technology used in freight	Air quality, GHG, accelerating market growth, benefiting priority populations	Incentive	Freight facilities	New zero and near-zero emission medium- and heavy-duty trucks and off-road equipment used in freight	Grantees selected in 2018

Program Name	Primary Goal(s)	Program Type	Targeted Party	Targeted or Eligible Vehicles	Status
Community Air Protection Incentives: provides incentives to improve air quality and reduce exposure to criteria and toxic air contaminants in communities most impacted by air pollution with priority given to ZEVs, equipment and infrastructure	Air quality, health, benefiting priority populations	Incentive	Selected disadvantaged and low-income communities	New zero and near-zero emission medium- and heavy-duty trucks, buses, and off-road equipment	Approved in 2017
Volkswagen Mitigation Trust for California: incentivizes scrap and replace projects that include zero-emission technologies to mitigate the excess NO_X emissions in California caused by VW's actions; $10 million is reserved for light-duty ZEV infrastructure	Air quality, health, benefiting priority populations	Incentive	Fleets and independent operators	Commercial zero-emission trucks, buses, off-road equipment, shore power; low NOx trucks and engines; Tier 4 freight switchers and harbor craft engines	Approved in 2018
Innovative Clean Transit: requires transit agencies to transition their bus fleet to 100% zero-emission by 2040	Air quality, GHG, accelerating market growth	Regulation	Public transit agencies	Zero-emission transit buses	Adopted in 2018
Zero-Emission Airport Shuttle: requires airport shuttle fleets to transition their fleet to zero-emission shuttles	Air quality, GHG, accelerating market growth	Regulation	Airport shuttle bus operators	Zero-emission shuttle buses	Adopted in 2019
Zero-Emission Powertrain Certification Regulation: establishes an alternative certification process for zero-emission vehicles that would require information transparency, support once deployed, and ease of repairability	Accelerating market growth	Regulation	Truck and bus manufacturers	New zero-emission medium- and heavy-duty trucks and buses	Adopted in 2019

Program Name	Primary Goal(s)	Program Type	Targeted Party	Targeted or Eligible Vehicles	Status
Advanced Clean Trucks: will require heavy-duty vehicle manufacturers to produce and sell zero-emission trucks in California	Air quality, GHG, accelerating market growth	Regulation	Truck manufacturers	New medium- and heavy-duty trucks and buses	Expected to be adopted in 2020
ZEV Truck Regulation: will require well-suited fleets to begin purchasing zero-emission trucks and may require large entities to hire fleets that have zero emission vehicles	Air quality, GHG, accelerating market growth	Regulation	Large entities and fleets	Medium- and heavy-duty trucks	Development to begin in 2020
Zero-Emission Transport Refrigeration Unit Regulation: will require TRUs to transition to zero-emission operation technologies	To be determined	Regulation	TRU owners and facility owners and operators	Transport Refrigeration Units	In development
Zero-Emission Drayage Truck Regulation: will phase-in the use of zero-emission operations technology in drayage trucks	To be determined	Regulation	To be determined	Drayage Trucks	In development

Table 3 CARB's ZEV Programs that Span the Light- and Heavy-Duty Sectors

Program Name	Primary Goal(s)	Program Type	Targeted Party	Targeted or Eligible Vehicles	Status
Low Carbon Fuel Standard (LCFS): provides incentives for 1) the purchase or lease of an eligible BEV or PHEV through utility programs funded by LCFS credits, 2) electricity dispensed at non-residential charging infrastructure and for hydrogen dispensed at hydrogen refueling stations, 3) electricity or hydrogen used to power buses and trucks through fleets and freight facilities, and 4) fast-charging and hydrogen station infrastructure development	Air quality, GHG, accelerating market growth	Regulation, incentive, and infra-structure and fuel	Residential electricity providers, consumers, manufacturers, fleets and operators, transit operators, freight facilities, refueling station operators	New light-duty vehicles, ZEV infrastructure and fuel	First adopted in 2009, carbon intensity reductions and credit generation started in 2011, and the most recent amendments and updates went into effect in January 2019 with carbon intensity reduction targets scheduled through 2030
Clean Mobility in Schools Pilot Project: incentivizes zero-emission buses and other mobility options at schools in disadvantaged communities	Air quality, GHG, health, market acceleration, benefiting priority populations	Incentive	School district in disadvantaged communities	New zero-emission light-, medium-, and heavy-duty vehicles including school buses and other clean options	Grantee selection expected in early 2020

Table 4 Supporting ZEV Programs that CARB Contributes to

Program Name	Primary Goal(s)	Program Type	Targeted Party	Targeted or Eligible Vehicles	Status
California Green Building Standards Code: requires EV Capable infrastructure in all new residential and commercial buildings	GHG	Infrastructure and fuel	Builders and developers		Building code updates every 18 months. CARB is active contributor
Assembly Bill 8 Hydrogen Fueling Infrastructure: CARB provides analytical support of the hydrogen fueling network and current and projected fuel cell vehicle deployment and makes recommendations to CEC on various aspects of their retail hydrogen fueling stations funding through the Clean Transportation Program[86]	GHG, market acceleration	Infrastructure and fuel	Hydrogen fueling station developers and operators		Took effect in 2014 and sunsets in 2024. Requires a minimum of 100 stations funded by 2024; roughly two-thirds of this goal have been funded to date and the program is anticipated to be able to exceed the minimum station requirement.
Volkswagen ZEV Investment Commitment for California: $800 million over 10 years for ZEV infrastructure (including developing and maintaining ZEV charging stations), ZEV public awareness, increased ZEV access, and Green City demonstration projects	Air quality, health, benefiting priority populations, market acceleration	Infrastructure and fuel; outreach and education	Infrastructure providers and operators; consumers and fleets; and cities	Zero-emission light-, medium-, and heavy-duty on-road vehicles and supporting charging infrastructure	Cycle 1 ZEV Investment Plan approved July 2017; Cycle 2 ZEV Investment Plan approved December 2018

[86] Previously known as the Alternative and Renewable Fuel and Vehicle Technology Program.

Program Name	Primary Goal(s)	Program Type	Targeted Party	Targeted or Eligible Vehicles	Status
Veloz: supports a brand-neutral statewide consumer education campaign focused on ZEVs; is a nonprofit organization focused on public-private collaboration	Market acceleration	Outreach and education	Consumers and fleets		Veloz was established in 2017. CARB is active contributor
California Fuel Cell Partnership: works to expand the market for hydrogen powered vehicles by supporting the rollout of vehicles and fueling stations through collaboration with its members; is a nonprofit organization focused on public-private collaboration	Market acceleration	Outreach and education; Collaboration	Government and industry		CARB is active contributor
Multi-State ZEV Task Force: develops collaborative strategies to transform the transportation section across the member states	Market acceleration	Collaboration	Policymakers		CARB is active contributor
International ZEV Alliance: utilizes collective action to accelerate the transition to electric-drive vehicles	Market acceleration	Collaboration	Policymakers		CARB is active contributor

ZEV Program Descriptions

This section describes the ZEV programs adopted or approved by CARB's Board and those that are under development. First, the light-duty programs are described followed by the heavy-duty ones. The programs that span between the light- and heavy-duty sectors are presented next followed by the supporting programs. More information about all of CARB's ZEV programs can be found in Appendix B.

i. Light-duty ZEV Programs

Because California has struggled with the air quality impacts of motor vehicle pollution for decades, California began regulating tailpipe emissions in 1959, and adopted its first ZEV requirements in 1990. The ZEV regulation has been amended multiple times as the technology has developed. The regulation was included in the broader Advanced Clean Cars program in 2012. The program requires vehicle manufacturers who sell light-duty vehicles in California to also produce a minimum number of ZEV credits or to purchase ZEV credits.[87] Manufacturers generate credits by producing a ZEV and delivering that vehicle to a dealer. For example, in model year 2018, the ZEV regulation required approximately 90,000 credits total (equal to about 36,000 200-mile BEVs). Over four times that amount of credits were generated in model year 2018 among all vehicle manufacturers.[88] As of model year 2018, all vehicle manufacturers are in compliance with the ZEV regulation. Because compliance is completed about a year after the model year, 2019 compliance will not be fully calculated until fall 2020. The next iteration of the program is under development for post-2025 model years.

The ZEV regulation ensures there are ZEVs for sale in California. However, California also must ensure these vehicles move from the showroom to the road in order to reduce criteria pollutant and GHG emissions as expected. To help support the ZEV market, CARB established the Clean Vehicle Rebate Project, which launched in 2010. CVRP provides a rebate for the purchase or lease of eligible light-duty new ZEVs and PHEVs in order to decrease their up-front cost compared to conventional vehicles in the early ZEV market. The amount of the incentives has changed over time.[89] Since 2016, CVRP has both an income cap limiting eligibility along with an increased rebate for lower-income households.[90] As the light-duty ZEV market has matured over time, the demand for incentives has also grown as ZEV buyers have expanded beyond early

[87] Cal. Code Regs., tit. 13, §§ 1962.1, 1962.2.
[88] CARB, 2019. October 31, 2019. "2018 Zero Emission Vehicle Credits." https://ww2.arb.ca.gov/sites/default/files/2019-11/2018%20ZEV%20Credit%20Annual%20Disclosure_103119.pdf.
[89] Center for Sustainable Energy (CSE), 2019. July 2019. "Summary of CVRP Rebate Eligibility and Funding Availability over Time." https://cleanvehiclerebate.org/eng/content/summary-cvrp-rebate-eligibility-and-funding-availability-over-time. Accessed Aug 1, 2019.
[90] CSE. "Income Eligibility" https://cleanvehiclerebate.org/eng/income-eligibility. Accessed Aug 1, 2019.

adopters. CVRP has rebated 354,064 ZEVs, PHEVs, and other eligible vehicles from project start through the end of September 2019.[91]

Beyond regulating vehicle manufacturers, CARB is now designing its first light-duty regulation for high-mileage fleets (i.e., transportation network companies[92]) that would mandate a percent of zero-emission miles traveled over total miles traveled through the Clean Miles Standard. This regulation should increase the emission benefits of zero-emission technology by focusing on vehicles with high usage. CARB is also developing amendments to the On-Road Motorcycle Regulation, with the aim of decreasing their reactive organic gas (ROG) emissions. Through the regulatory design process, staff is assessing the inclusion of zero-emission technology for these motorcycles.

Besides CVRP's equity features, three active light-duty equity programs are focused on low-income and disadvantaged communities that include ZEVs. In select air districts,[93] the Clean Cars 4 All program (formerly the Enhanced Fleet Modernization Program Plus-Up) incentivizes the retirement of a functioning, high-polluting vehicle with the replacement of a new or used conventional hybrid vehicle, plug-in hybrid, or a ZEV. Clean Cars 4 All has incentivized the purchase or lease of 4,017 ZEVs and PHEVs through September 2019.[94] The Financing Assistance for Lower-Income Consumers pilot project helps lower-income Californians overcome the barrier of obtaining financing for new and used conventional hybrid vehicles, PHEVs or ZEVs by providing low interest loans and vehicle price buy-downs to consumers. As of May 2019, nearly 400 participants purchased PHEVs and BEV through the program. Finally, the Clean Mobility Options for Disadvantaged Communities pilot project provides grants for projects designed to address the barriers and transportation needs of priority populations beyond vehicle ownership, such as car-sharing, bike-sharing and ride-hailing. Several battery electric vehicle car-sharing pilots have been established in Los Angeles, Sacramento, and the San Joaquin Valley that have served over 2,000 low-income residents and those living in disadvantaged communities. These programs are being expanded and three others are launching soon. These four light-duty incentives

[91] CSE, 2019. "CVRP Rebate Statistics." Last updated on June 26, 2019. https://cleanvehiclerebate.org/eng/rebate-statistics. Accessed December 11, 2019.

[92] A transportation network company (TNC) provides prearranged transportation services for compensation using an online-enabled application to connect drivers using their personal vehicles with passengers.

[93] As of August 2019, the program is operating in the South Coast Air Quality Management District, San Joaquin Valley Air Pollution Control District, and Bay Area Air Quality Management District. Clean Cars 4 All is also being expanded into other air districts.

[94] CARB, 2019. December 2, 2019. "EFMP Retire and Replace Program Statistics 2019 Q3." https://ww2.arb.ca.gov/sites/default/files/2019-12/2019_q3_1.pdf. Accessed December 15, 2019.

projects are part of the Clean Transportation Incentives funded through the California Climate Investment.[95, 96]

There are two other light-duty equity projects in development. In response to CARB's report that identified barriers that low-income Californians face in accessing zero-emission transportation options[97] pursuant to SB 350,[98] CARB is developing the One-Stop-Shop Pilot Project to increase awareness for low-income residents by expanding education and outreach on clean transportation and mobility options and to streamline the application for CARB's equity transportation projects. This pilot is expected to launch in early 2020. Finally, the Zero-Emission Assurance Project will help lower-income residents reduce the risk of buying a used ZEV or PHEV by providing a rebate for the purchase of a replacement battery or fuel cell component, pursuant to AB 193.[99]

ii. Heavy-duty ZEV Programs

This section begins by describing the heavy-duty incentive projects focused on near-term emission benefits by incentivizing the scrappage of high polluting vehicles and replacement with cleaner vehicles, including ZEVs. Next, this section presents the investment projects focused on the long-term transition to ZEVs in heavy-duty applications, which funds zero-emission technologies at various points along their commercialization arcs to support technologies providing emission reductions today, and helping the development of technologies needed to mature to meet future State goals. Finally, this section summarizes the adopted and proposed medium- and heavy-duty ZEV regulations. These regulatory programs support this transition by helping to make these vehicles available for purchase and by requiring zero-emission technology in specific applications where it would succeed and decrease emissions. CARB's regulations and investments in this transformation also support progress towards creating the jobs of the future and achieving and maintaining healthy and sustainable communities for all Californians.

CARB also has a suite of off-road vehicle and equipment programs (e.g., Funding Agricultural Replacement Measures for Emission Reductions [FARMER], Cargo Handling and Ground Support Equipment regulation, and the Harbor Craft Regulation) that support the ZEV transition, but they are not included here because they are

[95] CARB, 2019. September 2019. "Proposed Fiscal Year 2019-20 Funding Plan for Clean Transportation Incentives." https://ww2.arb.ca.gov/sites/default/files/2019-09/fy1920fundingplan.pdf.

[96] The funding for these programs originate from the California Climate Investments, which focuses on GHG reduction and priority population programs. CVRP was previously funded (and co-funded) through the Air Quality Improvement Program as well.

[97] CARB, 2018. "Low-Income Barriers Study, Part B: Overcoming Barriers to Clean Transportation Access for Low-Income Residents", https://ww2.arb.ca.gov/sites/default/files/2018-08/sb350_final_guidance_document_022118.pdf.

[98] De León, Chapter 547, Statutes of 2015.

[99] Cervantes, Chapter 363, Statutes of 2018.

outside of the scope of SB 498. However, programs that have both an on-road and off-road component are included in this report.

Incentive Programs

CARB investments for zero-emission heavy-duty vehicles are intended to support the transformation of this sector to one that utilizes zero-emission technologies wherever feasible by demonstrating emerging technologies, advancing commercial viability through pilot and other deployment projects, and catalyzing further technological development by the private sector. Development and commercialization of advanced heavy-duty technologies requires a portfolio of incentives that provide funding for the range of technologies to achieve both near-term and long-term emission reductions.

This section first presents incentive programs that require vehicle scrappage. These programs contribute to near-term emission reductions by removing older, highly polluting vehicles and replacing them with cleaner technologies, including zero-emission. Although these programs also contribute to the ZEV market growth in the long-run, their impact is concentrated in the near-term emissions. The near-term emission reduction incentive programs include Carl Moyer Program, the Proposition 1B Goods Movement Emission Reduction Program, Community Air Protection Incentives, Rural School Bus Pilot Project, and the Volkswagen Mitigation Trust for California.

The Carl Moyer Program, established in 1998, is a scrap and replace grant program implemented in coordination with the air districts. The Carl Moyer Program provides incentive funds to obtain early or extra NOx, ROG and PM emission reductions[100] that can also be credited toward California's legally enforceable obligations in the State Implementation Plan for attaining health-based national ambient air quality standards. The program funds the incremental cost of cleaner-than-required engines, equipment, vehicles and other sources of air pollution. In 2015, the Carl Moyer Program started providing increased incentives for zero-emission projects, but as of July 2019 has funded no on-road zero-emission projects.

The Proposition 1B Goods Movement Emission Reduction Program (Prop. 1B) was established in 2007 to provide incentives to reduce air pollution emissions and health risks from freight movement along California's four priority trade corridors in the Bay Area, Central Valley, Los Angeles/Inland Empire, and San Diego/Border. Prop. 1B is a scrap and replace grant program administered in coordination with local air districts and ports that incentivizes vehicles and equipment that reduce diesel particulate matter and NO_X emissions "not otherwise required by law or regulation." The Prop. 1B Program provides higher funding amounts for zero-emission equipment options to encourage the advancement of this technology. As of July 2019, almost 400 pieces of

[100] Before they are required by a regulation or by funding a replacement technology that goes above-and-beyond the standard.

higher emitting equipment have been replaced with cleaner zero-emission equipment including trucks, transport refrigeration units, and cargo handling equipment.

The Community Air Protection Incentives were established in 2017 to provide a community-focused approach to reducing exposure to criteria air pollutants and toxic air contaminants in the communities most affected by air pollution. First-year funds ($250M) are being used for cleaner vehicles, equipment and infrastructure through Carl Moyer and Proposition 1B projects. Second-year funds ($245M) can be used for similar projects and to reduce toxic and criteria emissions from stationary sources or for projects identified through local AB 617[101] Community Emissions Reduction Programs. Funding from both years has been prioritized for ZEVs. Community Air Protection Incentives is administered by local air districts in communities that CARB has identified for monitoring and community emissions reduction programs. Projects must benefit disadvantaged or low-income communities. As of July 2019, funds for 126 zero-emission vehicle replacements have been committed.

Because children's health is more sensitive to air pollution, CARB has an incentive project focused on cleaning the school bus fleet across the State in rural areas. The Rural School Bus Pilot Project, created in FY 2016-17, is a grant project designed to enhance the turnover of California school bus fleets to lower-carbon transportation choices by requiring scrappage or limiting use of older more polluting bus. The project provides funding for zero-emission and conventionally fueled school buses that use renewable fuels. Priority is given to school districts in small air districts that typically have the oldest and dirtiest bus fleets and have historically not had the opportunity to receive funds for replacement projects. So far the project has funded or committed funding for over 70 zero-emission school buses and supporting infrastructure in rural school districts.

The Volkswagen (VW) Mitigation Trust is a component of partial settlements with VW resulting from its use of illegal emissions cheating software in certain diesel cars sold in California. The Trust provides funding opportunities for specified eligible actions to mitigate the excess NO_X emissions through scrap-and-replace projects for the heavy-duty sector, including on-road freight trucks, transit and shuttle buses, school buses, and off-road equipment, with a commitment to invest in zero-emission technologies. Eligible projects also include funding for light-duty zero-emission vehicle infrastructure. At least 50 percent of the total funding is expected to benefit low-income or disadvantaged communities. Solicitations for projects opened in fall 2019.

Next, this section describes the incentive programs that do not require vehicle scrappage. These programs are considered long-term emission reduction programs. Although these programs contribute to emission reductions right-away, their impact on near-term emission reductions is not as large as for the programs that require scrappage. Instead, these programs have a greater impact on growing the ZEV market

[101] C. Garcia, Chapter 136, Statutes of 2017.

for long-term emission reductions. The long-term emission reduction incentive programs are: Advanced Technology Demonstration Project, Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP), Zero-Emission Truck and Bus Pilot Project, Clean Off-Road Equipment (CORE), and Zero and Near-Zero-emission Freight Facilities Project.

The Advanced Technology Demonstration Project was established in 2008 to demonstrate the viability of the next generation of advanced technology vehicles that reduce emissions in order to accelerate its path towards commercialization and full-scale deployment. From its inception, the program has funded pre-commercial demonstration projects that include zero-emission technology in trucks and off-road equipment. The program has funded the demonstration of almost 50 zero-emission trucks in addition to zero-emission off-road equipment.

The Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) was also launched in 2008, but originally only incentivized hybrid truck and buses since there were no zero-emission vehicles commercially available. Once zero-emission trucks and buses became commercially available in FY 2012-13, these were included in the program. The goal of this program is to accelerate the deployment of early commercial zero-emission and hybrid trucks and buses, as well as low NO_X engines, by providing incentives to reduce their upfront costs. As of October 1 2019, the program has funded nearly 800 zero-emission trucks and buses and over 160 trucks equipped with an electric power takeoff (ePTO) system.[102] In addition, the program has committed funding to over 2,600 zero-emission trucks and buses and 70 trucks equipped with ePTO.[103]

To bridge the gap between technology demonstration and commercial deployment, CARB created the Zero-Emission Truck and Bus Pilot Project in FY 2014–15. While the Advanced Technology Demonstration Project provides support for technology development and HVIP has enabled zero-emission technology to be widely deployed, the Zero-Emission Truck and Bus Pilot Project fills in the gap between the two commercialization phases by leveraging resources, promoting efficiencies and helping drive down per vehicle costs via large, location-specific deployments. The program is funding a total of 125 zero-emission trucks and buses along with supporting refueling infrastructure.

The Clean Off-Road Equipment (CORE) Voucher Incentive Project was established in 2017 in order to accelerate the market of zero-emission on-road freight vehicles and off-road equipment, including transport refrigeration units. CORE is expected to help drive wide-scale adoption of zero-emission freight vehicles and off-road equipment and the expansion of zero-emission infrastructure, which will drive down costs and

[102] CALSTART, 2019. "Deployed Vehicle Mapping Tool." https://www.californiahvip.org/tools-results/#deployed-vehicle-mapping-tool. Accessed December 15, 2019.
[103] Ibid.

strengthen the supply chain to support a broader zero-emission market. CARB selected a project administrator through a competitive solicitation process in July 2019 and expects to begin issuing vouchers in early 2020.

The Zero and Near-Zero-emission Freight Facilities Project was established in 2017 as a multi-faceted project designed to showcase the advanced technologies and strategies that holistically reduce GHG and criteria pollutant emissions in freight facilities and to help provide economic, environmental, and public health benefits to disadvantaged and low-income communities. The Freight Facilities Project also helps accelerate the commercialization of these cleaner technologies in the freight sector and supports the continued implementation of the California Sustainable Freight Action Plan.[104] Eligible vehicles and equipment include on-road trucks, cargo handling equipment, marine vessels, locomotives, and others including supporting infrastructure. Freight facility improvements are also eligible and include strategies for emission reductions such as preferential queuing, renewable energy generation and storage, and educational efforts. Over 240 zero-emission vehicles and equipment, besides other near-zero emission ones, have been funded through multiple projects.

Regulatory Programs

In the heavy-duty sector, incentive programs laid the foundation for developing zero-emission technology. Now, newly adopted and future heavy-duty ZEV regulations are creating a market pull. As the market continues to develop, regulations can be extended to a broader set of vehicle applications. As of June 2019, three heavy-duty ZEV programs have been adopted by the Board. More regulations are in development. Heavy-duty ZEV regulations target different parties: powertrain and vehicle manufacturers as well as specific fleets and usage. Because the zero-emission markets in the heavy-duty sectors are still young, these regulatory programs complement the various related incentive programs. All the heavy-duty ZEV programs send a strong signal that California is serious about transforming the transportation in all sectors allowing the private market time to invest in this transition.

CARB's first regulatory program requiring a fleet to transition to ZEVs was approved by the Board in late 2018. The Innovative Clean Transit regulation requires that transit agencies operating within California start purchasing 100 percent zero-emission transit buses in 2029 and fully transition to zero-emission vehicles by 2040. Similar to the Innovative Clean Transit, the Zero-Emission Airport Shuttle regulation will require private and public airport shuttle fleet owners to fully transition their fleet to zero-emission shuttles by 2035. Even though zero-emission bus technologies have advanced rapidly in recent years, continued improvements in zero-emission bus costs and performance are still needed to facilitate the full transition to zero-emission technologies. Therefore, transit agencies and airport shuttle bus fleet owners are encouraged to apply for federal, state, and local incentives to defray the increased cost

[104] "California Sustainable Freight Action Plan." July 2016. http://dot.ca.gov/hq/tpp/offices/ogm/cs_freight_action_plan/theplan.html.

of zero-emission technologies and related equipment. CARB's Innovative Clean Transit, the Zero-emission Airport Shuttle regulation, and the associated incentives are helping to create a market for heavy-duty zero-emission technology, new jobs, and investments in California's clean air future.

The Zero-Emission Powertrain Certification Regulation establishes an alternative certification process for heavy-duty electric and fuel cell vehicles that includes robust requirements that help ensure information regarding such vehicles and their powertrains are effectively and consistently communicated to purchasers, ensure such vehicles are well-supported by manufacturers once deployed, and ensure they can be effectively repaired. While the certification is optional for manufacturers, it can be incorporated into other regulations, such as it was for the Zero-Emission Airport Shuttle Regulation. The certification option will become available starting with model year 2021. The regulation was developed to help ensure the success of CARB's regulations and incentive programs targeting more mature zero-emission technology applications in the heavy-duty space.

Similar to the light-duty ZEV regulations, the proposed Advanced Clean Trucks regulation would require heavy-duty vehicle manufacturers to produce and sell zero-emission vehicles in California. Advanced Clean Trucks is being crafted to provide flexibility for manufacturers to choose which market segments to target and includes a proposed requirement for large entities to report information needed to develop future regulations that would require the use of zero-emission trucks through a new heavy-duty fleet regulation. Using data reported through Advanced Clean Trucks, this new ZEV Truck Regulation will identify operations where ZEV duty cycles meet fleet operational needs. The main goal of the Advanced Clean Trucks and the ZEV Truck Regulation, is to gradually increase the number of zero-emission trucks on the road over the next decade.

CARB is also developing a new Zero-Emission Transport Refrigeration Units Regulation that may require all straight truck mounted transport refrigeration units (TRU)[105] that operate in California to transition to 100 percent zero-emission operation. TRUs typically congregate at cold storage warehouses, distribution centers, grocery stores, ports, and other facilities, threatening the health of those that live and work nearby. Therefore, the new regulation would also limit the amount of time that internal combustion engine-driven trailer TRUs can operate while stationary at certain California facilities, and require those facilities to provide the infrastructure needed to support zero-emission operation on-site. In addition to producing significant emission reductions of criteria, toxic, and greenhouse gas pollutants, the regulation could help

[105] TRUs are refrigeration systems powered by diesel internal combustion engines designed to refrigerate or heat perishable products that are transported in various containers, including semi-trailers, truck vans, shipping containers, and rail car.

to advance zero- and near-zero-emission TRU commercialization by increasing the earlier penetration of infrastructure that will be needed for those technologies.

Finally, CARB will amend the existing Drayage Truck[106] Regulation, or adopt a new Zero-emission Drayage Truck Regulation, to direct a transition to zero-emission operations. CARB's current Truck and Bus regulation contains requirements for existing trucks to have an engine meeting 2010 or newer emissions standards, with full implementation in 2023. The new or amended drayage truck regulation would establish a schedule for phasing in the use of zero-emission technology. Options to be considered include, but are not limited to, requirements for full zero-emission technology (e.g., a battery or fuel-cell electric short haul truck) and zero-emission mile capability (e.g., a natural gas-electric hybrid that could drive interstate but switch to zero-emission electric mode while operating in impacted communities). ZEV infrastructure will be needed at ports and railyards to support the success of this regulation.

iii. Programs Spanning Both Light- and Heavy-Duty Applications

There are two ZEV programs that span both the light- and heavy-duty applications. These programs are described below.

The Low Carbon Fuel Standard (LCFS), originally adopted in 2009, encourages the production and use of cleaner low carbon fuels in California and reduce GHG emissions from the transportation sector. Fuel carbon intensity reduction is achieved by meeting a target in a given year. Regulated parties that bring fuel into California below the target generate credits that may be sold, while parties that provide fuel for use in California above the carbon intensity target generate deficits that must be offset with credits. The 2018 LCFS amendments substantially expanded the program's support for zero-emission vehicles. Additional crediting opportunities were created for residential charging applications that can meter electric vehicle charging to claim credits for reducing the carbon intensity of the electricity used to charge these vehicles. The amendments also allow infrastructure credits to be generated by owners of publicly accessible light-duty electric vehicle fast charging[107] stations and hydrogen fueling stations based on the capacity of the station to deliver fuel minus any actual fuel dispensed. In addition, utilities and vehicle manufacturers are developing a point-of-sale Clean Fuel Reward program for new light-duty battery electric and plug-in hybrid vehicles, using LCFS credit value with a maximum estimated incentive of approximately $1,500. The 2018 amendments also add a number of new credit generating categories covering freight transportation applications. Finally, the 2018 amendments promote the use of low carbon electricity for transportation applications by allowing matching of low carbon electricity generation to electric vehicle charging

[106] Drayage Trucks are those that have a gross vehicle weight rating of over 26,000 pounds and transport cargo going to or coming from a port or intermodal rail yard.

[107] Formally known as direct current fast chargers (DCFC), which provide a high power direct current, generally up to 120 kW, to the electric vehicle's battery without passing through the vehicle's onboard alternating current (AC)/DC converter.

through flexible mechanisms, and by allowing entities to earn credit by charging at times of the day when the carbon intensity of grid electricity is lower such as is done through smart charging.

The Clean Mobility in Schools Pilot Project, approved by the Board in 2018, will focus on creating an overall transformation of the entire school transportation system located within a disadvantaged community, including the bus fleet, other light-, medium-, and heavy-duty school vehicles, and showcasing a variety of clean mobility options through deploying and demonstrating GHG emission reduction techniques (e.g., active transportation projects, zero-emission lawn and garden equipment, installation of renewable energy generation and energy storage onsite, etc.), helping to facilitate 'greening' the school, and eventually leading to a larger Statewide project.

iv. Supporting Programs

CARB contributes to several ZEV programs that help address market barriers and support adoption. These programs are described below.

The California Green Building Standards (CALGreen) Code supports Statewide climate goals through mandatory and voluntary measures related to the planning, design, operation, construction, use, and occupancy of new construction and major alterations to existing buildings. One of the major CALGreen Code provisions includes electric vehicle charging infrastructure including the conduit raceway for future wiring and panel capacity to support future installation of charging stations. These provisions were started as voluntary measures and transitioned to mandatory in 2015 for all building types. For this effort, CARB staff provides technical and cost analysis to suggest revisions to the CALGreen Code.

The main goal of AB 8[108] Hydrogen Fueling Infrastructure is the establishment of at least 100 retail hydrogen fueling stations in California by 2024. Per AB 8, CARB provides support to the Energy Commission through analysis of the hydrogen fueling network and current and projected FCEV deployment in California. Through these analyses, CARB makes recommendations to the Energy Commission with respect to locations and appropriate hydrogen fueling capacity, technical and performance requirements for stations to be funded, and amount of the annual $20 million to be used in future funding efforts. CARB and the Energy Commission also collaborate on an annual joint agency report. As of June 2019, there are 40 open retail hydrogen stations throughout California with 24 more under development.

The Volkswagen (VW) ZEV Investment Commitment is a component of partial settlements between CARB, the United States Department of Justice, and VW that is intended to function as injunctive relief, complementing the punitive portions of the settlements by addressing the impact to California's ZEV market resulting from VW's sale of approximately 70,000 2.0 liter diesel vehicles in California that were marketed

[108] Perea, Chapter 201, Statutes of 2013.

as clean vehicles but equipped with emissions defeat devices. The ZEV Investment Commitment requires VW to invest $800 million in California over a 10 year period–in four consecutive $200 million, 30 month, ZEV Investment Plan cycles–to support the increased use and availability of ZEVs in the state. There are four areas of qualified investments: ZEV infrastructure (including developing and maintaining ZEV charging stations), ZEV public awareness, increased ZEV access, and Green City demonstration projects. Per SB 92,[109] CARB is to strive to ensure that, to the maximum extent allowable under the settlements, when approving a ZEV Investment Plan, at least 35 percent of Plan funds benefit low-income or disadvantaged communities disproportionately affected by air pollution. VW is implementing this commitment through its subsidiary, Electrify America with CARB reviewing and approving ZEV Investment Plans and serving an oversight role. CARB approved the Cycle 1 Plan in July 2017 and the Cycle 2 Plan in December 2018.

Veloz is a nonprofit organization made up of members from the private sector, public agencies and nonprofits. Its goal is to accelerate the shift to electric vehicles through public-private collaboration, pubic engagement and policy education innovation. It has several initiatives in development including an education and awareness campaign called "Electric For All" to address the needs of California's population of which more than half still do not consider an electric car for their driving needs. The first phase of "Electric For All" is completed and the next phase is in progress. It is also conducting webinars, planning for ride and drive events, and hosts three forums each year.[110]

The California Fuel Cell Partnership (CaFCP) is a public-private partnership among auto manufacturers, energy companies, fuel cell technology companies and government agencies. Its main objective is to expand the market for light- and heavy-duty fuel cell electric vehicles powered by hydrogen to help create a cleaner, more energy-diverse future with zero-emission vehicles. CaFCP members collaborate on activities that advance the technology as well as educate the public and first responders. CARB participates in the CaFCP meetings and advises members on hydrogen fueling stations and deployment strategy.

CARB also participates in two collaborative efforts with other jurisdictions. The Multi State ZEV Taskforce, a U.S. multi-state initiative comprised of California, Connecticut, Massachusetts, Maryland, New York, Oregon, Rhode Island, and Vermont, formed from the states' recognition that regulations alone would not be sufficient to achieve rapid expansion of the electric vehicle market in order to meet statewide GHG emission targets. The International ZEV Alliance (IZA) is a collaboration of 17 different jurisdictions representing approximately 40 percent of the global ZEV sales with the purpose of accelerating the ZEV market within their markets through collective action.

[109] Committee on Budget and Fiscal Review, Chapter 26, Statutes of 2017.

[110] See Electricforall.org to learn more about electric cars, charging and fueling electric cars and the benefits of driving electric.

CHAPTER 5: COSTS AND BENEFITS OF CARB'S ZEV PROGRAMS

This chapter presents the costs and benefits of CARB's ZEV programs, and is divided into two sections. First, the programs implemented as of July 2019 are assessed qualitatively followed by the quantitative cost-benefit analysis that was performed for the subset of programs that had sufficient data.

A. Qualitative Assessment of Benefits

Besides criteria pollutant and GHG emission reductions, there are other benefits achieved by the ZEV programs, including improved health outcomes, accelerating market transformation, benefiting priority populations, jobs, and petroleum and fuel cost savings. This section first presents a summary of the benefits of the light- and heavy-duty ZEV programs implemented as of July 2019 (Table 5). Then, each of these benefits is further discussed in its own subsection below. Because it is not appropriate to quantify these benefits beyond what is done in section 5.B., they were qualitatively assessed for this report based on available literature and CARB staff's expert judgement.

Table 5 presents the results of the qualitative assessment of the program benefits. If the program has a primary goal specific to a benefit, it is indicated by a star (☆). If the program has a positive impact, then it is indicated with a plus sign (+). If the benefit is not applicable to the program or has no impact it is indicated with (N.A.). Those benefits not related to the program's primary goals are considered co-benefits. Of the ZEV programs assessed, most provide qualitative benefits related to GHG, air quality and health, ZEV market acceleration, benefiting priority populations, jobs, and petroleum and fuel cost savings.

Table 5 Qualitative benefits from light- and heavy-duty ZEV programs implemented

Program	GHG	Air Quality	Health	Accelerating Market Transformation	Benefiting Priority Population	Jobs	Petroleum and Fuel Savings
ZEV regulation	☆	☆	+	☆	N.A.	+	+
Clean Vehicle Rebate Project (CVRP)	☆	☆	+	☆	+ for standard rebate; ☆ for increased rebates	+	+
Clean Cars 4 All	+	☆	+	+	☆	+	+
Clean Mobility Options	+	+	+	+	☆	+	+
Financing Assistance for Low-Income Consumers	+	+	+	+	☆	+	+
Low Carbon Fuel Standard	☆	☆	+	☆	N.A.	+	+
Proposition 1B: Goods Movement	+	☆	☆	+	☆	+	+
Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP)	☆	☆	+	☆	+	+	+
Advanced Technology Demonstration Project	☆	☆	+	☆	☆	+	+
Zero-Emission Truck and Bus Pilot Project	☆	☆	+	☆	☆	+	+
Rural School Bus Pilot Project	☆	☆	☆	☆	+	+	+
Zero and Near-Zero-Emission Freight Facilities	☆	☆	+	☆	☆	+	+
Community Air Protection Incentives	+	☆	☆	+	☆	+	+

Key: ☆ refers to primary goal; + refers to positive impact; N.A. refers to not applicable or no impact

i. GHG

As presented in Chapter 2, transforming the transportation sector to zero-emission technology eliminates tailpipe GHG emissions while also drastically reducing fuel production GHG emissions. Because it is designed to ensure that light-duty ZEVs are manufactured and supplied to the market, the ZEV regulation contributes to GHG emission savings. The ZEV incentive programs included in Table 5 also contribute to reduced GHG emissions because they help spur demand for these vehicles by encouraging consumers and fleet operators to purchase or lease ZEVs by offsetting some of the additional upfront costs of ZEVs compared to conventional vehicles or developing and testing new technologies through demonstrations and pilots to accelerate the market. The GHG emission reductions are quantified for a subset of these programs in section 5.B.

ii. Air Quality and Health

California experiences some of the highest concentrations of PM 2.5 in the nation.[111] The majority of California's population lives in areas that exceed the national and State PM 2.5 air quality standards.[112,113] These standards are set based upon assessments of scientific studies that link exposure to PM 2.5 to health effects, including hospitalization due to respiratory illness and premature death from cardiopulmonary disease.[114,115] According to a recent report, the U.S. EPA has determined that exposure to PM 2.5 plays a "causal" role in premature death, meaning that a substantial body of scientific evidence shows a relationship between PM 2.5 exposure and increased mortality, a relationship that persists when other risk factors such as smoking rates and socioeconomic factors are considered.[116] Particulate matter from diesel (DPM) also has a significant impact on California's population. It is estimated that about 70 percent of total known cancer risk related to air toxics in California is attributable to DPM.[117] Based on 2012 estimates of statewide exposure, DPM is estimated to increase Statewide cancer risk by 520 cancers per million residents exposed over a lifetime.[118] DPM is also associated with heart and respiratory diseases. NO_X emissions impact

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[111] U.S. EPA, 2013. "Fine Particle Concentrations Based on Monitored Air Quality from 2009 – 2011." https://www.epa.gov/sites/production/files/2016-04/documents/current_pm_table.pdf.

[112] CARB, 2013. "Area designations for State air quality standards." http://www.arb.ca.gov/desig/adm/2013/state_pm25.pdf.

[113] CARB, 2013. "Area designations for national air quality standards." http://www.arb.ca.gov/desig/adm/2013/fed_pm25.pdf.

[114] CARB, 2010. "Estimate of Premature Deaths Associated with Fine Particle Pollution (PM 2.5) in California Using a U.S. Environmental Protection Agency Methodology" http://www.arb.ca.gov/research/health/pm-mort/pm-report_2010.pdf.

[115] U.S. EPA, 2012. "Regulatory Impact Analysis for the Final Revisions to the National Ambient Air Quality Standards for Particulate Matter" http://www.epa.gov/ttn/ecas/regdata/RIAs/finalria.pdf.

[116] U.S. EPA, 2010. "Quantitative Health Risk Assessment for Particulate Matter." http://www.epa.gov/ttn/naaqs/standards/pm/data/PM_RA_FINAL_June_2010.pdf.

[117] CARB. "Overview: Diesel Exhaust & Health." https://ww2.arb.ca.gov/resources/overview-diesel-exhaust-and-health. Accessed July 15, 2019.

[118] Ibid.

human health because it becomes a component of PM 2.5 through photochemical reactions that convert NO_X into ammonium nitrate aerosol, and NO_X is also involved in the formation of ozone, a major constituent of smog and a potent lung irritant. ROG is also a smog precursor.[119]

As described in Chapter 2, ZEVs eliminate tailpipe emissions while being one of the best ways to reduce GHG and petroleum dependence, and CARB's ZEV programs are part of a broader set of programs that aim to improve air quality and health. A recent literature review found that the CARB's ZEV incentive programs funded through the Cap-and-Trade Proceeds are expected to result in air pollutant emission reductions.[120] Therefore, CARB staff expect that all ZEV incentive as well as regulatory programs assessed should also reduce negative health impacts, as indicated in Table 5, regardless of whether air quality and health are primary goals of the programs. The criteria pollutant emission reductions are quantified for a subset of these programs in section 5.B.

Several of CARB's heavy-duty incentive programs (e.g., Prop. 1B, HVIP, Advanced Technology Demonstration Project, Zero-Emission Truck and Bus Pilot Project, Zero- and Near-Zero Emission Freight Facilities, and Community Air Protection Funds) are also helping to protect community health in the most affected communities near freight hubs and other concentrated sources of air pollutants by reducing pollutant emissions. The California Sustainable Freight Action Plan calls for improved freight efficiency, a transition to zero-emission operations, and increased competitiveness of California's freight system. CARB's investments in heavy-duty vehicle programs that support pilot and demonstration projects for advanced technologies lay the groundwork for the large-scale deployment needed to transition the freight system. In addition, approximately 40 percent of all HVIP funding has gone to support the freight sector.

iii. Accelerating Market Transformation

As outlined in Chapter 2 and 4, in order to help achieve California's air quality and climate goals, ZEVs must be deployed rapidly which requires accelerating the market. Because all ZEV programs contribute to this acceleration, as described below, Table 5 shows this as a benefit for the all programs implemented.

A recent literature review concluded ZEV incentive programs funded through the Cap-and-Trade Proceeds qualitatively accelerate the market transformation, noting that it is impossible at this time to quantify the impact due to lack of research in this area.[121]

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[119] CARB, 2009. "Definitions of VOC and ROG." https://ww3.arb.ca.gov/ei/speciate/voc_rog_dfn_1_09.pdf.

[120] CARB, 2017. August 2017. "Methods to Assess Co-Benefits of California Climate Investments: Air Pollutant Emissions." https://ww3.arb.ca.gov/cc/capandtrade/auctionproceeds/carb_air_pollutant_emissions_transenergy.pdf.

[121] Xu and Eisenstein, 2017. October 27, 2017. "Methods to Assess Co-Benefits of California Climate Investments: Accelerated Implementation of Technology." https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/ucb_lit_rev_on_accelerated_implementation_technology.pdf.

This finding is likely applicable to other ZEV incentive programs. For the light-duty incentive programs, CVRP accelerates the market transformation in the general population and fleets, while CVRP, Clean Cars 4 All, Clean Mobility Options, and Financing Assistance for Lower-Income Consumers do so in priority populations faster than the market would otherwise. A different literature review concluded that California's light-duty ZEV regulation has also had a positive impact on innovation activity based on vehicle manufacturers increasing research and development, forming partnerships, and filing patents.[122] Although no causality has been determined, the review found an association between the presence of a ZEV mandate and the status of the ZEV market. The ZEV regulation and CVRP have not only helped with advancing the new ZEV and PHEV markets within California, but they have also helped create the used ZEV and PHEV market. Further, increases in vehicle volumes sold have effects that go beyond reducing manufacturing costs, such as increasing dealer and consumer familiarity and building robust supply chains necessary for innovation. Clean Cars 4 All and the Financing Assistance for Lower-Income Consumers has also helped accelerate the new and used ZEV market within the San Joaquin Valley and the South Coast Air Quality Management Districts.

For heavy-duty incentive programs, the former literature review found that the acceleration of technology is also likely to be significant compared to what would have happened absent the funding for investments either directly through technology development (e.g., Advanced Technology Demonstration Projects), deployment or adoption of novel technologies (e.g., Prop. 1B and HVIP), or the financing of vehicles that are relatively expensive compared to more carbon-intensive alternatives (e.g., Zero-Emission Truck and Bus Pilot Project, Rural School Bus Pilot Project, and Zero and Near-Zero-emission Freight Facilities). However, programs that fund technology at earlier commercialization phases, such as the Advanced Technology Demonstration Projects, have a greater effect on the transition.[123] The transition toward cleaner, more efficient heavy-duty vehicles will require a substantial financial commitment from the public and private sectors. The relatively low price of diesel fuel, current lack of high volume advanced technology vehicle manufacturing, severe lack of ZEV fueling infrastructure for heavy-duty technologies, and resulting large price differential are all obstacles to market growth. CARB's investments made thus far have had a positive impact, moving towards achieving lifecycle cost parity between conventional and advanced technology. For example, the costs associated with zero-emission transit buses, both battery electric and fuel cell electric, have dropped in recent years due to early commercial deployment projects such as the Zero-Emission Truck and Bus Pilot Project and HVIP. As technologies continue to advance, technology transfers to new

[122] Hardman, et al., 2018b. International EV Policy Council Policy Guide. August 2018. "Driving the Market for Plug-in Vehicles: Understanding ZEV Mandates." https://phev.ucdavis.edu/wp-content/uploads/zev-mandates-policy-guide.pdf.
[123] Xu and Eisenstein, 2017.

applications, such as drayage trucks and off-road equipment.[124] CARB's heavy-duty incentive programs are paving the way for this transition. Also, building on the success of past HVIP investments, new manufacturers are entering the market with technologies transferring to heavier weight classes, such as 60-foot transit buses and class 8 trucks.

As the Low Carbon Fuel Standard increases in stringency, there is greater incentive to adopt low-carbon vehicle technologies and the supporting fueling infrastructure, such as hydrogen fueling stations and DC Fast Chargers. The LCFS also provides an additional incentive for ZEV fueling infrastructure, which helps increase investment certainty for building infrastructure prior to sufficient vehicles being available to fully utilize the installed capacity. The LCFS provides a further nudge for fleet operators to transition heavy-duty vehicles to zero-emission technology, since zero-emission fleet operators (including transit agencies that operate electric transit buses) are eligible to generate LCFS credits. As the carbon intensity reduction targets of the LCFS tighten over time, the value of this incentive for fleets to adopt zero-emission technologies will continue to grow.

iv. Benefiting Priority Populations

As described below and shown in Table 5, the light- and heavy-duty incentives implemented benefit disadvantaged communities and low-income households and communities. Compared with the general California population, the ZEV regulation provides no specific benefit to priority populations as shown in Table 5.

The light-duty incentive programs benefit priority populations. Clean Cars 4 All, Financing Assistance Program for Lower-Income Consumers, Clean Mobility Options, and the increased incentives for low-income consumers through CVRP aim to ensure that the benefits of ZEV adoption are spread equitably across the economic spectrum by helping low-income consumers and disadvantaged community members to access cleaner vehicles and transportation. Clean Cars 4 All is limited to lower-income consumers living in disadvantaged community census tracks and zip codes. Through the end of June 2018, 88 percent of program participants who have gotten a BEV or PHEV had annual incomes below 225 percent of the federal poverty level. Clean Cars 4 All has directly helped approximately 2,000 lower-income Californians living in disadvantaged communities replace an old, often unreliable, higher-polluting vehicle with a more reliable BEV or PHEV. The more recently established Financing Assistance for Lower-Income Consumers program has directly helped nearly 400 lower-income Californians into a ZEV or PHEV as of May 2019. The Clean Mobility Options program benefits lower-income Californians and disadvantaged communities by providing clean mobility options beyond vehicle ownership. The two implemented ZEV carsharing pilots have provided mobility access to over 2,000 lower-income Californians and

[124] CARB, 2017. November 9, 2017. "Part II: Three-year Investment Strategy for Heavy-duty Vehicles and Off-road Equipment from Low Carbon Transportation Investments and AQIP." https://ww3.arb.ca.gov/msprog/aqip/fundplan/proposed_1718_funding_plan_final.pdf.

disadvantaged community members. Approximately a quarter of CVRP's total lifetime funding, or $116M, has benefited disadvantaged or low-income communities as defined by AB 1550,[125] and 13 percent of CVRP funding has gone to Increased Rebates for Lower-Income Consumers since their creation in March 2016.[126] Through June 2019, over 13,000 lower-income Californians have gotten a BEV, PHEV, or FCEV with an increased rebate from CVRP.[127]

Besides increased mobility and more reliable transportation, these four light-duty incentive programs improve public health and reduce exposure to environmental contaminants by reducing emissions from vehicles operating in or near disadvantaged and low-income communities and provide an economic benefit to those priority populations that participate. Reducing the cost of vehicle ownership increases participants' disposable income that they can spend in their local economies. Because Clean Cars 4 All focuses on low-income drivers in areas of the State with the greatest air quality burden, the program helps households who will benefit the most from owning a newer, cleaner, and more reliable car. Replacing an older and less reliable car with an advanced technology vehicle also reduces the overall cost of car ownership through increased fuel efficiency, reduced repair costs, and fewer days missed at work. A low-interest loan, such as the ones offered through the Financing Assistance for Lower Income Consumers, can provide an avenue for a consumer to build or rebuild their credit.

CARB's investment in the heavy-duty vehicle projects is intended to accelerate development and deployment of the cleanest feasible mobile source technologies, such as zero-emission transit buses, in order to improve air quality and enhance access to clean transportation in disadvantaged communities. In designing the heavy-duty investments, CARB strives to maximize the benefits for disadvantaged communities, low-income communities, and low-income households as defined by AB 1550. Project solicitations and implementation requirements incorporate provisions to help ensure that CARB exceeds minimum disadvantaged community investment targets. Indeed, all of the implemented Advanced Technology Demonstration Projects and Zero- and Near-Zero-Emission Freight Facilities projects are located within disadvantaged communities, with the majority of those from the Community Air Protection Funds, Zero-Emission Truck and Bus Pilot Projects as well.[128],[129] Additionally, HVIP provides voucher enhancements for heavy-duty vehicles deployed in disadvantaged communities. As a result, over two-thirds of HVIP voucher funding has been invested in AB 1550 priority populations. Despite the Rural School Bus Pilot Project not having

[125] Gomez, Chapter 369, Statues of 2016.
[126] Under the equity statistics tab https://cleanvehiclerebate.org/eng/rebate-statistics. Accessed July 1, 2019.
[127] Ibid.
[128] CARB, 2019. "Annual Report to the Legislature on California Climate Investments Using Cap-and-Trade Auction Proceeds" https://ww3.arb.ca.gov/cc/capandtrade/auctionproceeds/2019_cci_annual_report.pdf.
[129] CARB, 2018. Press release #18-50. September 26, 2018. "CARB announces more than $200 million in new funding for clean freight transportation." https://ww2.arb.ca.gov/news/carb-announces-more-200-million-new-funding-clean-freight-transportation. Accessed July 1, 2019.

any requirements to benefit priority populations, nearly a third of the funds have gone to rural school districts located within low-income and disadvantaged communities. Finally, despite Prop. 1B predating the current priority population definition, it requires emission reductions in communities heavily impacted by freight movement.

v. Jobs

There are two different types of job benefits resulting from CARB's ZEV programs: direct and indirect jobs. The direct job creation results from the investment or regulation, while the indirect job creation occurs in industries supplying goods and services to the directly affected industries. A recent literature review concluded that job creation will be a significant co-benefit for virtually all ZEV incentive programs.[130] As described below and shown in Table 5, ZEV programs create direct and indirect jobs in advanced transportation and supporting industries. Job creation is a co-benefit for all programs qualitatively assessed.

A recent literature review concluded that ZEV incentive programs funded through Cap-and-Trade Proceeds should led to more jobs in the ZEV related industries.[131] The same is likely true for other ZEV incentive and regulatory programs because increasing ZEV adoption in California through ZEV programs will cause a growth in ZEV-related manufacturing and infrastructure jobs as well as businesses that enable ZEV and PHEV adoption. Production of ZEVs and PHEVs relies heavily on advancements in battery, fuel cell, and grid technologies by engineering and manufacturing firms, many of which are in California. Manufacturing jobs stemming from vehicle, parts and battery manufacturers will increase as well as jobs from alternative fuel producers and suppliers; charging and hydrogen infrastructure providers; vehicle and grid software developers; utility providers and others. These job gains may be somewhat offset by job losses in occupations tied to manufacturing, supplying and servicing of conventional vehicles and jobs related to the oil and gas industry.

California's clean light- and heavy-duty transportation policies has leveraged $4 billion[132] in private sector investments in California companies over the past decade. Because of California's policies and continued private and public sector investments in clean transportation technology, one study estimates that as many as 25,000 more jobs in ZEV manufacturing will be available in California by 2020.[133] A lot of these jobs benefits will be felt throughout the United States, as more light-duty electric vehicles are being manufactured in the country. In 2018, 75 percent of the ZEVs sold

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[130] Roland-Holst, et al., 2017. November 2, 2017. "Methods to Assess Co-Benefits of California Climate Investments: Jobs." https://ww3.arb.ca.gov/cc/capandtrade/auctionproceeds/ucb_lit_rev_on_jobs.pdf.
[131] Ibid.
[132] Next 10, 2018. "2018 California Green Innovation Index 10th Edition." https://www.next10.org/sites/default/files/2018-ca-green-innovation-index.pdf.
[133] Schuchard, et al., 2016. CALSTART. August 2016. "California's Clean Transportation Technology Industry." https://calstart.org/wp-content/uploads/2018/11/Californias-Clean-Transportation-Technology-Industry-2016.pdf.

nationwide were made in the United States.[134] Together, the combined public and private investments are bringing vehicle manufacturing back to California. Zero-emission trucks and buses are also being built in California by manufacturers like El Dorado National-California, Proterra, BYD, Gillig, GreenPower, Phoenix Motorcars, Motiv Power Systems, and TransPower. Additionally, traditional bus manufacturers, such as Gillig and El Dorado National, have installed new production lines at their facilities to build advanced technology buses here in California. Complete Coach Works is converting conventional buses to zero-emission in California. New Flyer, the largest transit bus manufacturer in North America, has built new production facilities in numerous states and closely supports its Californian customers with service centers here. In addition, both BYD and Proterra have battery production plants in California. Tesla, the largest vehicle manufacturer in California, is also planning production of a class 8 electric truck in 2020. The Low Carbon Fuel Standard will increase the demand for low carbon fuels, including electricity and hydrogen to power ZEVs, which provides an opportunity for businesses, both in-state and out-of-state, to increase revenue from the sale of low carbon fuels in California.

In addition, expanding low-income residents' access to reliable sources transportation to get to a job site can also support employment. Scientific literature has associated vehicle ownership with increased likelihood of employment in low-income population.[135] Therefore, it is likely that the light-duty equity programs have also improved participants' ability to access jobs by having a reliable vehicle or other mobility option.

vi. Energy and Fuel Cost Savings

Transitioning the transportation sector to zero-emission technology will reduce petroleum energy usage and provide fuel cost savings, as described below and in Table 5. Petroleum and fuel cost savings is a co-benefit of all ZEV programs currently implemented. The cost to charge an electric vehicle will vary depending on the type of electric vehicle supply equipment (EVSE) used (e.g., level 1, 2 or DC Fast Charger) whether charging at home or at a free or paid public or work charging station, the time of day, and the utility providing the electricity. Additionally, vehicle manufacturers provide free access to some charging station networks and hydrogen refueling sites for the first few years for certain light-duty BEVs and all FCEVs currently available for purchase or lease.

A recent literature review concluded that the participants of ZEV incentive programs funded through Cap-and-Trade Proceeds should be using less energy and spending

[134] Fact of the Week #1086. June 17, 2019. "Seventy-five Percent of Plug-in Vehicles Sold in the United States in 2018 were Made in the United States." https://www.energy.gov/eere/vehicles/articles/fotw-1086-june-17-2019-seventy-five-percent-plug-vehicles-sold-united-states. Accessed July 1, 2019.

[135] Ong, 2002. "Car Ownership and Welfare-to-Work." Journal of Policy Analysis and Management. Vol 21, Issue 2. Spring 2002. Pages 239-252. https://doi.org/10.1002/pam.10025.

less on fuel expenses.[136] This finding is likely applicable to CARB's ZEV programs implemented by July 2019. For ZEV programs that require scrappage (e.g., Clean Cars 4 All, Prop. 1B, Community Air Protection Funds), replacing an old and higher-polluting conventional vehicle, which typically have low fuel economy, with a ZEV or PHEV (or other eligible vehicles) results in reduced petroleum and fuel costs. ZEV programs that do not have a scrappage component (e.g., the ZEV regulation, CVRP, Financing Assistance for Lower-Income Consumers, Clean Mobility Options, HVIP, Advanced Technology Demonstration Projects, Zero-Emission Truck and Bus Pilot Projects, Rural School Bus Pilot Project, and Zero- and Near-Zero-Emission Freight Facilities) can also reduce petroleum usage and fuel costs compared to trips that would have been made on a conventional vehicle. Finally, LCFS substantially decreases the cost of electricity used for electric vehicles or costs of electric vehicle ownership by allowing utilities to generate credit for every kWh of electricity dispensed for residential charging. Utilities must use revenue from the sale of LCFS credits to benefit electric vehicle drivers, which have taken the form of annual utility bill reductions, purchase rebates, and charging infrastructure discounts. The LCFS provides additional incentives to match low carbon and zero-carbon electricity with electric vehicle charging to further reduce GHG emissions. For non-residential charging, charging operators receive LCFS credit for each kWh of electricity dispensed, which is substantial and can offset rates that electric vehicle owners pay when charging at public charging infrastructure.

B. Cost-Benefit Analysis

This section focuses on the costs and benefits of a subset of CARB's ZEV programs, two light-duty and two heavy-duty programs, which have sufficient data on costs and emissions associated with the programs to conduct the retrospective analysis required for this report. On the light-duty side, CVRP supports growing the light-duty ZEV market across all consumer segments, while Clean Cars 4 All supports scrappage of higher-polluting vehicles and growth in the ZEV market within priority populations. On the heavy-duty side, HVIP supports commercially available ZEV technologies, while the Zero-Emission Truck and Bus Pilot Project supports ZEVs in the pre-commercialization phase. The section is divided into each of these four programs, followed by a comparison of the cost-benefit analysis across programs. Because these programs were established to meet different goals, they cannot be compared solely in terms of cost-effectiveness. Other impacts, such as increasing social equity and market advancement, should be considered as well.

CARB staff did not conduct a cost-benefit analysis for programs where there was either insufficient data for quantification or no valid way to quantify emission benefits. Several programs in this report are young, smaller in scale, or limited with respect to ZEVs (e.g., Prop. 1B and Community Air Protection Funds) and therefore have limited data to date. Regulatory programs (e.g., ZEV regulation and LCFS) do not collect actual cost

[136] Litke, et al., 2017. October 13, 2017. "Methods to Assess Co-benefits of California Climate Investments: Energy and Fuel Costs." https://ww3.arb.ca.gov/cc/capandtrade/auctionproceeds/ucb_lit_rev_on_energy_fuel_cost.pdf.

information from the regulated parties, and CARB relies on its emission inventory efforts to assess the success of these regulatory efforts. For programs focused on funding pre-commercial technologies to support market development (e.g., Advanced Technology Demonstration Projects) there is no methodology established that quantifies the program's emission benefits from accelerating the ZEV market transformation.[137] Costs and benefits of supporting programs are not included in this report because of insufficient data, such as lack of cost information and the complexity of attributing ZEV adoption to the programs.

The cost-benefit analysis is based on data from vehicles incentivized during the four most recent fiscal years (FY) for which the data is available: FY 2014-15 through FY 2017-18. An additional report for AB 615 covers the entire life of CVRP.[138] The total emissions quantified include emission reductions that have happened in the past and will happen based on assumptions about the duration of benefits that are specific to each program. For CVRP, emissions benefits are assumed to last for 2.5 years, compared to 3 years for Clean Cars 4 All, and 15 years for both HVIP and the Zero-Emission Truck and Bus Pilot Project. If these vehicles remain on California's roads beyond their quantification period, their emissions benefits will be greater than what is reported here. For detailed quantification methodologies, please see Appendix C. Clean Cars 4 All and HVIP have also incentivized a large number of other vehicles outside the scope of this report, such as conventional hybrid and low-NO_X vehicles. When adding in the benefits of those other vehicles, the total benefits of the respective programs would increase.

i. Clean Vehicle Rebate Project (CVRP)

CVRP offers vehicle rebates for light-duty ZEVs, PHEVs, and other eligible vehicles on a first-come, first-served basis. A more in-depth program description can be found in Appendix B. During fiscal years 2014-15 through FY 2017-18,[139] CVRP spent approximately $465 million to incentivize the purchase or lease of 124,377 BEVs, 72,368 PHEVs, and 4,552 FCEVs. The costs and benefits for CVRP were quantified in two separate ways: first by the vehicle technology incentivized, and second by the rebate recipient type, as shown in Table 6 and Table 7. Both of these tables—and through Table 10—present, by category and overall total, the amount of State funds spent, the amount of the incentive, the number of vehicles incentivized, and the GHG and criteria air pollutant emission reductions attributed. In addition, these tables include the qualitative benefits described in section 5.A. in order to present a more

[137] Xu and Eisenstein, 2017.

[138] CARB, 2019. "Assembly Bill 615 Report to the Legislature on the Impact of the Clean Vehicle Rebate Project on California's Zero-Emission Vehicle Market" https://ww3.arb.ca.gov/research/apr/reports/AB%20615-Clean%20Vehicle%20Rebate.pdf.

[139] Data for FY 2017-18 is partial because the data was analyzed prior to reconciling the full dataset since there is a time delay between receiving applications, processing, verifying, approving and mailing the rebate check.

complete view of the programs. A more detailed description of the quantification methods for this analysis can be found in Appendix C.

Table 6 shows the cost-benefit analysis for CVRP broken down by vehicle technology (e.g., PHEV, BEV, and FCEV). Overall, approximately 1.5 million metric tons of GHG reduction[140] are attributed to vehicles incentivized during this these fiscal years, with the majority of these reductions coming from BEVs (63 percent) followed by PHEVs (35 percent). BEVs have a higher per vehicle emission reduction than PHEVs, and there were 42 percent more BEVs incentivized than PHEVs during this period. Similarly, the majority of the NO_X, PM 2.5 and ROG benefits come from BEVs. FCEVs comprise a small share of the program and as a result the total emission reductions from incentivizing these vehicles has been proportionately small, even though each individual FCEV provides emissions reductions comparable to a BEV.[141] As the young fuel cell electric vehicle market matures and more FCEVs are deployed, CARB staff expect the emissions benefits per FCEV to remain steady or improve; therefore, as more of these vehicles are incentivized their total emissions reduction will grow over time.

Table 7 shows the costs and benefits broken down by rebate recipient type (e.g., standard rebate for individuals, increased rebate for low-income individuals, and fleet operators). Here, fleet refers to a local, state, or federal government as well as to a commercial or non-profit entity. Although the vast majority (97 percent) of incentives went to individuals during the analysis period, CVRP for Public Fleets is a sub-program of CVRP that offers an incentive of up to $7,000 to public agencies for eligible vehicles —up to 30 rebates a year. Public agencies such as local, state, and tribal government entities are eligible for this increased fleet rebate if the location of the facility is within a California disadvantaged community census tract. The per vehicle emission reductions of vehicles purchased by fleets are less than those of individuals because of their assumed vehicle usage (i.e., fleet vehicles are typically driven less than personally owned vehicles), as discussed in Appendix C.[142] Overall, the majority of GHG emission benefits (98 percent) come from vehicles purchased by individuals.

The increased rebate for low-income consumers, defined as those with a household income of less than 300 percent of the federal poverty level[143] (which for a family of four is a household income of less than $75,300), was available starting in 2016. Nearly 8 percent of all CVRP incentives for individuals were increased rebates for low-income consumers between March 2016 (when the increased rebate was first available) and

[140] This number is significantly lower than the ~5.5 million $MTCO_2e$ reported in the 2019 California Climate Investments Annual Report. This difference is mostly due to a change in the quantification period from 15 years in 2015 and 2016 quantification methodologies and 2.5 years in 2017 and 2018. This report also uses a consistent quantification period of 2.5 years since this is the minimum vehicle ownership requirement for CVRP.
[141] On a per vehicle basis, FCVEs reduce 78% fewer emissions than BEVs.
[142] In addition, approximately four percent of fleet rebates were under the reduced ownership provision and were assigned a one-year quantification period compared to the 2.5 years assigned otherwise.
[143] The federal poverty level varies by household size and income.

mid-2018, accounting for about 14 percent of the funds. CVRP rebates are available on a first-come, first-serve basis, except when CVRP funds near depletion, at which point staff create a reserve for low-income consumers and a waitlist for everyone else. Because it takes many months to process and verify CVRP rebate applications before approval, CARB staff also prioritize application processing for low-income applicants. In total, 9,859 individual rebates for households with incomes less than 300 percent of the federal poverty level received $40 million for increased rebates during the period evaluated in this report. Since the increased rebate for low-income consumers went into effect, over 20 percent[144] of CVRP funds have benefitted disadvantaged or low-income communities as defined by AB 1550.[145] In addition, public fleets domiciled and primarily operated within disadvantaged communities also received an increased rebate for 773 vehicles—735 of which were rebated through the Public Fleet Pilot Program before it was integrated into CVRP.

Overall, it cost approximately $307 per metric ton of GHG emissions reduced[146] during the 2.5 year vehicle ownership requirement. The values presented here are conservative, because the majority of the rebated vehicles will continue to be driven after this ownership requirement so that the real world emission benefits are likely to be higher, and cost less per ton.[147] The cost per GHG reduction varies by vehicle and recipient type. For example, the increased rebate for low-income consumers is less cost-effective compared to the standard rebate simply due to the $2,000 higher incentive amount. For the increased rebates for low-income individuals, the average cost is $510 per metric ton of GHG reduced compared to $288 for the standard rebate. Despite the higher cost, these increased rebates for low-income consumers are important to achieve social equity goals. Fleet incentives are the least cost-effective, with an average cost of $655 per metric ton of GHG reduced, because they are assumed to typically drive fewer miles creating smaller emission benefits and also have a higher average incentive amount. However, it is also important to ensure that fleets transition to cleaner vehicles to increase ZEV exposure for employees and in the community. In terms of vehicle type, PHEVs are the most cost-effective from an emissions perspective with $221 per metric ton of GHG reduced compared to BEVs at $339. This is because the standard incentive amount for a PHEV is $1,000 less than for a BEV and annual vehicle miles traveled for a PHEV are assumed to be higher than a BEV.[148] In contrast, FCEVs are the least cost-effective, at $852, because of the higher incentive.

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[144] Under the equity statistics tab https://cleanvehiclerebate.org/eng/rebate-statistics. Accessed July 1, 2019.
[145] Gomez, Chapter 369, Statutes of 2016.
[146] This number is also significantly different than the $88 reported in the 2019 California Climate Investments Annual Report because of the change in quantification period as described in footnote #133.
[147] For example, assuming a quantification period using the average age of light-duty vehicles of 11.6 years, the cost would be $66 per metric ton reduction of GHG emissions.
[148] PHEV = 14,855 miles/year and BEV = 11,059 based on Smart, et al., 2013. "Extended Range Electric Vehicle Driving and Charging Behavior Observed Early in the EV Project," SAE Technical Paper 2013-01-1441.

Another way to analyze the CVRP emission benefits is to identify who needed a rebate in order to purchase their ZEV or PHEV. As described in previous work,[149] program participants[150] that would not have purchased the rebated vehicles without the rebate[151] are considered "rebate-essential"—that is not free-riders. Results indicate that 56 percent of CVRP GHG emission benefits from FY2014-15 through FY2017-18 were from rebate-essential participants. Like cost per GHG reduction, rebate essentiality also varies by rebate type such that the less cost-effective rebates correspond to larger proportions of rebate-essential GHG reductions. For example, comparing the GHG reductions by vehicle types indicates that 46 percent of PHEV, 61 percent of BEV, and 67 percent of FCEV GHG reductions are associated with "rebate-essential" participants.

Overall, cost-effectiveness is largely tied to rebate amount. Rebates for public fleets and low-income consumers are less cost-effective than the standard rebates due to their increased amount, but are important for accelerating the transition of public fleets and for encouraging equitable access to ZEVs. Rebates for PHEVs, because of their lower amount and the higher assumed mileage driven, are more cost-effective than for BEVs or FCEVs, but research affirms the wisdom of offering higher rebates for BEVs than PHEVs because consumers need a slightly larger nudge to transition all the way to a ZEV.[152]

http://papers.sae.org/2013-01-1441/ and Smart and Schey, 2012. "Battery Electric Vehicle Driving and Charging Behavior Observed Early in The EV Project," SAE Int. J. Alt. Power. 1(1):27-33, 2012 http://papers.sae.org/2012-01-0199/. These are assumptions that CARB staff have been continuously examining.

[149] Johnson and Williams, 2017. "Characterizing Plug-In Hybrid Electric Vehicle Consumers Most Influenced by California's Electric Vehicle Rebate," Transportation Research Record, vol. 2628, January 2017. https://journals.sagepub.com/doi/abs/10.3141/2628-03.

[150] Fleet recipients were not invited to respond to the survey.

[151] Those who answer "No" to CVRP's Consumer Survey question, "Would you have purchased your [rebated EV model] without the CVRP rebate?" are categorized as "rebate-essential."

[152] DeShazo, 2017. Final Research Report. May 2017. "Examining Factors that Influence ZEV Sales in California." https://ww3.arb.ca.gov/research/single-project.php?row_id=65197.

Table 6 Costs and Benefits of the ZEVs and PHEVs Incentivized through CVRP from FY 2014-15 through FY 2017-2018[153] by Vehicle Type[154,155]

Vehicle Type	Funds Spent ($ in millions)	Max Rebate per Vehicle Type[156]	Vehicles Funded	GHG Reduction (1,000 of metric tons of CO_{2e})	NOx Reduc-tion (tons)	PM 2.5 Reduc-tion (tons)	ROG Reduc-tion (tons)	Health	Accele-rating Market Transfor-mation	Benefiting Priority Populations	Jobs	Energy and Fuel Savings
PHEV	$118	$3,500	72,368	534 ($221/MT)	50	26	10	+	☆	+: standard rebate; ☆: increased rebates for low-income consumers and public fleets in DACs	+	+
BEV	$323	$4,500	124,377	954 ($339/MT)	125	36	25					
FCEV	$23	$7,000	4,552	27 ($852/MT)	4	1	1					
TOTAL	$465		201,297	1,515 ($307/MT)	179	64	36					

Key: ☆ refers to primary goal; + refers to positive impact

[153] Totals contain partial data for FY 2017–2018 because of the time delay between receiving applications, processing, verifying, approving and mailing the rebate check.

[154] Assumes a quantification period of 2.5 years based on vehicle ownership requirement.

[155] Totals may not add up due to rounding.

[156] A small portion of the incentives were from the Public Fleet Pilot Project and received maximum rebate amounts of PHEV: $5,250, BEV: $10,000; FCEV: $15,000.

Table 7 Costs and Benefits of the ZEVs and PHEVs Incentivized through CVRP from FY 2014-15 through FY 2017-2018[157] by Rebate Type[158,159]

Incentive Type	Funds Spent ($ in millions)	Max Rebate per Recipient Type	Vehicles Funded	GHG Reduction (1,000 of metric tons of CO_{2e})	NOx Reduc-tion (tons)	PM 2.5 Reduc-tion (tons)	ROG Reduc-tion (tons)	Health	Accele-rating Market Transfor-mation	Benefiting Priority Populations	Jobs	Energy and Fuel Savings
Standard Rebate for Individuals	$406	PHEV: $1,500 BEV: $2,500 FCEV: $5,000	184,849	1,409 ($288/MT)	167	59	34	+	☆	+	+	+
Increased Rebate for Low-Income Individuals	$40	PHEV: $3,500 BEV: $4,500 FCEV: $7,000	9,859	77 ($510/MT)	8	3	2			☆		
Rebates for Fleets	$19	PHEV: $3,500 BEV: $4,500 FCEV: $7,000[160]	6,589[161]	29 ($655/MT)	4	1	1			+: standard rebate; ☆: increased rebate for public fleets in DACs		
TOTAL	$465		201,297	1,515 ($307/MT)	179	64	36			+: standard ☆: increased rebates		

Key: ☆ refers to primary goal; + refers to positive impact; N.A refers to not applicable or no impact

[157] Totals contain partial data for FY 2017–2018.

[158] Assumes a quantification period of 2.5 years based on vehicle ownership requirement.

[159] Totals may not add up due to rounding.

[160] The maximum rebate for the Public Fleet Pilot Project used to be higher (PHEV: $5,250, BEV: $10,000; FCEV: $15,000) than is currently available for public fleets located in or primarily operating within disadvantaged communities. Other fleets receive the standard rebate amounts.

[161] A total of 735 of these were an increased rebate for public fleets located or operating mainly within disadvantaged communities through the Public Fleet Pilot Project.

ii. Clean Cars 4 All

Clean Cars 4 All (formerly known as the Enhanced Fleet Modernization Program Plus-Up or EFMP Plus-Up) aims to improve transportation equity by helping lower-income Californians living in disadvantaged communities afford and benefit from clean transportation options. The incentive amounts provided through Clean Cars 4 All increase with decreasing income level of participating households. A more in-depth program description can be found in Appendix B. In terms of equity, the program has been very effective, with over 88 percent (i.e., 1,685) of BEV and PHEV participants reporting annual incomes below 225 percent of the federal poverty level, which is $56,475 per year for a family of four. The costs and benefits quantified for the first three years of the Clean Cars 4 All program for the BEVs and PHEVs incentivized are shown in Table 5. Because this program targets low-income consumers, CARB staff expects that few free-riders[162] have participated in Clean Cars 4 All.

During the first three years of the program,[163] Clean Cars 4 All spent approximately $17 million State dollars to incentivize the scrappage of functioning, high-polluting vehicles and replacement with 1,396 PHEVs and 518 BEVs. A total of 15,000 metric tons of GHG[164] is attributed to these vehicles,[165] with about a third of these reductions coming from BEVs and the rest from PHEVs. A more detailed description of the quantification methods for this analysis can be found in Appendix C. Clean Cars 4 All also incentivizes conventional hybrids and mobility options such as transit passes, but those are not quantified here because they are outside of the scope of SB 498. Although there were no fuel cell electric vehicles incentivized by the program during the first three years, two were funded in FY 2018–19.

The average cost-effectiveness is $1,133 per metric ton of GHG reduced[166] for Clean Cars 4 All during the three-year vehicle ownership requirement. As with CVRP, this is likely a conservative estimate, since the majority of the incentivized vehicles remain in California after this ownership requirement, and as a result the emission benefits are likely to be higher and cost less per ton. As shown in Table 8, the cost-effectiveness varies by vehicle technology. For BEVs, the average cost-effectiveness is $1000 per metric ton of GHG reduction compared to $1,300 for a plug-in hybrid vehicle. The difference is attributed to a greater emission reduction per vehicle for BEVs compared

[162] A free-rider in this case would be individuals receiving an incentive who would have purchased a ZEV even in the absence of the incentive.
[163] The program was first implemented in FY 2015-16.
[164] This number is similar to the 19,000 $MTCO_2e$ reported in the 2019 California Climate Investments Annual Report. This difference is mostly due to this report excluding the conventional hybrid vehicles that were incentivized.
[165] Although the vehicles were incentivized during the fiscal years analyzed, the emission benefits are calculated for a quantification period of three years based on the vehicle ownership requirement for Clean Cars 4 All. So for vehicles funded in FY 2016-17 and FY 2017-18 the emissions quantified include those that haven't happened as of publication of this report.
[166] This value is similar to the $1,138 per $MTCO_2e$ reported in the 2019 California Climate Investments Annual Report.

to PHEVs and because the monetary incentive is the same regardless of vehicle type for households with the same income. However, program participants have preferred getting a PHEV over a BEV.

Table 8 Costs and Benefits of the ZEVs and PHEVs Incentivized through the Clean Cars 4 All from FY 2015-16 through FY 2017-2018[167, 168]

Vehicle Type	Funds Spent ($ in millions)	Rebate by Income	Vehicles Funded	GHG Reduction (1,000 of metric tons of CO_{2e})	NOx Reduc-tion (tons)	PM 2.5 Reduc-tion (tons)	ROG Reduc-tion (tons)	Health	Accele-rating Market Transfor-mation	Benefiting Priority Popula-tions	Jobs	Energy and Fuel Savings
PHEV	$13	Based on federal poverty level: $9,500 for ≤ 225%, $7,500 for ≤ 300%, and $5,500 for ≤ 400%	1,396	10 ($1,300/MT)	15	<1	5	+	+	☆	+	+
BEV	$5		518	5 ($1,000/MT)	6	<1	2					
TOTAL	$17		1,914	15 ($1,133/MT)	20	1	6					

Key: ☆ refers to primary goal; + refers to positive impact

[167] Assumes a quantification period of 3 years based on vehicle ownership requirement.

[168] Totals may not add up due to rounding.

iii. Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP)

HVIP accelerates the deployment of zero-emission trucks and buses in California. A more in-depth program description can be found in Appendix B. The costs and benefits quantified for the ZEVs supported by HVIP during fiscal years 2014-15 through 2017-18 are shown in Table 9, based upon 15 years of assumed vehicle life. A more detailed description of the quantification methods for this analysis can be found in Appendix C.

For the purposes of this quantification, the ZEVs incentivized by HVIP were categorized into five groups: electric heavy-duty trucks, electric urban buses, fuel cell electric fuel buses, electric school buses, and utility trucks equipped with an electric power takeoff system. During these fiscal years, HVIP spent approximately $188 million to incentivize 1,268 zero-emission heavy-duty trucks, 548 zero-emission buses, and 189 utility trucks equipped with an ePTO.[169] It should be noted that the above numbers are an estimate based on the vouchers that have been requested and redeemed. HVIP vouchers are redeemed after a vehicle has been delivered and adjustments to the numbers above may occur. As August 1, 2019, nearly 600 vehicles have been delivered—with funding from between FY 2014-15 and FY 2017-18—and are operating on California roads.

Table 9 shows approximately 850,000 tons of GHG emission reductions[170] are attributed to the vehicles funded during these fiscal years. About equal GHG emission reductions come from the electric urban buses (40 percent) and the trucks equipped with ePTO (36 percent), followed by the electric heavy-duty trucks (19 percent). Electric urban buses had the largest per vehicle average emission reductions due to their high usage compared to the other vehicle categories (see Appendix C for details), but there were more utility trucks equipped with ePTO incentivized. HVIP does incentivize conventional hybrids and low NO_X technology, but those are not quantified here because they are outside of the scope of this report on ZEV vehicles.

The average cost is $221 per metric ton of GHG reduced[171] over 15 years of vehicle life for the zero-emission trucks and buses incentivized through HVIP. As shown in Table 9, incentivizing trucks equipped with ePTO is more cost-effective from an emissions reduction perspective due to the relatively small average incentive provided for this category compared to incentivizing the other vehicle categories (e.g., about $24,000 compared to an average of $94,000). For example, it cost $39 per metric ton of GHG reduction for a truck equipped with ePTO versus $667 for a fuel cell electric urban bus, and $382 for an electric heavy-duty truck. However, to help transition all trucks and

[169] These values are for the combined number of HVIP vouchers requested and redeemed. HVIP vouchers are paid to the dealer upon the delivery of the vehicles to the customer.

[170] This number is similar to the 879,000 $MTCO_2e$ reported in the 2019 California Climate Investments Annual Report. This difference is mostly due to this report excluding the conventional hybrid and low NOx vehicles that were incentivized.

[171] This value is similar to the $259 per $MTCO_2e$ reported in the 2019 California Climate Investments Annual Report.

buses in California to zero-emission technology to meet the State's air quality and climate goals, the California should continue investing in the heavy-duty ZEV market until it has matured to the point where the incentives are no longer needed.

Table 9 Costs and Benefits of the Zero-Emission Trucks and Buses Incentivized through HVIP from FY 2014-15 through FY 2017-2018 by Vehicle Type[172,173]

Vehicle Type	Funds Spent[174] ($ in millions)	Average Rebate per Vehicle Type ($ in thousands)	Vehicles Funded	GHG Reduction (1,000 of metric tons of CO_{2e})	NOx Reduc-tion (tons)	PM 2.5 Reduc-tion (tons)	ROG Reduc-tion (tons)	Health	Accele-rating Market Transfor-mation	Benefiting Priority Popula-tions	Jobs	Energy and Fuel Savings
Electric Heavy-Duty Trucks[175]	$112	$88	1,268	293 ($382/MT)	223	8	10	+	☆	+	+	+
Electric Urban Buses	$60	$124	483	438 ($137/MT)	195	44	6					
Fuel Cell Electric Urban Buses	$2	$300	5	3 ($667/MT)	2	<1	<1					
Electric School Buses	$10	$160	60	16 ($625/MT)	17	2	1					
Trucks with ePTO	$4	$24	186	102 ($39/MT)	228	<1	1					
TOTAL	$188	$94	2,005	852 ($221/MT)	662	54	17					

Key: ☆ refers to primary goal; + refers to positive impact

[172] Assumes a quantification period of 15 years.

[173] Totals may not add up due to rounding.

[174] Total include funds spent and requested during these fiscal years.

[175] This category includes medium-heavy-duty and heavy-heavy-duty vehicles combined with 94 percent being in the medium-heavy-duty category.

iv. Zero-Emission Truck and Bus Pilot Projects

The Zero-Emission Truck and Bus Pilot Projects place a number of zero-emission trucks and buses in a handful of strategic truck or bus "hubs," encouraging advanced technology clusters with infrastructure, marketing, workforce training, and other synergies. The truck or bus hubs are intended to support economies of scale in manufacturing, workforce training and vehicle maintenance and repair, and infrastructure/grid issues. A more detailed project description can be found in Appendix B. The costs and benefits quantified for the ZEVs supported by this project during fiscal years 2014-15 through 2017-18 are shown in Table 10, based upon 15 years of assumed vehicle life. A more detailed description of the quantification methods for this analysis can be found in Appendix C.

During these fiscal years, approximately $80 million incentivized 46 electric heavy-duty trucks, 50 zero-emission urban buses, 29 electric school buses and supporting refueling infrastructure. Table 10 shows approximately 56,000 metric tons of GHG emission reduction[176] are attributed to the vehicles funded by this project during this period, with the most GHG emission reductions coming from the electric urban buses (41 percent) followed by the fuel cell electric urban buses (27 percent), and heavy-duty electric trucks (18 percent). The electric and fuel cell urban buses have the largest emission reductions per vehicle due to their high usage compared to the other vehicle categories (see Appendix C for details), similarly as for HVIP.

The average cost is $1,429 per metric ton of GHG[177] reduced over 15 years of vehicle life for the zero-emission trucks and buses incentivized through the Zero-Emission Truck and Bus Pilot Projects. Incentivizing both electric urban and school buses are more cost-effective from an emissions reduction perspective compared to incentivizing the other vehicle categories. For example, it cost $1,000 per metric ton of GHG reduction on average for both the electric urban buses and the electric school buses versus $2,333 for the fuel cell electric urban buses. Due to the higher initial cost of hydrogen refueling infrastructure, the fuel cell electric urban bus received the highest funding per vehicle compared to the other categories. However, unlike the electric vehicle deployments, the transit agencies can purchase additional fuel cell electric urban buses with no additional infrastructure investment.

[176] This number is significantly lower than the 107,000 $MTCO_2e$ reported in the 2019 California Climate Investments Annual Report. This difference is mostly due to different vehicle usage assumptions. The CCI report uses grantee provided projections, while this report uses published values that are much smaller than the projected. For example, for the CCI report the weighted average usage of zero-emission transit buses is 53,000 miles per year while for this report it is 30,000 miles per year. Once the projected usage values numbers have been verified they can be used in future analysis.

[177] This number is also significantly lower than the $778 per $MTCO_2e$ reported in the 2019 California Climate Investments Annual Report due to the difference in vehicle usage assumptions.

Table 10 Costs and Benefits of the Zero-Emission Trucks and Buses Incentivized through Truck and Bus Pilot Projects from FY 2014-15 through FY 2017-2018 by Vehicle Type[178, 179]

Vehicle Type	Funds Spent ($ in millions)	Average Incentive per Vehicle Type ($ in thousands)	Vehicles Funded	GHG Reduction (1,000 of metric tons of CO_{2e})	NOx Reduc-tion (tons)	PM 2.5 Reduc-tion (tons)	ROG Reduc-tion (tons)	Health	Accele-rating Market Transfor-mation	Benefiting Priority Popula-tions	Jobs	Energy and Fuel Savings
Electric Heavy-Duty Trucks[180]	$14	$321	46	10 ($1,400/MT)	8	<1	<1	+	☆	☆	+	+
Electric Urban Buses	$23	$917	25	23 ($1,000/MT)	10	2	<1					
Fuel Cell Electric Urban Buses	$35	$1,397	25	15 ($2,333/MT)	10	2	<1					
Electric School Buses	$8	$265	29	8 ($1,000/MT)	8	1	<1					
Overall	$80	$640	125	56 ($1,429/MT)	36	6	1					

Key: ☆ refers to primary goal; + refers to positive impact

[178] Assumes a quantification period of 15 years.

[179] Totals may not add up due to rounding.

[180] This category includes medium-heavy-duty and heavy-heavy-duty vehicles combined.

v. Comparison of Cost-Benefit Results across Programs

This section compares the results of the cost-benefit analysis for CVRP, Clean Cars 4 All, HVIP, and the Zero-Emission Truck and Bus Pilot. Table 11 presents the overall program summary of the costs and benefits of the ZEVs and PHEVs incentivized with funds from fiscal years 2014-15 through 2017-18 for these programs, including the quantitative GHG and criteria pollutant emission benefits, along with the qualitative health, accelerating market transformation, benefiting priority populations, jobs, and energy and fuel savings benefits.

During these four fiscal years, CVRP spent the most to incentivize ZEVs and PHEVs, approximately 27 times as much as Clean Cars 4 All, 2.5 times as much as HVIP, and 6 times as much as the Zero-Emission Truck and Bus Pilot Projects. As a result, it is not surprising that CVRP has been a leading contributor to GHG emission reductions in transportation. CVRP has reduced GHG emissions by approximately 100 times more than Clean Cars 4 All, about 2 times as much as HVIP, and 27 times as much as the Zero-Emission Truck and Bus Pilot Project.

On a dollars-per-ton basis, CVRP and HVIP have similar cost-effective values ($307 vs $221 per metric ton of GHG emission reductions), while Clean Cars 4 All and the Zero-Emission Truck and Bus Pilot Project ($1,133 and $1,429 per metric ton of GHG emission reductions, respectively) are between 4 to 6 times less cost-effective than the former projects. Between the light-duty programs, the cost per metric ton of GHG reduced is much higher for Clean Cars 4 All compared to the Clean Vehicle Rebate Project because the per-vehicle incentive for Clean Cars 4 All is larger (up to $9,500 compared to $7,000), but the Clean Cars 4 All program is important for encouraging equitable access to ZEVs, including used ZEVs. Higher incentives are needed for programs aimed at low-income households in order to make these cleaner vehicle purchases possible, thus making them less cost-effective.

The cost per metric ton of GHG reduced is much higher for the Zero-Emission Truck and Bus Pilot Project program compared to that of HVIP because the incentives per vehicle for this program are much larger due to the "hub" design of the program. For example, the average spent per vehicle for Zero-Emission Truck and Bus Pilot Project was approximately $640,000 in contrast to approximately $94,000 for HVIP. For HVIP, the incentive reduces most of the upfront incremental costs of purchasing zero-emission heavy-duty trucks and buses. For the Zero-Emission Truck and Bus Pilot Project, while there is a 25 percent minimum matching funds requirement, the funding through this program covers a larger fraction of the total vehicle and infrastructure cost. It is worth emphasizing this is an early commercial program that seeks to advance zero-emission technology costs reductions and technology adoption by funding large deployments of these vehicles including the fueling and maintenance facilities, and training programs necessary to operate these vehicles within hubs to help gather data and lessons learned to educate others to help advance the ZEV market.

While the criteria pollutant emission reductions presented in Table 11 for CVRP, Clean Cars 4 All, HVIP, and the Zero-Emission Truck and Bus Pilot Project are modest relative to total PM 2.5, NO_X, and ROG emissions in California, in absolute terms these reductions are expected to reduce the incidence of illness and premature death associated with air pollution exposure. Due to the types of vehicles incentivized, the zero-emission trucks and buses incentivized through HVIP reduced the greatest NO_X emissions, but the light-duty vehicles incentivized through CVRP were the most effective at reducing PM 2.5 and ROG. As the ZEV market matures and the cost of the vehicles comes down, their associated air quality and health benefits are expected to increase.

Collectively, these ZEV programs are encouraging manufacturers to produce ZEVs, helping to build a sustainable consumer market for ZEVs, encouraging priority populations to access ZEVs, reducing GHG emissions, improving air quality and health, creating jobs in the ZEV market, and reducing petroleum usage and fuel costs. Therefore, these programs are helping to meet California's public health, air quality and climate goals while at the same producing other co-benefits. However, the magnitude and speed of change needed to achieve California's goals is unprecedented. Much more must be done to decrease the emissions from the transportation sector by decreasing the number of vehicles on the road, reducing both the number of miles they are driven and the time they idle, and electrifying the remaining vehicles in order to achieve these goals.

Table 11 Summary Comparison of the Costs and Benefits of the ZEVs and PHEVs Incentivized through the CARB Programs Quantified in this Report for Fiscal Years 2014-2015 through 2017-2018[181]

Vehicle Sector	Program	Funds Spent[182] ($ in millions)	GHG Reduction (1,000 of metric tons of CO_{2e})	NOx Reduc-tion (tons)	PM 2.5 Reduc-tion (tons)	ROG Reduc-tion (tons)	Health	Accelera-ting Market Transfor-mation	Percent of Funds Benefiting Priority Populations[183]	Jobs	Energy and Fuel Savings
Light-Duty	CVRP	$465	1,515 ($307/ton)	179	64	36	+	☆	27%[184] ($126M)	+	+
	Clean Cars 4 All	$17	15 ($1,133/ton)	20	1	6	+	+	100% ($17M)	+	+
Heavy-Duty	HVIP	$188	852 ($221/ton)	664	54	17	+	☆	69% ($22M)	+	+
	Zero-Emission Truck and Bus Pilot Project	$80	56 ($1,429/ton)	36	6	1	+	☆	78% ($62M)	+	+

Key: ☆ refers to primary goal, + refers to positive impact

[181] The quantification period varied by program based on program design as follows: CVRP = 2.5 years, Clean Cars 4 All = 3 years, HVIP and Zero-Emission Truck and Bus Pilot Project = 15 years. More details can be found in Appendix B.

[182] For HVIP, Total include funds spent and requested during these fiscal years.

[183] For all vehicle technologies funded through Clean Cars 4 All, HVIP, and the Zero-Emission Truck and Bus Pilot Project (including conventional hybrid and low NOx vehicles) funded by the California Climate Investments beginning in Fiscal Year 2014-2015, as reported in the 2019 CCI report (https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/2019_cci_annual_report.pdf).

[184] Based on AB 1550 (Gomez, Chapter 369, Statute of 2016) definition for priority populations and reporting for FYs 2014-2015 through 2017-2018, https://cleanvehiclerebate.org/eng/rebate-statistics CVRP Stats downloadable dataset. Last updated June 26, 2019. Accessed July 15, 2019.

CHAPTER 6: COMPARISON WITH OTHER STATES' AND COUNTRIES' PROGRAMS

This section compares CARB's ZEV programs with those of other states and countries, as required by SB 498. Section A compares the purchase incentive programs and section B compares the regulatory programs.

A. ZEV Purchase Incentive Programs

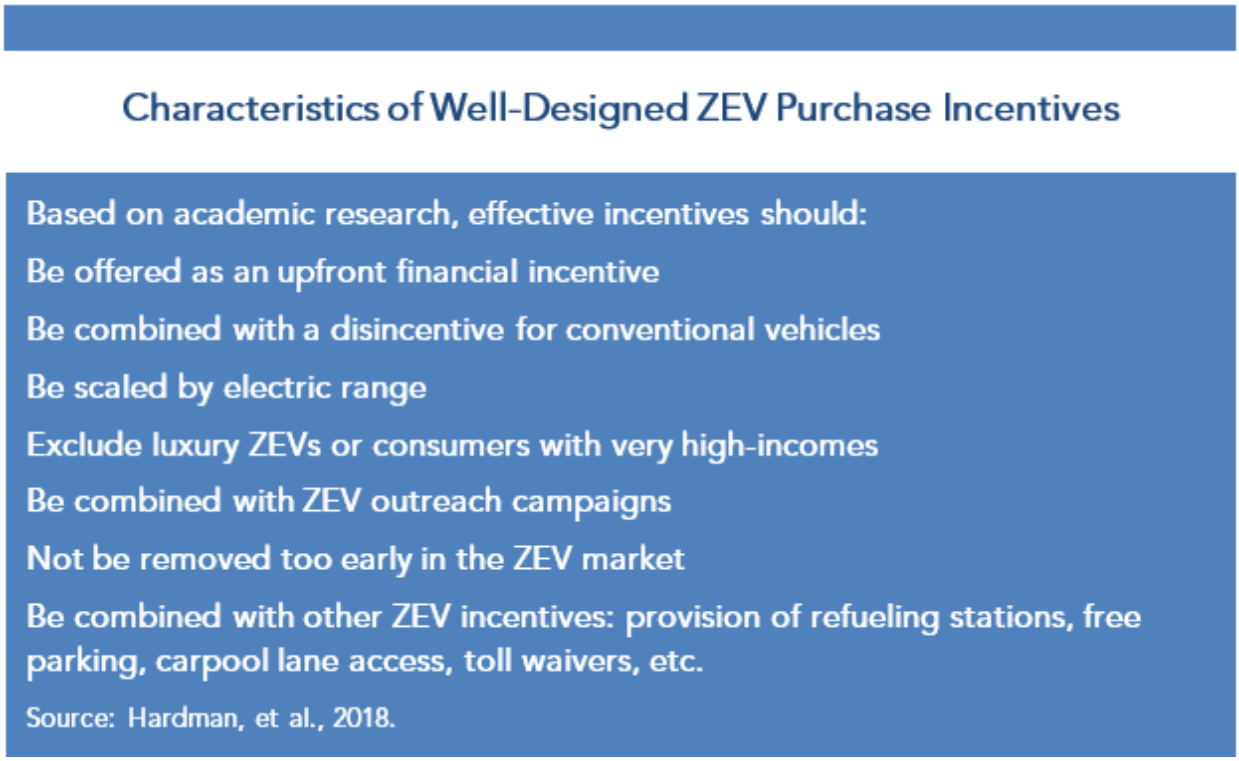
Many jurisdictions outside of California incentivize the purchase of ZEVs to accelerate the ZEV market, improve local air quality, and reduce GHG emissions. There are a variety of types of purchase incentives: rebates, point-of-sale rebates, tax-based incentives (exemptions, subsidies, and credits), and feebate systems. Program structures also vary widely, regarding eligible vehicle technologies, electric driving range, the incentive each technology receives, whether they have a cap (either on the price of eligible vehicles or the number of incentives allowed per individual or household), whether used vehicles are included, etc. This section compares CARB's light-duty and heavy-duty purchase incentive programs with incentive programs in other jurisdictions.

California's main light-duty ZEV purchase incentive is the Clean Vehicle Rebate Project. This program provides a rebate after the vehicle is purchased, and the rebate amount varies by vehicle technology type, excludes PHEVs with an electric range below 35 miles, and is higher for lower-income consumers (those with household incomes at or below 300 percent of the federal poverty level). The program restricts the number of rebates a single individual can receive to two.[185] Participation in the program for BEV and PHEV consumers is restricted to single filers that earn less than $150,000, head-of-household filers that earn less than $204,000, and households that earn less than $300,000 a year.[186] Starting in December 2019, eligible vehicle have a base Manufacturer Suggested Retail Price (MSRP) of $60,000 or less, excepting FCEVs. CVRP is testing a pilot program in San Diego County that give applicants the option of prequalifying for CVRP they so can receive the incentive at the vehicle point-of-sale. A new point-of-sale purchase incentive for new light-duty electric vehicles, which will be available across the State starting in 2020, is being finalized by the CPUC and utilities and to be funded with Low Carbon Fuel Standard credit revenue.

Incentives provided during purchase, such as point-of-sale rebates and tax exemptions, have been more effective in inducing ZEV uptake, while tax credit incentives are the

[185] Starting in January 1, 2015.
[186] For complete income eligibility see https://cleanvehiclerebate.org/eng/income-eligibility.

least effective.[187] Table 12 shows the incentives offered by other jurisdictions studied for this report. British Columbia and Germany offer a rebate style incentive, as CVRP does. The U.S. provides an income tax credit of up to $7,500 as the purchase incentive, which means ZEV consumers must have enough tax liability for the incentive to matter. Additionally, consumers can receive the incentive more than one year after the vehicle purchase depending on when they bought it during the tax year. Canada and the United Kingdom both offer a point-of-sale incentive of up to $4,500.[188] France and Sweden both have a feebate system, which rewards or penalizes the purchase of vehicles based on their carbon dioxide emissions per distance driven.[188] The remaining type of ZEV purchase incentive involves some type of tax exemption, such as purchase, excise, value added tax, and registration tax. These tax incentives work because these countries have higher taxes for purchased goods than California and the U.S.



In contrast to countries, most states offer a rebate program similar to California's. New York recently launched a point-of-sale incentive provided at the vehicle dealership. In Connecticut, consumers can choose between a point-of-sale incentive applied to their vehicle purchase directly at the vehicle dealership or choose to have the incentive sent directly to them at a later time. A 2017 program evaluation found that approximately

[187] Hardman, et al., 2017. "The effectiveness of financial purchase incentives for battery electric vehicles – A review of the evidence." Renewable and Sustainable Energy Reviews, Volume 80, December 2017, Pages 1100-1111. https://doi.org/10.1016/j.rser.2017.05.255.

[188] Kong and Hardman, 2019. "Electric Vehicle Incentives in 13 Leading Electric Vehicle Markets." UCD-ITS-RR-19/04. https://escholarship.org/uc/item/0fm3x5bh.

80 percent of customers opted for rebates at the point-of-sale.[189] Maryland offers an excise tax reduction while New Jersey and Washington offer a sales tax exemption.

There are different requirements and eligibility for each jurisdiction's purchase incentive program. And these have changed over time. Some countries and states, such as Spain, the United Kingdom, Massachusetts, New Jersey, do not incentivize the purchase of PHEVs. Most jurisdictions provide a smaller incentive for PHEVs. Other jurisdictions do not incentivize the purchase of FCEVs, while others provide a large incentive towards FCEVs. Some jurisdictions have Manufacturer's Suggested Retail Price (MSRP) caps to exclude luxury vehicles, which California implemented starting in December 2019. Additionally, California excludes individuals and households with high-income from participating in the program. Two jurisdictions, Oregon and Pennsylvania, offer an increased incentive for low-income consumers similar to California. Few countries and states incentivize used ZEVs and PHEVs, with France, New Jersey and Oregon being the exceptions. California does incentivize the purchase of used ZEVs and PHEVs, but only for lower-income consumers through the Financing Assistance for Lower-Income Consumers Project and Clean Cars 4 All.

Regarding heavy-duty purchase incentives, there are only a handful of other jurisdictions with some type of incentive for this sector (Table 13). Through HVIP, California provides a point-of-sale incentive for commercial zero-emission trucks and buses and other eligible vehicles with higher amounts given to vehicles within disadvantaged communities. The heavy-duty incentives in New York city and state, and India are similar to California's. Colorado and British Columbia offer incentives after the purchase of the vehicles. Each jurisdiction provides differing incentive amounts based on the specific vehicle type and weight. India only incentivizes buses.

[189] CSE, 2017. June 2017. "Evaluating the Connecticut Dealer Incentive for Electric Vehicle Sales." https://energycenter.org/sites/default/files/docs/nav/research/CT-Dealer-IncentiveEvaluation-CSE-2017.pdf.

Table 12 Comparison of Light-Duty Purchase Incentive Programs across Jurisdictions

Jurisdiction	Type of Incentive	BEV - Max. Incentive ($ U.S)	PHEV - Max. Incentive ($ U.S)	FCEV - Max. Incentive ($ U.S)	Restrictions	Notes
California	Rebate (Clean Vehicle Rebate Project)	$2,000 or $4,500	$1,000 or $3,500	$4,500 or $7,000	Two rebates per household; Eligibility restricted for BEV and PHEV for single filers that earn > $150,000, head-of-household filers that > $204,000, and households that earn > $300,000 a year. PHEVs eligible with electric range > 35 miles. MSRP cap at $60,000	Effective 12/3/19. Higher incentive for low-income consumers (≤ 300% federal poverty level).
British Columbia[190]	Rebate	$2,275	$1,125 or $2,275	$2,275	MSRP cap at $42,000; Only 1 rebate per individual	Effective 6/22/19; for PHEVs higher incentive available for vehicles with electric range > 52 miles.
Canada[191]	Point-of-sale	$3,800	$3,800 or $1,900	$3,800	Vehicles with fewer than 6 seats must have MSRP < $33,800; incentive drops 75% in 2024 and 55% by 2026	Effective 5/1/19; Long-range PHEVs (battery > 15kWh) receive the larger incentive while smaller-range PHEVs the smaller incentive.

[190] Canadian Broadcasting Corporation, 2019. "B.C. government reduces EV rebates to between $1.5K and $3K per vehicle" Posted June 22, 2019. https://www.cbc.ca/news/canada/british-columbia/b-c-government-reduces-ev-rebates-1.5186429. Accessed July 1, 2019.
[191] Kong and Hardman, 2019. "Electric Vehicle Incentives in 13 Leading Electric Vehicle Markets." UCD-ITS-RR-19/04. https://escholarship.org/uc/item/0fm3x5bh.

Jurisdiction	Type of Incentive	BEV - Max. Incentive ($ U.S)	PHEV - Max. Incentive ($ U.S)	FCEV - Max. Incentive ($ U.S)	Restrictions	Notes
China[191, 192]	Subsidy, acquisition and excise tax exemption	$3,700	$1,500		BEVs < 400 km range and PHEVs < 50 km range	Incentive based on electric range. Tax relief extended through 2020.[193]
Colorado[194]	Tax credit	$5,000	$1,900		Leased vehicles get half the credit	Amount decreases over time and phases out in 2022.
Connecticut[195]	Point-of-sale rebate and rebate	$2,000	$1,000	$5000	MSRP cap > $50,000 for BEV/PHEV and > $60,000 for FCEV; One rebate per individual, two for entities	Incentive scales with electric range; dealer fills out paperwork; incentive can be applied to purchase or lease at dealer or given directly to consumer after purchase; separate incentive for dealer ($150 per vehicle sold).

[192] He and Cui, 2019. ICCT Policy Update. "China announced 2019 subsidies for new energy vehicles." Posted June 18, 2019. https://theicct.org/publications/china-announced-2019-subsidies-new-energy-vehicles. Accessed July 15, 2019.

[193] Ren 2019. South China Morning Post. June 30, 2019. "Beijing's move to keep tax break on purchases of new-energy vehicles to support troubled auto sector, help biggest players." https://www.scmp.com/business/companies/article/3016692/beijings-move-keep-tax-break-purchases-new-energy-vehicles. Accessed July 15, 2019.

[194] Colorado Department of Revenue Taxation Division, 2019. "Income 69: Innovative Motor Vehicle and Innovative Truck Credits." https://www.colorado.gov/pacific/sites/default/files/Income69.pdf.

[195] State of Connecticut Department of Energy & Environmental Protection, 2018 "Connecticut Hydrogen and Electric Automobile Purchase Rebate." https://www.ct.gov/deep/cwp/view.asp?a=2684&q=561422&deepNav_GID=2183. Accessed May 15, 2019.

Jurisdiction	Type of Incentive	BEV - Max. Incentive ($ U.S)	PHEV - Max. Incentive ($ U.S)	FCEV - Max. Incentive ($ U.S)	Restrictions	Notes
Delaware[196]	Rebate	$3,500	$1,500		If MSRP > $60,000 then incentive is only $1,000	
France[191]	Feebate	$9,100	$1,000	$9,100		Feebate based on gCO2/km: 20 = $6,800; 21-60 = $1,100; 60-120 = no subsidy; > 120 pay emission fee based on CO_2 emissions; extra incentive of $1,200 for getting used BEV.
Germany[191]	Rebate and tax exemption	$4,600	$3,400	$4,600	MSRP cap of $67,000[197]	In effect through 2020.
India[198]	Subsidy				MSRP cap of $21,000	Based on battery capacity at $140 per kWh.

[196] Department of Natural Resources and Environmental Control. "The Delaware Clean Vehicle Rebate Program." https://dnrec.alpha.delaware.gov/climate-coastal-energy/clean-transportation/vehicle-rebates/. Accessed May 15, 2019.
[197] Manthey, 2019. In Electrive.com. June 30, 2019. "Environmental Bonus Officially extended in Germany." https://www.electrive.com/2019/06/30/environmental-bonus-officially-extended-in-germany/ Accessed Aug 1, 2019.
[198] Reuters, 2019. "India approves $1.4 billion electric vehicle incentive scheme." Posted February 28, 2019. https://www.reuters.com/article/us-india-electric-policy/india-approves-14-billion-electric-vehicle-incentive-scheme-idUSKCN1QH29F. Accessed July 1, 2019.

Jurisdiction	Type of Incentive	BEV - Max. Incentive ($ U.S)	PHEV - Max. Incentive ($ U.S)	FCEV - Max. Incentive ($ U.S)	Restrictions	Notes
Japan[191]	Purchase tax subsidy	$3,500	$1,700	66% of similar gasoline vehicle price		Incentive based on electric range.
Maryland[199]	Excise tax reduction	$3,000	$3,000		MSRP < $63,000; minimum PHEV battery capacity of 5 kWh	$100 tax credit for every kWh battery capacity.
Massachusetts[200]	Rebate	$1,500	none	$1,500	MSRP < $50,000	Funding available for purchases through September 2019, then program ends; no fleet rebates.
Netherlands[191]	Registra-tion tax exemption and motor tax discount	$8,000	$3,800			Incentive based on gCO_2/km.

[199] Maryland Department of Transportation Motor Vehicle Administration. "Titling - Excise Tax Credit for Plug-in Electric Vehicles." http://www.mva.maryland.gov/about-mva/info/27300/27300-71T.htm. Accessed August 15, 2019.
[200] Massachusetts Offers Rebates For Electric Vehicles, 2019. https://mor-ev.org/. Accessed July 15, 2019.

Jurisdiction	Type of Incentive	BEV - Max. Incentive ($ U.S)	PHEV - Max. Incentive ($ U.S)	FCEV - Max. Incentive ($ U.S)	Restrictions	Notes
New Jersey[201]	Sales Tax Exemption		none			Includes used ZEVs.
New York[202]	Point-of-sale	$2,000	$1,700		If MSRP > $60,000 then incentive is only $500	Incentive scales with electric range; point-of-sale rebate provided at dealership.
Norway[191]	Value added tax (VAT) and purchase tax exemptions	$11,600[203]	$10,000			VAT based on 25% of purchase price; purchase tax is based on gCO_2/km, gNOx/km and vehicle weight; BEV are exempt from both taxes.

[201] State of New Jersey Department of Environmental Protection Bureau of Mobile Sources, 2018. "Sales Tax Exemption – Zero Emission Vehicles." https://www.drivegreen.nj.gov/zev.html. Accessed July 1, 2019.
[202] New York State. "How the Drive Clean Rebate Works." https://www.nyserda.ny.gov/All-Programs/Programs/Drive-Clean-Rebate/How-it-Works. Accessed July 1, 2019.
[203] Estimate based on what comparable conventional vehicle would pay.

Jurisdiction	Type of Incentive	BEV - Max. Incentive ($ U.S)	PHEV - Max. Incentive ($ U.S)	FCEV - Max. Incentive ($ U.S)	Restrictions	Notes
Oregon[204]	Point-of-sale rebate	$2,500	$1,500		MSRP < $50,000	Have a separate low- and moderate-income incentive ($2,500 for used BEV and $5,000 for new BEV); eligibility based on household income <120% of the area median income for closest metropolitan statistical area.
Pennsylvania[205]	Rebate	$1,500	$1,000	$1,500	MSRP < $50,000 for BEV/PHEV and < $75,000 for FCEV	$1,000 rebate for used ZEVs with <75,000 miles bought through dealer $1,000 additional incentive for low-income consumers (< 200% federal poverty level).

[204] Department of Environmental Quality. "Oregon Clean Vehicle Rebate Program." https://www.oregon.gov/deq/aq/programs/Pages/ZEV-Rebate.aspx. Accessed July 1, 2019.

[205] Pennsylvania Department of Environmental Protection, 2019. "Alternative Fuel Vehicle Rebate Program Guidance." June, 2019. http://www.depgreenport.state.pa.us/elibrary/GetDocument?docId=1459887&DocName=ALTERNATIVE%20FUEL%20VEHICLE%20REBATE%20PROGRAM%20GUIDANCE%202019.PDF. Accessed July 1, 2019.

Jurisdiction	Type of Incentive	BEV - Max. Incentive ($ U.S)	PHEV - Max. Incentive ($ U.S)	FCEV - Max. Incentive ($ U.S)	Restrictions	Notes
Portugal[191]	National subsidy and tax exemption	$3,400	$1,300		Vehicle MSRP < $70,600	
South Korea[191]	Purchase subsidy and tax reduction	$13,200	$6,700			
Spain[191]	National subsidy and tax benefits	$6,400	none			
Sweden[191]	Feebate	$6,500	$2,400		Incentive cannot exceed 25% of the vehicle's new price	Feebate rewards vehicles with < 60 gCO_2/km and penalizes those with > 95 gCO_2/km. Before June 2018, incentive was a rebate.
United Kingdom[191]	Point of sale	$4,500	none			Incentive based on electric range; Incentive changed on November 2018.

Jurisdiction	Type of Incentive	BEV - Max. Incentive ($ U.S)	PHEV - Max. Incentive ($ U.S)	FCEV - Max. Incentive ($ U.S)	Restrictions	Notes
United States[206]	Federal tax credit	$7,500	$7,500	none	Maximum incentive decreases in half every time vehicle manufacturer sells 200,000 PEVs. As of June 2019, Cadillac, Chevrolet, and Tesla have all sold > 200,000 PEVs.	Incentive based on the size of the battery capacity.
Washington[207]	Sales and use tax exemption				MSRP < $45,000 for new vehicles and < $30,000 for used vehicles	Exemption applies to all or a portion of the vehicle's selling price that decreases over time. Used ZEVs are eligible for incentive.

[206] U.S. Department of Energy Office of Energy Efficiency & Renewable Energy, 2019. "Federal Tax Credits for All-Electric and Plug-in Hybrid Vehicles." Last updated June 20, 2019. https://www.fueleconomy.gov/feg/taxevb.shtml . Accessed July 15, 2019.

[207] Department of Revenue Washington State, 2019. "Clean alternative fuel and plug-in hybrid vehicles - sales/use tax exemptions." https://dor.wa.gov/content/clean-alternative-fuel-and-plug-hybrid-vehicles-salesuse-tax-exemptions. Accessed August 1, 2019.

Table 13 Comparison of Heavy-Duty Purchase Incentive Programs across Jurisdictions

Jurisdiction	Type of Incentive	Max. Amount of Incentive ($ U.S. dollars)	Vehicles Eligible	Notes
California[208]	Point-of-sale voucher (HVIP)	$315,000 depending on vehicle vocation, GVWR / bus length	Trucks: GVWR >5,001 lbs Transit Buses: > 20 ft Shuttle Buses: >8,501 lbs School Buses: >5,001 lbs Trucks equipped with ePTO (up to 50% of incremental cost): > 3 kWh	Higher amounts given to vehicles within disadvantaged communities and to fuel cell technology. Between 2020-24, California is exempting State sales and use taxes from transit buses if purchased by an eligible transit agency.
British Columbia[209]	After purchase rebate (Specialty-Use Vehicle Incentive Program)	$38,000 or 35% of MSRP	On-road medium- and heavy-duty vehicles, forklifts, airport and port specialty vehicles	5 rebates per fleet; applications must be received within 90 days after purchase; until March 1, 2020; incentive depends on MSRP and battery capacity.
China[210, 211]	Acquisition tax and excise tax exemption	$7,700 for BEVs,$4,900 for PHEVs, $58,000 for FCEVs		These incentives go into effect in mid-2019 and are about half of the previous incentives. Determined as a function of battery capacity and type of technology, with a base subsidy for BEVs of $50/kWh and PHEVs of $70/kWh. This base subsidy is multiplied by a vehicle weight factor that is larger for BEVs than PHEVs and increases with increasing weight.

[208] CALSTART, 2019. "California HVIP." https://www.californiahvip.org/. Accessed August 15, 2019.
[209] "Specialty-Use Vehicle Incentive Program." https://pluginbc.ca/suvi/. Accessed August 1, 2019.
[210] He and Cui, 2019. ICCT Policy Update. "China announced 2019 subsidies for new energy vehicles." Posted June 18, 2019. https://theicct.org/publications/china-announced-2019-subsidies-new-energy-vehicles. Accessed July 15, 2019.
[211] https://www.scmp.com/business/companies/article/3016692/beijings-move-keep-tax-break-purchases-new-energy-vehicles.

Jurisdiction	Type of Incentive	Max. Amount of Incentive ($ U.S. dollars)	Vehicles Eligible	Notes
New York[212]	Point of sale	$150,000 or up to 80% of incremental cost per vehicle depending on GVWR	Applies to class 3 - 8 Private and Public Fleet Vehicles	Vehicle must be domiciled and operated 70% of the time in one of New York State's 30 counties in non-attainment.
New York City[212]	Point of sale	$60,000 or up to 80% of incremental cost per vehicle depending on GVWR	Applies to class 2 - 8 vehicles	Vehicle must be domiciled (registered and garaged) and operate 70% of the time in the five boroughs of New York City.
Colorado[213]	Tax credit	$20,000 for trucks GVWR >26,000	GVWR > 10,000	Amount decreases over time and phases out in 2022; leased vehicles get half the credit; includes a higher incentive for the heaviest platform ($20K for GVWR >26,000).
India[214]	Subsidy	Up to $140,000	Buses (no trucks)	Based on battery capacity at $140 per kWh. Estimate funding will cover 7,090 buses; higher incentives given for vehicles produced within India.

[212] https://truck-vip.ny.gov/

[213] Colorado Department of Revenue Taxation Division, 2019. "Income 69: Innovative Motor Vehicle and Innovative Truck Credits." https://www.colorado.gov/pacific/sites/default/files/Income69.pdf.

[214] Bahree, 2019. Forbes. "India Offers $1.4 Billion In Subsidies To Support The Domestic Electric Vehicle Industry." Posted March 9, 2019. https://www.forbes.com/sites/meghabahree/2019/03/09/india-offers-1-4-billion-in-subsidies-to-support-the-domestic-electric-vehicle-industry/#c499f22610a0. Accessed July 15, 2019.

B. ZEV Regulations

This section provides a high-level overview of California's ZEV adopted and proposed regulations for light-, medium-, and heavy-duty vehicles compared with other states and countries, as shown in Table 14. There are several types of regulations that states and countries have adopted. Some apply strictly to vehicle manufacturers and require them to produce ZEVs for sale in the applicable state or country. Other regulations may require vehicle manufacturers to reduce CO_2 emissions of the vehicles they sell with flexibility in meeting those standards by producing ZEVs. Another type of regulation requires fleets to operate with certain number of ZEVs or zero-emission miles.

Since 1990, California's light-duty ZEV regulation has led the way for other states and countries as they pursue air quality and climate goals. As of August 15, 2019, California's ZEV regulation has been adopted by ten other states, called the Section 177 ZEV states.[215] China and Canada's provinces of Québec and British Columbia patterned their light-duty ZEV regulations after California's. The European Union is very close to adopting new CO_2 emission performance standards for light-, medium-, and heavy-duty vehicles, with a mechanism to incentivize ZEV sales. India has no light-duty GHG emission or ZEV regulation, but has a ZEV target and supporting policies.

To date, there are no medium- and heavy-duty vehicle ZEV regulations in the world except for California's recently approved fleet requirement through the Innovative Clean Transit Regulation and Zero-Emission Airport Shuttle Bus Regulation. California is also proposing an Advanced Clean Truck Regulation for adoption in 2019 or 2020 and a Clean Miles Standard targeting transportation network companies. The United States and the European Union have GHG emission standards for light-, medium- and heavy-duty vehicles. Cities such as Shenzhen in China have ambitious transportation electrification goals and have already transitioned 100 percent of its transit buses to ZEVs.

For a more in-depth review of all ZEV mandates, please refer to the International Council on Clean Transportation's "Overview of Global Zero-Emission Vehicle Mandate Programs."[216]

[215] Section 177 of the Clean Air Act (42 U.S.C. §7507) authorizes other states to choose to adopt California's standards in lieu of federal requirements. States are not required to seek U.S. EPA approval before adopting California's standards. Thirteen other states have adopted California's Low Emission Vehicle Regulations and ten of those have adopted California's ZEV Regulation.

[216] Rokadiya and Yang, 2019. ICCT Briefing, "Overview of Global Zero-Emission Vehicle Mandate Programs." April 2019. https://theicct.org/publications/global-zero-emission-vehicle-mandate-program. Accessed August 1, 2019.

Table 14 Jurisdictions with Light-, Medium-, and Heavy-Duty ZEV Regulations Adopted and Proposed

Jurisdiction	ZEV Regulation	Type of Requirement
California	Light-duty ZEV regulation through MY 2025	Manufacturer vehicle production
	Innovative Clean Transit Regulation begins in 2020 with 100 percent zero-emission public transit bus fleet by 2040	Fleet requirement: transit agencies
	Zero-Emission Airport Shuttle Bus Regulation begins in 2022	Fleet requirement: airport shuttles
	Advanced Clean Trucks Regulation in development; 2024-2030 implementation period	Manufacturer vehicle production
	Clean Miles Standard, in development to begin in 2023	Fleet requirement: transportation network companies
Section 177 ZEV States[217]	Light-duty ZEV regulation same requirements as California's ZEV regulation	Manufacturer vehicle production
Québec, Canada	Light-duty ZEV regulation through MY 2025	Manufacturer vehicle production (new and used eligible vehicles)
British Columbia, Canada	Light-duty ZEV regulation for MY 2020 and beyond	Manufacturer vehicle production
China	Light-duty New Energy Vehicle (NEV) regulation 2019-2020 adopted; regulation for 2021-23 in development	Manufacturer vehicle production
European Union	Light-, medium-, and heavy-duty vehicles fleet-wide CO_2 emission targets for 2025, 2030 with voluntary ZEV quotas as a compliance flexibility	Manufacturer's fleet-wide CO_2 emissions reduction
India	ZEV target of 30% of all vehicle sales by 2030 with 3-year electrification program (no CO_2 emissions reduction or ZEV mandate)	ZEV targets but no requirements

[217] These states are: Colorado, Connecticut, Maine, Maryland, Massachusetts, New York, New Jersey, Oregon, Rhode Island and Vermont.

i. California

Light-Duty Vehicle Manufacturer Regulations. As described earlier in this report and in Appendix B, CARB's Advanced Clean Cars is a package of coordinated standards that controls smog-causing pollutants and GHG emissions from passenger vehicles in California. It includes the Low-Emission Vehicle (LEV) Criteria Pollutant Emissions Program, the Greenhouse Gas Vehicle (GHG) Program, and the ZEV program. The ZEV program is the technology-forcing component that requires vehicle manufacturers to produce a number of ZEVs and plug-in hybrids each year, based on the total number of vehicles sold in California by the manufacturer. Manufacturers with higher overall sales of all vehicles must make more ZEVs. Requirements range from 4.5 percent in terms of credits in 2018 to 22 percent by 2025 and are based on electric driving range. Credits not needed for compliance in any year can be banked for future use, traded, or sold to other manufacturers. CARB releases annual credit bank balances, the total number of vehicles produced for that model year, and the total number of ZEVs and PHEVs.[218] Because the ZEV regulation is a credit requirement, it is difficult to precisely predict the number of vehicles that will result from the regulation. Updated estimates using publicly available information show about 8 percent of California new vehicle sales in 2025 are expected to be ZEVs and PHEVs.[219]

Medium- and Heavy-Duty Fleet Regulations. CARB approved the first-of-its kind regulation in the U.S. that sets a goal for public transit agencies to gradually transition to 100 percent zero-emission bus fleets by 2040. The Innovative Clean Transit rule was adopted on December 14, 2018. To transition to an all zero-emission bus fleet by 2040, each transit agency will submit a rollout plan demonstrating how it plans to purchase clean buses, build out necessary infrastructure, and train the required workforce. The rollout plans are due in 2020 for large transit agencies and in 2023 for small agencies. Agencies will then follow a phased schedule from 2023 until 2029, by which date 100 percent of annual new bus purchases will be zero-emission. To encourage early action, the zero-emission purchase requirement would not start until 2025 if a minimum number of zero-emission bus purchases are made by the end of 2021.[220]

On June 27, 2019, CARB approved the Zero-Emission Airport Shuttle rule that will require airport shuttles with fixed routes serving California's 13 largest airports to

[218] CARB. "Zero-Emission Vehicle Program." https://ww2.arb.ca.gov/our-work/programs/zero-emission-vehicle-program/about. Accessed July 1, 2019.
[219] CARB. "Advanced Clean Cars Program." https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/about. Accessed July 1, 2019.
[220] CARB, 2018. Press release # 18-65. December 14, 2018. "California Transitioning to all-electric public bus fleet by 2040." https://ww2.arb.ca.gov/news/california-transitioning-all-electric-public-bus-fleet-2040. Accessed July 1, 2019.

transition to 100 percent zero-emission vehicles by 2035.[221] The rule will be phased in over a 13-year period beginning in 2022. CARB is also developing a proposal for zero-emission airport ground support equipment.

The Zero-Emission Powertrain Certification Regulation, approved on June 27, 2019, establishes a new optional certification pathway for heavy-duty electric and fuel cell electric vehicles and the zero-emission powertrains they use. It provides additional market transparency and helps ensure effective in-use support for such vehicles and powertrains.[222]

The Advanced Clean Truck Regulation is part of a holistic approach to accelerate a large-scale transition to zero-emission medium- and heavy-duty vehicles from class 2B to class 8. The proposed regulation has two components including a manufacturer's sales requirement and a reporting requirement:[223]

- Zero-emission truck sales: Manufacturers who certify class 2B-8 chassis or complete vehicles with combustion engines would have to sell zero-emission trucks as an increasing percentage of their annual California sales from 2024 to 2030. By 2030, zero-emission truck/chassis sales would need to be 50 percent of class 4 – 8 straight trucks sales and 15 percent of all other truck sales.

- Company and fleet reporting: Large employers including retailers, manufacturers, brokers and others would have to report information about shipments and shuttle services. Fleet owners, with 100 or more trucks, would have to report about their existing fleet operations. This information would help identify future strategies to ensure that fleets purchase zero-emission trucks and place them in service where suitable to meet their needs.

The proposal is still in development. The first Board hearing was held in December 2019 with the second hearing expected in 2020.

ii. Section 177 ZEV States

Other U.S. states can adopt California's standards through Section 177 of the Federal Clean Air Act, hence why they are often called the Section 177 states. There are 13 states that have adopted California's LEV regulation and of those, ten states have adopted California's ZEV regulation: Colorado, Connecticut, Maine, Maryland,

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[221] CARB, 2019. Press release # 19-30. June 27, 2019. "California Air Resources Board Approves Comprehensive Effort to Clean up Airport Shuttles." https://ww2.arb.ca.gov/news/california-air-resources-board-approves-comprehensive-effort-clean-airport-shuttles. Accessed July 15, 2019.

[222] CARB, 2019. "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." https://ww2.arb.ca.gov/rulemaking/2019/zepcert2019. Accessed July 15, 2019.

[223] CARB, 2019. July 2, 2019. "Advanced Clean Trucks (ACT) Fact Sheet." https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-trucks-act-fact-sheet. Accessed July 15, 2019.

Massachusetts, New York, New Jersey, Oregon, Rhode Island and Vermont. Together with California, these states represent nearly 30 percent of new light-duty vehicle sales in the United States.

iii. Québec

Québec was the first province in Canada to adopt a ZEV standard patterned largely after California's ZEV regulation.[224] The standard applies to intermediate and large volume vehicle manufacturers, and credits are earned on the sale or lease of ZEVs, conventional hybrid vehicles and hydrogen combustion engine vehicles in the Québec market.[225] Manufacturers had to earn credits starting with model year 2018, with a target of 3.5 percent of their new light-duty vehicles sales in credits increasing to 22 percent in 2025. In 2020, the target for large volume manufacturers is 9.5 percent, and 6 percent of their credits must be exclusively from the sales or leases of ZEVs. One unique feature of Québec's ZEV regulation is that used vehicles that are reconditioned by vehicle manufacturers and registered in Québec are eligible for credits.[226]

iv. British Columbia

On May 29, 2019, British Columbia (BC) passed the Zero-Emission Vehicles Act (ZEVA), which will require all new light-duty vehicles sold in the province to be zero-emission by 2040. The target will be phased in with 10 percent of new light-duty vehicle sales by 2025, 30 percent by 2030, and 100 percent by 2040. Vehicle manufacturers will have to meet the standards beginning with model year 2020.[227] The government committed to the ZEV mandate in November 2018 as part of its CleanBC[228] initiative, which targets cleaner transportation including battery electric, plug-in hybrid and hydrogen fuel cell vehicles. The BC ZEV mandate will be based on regulations already in effect in Québec and California.[229]

v. China

In China, New Energy Vehicles (NEVs) refer to vehicles with powertrains driven completely by new energy sources, including PHEVs, BEVs and FCEVs (what we call

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[224] Ministère de l'Environnement et de la Lutte contre les changements climatiques, 2019. "The Zero-Emission Vehicle (ZEV) Standard." http://www.environnement.gouv.qc.ca/changementsclimatiques/vze/index-en.htm. Accessed August 1, 2019.

[225] Ministère de l'Environnement et de la Lutte contre les changements climatiques. "Québec Leads the Way with its ZEV Standard." http://www.environnement.gouv.qc.ca/changementsclimatiques/vze/feuillet-vze-reglement-en.pdf. Accessed August 1, 2019.

[226] List of ZEV Standard new or reconditioned motor vehicles eligible for credits available at http://www.environnement.gouv.qc.ca/changementsclimatiques/vze/ListeVZE_admissibles.pdf.

[227] Green Car Congress, 2019. June 3, 2019. "British Columbia passes Zero-Emission Vehicles Act; 10 percent LDVs ZEV by 2025, 100 percent by 2040." https://www.greencarcongress.com/2019/06/20190603-bc.html. Accessed August 1, 2019.

[228] British Colombia CleanBC, "Cleaner Transportation", https://cleanbc.gov.bc.ca/. Accessed August 1, 2019.

[229] Energy, Mines and Petroleum Resources British Columbia, 2019. May 29, 2019. "New Act Ensures B.C. Remains Leader on Clean Energy Vehicles." https://news.gov.bc.ca/releases/2019EMPR0018-001077#. Accessed August 1, 2019.

ZEVs). China's NEV mandate is a modified version of California's and is implemented at the national level. For a more in-depth description, see the International Council on Clean Transportation's (ICCT) report on China's ZEV mandate policy published in January 2018.[230]

In 2017, China finalized the NEV mandate policy for passenger vehicles which took effect April 1, 2018. While modeled after California's program, China's rule has additional compliance flexibility related to China's existing fuel consumption regulation. NEV sales generate credits based on characteristics such as electric range, energy efficiency, and for FCEVs—the rated power of fuel cell systems. The credits apply to all vehicle manufacturers with annual production or import volume of at least 30,000 conventional passenger vehicles. The rule established NEV credit targets of 10 percent of the conventional passenger vehicle market in 2019 and 12 percent in 2020. ICCT estimates that the NEV mandate will cause 2 percent to 10.7 percent market share for NEVs by 2020.[231] The target for total NEVs in 2020 is 5 million, representing 20 percent of annual automobile production in China.

In July 2019, China updated the NEV regulation and added NEV credit requirements of 14 percent in 2021, 16 percent in 2022 and 18 percent in 2023.[232] The recent NEV credit policy update is twice as stringent per vehicle as the 2019-2020 credit requirement. The NEV policy update also allows credit banking for up to 4 years, but after the first year, remaining credits are discounted by 50 percent each year.[233] They can also be used to offset deficits in corporate average fuel consumption (CAFC) standards if manufacturers fail to meet NEV credit targets. China can deny approval for new models that do not meet their specific fuel consumption standards until NEV credit deficits are met

Cities within China have their own ZEV targets and policies, including the Shenzhen megalopolis, which has completely electrified its bus fleet of over 16,000 buses in the last decade. There are over 385,000 fully-electric buses in the world and 99 percent of them are in China.[234, 235]

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[230] Cui, 2018. ICCT Policy Update. January 2018. "China's New Energy Vehicle Mandate Policy (Final Rule)". https://www.theicct.org/publications/china-nev-mandate-final-policy-update-20180111.

[231] Rokadiya and Yang, 2019.

[232] Shen, 2019. Technode. July 10, 2019. "China Refines NEV Mandate Policy to Boost Overlooked Hybrid Vehicles." https://technode.com/2019/07/10/china-new-policy-hybrid/. Accessed August 1, 2019.

[233] For example, 100 credits in the year the credits are awarded would decrease to 50 credits in the 2nd year, 25 credits in the 3rd year, and 12.5 in the 4th year.

[234] Poon, 2018. CityLab. May 8, 2018. "How China Took Charge of the Electric Bus Revolution." https://www.citylab.com/transportation/2018/05/how-china-charged-into-the-electric-bus-revolution/559571/. Accessed August 1, 2019.

[235] Bloomberg New Energy Finance, 2018. March 29, 2018. "Electric Buses in Cities." http://c40-production-images.s3.amazonaws.com/other_uploads/images/1726_BNEF_C40_Electric_buses_in_cities_FINAL_APPROVED_%282%29.original.pdf?1523363881. Accessed August 1, 2019.

vi. European Union

Light-Duty Vehicle Manufacturer Regulations. Although the European Union (EU)[236] has no ZEV regulation, they have adopted a regulation setting a CO_2 emission performance standard for new passenger cars and light commercial vehicles (vans) in the EU for the period after 2020. Manufacturers must meet the new targets set for fleet-wide average emissions in a calendar year from 2025 onward with stricter targets applying in 2030.[237] The targets are defined as a percentage reduction from 2021:

- Cars: 15 percent reduction from 2025 onward and 37.5 percent reduction from 2030 onward
- Vans: 15 percent reductions from 2025 onward and 31 percent reduction from 2030 onward

To incentivize zero-emission or low emission vehicles (ZLEVs), the EU will institute a crediting system starting in 2025 which results in relaxing the CO_2 emission target if these benchmarks met:

- Cars: 15 percent ZLEV from 2025 onward and 35 percent ZLEV from 2030 onward
- Vans: 15 percent ZLEV from 2025 onward and 30 percent ZLEV from 2030 onward

Additional details of the incentives include a maximum 5 percent cap on the CO_2 emissions target relaxation.

The new regulation is expected to result in a 23 percent reduction of GHG emissions from on-road transportation in 2030 compared to 2005 and a gradual transition to zero-emission mobility with sufficient time for the automotive workforce to adapt.

Heavy-Duty Vehicle Manufacturer Regulations. For the first time in the European Union, on February 19, 2019, representatives agreed on a compromise setting CO_2 emission standards for new heavy-duty vehicles. The targets reduce the average CO_2 emissions from the highest-emitting HDV segments by 15 percent in 2025 and by 30 percent in 2030, both relative to a baseline determined from 2019 and 2020 data.[238] The new standards include a strategy to account for ZLEVs in the fleet with super-credits available from 2019 to 2024, and from 2025 onward a ZLEV benchmark applies. The ZLEV incentives, however, can reduce the average emissions of a manufacturer

[236] EU is comprised of 28 member countries.

[237] European Commission, 2019. "Post-2020 CO2 Emission Performance Standards for Cars and Vans." https://ec.europa.eu/clima/policies/transport/vehicles/proposal_en. Accessed August 1, 2019.

[238] Rodriguez, 2019. ICCT Policy Update. April 16, 2019. "CO2 Standards for Heavy-Duty Vehicles in the European Union." https://www.theicct.org/publications/co2-stds-hdv-eu-20190416. Accessed August 1, 2019.

only by a maximum of 3 percent. The standards are expected to be adopted by the European Parliament and European Council with no further modifications.[239]

vii. India

India does not currently have a ZEV regulation but it has been moving forward with transportation electrification and targets for electric vehicle adoption. In 2013, the Government of India launched a National Electric Mobility Mission Plan 2020[240] which provides the vision and roadmap for the fast adoption of the full range of hybrid and electric vehicles as well as their manufacturing in India. On April 1, 2015, India established the first phase of the scheme for Faster Adoption and Manufacturing of Hybrid and Electric Vehicles in India (FAME India). After some delays and extensions, India established the three year FAME 2 program to begin on April 1 2019. FAME 2 has a budget of 1.4 billion dollars and will support the purchase of 1 million electric motorbikes, 500,000 three-wheelers, 55,000 electric four-wheelers, and 7,000 electric buses, as well as charging infrastructure.[241] India also launched the EV@30 campaign as a member of Electric Vehicles International (EVI) to have electric vehicles contribute 30 percent of all vehicle sales by 2030. There are also several Indian states committing to adopting electric vehicle policies such as attracting investments, consumer incentives, charging infrastructure, research, manufacturing incentives, and job creation.[242]

[239] Ibid

[240] Department of Heavy Industry Government of India, 2012. "National Electric Mobility Mission Plan 2020." https://dhi.nic.in/writereaddata/Content/NEMMP2020.pdf. Accessed August 1, 2019.

[241] Shah, 2019. Reuters. February 28, 2019. "India Approves $1.4 Billion Electric Vehicle Incentive Scheme." https://www.reuters.com/article/us-india-electric-policy/india-approves-14-billion-electric-vehicle-incentive-scheme-idUSKCN1QH29F. Accessed August 1, 2019.

[242] Poojary, 2019. Yourstory. March 29, 2019. "Eight States in India are Racing Ahead, Boosting Electric Vehicles through Policy Groundwork." https://yourstory.com/2019/03/india-government-electric-vehicles-policies-mvqiyx. Accessed August 1, 2019.

CHAPTER 7: LESSONS LEARNED

CARB has learned many lessons, which inform this report's policy recommendations, through the implementation of ZEV programs to date and from other State agencies and global partners. This chapter summarizes lessons learned, including best practices and opportunities for improvement. Data from demonstrations and pilots can inform wider-scale rollouts.

A. Both Supply and Demand Side Programs are Important to Accelerate the ZEV Market

As discussed in Chapter 3, the light- and heavy-duty ZEV markets are growing rapidly, but still require government support to lower the increased upfront costs of ZEVs compared to conventional vehicles as the market continues to mature. The combination of regulations and consumer demand will help accelerate the ZEV market quickly.

Regulations help accelerate ZEV market. California's light-duty ZEV regulation helps create supply by ensuring vehicles are available on dealer lots, while the heavy-duty Innovative Clean Transit and Zero-Emission Airport Shuttle regulations, in combination with incentives programs, are creating a demand for ZEVs for transit and airport shuttle applications. Future ZEV regulations will contribute to growing both the supply of ZEVs available in California (e.g., Advanced Clean Trucks and amendments to the On-Road Motorcycle regulations) and the consumer and fleet demand of the vehicles (e.g., ZEV Truck Regulation and Clean Miles Standard) to help ensure a healthy market occurs quickly. ZEV requirements provide the stable, long-term signal that encourages manufacturers to make and sell ZEVs in the early market. By requiring all manufacturers to produce ZEVs, ZEV requirements also reward manufacturers that make early ZEV investments.

Strong consumer demand supports ZEV market growth. To ensure ZEVs can help achieve the State's air quality, public health, and climate goals, ZEV manufacturers and infrastructure providers need strong and sustained consumer demand to build sustainable business models. Programs that increase consumer demand for ZEVs are important, but California only has programs that indirectly do this, through incentives, outreach, and education. These programs are important to help make the price of ZEVs comparable to conventional vehicles and to make consumers aware of these vehicles. However, California lacks programs that directly affect consumer choice. Additionally, research is needed to identify the most effective strategies to increase ZEV adoption and to inform optimal structure of incentive programs as the ZEV market continues to grow beyond early adopters.

Thoughtful pricing signals could increase ZEV demand. As previously highlighted by CARB, California has an opportunity to develop and pilot fiscally-sustainable and equitable methods of funding the transportation system that support climate-friendly travel choices and incentivize shifts in travel behavior.[243] This includes ZEVs and zero-emission transportation. Other jurisdictions, as discussed in Chapter 6, have implemented a feebate system, which financially rewards the choice of ZEVs and penalizes the choice of vehicles that emit high concentrations of carbon dioxide, as a way to drive consumer demand for cleaner vehicles. Additionally, some cities, like London and Stockholm, have implemented congestion charging schemes that exempt ZEVs, which can also increase the demand for ZEVs.

While ZEV purchase incentives ultimately lower the cost of purchase down to comparable levels to conventional vehicles, the sales and use taxes are based on the sales price (i.e., excluding all incentives), which can counteract a significant portion of the purchase incentive. This is especially true for heavier vehicles which tend to cost more than lighter vehicles in general and because the ZEV market is younger in this area. For example, for a 40 foot battery electric urban bus that costs approximately $770,000 today, the local and State sales taxes add approximately $65,000 to its purchase cost. Even if the vehicle owner receives purchase incentives to reduce the upfront purchase cost, such as the $150,000 voucher from HVIP this bus would be eligible for, the vehicle's taxes are calculated from its purchase price, excluding all incentives. For comparison, a similar urban bus fueled with diesel or compressed natural gas costs approximately $500,000 resulting in a sales tax bill of nearly $40,000. Although the Legislature recently passed a bill exempting State sales and use taxes from zero-emission transit buses purchases by eligible transit agencies,[244] other vehicle types (e.g., light-duty vehicles and medium- and heavy-duty trucks) as well as buses not purchased by transit agencies are not exempt. Because vehicle registration fees are also based on the vehicle's full purchase price, they are more expensive for ZEVs than comparable conventionally fueled vehicles.

A robust secondary ZEV market supports consumer demand. Since only a small fraction of households in California buy new vehicles in a year, the secondary (i.e., used car) market is more than twice the size of the new light-duty vehicle market. Growing the secondary ZEV market is important in order to get ZEVs into a broader set of

[243] CARB, 2018. "2018 Progress Report: California's Sustainable Communities & Climate Protection Act." https://ww2.arb.ca.gov/sites/default/files/2018-11/Final2018Report_SB150_112618_02_Report.pdf. November, 2018.
[244] Mullin, Chapter 684, Statutes of 2019.

households across all income groups,[245,246] but depends on a robust market for new vehicles to provide enough used vehicles to satisfy consumer demand. Research has shown only a slight preference for used BEVs and PHEVs in disadvantaged communities over new versions of these vehicles,[247] which could be due to the perceived risk of buying a used ZEV because of the unknown long-term reliability inherent in new technologies. Incentives for used ZEVs and programs designed to boost consumer confidence, such as the Zero-Emission Assurance Project which will provide support for the replacement of batteries and fuel cell components for low-income consumers, address some of the known barriers to purchase used ZEVs.

Demonstration and pilot projects show ZEV technology is maturing quickly. Zero-emission technologies utilized in the heavy-duty demonstration and pilot projects have succeeded in meeting the demands and expectations for vehicle performance.[248] Performance metrics such as vehicle availability, road call frequency with buses, fuel efficiency and related factors, refueling or charging time and frequency, and parts availability indicate viability and reliability of these technologies. The available range of zero-emission trucks and buses, in many cases, is meeting operational needs. The vehicle performance is close to or on par with the conventional technology vehicle. Furthermore, operators of heavy-duty ZEVs are very receptive to their enhanced machine operation and increased performance. A Zero-Emission Truck and Bus Pilot Project grantee noted that the technology has matured quickly; for instance, battery density has improved by approximately 10 kWh with each subsequent new battery electric bus delivered for their project.[249]

B. Long-term, Stable Signals are Important

California's light-duty ZEV regulation and consumer-facing light-duty incentive programs (i.e., CVRP, Clean Cars 4 All, and Financing Assistance for Lower-Income Consumers) underscore the need for market stability, but the need for stability applies to the heavy-duty vehicle market as well, and funding availability remains a challenge. Stability from California is especially important at this time to counter the instability created by a federal administration disrupting regulatory and market environments. Manufacturers and developers of clean technology have an even greater need for assurance that zero-emission technology will be required and encouraged in the State

[245] Tal and Rapson, 2018. Final Research Report. April 13, 2018. "The Dynamics of Plug-in Electric Vehicles in the Secondary Market and Their Implications for Vehicle Demand, Durability, and Emissions." https://ww3.arb.ca.gov/research/apr/past/14-316.pdf.

[246] Fact of the Week #109. July 15, 2019. "Used Vehicle Sales Are More Than Double the Number of New Vehicle Sales." https://www.energy.gov/eere/vehicles/articles/fotw-1090-july-15-2019-used-vehicle-sales-are-more-double-number-new-vehicle. Accessed August 1, 2019.

[247] Canepa, Hardman and Tal, 2019. June 2019. "An early look at plug-in electric vehicle adoption in disadvantaged communities in California." Transport Policy. Volume 78, Pages 19-30. https://doi.org/10.1016/j.tranpol.2019.03.009.

[248] CARB. "Moving California. Printable Summary Pages." https://www.arb.ca.gov/msprog/lct/posters.htm. Accessed July 15, 2019.

[249] CARB. "City of Porterville Transit Electrification." https://www.arb.ca.gov/msprog/lct/pdfs/porterville.pdf.

through all available legal and policy means because of the investments they must make years before vehicles make it to the showroom.

ZEV Programs are More Impactful with Long-Term Support. ZEV incentive programs and education campaigns administered and supported by nonprofit organizations and government agencies benefit from long-term certainty that funding and program support will be available beyond the annual funding cycle. Not knowing if, or when, additional funding can be expected can strain future planning, delay program implementation, hinder capacity building, and thus impact program success. Fleet managers and individual car buyers depend on the long-term availability of incentives to offset the current higher upfront cost of a ZEV when deciding on a vehicle purchase or lease. The certainty that incentives will be available also allows vehicle manufacturers and dealers to better budget costs, since manufacturers and parts suppliers typically plan for the long-term because they need sufficient lead-time to develop and implement new technologies across their vehicle lines, and dealerships are reluctant to promote incentive programs if the funds may be unavailable to buyers. Finally, not having long-term signals supporting the growth of the ZEV market means educational institutions and employers may not want to invest in identifying skill gaps and training the workforce in this area.

C. Electricity Costs are Difficult to Predict and Hydrogen is Expensive

Predictable, cost-competitive and stable fuel costs are critical to encourage consumers and fleets to choose light- and heavy-duty ZEVs.

Electricity pricing is confusing for ZEV consumers to predict. Estimating electricity costs to power electric vehicles is complicated,[250, 251] so CARB staff created a calculator to help estimate annual electricity costs for battery electric truck and bus deployments.[252] Electricity rate varies with factors such as electric utility, number of battery electric heavy-duty vehicles deployed in a fleet, and charging strategy. Electric utilities typically charge commercial customers in three ways: 1) usage-independent fee as a fixed fee for each electricity meter ($/month), 2) usage charges in cost per kilowatt-hours ($/kWh) sometimes broken down by the time-of-use period the electricity is utilized, and, 3) demand charges in cost per kilowatt ($/kW) based on how fast electricity is drawn during different time-of-use periods. Whether a fleet's vehicles are charged during daytime or nighttime to avoid on-peak usage charges, and whether the vehicles are charged simultaneously or sequentially to reduce demand charge can significantly affect the electricity rate. Early planning of zero-emission heavy-duty

[250] Nicholas, 2018. ICCT Briefing. February 2018. "Ensuring Driving on Electricity is Cheaper than Driving on Gasoline." https://theicct.org/sites/default/files/publications/Driving-on-electricity-versus-gasoline_ICCT-Briefing_26022018_vF.pdf.

[251] Lee and Clark, 2018. Harvard Faculty Research Working Paper Series RWP18-026. September 2018. "Charging the Future: Challenges and Opportunities for Electric Vehicle Adoption." https://projects.iq.harvard.edu/files/energyconsortium/files/rwp18-026_lee_1.pdf.

[252] CARB, 2018. Updated December 2018. "Battery-Electric Truck and Bus Charging Cost Calculator." https://ww2.arb.ca.gov/resources/documents/battery-electric-truck-and-bus-charging-cost-calculator.

vehicle procurement as well as infrastructure and charging strategies can help reduce charging costs and increase cost certainty. There are also options for fleets to reduce or manage electricity costs, such as a fleet management system that uses software to do strategic charging. Other options that can mitigate peak demand and commodity charges include on-site electricity generation or off-grid charging, as well as energy storage that utilizes electricity when it is in low demand and therefore cheaper, which can later be delivered to vehicles as needed.

Cheaper hydrogen fuel achieved by scaling up and reducing investment risk. Due to the early nature of the market, the average cost of hydrogen at a fueling station is $13.99 per kilogram or $0.21 per mile, compared to $0.13 per mile for a gasoline vehicle paying $3.50 per gallon.[253] However, light-duty FCEV drivers do not currently pay for their hydrogen, as it is included in their lease. Fleets with large and consistent amount of fuel utilized may be able to negotiate hydrogen fuel prices with fuel providers. As of today, Hydrogen fuel and FCEV deployment barriers are largely a matter of economic scale and reducing investment risk. Technology is available today to make widespread hydrogen fuel use a reality. However, costs are high in the early market development because most development to date has not been large enough to unlock economies of scale in the supply chain. Costs for deployment of hydrogen and fuel cell technologies are expected to decline if there is appropriate support to enable large-scale development that brings cost savings throughout the supply chain. The greatest financial barrier to enhanced hydrogen deployment is lack of certainty, due to the unique aspect of requiring coordinated co-deployment of both a new vehicle technology and a new fueling infrastructure. For example, the Orange County Transportation Authority, as part of Zero-Emission Truck and Bus Pilot Projects, contracted with the fuel provider for set pricing on delivered hydrogen. Programs and policies that reduce investment risk have the greatest effect on accelerating deployment; example mechanisms include maximizing publicly-available information to drive business decisions, providing supplementary station income streams that can augment limited revenue streams in the earliest years of FCEV deployment, and providing long-term capital grant funding programs structured to enable large-scale network-wide development. These goals are achieved in California through the provision of infrastructure credits through the Low Carbon Fuel Standard, and the proposed Draft Solicitation Concepts for the next CEC funding opportunity.

These efforts are designed to enable accelerated station deployment through reduced financial risk and burden; however, as CARB has previously noted,[254] station deployment is not the only major infrastructure-related challenge. Potentially even more challenging, and not as well-addressed by State efforts, is the investment needed

[253] CEC and CARB, 2015. CEC-600-2015-016 "Joint Agency Staff Report on Assembly Bill 8: Assessment of Time and Cost Needs to Attain 100 Hydrogen Refueling Stations in California." https://ww2.energy.ca.gov/2015publications/CEC-600-2015-016/CEC-600-2015-016.pdf.

[254] CARB, 2017. August 2017. "2017 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development." https://ww2.arb.ca.gov/sites/default/files/2018-12/ab8_report_2017.pdf.

to develop a network of at-scale hydrogen fuel production facilities. Preferably, this network of hydrogen production facilities would result in hydrogen fuel that is both increasingly sourced from renewable and low- to zero-carbon resources and reduces the cost of hydrogen production. Achieving these targets would ultimately provide FCEV drivers with cheaper and more environmentally beneficial hydrogen fuel. The Energy Commission has begun to provide grant funds for renewable hydrogen production facilities, but these investments are likely not sufficient to achieve the scale required to meet both cost and emission goals simultaneously and are primarily able to address capital costs. Another, and potentially more powerful, opportunity exists within the California Public Utilities Commission's implementation of Transportation Electrification pursuant to SB 350, which enables utility investments in infrastructure and development of electricity rate structures to support the deployment of vehicles that rely on electrical power. Although FCEVs are electrically-driven vehicles, to date hydrogen for FCEVs has not been deemed to fall within the definition of "transportation electrification." This has meant that utilities and other stakeholders interested in investing private funds into this zero-emission technology have not been able to work together and with the State to develop this critical hydrogen infrastructure. Notably, development and planning for hydrogen production facilities that can or will support California's FCEV market has occurred in other neighboring states with generally more favorable business environments or with utility policies specifically supportive of hydrogen (like Washington).[255],[256] Those states then stand to inherit the benefits such as new clean energy jobs, and the hydrogen that is delivered to California's fueling station network then incurs greater distribution-related emissions than if the hydrogen was produced in-State.

D. ZEV Infrastructure is Still Lacking and Installation is Complex

Current ZEV infrastructure cannot support the growing population of light- and heavy-duty ZEVs, and ZEV drivers need better data on where to find ZEV refueling and charging.

Publicly accessible ZEV infrastructure is still lacking. Convenient access to electric vehicle recharging is a key barrier to the adoption of plug-in vehicles,[257] and light-duty ZEV infrastructure is not yet keeping up with ZEV market growth.[258] ZEV infrastructure

[255] Air Liquide, 2018. November 26, 2018. "Air Liquide to build first world scale liquid hydrogen production plant dedicated to the supply of Hydrogen energy markets." https://en.media.airliquide.com/news/air-liquide-to-build-first-world-scale-liquid-hydrogen-production-plant-dedicated-to-the-supply-of-hydrogen-energy-markets-1cde-56033.html. Accessed August 15, 2019.

[256] Office of Senator Hawkins, 2019. April 17, 2019. "Governor signs Hawkins' bill allowing PUD production and sale of renewable hydrogen." http://bradhawkins.src.wastateleg.org/governor-signs-hawkins-bill-allowing-pud-production-and-sale-of-renewable-hydrogen/. Accessed August 15, 2019.

[257] Singer, 2017. NREL Report NREL/TP-5400-70371. November 2017. "The Barriers to Acceptance of Plug-in Electric Vehicles: 2017 Update." https://www.nrel.gov/docs/fy18osti/70371.pdf.

[258] Nicholas, et al., 2019. ICCT White Paper. January 2019. "Quantifying The Electric Vehicle Charging Infrastructure Gap Across U.S. Markets." https://theicct.org/sites/default/files/publications/US_charging_Gap_20190124.pdf.

at a variety of locations (such as at residences, workplaces, highway rest stops, shopping centers) is anticipated to enable a larger share of vehicle travel to be zero-emission and to provide more equitable access to clean transportation modes.[259] Based on a scenario using Statewide travel data from 2010-2012 and expected technology advancement, California has a projected gap of 229,000 to 279,000 public destination chargers to refuel 1.5 million electric vehicles by 2025.[260] Independent analysis also shows that California's metropolitan areas need a 20 percent annual growth in their public and workplace charging infrastructure from 2017 to 2025 to meet 2025 projected sales growth.[261] Because the installation costs can be a burden to low-income residents, electric vehicle infrastructure incentive programs can help this population access clean transportation. Renters and residents of multi-unit dwellings face a greater barrier to install electric vehicle infrastructure since they need permission from their landlord and home owner's association to install a charger onsite. Additionally, residents of multi-unit dwellings and older homes are subject to higher installation costs due to parking location being further from electric panel or needing upgrades to support higher panel capacity.[262] Requiring supporting electric vehicle infrastructure (i.e., panel capacity and wiring raceway) and actual charging stations in new and existing buildings can help increase access to charging. Another solution, specifically for renters, residents of multi-unit dwelling, those without dedicated parking or unable to pay for the installation costs, is to have convenient and reliable recharging stations nearby.

Similarly, increasing the number of hydrogen retail stations throughout California is important to drive growth in the number of light-duty hydrogen-powered FCEVs sold. The network of 64 open and funded hydrogen stations in California provides coverage to only 41 percent of the State's population within a 15-minute drive;[263] 21 percent of the covered population lives within a disadvantaged community. Hydrogen fueling networks of 200 and 1,000 stations (reflecting the goals of Executive Order B-48-18[264] and the California Fuel Cell Partnership's Revolution,[265] respectively) could provide coverage to 68 percent and 94 percent of the state's population. Additionally,

[259] Tal, et al., 2019. Final Research Report. September 2019. "Advanced Plug-In Electric Vehicle Usage and Charging Behavior." https://ww3.arb.ca.gov/research/single-project.php?row_id=65206.
[260] Bedir, et al., 2018. "California Plug-In Electric Vehicle Infrastructure Projections: 2017-2025." https://efiling.energy.ca.gov/GetDocument.aspx?tn=224521&DocumentContentId=55071.
[261] Nicholas, et al., 2019. ICCT White Paper. "Quantifying the Electric Vehicle Charging Infrastructure Gap Across U.S. Markets." https://theicct.org/sites/default/files/publications/US_charging_Gap_20190124.pdf.
[262] DeShazo, et al., 2017. November 2017. "Overcoming Barriers to Electric Vehicle Charging in Multi-unit Dwellings: A Westside Cities Case Study." https://innovation.luskin.ucla.edu/wp-content/uploads/2019/03/Overcoming_Barriers_to_EV_Charging_in_MUDs-A_Westside_Cities_Case_Study.pdf.
[263] CARB, 2018. July, 2018. "2018 Annual Evaluation of Fuel Cell Electric Vehicle Deployment & Hydrogen Fuel Station Network Development." https://ww2.arb.ca.gov/sites/default/files/2018-12/ab8_report_2018_print.pdf.
[264] Executive Order B-48-18. January 26, 2018. https://www.ca.gov/archive/gov39/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/index.html.
[265] California Fuel Cell Partnership, 2018. July 2018. "The California Fuel Cell Revolution: A Vision for Advancing Economic, Social, and Environmental Priorities." https://cafcp.org/sites/default/files/CAFCR.pdf.

California faces challenges due to the limited availability of hydrogen production, storage, and distribution resources to support the hydrogen fueling station network. While AB 8[266] addresses the challenge of establishing the fueling network, there are no State programs that address these upstream challenges as thoroughly. Hydrogen fuel customers need a resilient and reliable hydrogen supply chain to be in place to ensure consistent availability of fuel. While the hydrogen fueling station network itself faces this challenge, it is also true of the supply and distribution network. Just as a customer with access to a local hydrogen station network with zero or little redundancy (as in many communities today) can lose access to fuel when a single fueling station has an operational outage, disruptions at the limited number of production and distribution facilities in the State can and have resulted in many customers losing access to hydrogen fuel for extended periods of time. Developing redundant and backup supply options will help avoid severely limiting FCEV adopters' ability to utilize their vehicles.

Infrastructure supporting the growing heavy-duty ZEV market is also needed. Just as the heavy-duty ZEV market is lagging behind the light-duty market, the heavy-duty ZEV infrastructure is too. The CEC and CPUC, in collaboration with CARB, have new and ongoing efforts focused on assessing the charging infrastructure needs across all on-road and off-road vehicle applications. The new infrastructure planning efforts are in response to AB 2127[267] and SB 350.[268] These efforts focused on the infrastructure needs for the medium- and heavy-duty and off-road vehicles will provide a foundation for the successful establishment of a ZEV refueling network that supports the accelerated deployment of heavy-duty and off-road ZEVs expected by recently approved and upcoming regulations. For these regulations to succeed, zero-emission bus, truck, and transport refrigeration unit infrastructure is needed at transit centers, cold storage facilities, grocery stores, seaports, railyards, truck stops and many other locations throughout the State.

ZEV infrastructure is costly. Installing recharging infrastructure can be expensive, especially in places with limited supporting electrical infrastructure and space. Often times, the cost of upstream transmission and distribution systems are very high, especially with lack of long-term planning. For instance, Philadelphia spent $1.5 million to upgrade their electrical system in their bus depot in order to install a substation that can power 20 vehicles.[269] Recently, Los Angeles County Metropolitan Transportation Authority (Metro) estimated that it would cost between $700,000 and $1,000,000 to

[266] Perea, Chapter 401, Statutes of 2013.
[267] Ting, Chapter 365, Statutes of 2018.
[268] De León, Chapter 547, Statutes of 2015.
[269] Poon, 2019. CityLab. June 27, 2019. "Why U.S. Cities Aren't Using More Electric Buses." https://www.citylab.com/transportation/2019/06/electric-bus-china-grid-ev-charging-infrastructure-battery/591655/. Accessed August 15, 2019.

add the required infrastructure to support the transition of their transit buses to zero-emission vehicles per the Innovative Clean Transit regulation.[270]

Installing charging infrastructure is complicated. Electric vehicle chargers are relatively simple electrical appliances, but in some cases, permitting for charging stations in California can take nearly twice as long as the national average, with permitting delays and recommended design changes for charging stations contributing to extended project timelines and budget implications. The permitting and interconnection[271] processes for electric vehicle charging infrastructure vary across local jurisdictions and utility territories. This is a barrier to electric vehicle charger deployment because each infrastructure project requires additional time to research and satisfy the local permitting and utility interconnection requirements, leading to increased cost and delays. AB 1236[272] requires California cities and counties to implement permit streamlining for electric vehicle charging stations. However many local jurisdictions have not taken adequate steps to implement the bill's requirements. In July 2019, GO-Biz issued a permitting Guidebook and initiated a formal evaluation of compliance with AB 1236.[273]

For CARB programs that involve installing ZEV infrastructure (e.g., the Zero-Emission Truck and Bus Pilot Project, the Advanced Technology Demonstration Projects, and the Clean Mobility Options) one lesson learned is that the design and installation of electric vehicle infrastructure is a complex process often delayed by technical issues, prolonged permitting, and an evaluation process involving multiple agencies, leading to time delays and unanticipated expenses.[274] In several cases, delays in having the supporting infrastructure in place put the whole project on hold. Therefore, ZEV projects that will rely upon on-site infrastructure should hire a dedicated infrastructure manager with a strong planning and engineering background and expertise to help streamline the process in the early stage of design. Projects deploying infrastructure at active terminals and work sites require creative solutions and long lead times in order to minimize disruption to ongoing work. Successful infrastructure implementation requires active and early collaboration between site managers, utilities, and technology providers. Local leadership is also crucial to ensure strong inter-agency collaboration to expedite this process.

[270] Metro, 2019. Operations, Safety and Customer Experience Committee Board Report. July 18, 2019. File # 2019-0458.

[271] Interconnection refers to the connection between the electric vehicle charging infrastructure and the electrical grid.

[272] Chiu, Chapter 598, Statutes of 2015.

[273] See https://www.business.ca.gov/ZEVReadiness.

[274] Some of the issues that cause these problems include delays in construction of infrastructure due to unanticipated issues with requirements, regulations, permitting, and inspections as well as utility upgrades needed to support on-site infrastructure.

For hydrogen, the process of installing fueling stations can be similarly complex, especially since hydrogen as a fuel in a retail sales environment is a new concept for many jurisdictions. Given the early stage of development of the hydrogen fueling network, there is often a learning curve that must be addressed for permitting agencies, and Authorities Having Jurisdiction (AHJs). In addition, many of the companies that develop and operate hydrogen fueling stations have themselves undergone a learning process to understand the requirements of development for retail customer services and sales, and the variations of permitting requirements across California. In spite of these challenges, much progress has been made. The Energy Commission has been working to fund at least 100 hydrogen stations in response to AB 8[275] through a series of grants that provide State cost-share for both capital and operating expenses. The average time needed for station development has decreased dramatically, especially for development phases prior to construction from an average of nearly 1,500 days for stations funded in 2010 to less than 800 days for the most recent stations funded in 2014.[276] Several factors have led to this improvement: 1) More recent Energy Commission grant opportunities have required applicants to hold meetings with AHJs prior to submission of applications for grants and provide documentation of these meetings in their application materials; 2) the Energy Commission has implemented progressively more stringent requirements to meet Critical Milestones, which address the permitting process and other key development considerations, during station development in order for awardees to be eligible to continue receiving funds under their grant agreement; and 3) the Energy Commission and GO-Biz have shared their expertise with several jurisdictions, primarily by providing support at public city council meetings during which awarded hydrogen fueling stations are discussed. GO-Biz has also published a Hydrogen Station Permitting Guidebook[277] to help AHJs and station developers identify and work toward a common set of best practices for the development and permitting of hydrogen fueling stations.

ZEV drivers need refueling and charging station information. Transparent, clearly presented, current, and publicly accessible information is critical to support early ZEV adopters' needs. For example, as the hydrogen fueling network is being established and as it continues to expand into new communities, information like the California Fuel Cell Partnership's Station Operational Status System[278] and the annual reporting through CARB and CEC[279] enable potential adopters to make informed purchase decisions based on station locations and allow current FCEV drivers to reliably plan fueling for their travel needs.

[275] Perea, Chapter 401, Statutes of 2013.
[276] CEC and CARB, 2018. December 2018. "Joint Agency Staff Report on Assembly Bill 8: 2018 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California." https://ww2.energy.ca.gov/2018publications/CEC-600-2018-008/CEC-600-2018-008.pdf.
[277] GO-Biz, 2015. November 2015. "Hydrogen Station Permitting Guidebook." http://www.businessportal.ca.gov/wp-content/Documents/ZEV/Hydrogen-Permitting-Guidebook.pdf.
[278] California Fuel Cell Partnership, 2019. "Station Status." https://m.cafcp.org/. Accessed August 15, 2019.
[279] CARB, 2019c.

Similarly, to continue support for the growing number of BEVs and PHEVs being added to California roads each month, consumers need education about and convenient access to charging infrastructure. Consumers are generally unaware of electric vehicle charging infrastructure in locations they frequently visit and they are concerned about the lack of public charging. Greater charging confidence and convenience for current and future ZEV drivers would be bolstered by improved billing transparency, available data on charging station locations, and accessible payment methods paired with complementary marketing, education, and outreach. CARB adopted regulatory requirements for new and existing public electric vehicle supply equipment (EVSE)[280] in response to SB 454,[281] The Electric Vehicle Charging Stations Open Access Act. The requirements will ensure consumers have familiar payment methods, clear pricing information, and uniform information on charging infrastructure locations, cost, and capacity. Under SB 454, charging infrastructure service providers will be required to regularly report all publicly available EVSE locations to the National Renewable Energy Laboratory Alternative Fuel Data Center (AFCD).[282] This AFCD database, which serves as a central clearinghouse of alternative fueling stations, is utilized by several applications that consumers use to locate a charging station near them.

Lower-income consumers prefer plug-in hybrid vehicles. For many lower-income consumers participating in CARB's ZEV programs, the availability of public and at home charging stations and long commute distances make a plug-in hybrid a good lifestyle fit. Hopefully, as hydrogen refueling and electric vehicle charging stations become more common throughout California, and the diversity of ZEV models and the driving range both increase, more low-income consumers will be able to opt for ZEVs instead of PHEVs.

E. ZEV Awareness Remains Low

Awareness of both light-duty and heavy-duty ZEVs remains low, affecting consumer acceptance and implementation of supporting policies like infrastructure.

Despite investments, consumer awareness of ZEVs remains low. Most research shows that consumer awareness, knowledge and experience with ZEVs is low and has changed little despite increasing availability in the number of ZEV models and investments in charging and refueling stations.[283] However, a recent study shows an increase in the intent to purchase a ZEV between 2011 and 2017 in the 21 largest U.S.

[280] Commonly thought of as electric vehicle chargers or charging stations.
[281] Corbett, Chapter 418, Statutes of 2013.
[282] Alternative Fuel Data Center. Energy Efficiency & Renewable Energy, U.S. Department of Energy. "Alternative Fueling Station Locator." https://afdc.energy.gov/stations/. Accessed August 15, 2019.
[283] Turrentine, et al., 2018. International EV Policy Council Policy Guide. March 2018, "Driving the Market for Plug-in Vehicles: Increasing Consumer Awareness and Knowledge." https://phev.ucdavis.edu/wp-content/uploads/Consumer-Education-Policy-Guide-March-2018.pdf.

cities.[284] Research shows that an effective way to increase the likelihood of a consumer purchasing or leasing a ZEV is to experience driving or using a ZEV.[285] Although the California has supported consumer education and outreach efforts such as the DriveClean website,[286] the Clean Vehicle Rebate Project outreach[287], ride-and-drives, and more recently, Veloz's Statewide consumer awareness campaign,[288] additional outreach and education resources would increase awareness and lead to greater consumer acceptance of ZEVs. For example, the more consumers know about ZEVs, the more interested they are in acquiring one.[289] Additionally, exposure to ZEVs through participation in ride-and-drives and carsharing programs has been shown to have an increased interest in ZEV adoption.[290]

Consumer outreach tailored to the community. In order to address the needs of low-income and disadvantaged communities, the State's approach to consumer education and outreach must resonate with those audiences and be uniquely tailored to meet their needs.[291] These strategies are often not the same tactics used in general consumer awareness initiatives. As a result, the One-Stop Shop Pilot Project[292] has been developed to fulfill this gap.

F. Equity Requires More Resources

Competing priorities for incentive programs often lead to complexity. For example, light-duty rebate income caps make it nearly impossible to provide the rebates at the point-of-sale, even though point-of-sale rebates are one of the most effective vehicle purchase incentives.[293] Equity-focused light-duty incentive programs to date are also in high demand, but require more resources to administer effectively.

Income verification is important but costly. Programs like Clean Cars 4 All, Financing Assistance for Lower-Income Consumers, and the increased CVRP rebate for low-

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[284] Carley, et al., 2019. May 2019. "Evolution of plug-in electric vehicle demand: Assessing consumer perceptions and intent to purchase over time." Transportation Research Part D. Vol 70, Pages 94-111. https://doi.org/10.1016/j.trd.2019.04.002.

[285] Turrentine, et al., 2018.

[286] CARB. "DriveClean." https://www.driveclean.ca.gov/. Accessed August 1, 2019.

[287] See https://cleanvehiclerebate.org/eng/ev and https://cleanvehiclerebate.org/eng/local-events-and-workshops.

[288] Veloz, 2019. "Electric For All." https://www.veloz.org/initiatives/electric-for-all/. Accessed August 15, 2019.

[289] Consumer Federation of America, 2016. September 19, 2016. "New Data Shows Consumer Interest in Electric Vehicles Is Growing." https://consumerfed.org/press_release/new-data-shows-consumer-interest-electric-vehicles-growing/. Accessed August 15, 2019.

[290] Shaheen, et al. 2020. "Zero-emission vehicle exposure within U.S. carsharing fleets and impacts on sentiment toward electric-drive vehicles." Transport Policy 85, A23-32. https://doi.org/10.1016/j.tranpol.2019.09.008.

[291] CARB, 2018. "Low-Income Barriers Study, Part B: Overcoming Barriers to Clean Transportation Access for Low-Income Residents", https://ww2.arb.ca.gov/sites/default/files/2018-08/sb350_final_guidance_document_022118.pdf.

[292] Which will provide coordinated community-based outreach and education, including a single application to maximize participation in CARB's Low Carbon Transportation Equity Projects to promote advanced technology vehicle adoption in disadvantaged communities, low-income communities, and low-income household.

[293] Hardman, et al., 2018.

income consumers that involve income verification, collection of documents, and intensive, hands-on customer service are resource-intensive due to the costs of staff time and processing of participant applications. With CVRP's income cap, which serves not to provide additional incentives to lower-income car buyers but to exclude higher-income consumers from participation, additional unintended consequences have been discovered, including: 1) dealer reluctance to discuss the rebate at all due to uncertainty about consumer eligibility and fear of liability if they provide inaccurate information, 2) consumer confusion about incentive eligibility, 3) increased application complexity, processing times and costs for all applicants, including those who need it most, 4) consumer resistance due to increased intrusiveness (e.g., collection of tax forms), 5) the introduction of fraud and loopholes, 6) increased administrative and transactional costs (systems and application processing), and, perhaps most important, 7) the preclusion of the option to make CVRP a point-of-sale incentive with the benefits of a "cash-on-the-hood" motivation for dealers and time-of-sale discounts for those consumers that cannot afford to wait for reimbursement, as has been done for ZEV incentive programs in New York, Connecticut, and (soon) Oregon.

High demand for equity programs. The Statewide Financing Assistance Project[294] became oversubscribed five months after launching, which highlights the demand for this program. As knowledge of the program spreads, especially with the launch of the One-Stop-Shop Pilot Project, it is important to ensure adequate staff to process applications with reasonable turnaround times, especially with point-of-sale incentives. Some intensive, hands-on case management is likely to be required even with streamlined processes. Equity programs, such as the Financing Assistance for Lower-Income Consumers and Clean Cars 4 All, require staff time to educate consumers on clean vehicle technology and financial literacy. This step is important to ensure consumer protection and program success regarding meeting program participants' needs. The increased cost of intensive, hands-on customer service should be considered when evaluating funding needs.

Trust networks are key to the success of equity pilots. An important component of program success is building on community involvement and neighborhood capacity by engaging key community influencers and local advocates. Additionally, it is worth considering involving local ambassadors who know the prominent language of that community to build trust. When designing Clean Mobility Options pilot projects, an important lesson learned is the need to engage participants in each phase of the decision-making process and consider the type of marketing that is appropriate for that specific community. A key benefit of using nonprofit organizations with an equity focus as administrators for Clean Cars 4 All, Financing Assistance for Lower-Income Consumers, Clean Mobility Options, and CVRP has been their ability to leverage existing trust networks in outreach to priority populations. Partnerships with

[294] One of the pilots funded through the Financing Assistance for Lower-Income Consumers Project: https://cleanvehiclegrants.org/.

community-based organizations, along with word of mouth and social media, have been strong channels for outreach.

G. The ZEV Transition will require a Growing Workforce

The ZEV transition will require a growing workforce that can manufacture, service, and operate zero-emission vehicles and infrastructure. With California leading the ZEV market, this creates opportunities for quality job creation

Workforce training is important. Workforce training pipelines into the zero-emission vehicle and infrastructure technology sector will be critical to meeting the demand for workers to support the growing ZEV market and it is possible to engage with local communities and include disadvantaged community members in these efforts.[295] Vehicle and infrastructure manufacturers, fleets, and freight facilities, in collaboration with educational institutions, should begin identifying long-term skill and job gaps expected to come from electrifying the transportation sector in order to be prepared, such as some have begun doing with funding from CEC.[296] One example of success in workforce training is the over 100 hydrogen fuel outreach and training events provided by the California Fuel Cell Partnership and the Pacific Northwest National Laboratory that reached more than 8,000 first responders and permitting officials in California.[297] The first responder training has been a particularly effective tool, providing unique live-fire training to fire fighters and other emergency responders; this training has now been incorporated into the American Institute of Chemical Engineer's new Center for Hydrogen Safety to provide a national resource as hydrogen fueling network development expands beyond California.[298] There are opportunities to improve fleet performance through driver and operator trainings as well. For instance, operator behavior and environmental conditions can have a large effect on transit electric bus range. Finally, few studies have been performed that analyze the impact of ZEV market on California's economy, and in particular the impact of regulations and incentives, and the quality of jobs that have been created through these programs.

H. Expenditure Deadlines are a Barrier to Implementation

Agencies administering ZEV incentive and infrastructure programs need longer expenditure deadlines for funding to respond to the rapidly evolving ZEV market and support ZEV development especially in the earliest stages of commercialization.

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[295] Milbes, 2017. June 17, 2017. "Labor and Community Groups Sign Landmark Agreement with Electric Bus Manufacturer BYD in Los Angeles" https://jobstomoveamerica.org/labor-community-groups-sign-landmark-agreement-electric-bus-manufacturer-byd-los-angeles/. Accessed August 15, 2019.

[296] Infusino, et al., 2019. Long Beach City College. "Zero-Emission Port Equipment Workforce Assessment." http://www.polb.com/civica/filebank/blobdload.asp?BlobID=15015. Accessed August 15, 2019.

[297] Barilo, et al., 2017. "First responder training: Supporting commercialization of hydrogen and fuel cell technologies." International Journal of Hydrogen Energy. Vol 42, Issue 11, Pages 7536-7541. https://www.osti.gov/pages/servlets/purl/1339272. Accessed August 15, 2019.

[298] American Institute of Chemical Engineers, 2019. "Center for Hydrogen Safety." https://www.aiche.org/CHS. Accessed August 15, 2019.

Expenditure deadlines do not always match implementation timelines. Beginning in FY 2015-16, the expenditure deadline for CARB's Clean Transportation Incentives funding was reduced to four years (two years to encumber and two years to fully expend) from six years. This shortened time period is particularly challenging for the demonstration and pilot projects funded through the Clean Transportation Incentives because they must go through a public stakeholder process, contract approval process, permitting including CEQA review, construction and vehicle manufacturing, and installation of supporting infrastructure before being able to operate the vehicles and gather data. As a result, expenditure deadlines may cause problems since they may be too short to provide enough time to complete projects or to gather data to inform future program design. The 2019-2020 budget, which allows four years to liquidate and two years to encumber the funds, does provide sufficient time.

I. Other Modes of Transportation are Less Popular than Personal Vehicles

As critical as ZEVs are to reaching California's air quality, climate, and public health goals, ZEVs alone are not enough.

Alternative modes of transportation are not as appealing. Reducing vehicle miles traveled remains an important strategy to reach the same underlying air quality and climate goals. However, Statewide and local efforts to ensure Californians drive less, such as through pilots and pricing signals, are lacking. Few Clean Cars 4 All participants had chosen the option to retire their high polluting vehicle and receive a mobility option voucher in lieu of a replacement vehicle, therefore CARB recently amended the program to increase this incentive from $4,500 to $7,000 to make this choice more appealing.[299] In addition, the mobility option voucher has been expanded beyond public transit to now also include car sharing, bike sharing, or electric bicycles, per SB 400.[300] These changes will ensure the mobility option is competitive with the vehicle replacement option.

[299] These conventional hybrid vehicles must have a minimum fuel economy of 35 miles per gallon.
[300] Umberg, Chapter 271, Statutes of 2019.

CHAPTER 8: POLICY RECOMMENDATIONS TO ACCELERATE ZEV ADOPTION AND IMPROVE ZEV PROGRAMS

The eight sets of policy recommendations in this report outline areas of opportunity that would either require or benefit from legislative action to further accelerate the adoption and use of ZEVs in California, and to continue to foster the investment and innovation that the ZEV market still requires. These recommendations support Governor Newsom's recent Executive Order N-19-19 that outlines a number of actions that California State agencies must take to reduce GHG emissions in order to keep California on the path to meet our ambitious climate goals. Additionally, these recommendations build on actions previously identified by the Governor's interagency working group on zero-emission vehicles,[301, 302, 303] and are informed by the review of CARB programs and comparison with other jurisdictions. These policy recommendations have been refined and improved based on feedback from external stakeholders, including comments from other State agencies and UC-ITS researchers, and from the public in response to a workshop on May 31, 2019. CARB staff are working to incorporate all of the feedback in this report, and staff are working to incorporate stakeholder comments into this draft.

1) Incentives and pricing strategies

CARB staff recommend providing consistent and sustained incentive funding into the future. Reducing ZEV purchase costs is critical to spur the level of consumer demand needed to grow the ZEV market beyond early adopters, and to ensure equitable access to zero-emission mobility.

a. Provide predictable and expanded funding for CARB's ZEV incentive programs that is sufficient to drive consumer demand.

Rebate waitlists and unpredictable future rebate funding inhibit ZEV production and sales. Incentive certainty entices consumers and fleet operators to opt for light-, medium-, and heavy-duty ZEVs, and nudges vehicle manufacturers to invest and innovate to bring a wider array of ZEVs to market. Demand for

[301] Governor's Interagency Working Group on Zero-Emission Vehicles, 2013. February 2013. "2013 ZEV Action Plan: A Roadmap Toward 1.5 Million Zero-Emission Vehicles." http://opr.ca.gov/docs/Governors_Office_ZEV_Action_Plan_(02-13).pdf..

[302] Governor's Interagency Working Group on Zero-Emission Vehicles, 2016. October 2016. "2016 ZEV Action Plan: An Updated Roadmap Toward 1.5 Million Zero-Emission Vehicles on California Roadways by 2025." https://www.ca.gov/archive/gov39/wp-content/uploads/2018/01/2016_ZEV_Action_Plan-1.pdf.

[303] Governor's Interagency Working Group on Zero-Emission Vehicles, 2018. September 2018. "2018 ZEV Action Plan: Priorities Update." http://business.ca.gov/Portals/0/ZEV/2018-ZEV-Action-Plan-Priorities-Update.pdf.

incentives outstrips the available funding, leading to waitlists. However, beyond the waitlists, predictable future incentive funding would allow consumers, fleets, manufacturers, and administering program grantees to better plan future ZEV deployments. CARB staff recommend strengthening ZEV consumer confidence by providing predictable, long-term funding for CARB's ZEV incentive programs. This recommendation would minimize disruptions in funds that incentivize ZEV purchases and that encourage vehicle manufacturers to produce ZEVs.

In recent years, CARB's light- and heavy-duty Low Carbon Transportation Investments have gone through a boom and bust funding cycle that disrupts long-term planning, confuses consumers, and demotivates dealers. CVRP has had to institute waitlists seven times since 2011 due to the annual funding being exhausted prior to the end of the funding cycle, including one time due to funding delays in budget appropriations.[304] The Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) has also been impacted by waitlists, including one now.

b. Provide CARB with increased incentive funding to ensure priority populations[305] and school districts can access zero-emission transportation.

Low-income and disadvantaged community residents need more help to afford ZEVs and benefit from having zero-emission transportation they can access in their communities, such zero-emission transit. Programs to serve priority populations need to be designed with community input. Additionally, equity programs require more staff time to be successful. CARB staff recommend continued funding for programs aimed at increasing the low- and moderate-income and disadvantaged communities' access to ZEV ownership, including incentives to lower the costs of owning, leasing, or sharing a ZEV for priority populations by reducing fees, subsidizing vehicle insurance, and discounting refueling costs, and zero-emission multimodal transportation, while continuing to grow the ZEV market overall.

Cleaning up the school bus fleet is an opportunity to reduce direct pollutant exposure to children and the surrounding community, while supporting California's air quality and climate goals, and educating the students and community about zero-emission technologies. CARB's school bus replacement programs need increased funding since schools have limited budgets for expenditures for transporting students and many of the underfunded schools

[304] In addition to the waitlist that began on 6/5/19 and is ongoing as of the publishing of this report, there have been six previous waitlists, as reported by CSE here: https://cleanvehiclerebate.org/eng/content/summary-cvrp-rebate-eligibility-and-funding-availability-over-time. Accessed July 3, 2019.

[305] Priority populations include disadvantaged communities (DACs), low-income communities, and low-income households. DACs are defined as the top 25 percent of communities experiencing disproportionate amounts of pollution, environmental degradation, and socioeconomic and public health conditions according to the CalEnviroScreen tool (https://oehha.ca.gov/calenviroscreen). Low-income communities and households are those with incomes either at or below 80 percent of the Statewide median or below a threshold designated as low-income by the Department of Housing and Community Development.

also have the oldest, dirtiest school buses. Replacing all polluting diesel school buses is an imperative societal responsibility to support healthy, thriving students and to improve the air quality within the community around the bus route.

c. Establish Statewide incentives that promote ZEVs through pricing strategies, such as usage- or emission-based fees, registration fee exemptions, and temporary sales tax exemptions for more vehicle types to provide relief to ZEVs, and zero-emission truck lanes along freight corridors.

Pricing strategies that favor ZEVs, including reduced or exempt road usage-based pricing (such as in high-occupancy toll lanes) and parking rates at State facilities, or emissions-based pricing (such as fees on non-ZEVs in households for newly registered vehicles that already have multiple vehicles) are statutory changes that would send a strong signal to encourage the adoption of ZEVs and would be a new funding source for ZEV purchase incentives. Additionally, fees on vehicles with high GHG emissions would be a new funding source for ZEV incentives and also discourage the purchase of high-emitting vehicles.[306] These pricing strategies can be designed to improve transportation equity for priority populations, including providing incentives for scrapping old and highly polluting vehicles, and taking into account whether the vehicle is used for work.[307] Vehicle taxes and fees are another source of pricing signals that can be help drive consumer demand. Because ZEV technologies are mostly more expensive than their conventional counterparts today, sales taxes and registration fees, which are both based on the full purchase price not including any purchase incentives, also cost more. CARB staff recommend exempting sales taxes in vehicle classes beyond transit buses, as called out in the 2018 ZEV Action Plan Priorities Update,[308] and registration fees for new ZEVs. This recommendation is especially important for the larger platform ZEVs because the price difference between a conventional medium- or heavy-duty vehicle and a comparable ZEV in the early ZEV market can be hundreds of thousands of dollars leading to unexpectedly high sales tax bills for early ZEV buyers. As the ZEV market matures, the price difference between zero-emission and conventional vehicles will decrease, and this tax and fee relief will no longer be needed. As discussed in Chapter 6, other states and countries, such Maryland, New Jersey, Washington, China, Japan, Netherlands, Norway, and others, provide some type of sales tax relief to ZEV owners and California should too.

[306] Hardman, et al., 2018.

[307] For example, a pickup truck needed to move lawn and garden equipment.

[308] Governor's Interagency Working Group on Zero-Emission Vehicles, 2018. September 2018.

Finally, dedicated zero-emission truck lanes along busy freight corridors, such as the Interstate 710 highway, would encourage truck operators to switch to zero-emission technology in order to save time. ZEV infrastructure should be installed nearby these zero-emission truck lanes for maximum uptake.

2) Fuel costs

Predictable, cost-competitive and stable fuel costs are critical to encourage consumers and fleets to choose ZEVs. Electricity costs for transportation electrification are difficult to predict and can be high, especially for commercial entities.[309, 310] Individuals and fleet operators have a difficult time estimating their electricity bill, fuel production costs due to complex electricity rate structures and demand charges.[311] The California Public Utilities Commission (CPUC) has an open rulemaking[312] that includes developing electricity rates for transportation electrification for the investor-owned utilities in response to SB 350[313] and SB 1000.[314]

a. Define SB 350 transportation electrification to be inclusive of renewable hydrogen.

CARB staff recommend amending SB 350[315] to include renewable hydrogen fuel in the definition of transportation electrification in order for utilities to develop electricity rate structures that reduce the cost of hydrogen production. This could attract private investments to generate more renewable hydrogen production thereby supporting the expanding number of hydrogen fueling stations. Renewable hydrogen production, storage, and distribution is energy intensive and may not be economic under currently available electric rate structures. Electricity rates designed to reduce the cost of renewable hydrogen production can also encourage hydrogen production to occur when it is most beneficial to the electricity grid. There is currently very little publicly available hydrogen fueling infrastructure, which could delay the deployment of hydrogen-powered fuel cell electric vehicles. These vehicles can play a complementary role in electrifying the medium- and heavy-duty transportation sector as well as the passenger vehicle market. It is also currently difficult to directly track and measure the use of renewable hydrogen by transportation electrification uses. Dedicated renewable hydrogen facilities specifically for transportation

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[309] Nicholas, 2018.

[310] Lee and Clark, 2018. Harvard Faculty Research Working Paper Series RWP18-026. September 2018. "Charging the Future: Challenges and Opportunities for Electric Vehicle Adoption." https://projects.iq.harvard.edu/files/energyconsortium/files/rwp18-026_lee_1.pdf.

[311] Because demand charges are based on the maximum load, rather than the average, they penalize short bursts of high power demanded from charging electric vehicles, especially with the faster chargers. Demand charges favor consistent loads, even if high.

[312] CPUC, 2018. December 13, 2018. "Order Instituting Rulemaking to Continue the Development of Rates and Infrastructure for Vehicle Electrification: Rulemaking 18-12-006." http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M252/K025/252025566.PDF.

[313] De León, Chapter 547, Statutes of 2015.

[314] Lara, Chapter 368, Statutes of 2018.

[315] De León, Chapter 547, Statutes of 2015.

electrification uses would facilitate the development and deployment of technology-specific electric rates.

b. **Set targets for technologies and strategies that integrate electric vehicles with the electricity grid to lower the cost of fueling.**

   CARB staff recommend setting targets for the deployment of low carbon distributed energy resources and load management strategies because these strategies, which require statutory changes, help build in predictability and reduce the costs of using electricity and hydrogen as a transportation fuel. Distributed energy resources include on-site renewable energy generation and energy storage systems. Here, load management strategies encompass demand response, time-of-use pricing, and vehicle grid integration, which includes smart charging. Some of these strategies, like smart charging and using low carbon distributed energy resources, allow charging of multiple vehicles at the same time without overtaxing the electrical system. In addition, these strategies can also increase renewable power integration and provide other grid services. Utilizing electric vehicles as a grid resource and compensating vehicle owners for the value to the grid can help drive down the costs of transportation electrification, especially when they reduce or eliminate demand charges. In collaboration with CARB and other State agencies, the CEC is expected to publish an update to the California Vehicle-Grid Integration Roadmap in 2019.

c. **Require the Integrated Resource Plans submitted by publicly owned utilities (POUs) to the California Energy Commission (CEC) include details of electricity rate design for transportation electrification.**

   CARB staff recommend requiring POUs develop electricity rates that support transportation electrification and report on the progress made. Although some publicly owned utilities have already deployed electricity rates to support ZEVs,[316] more should do so.

3) ZEV refueling infrastructure

Current ZEV fueling and charging infrastructure is insufficient to support the growing population of ZEVs. Long-term, holistic infrastructure planning is critical to giving consumers confidence in ZEVs, to expand ZEVs to more market segments and heavy-duty applications, and to increase zero-emission miles in PHEVs.

a. **Extend CEC's Clean Transportation Program beyond 2023 and promote ZEV fuels.**

[316] These include Alameda Municipal Power (https://afdc.energy.gov/laws/12105), Azusa Light and Water (https://afdc.energy.gov/laws/12106), Burbank Water and Power (https://afdc.energy.gov/laws/12107), Los Angeles Department of Water and Power (https://afdc.energy.gov/laws/6142), and Sacramento Municipal Utility District (https://afdc.energy.gov/laws/4241). Accessed July 1, 2019.

Both electric vehicle and hydrogen refueling infrastructure investment will continue to be needed after 2023, when the funding sunsets, in order to continue closing the large gap between needed electricity and hydrogen refueling infrastructure and the State's ZEV deployment targets.[317, 318] State support is critical to ensure that refueling stations are distributed throughout the State to serve all markets and to allow the ZEV market to mature sufficiently for infrastructure to become a sustainable business model.

b. Convene a multi-agency working group with the goal of accelerating heavy-duty and off-road ZEV infrastructure (especially hydrogen) to be on par with light-duty ZEV infrastructure.

Infrastructure that supports zero-emission heavy-duty and off-road will be crucial for the accelerated ZEV deployment driven by recent and upcoming regulations.[319] CARB staff recommend that the Governor's Interagency Working Group on Zero-Emission Vehicles convene a taskforce, in collaboration with industry partners, to develop strategies that reduce the cost of producing renewable hydrogen fuel. This group should ensure heavy-duty and off-road ZEV infrastructure is on par with light-duty ZEV infrastructure, create a level playing field between hydrogen and electricity, address broader infrastructure issues such as implications for electricity transmission and distribution, compare ZEV infrastructure costs across State agencies' ZEV programs, identify cost-effective investment strategies, maintain a database of heavy-duty and off-road ZEVs in California, and monitor progress.

To support further adoption of ZEVs, the State must continue planning and investing in hydrogen and electricity refueling infrastructure. The CEC and CPUC, in collaboration with CARB, have ongoing and new efforts focused on assessing the electric vehicle infrastructure needs across all transportation applications. The new infrastructure planning efforts are in response to AB 2127[320] and SB 350.[321] This assessment's inclusion of infrastructure needs for medium- and heavy-duty and off-road vehicles will be crucial to the successful establishment of a ZEV infrastructure network that will address near-term needs for a system to accommodate the accelerated deployment of ZEVs driven by CARB's recent ZEV transit regulation and upcoming ZEV freight regulations. In order for these regulations to be successful, zero-emission bus, truck, and transport refrigeration unit infrastructure is needed at transit centers, cold storage facilities, grocery stores, seaports, railyards, truck stops and many other locations throughout the State. Large-scale deployments of electric-fueled

[317] Bedir, et al., 2018.
[318] CARB, 2018b. July 2018.
[319] The Innovative Clean Transit and the Zero-Emission Airport Shuttle regulations have been adopted. The Advanced Clean Trucks, ZEV Truck Regulation, Zero-Emission Transport Refrigeration Unit Regulation, and the Zero-Emission Drayage Truck Regulation, among others, are being developed.
[320] Ting, Chapter 365, Statutes of 2018.
[321] De León, Chapter 547, Statutes of 2015.

vehicles could require broader distribution and transmission system upgrades and the costs to accommodate the incremental load at each site can be hard to predict. This working group could identify strategies to holistically plan for the broad system upgrades needed to transition fleets to zero-emission vehicles. Furthermore, the group could find alternative recharging locations off-site that minimize expensive renovations needed to support on-site charging infrastructure.

On the hydrogen refueling side, current efforts have been focused primarily on the light-duty sector but there is greater potential to achieve affordable hydrogen fuel prices at an earlier date if hydrogen-fueled vehicle deployment can be accelerated and expanded to the off-road, medium- and heavy-duty sectors, since these have greater per-vehicle energy demands.[322] Therefore, CARB staff recommend increased planning and investments in the hydrogen off-road and medium- and heavy-duty sectors in addition to the continued support for the hydrogen light-duty sector so that these catch up to the ongoing ZEV infrastructure planning efforts and to plan holistically across both fuels through a multi-agency effort led by the GO-Biz through the Interagency ZEV Task Force.

c. Require that electric vehicle charging infrastructure provisions in California's Green Building Standards (CALGreen) Code include mandatory installation of level 2 charging in new construction, and require infrastructure installation at existing buildings undergoing major renovations.

One of the main barriers to ZEV adoption is limited access to charging stations. California's Green Building Standards (CALGreen) Code requires low-cost charging infrastructure in new buildings to support future installation of level 2 charging stations. Since new buildings represent a very small percent of total buildings Statewide, it is essential that building standards are expanded to include cost-effective provisions to install charging infrastructure in existing buildings. Additionally, actual charging stations are needed to meet the demand for electric vehicle recharging. CARB staff recommend that the Building Standards Commission (BSC), Housing and Community Development (HCD), and the Division of the State Architect (DSA) update the CALGreen Code to include cost-effective requirements for installation of charging infrastructure in existing buildings. Furthermore, BSC, HCD, and DSA should evaluate options to update the CALGreen Code with provisions for the installation of charging stations.

d. Exempt sales tax on ZEV infrastructure.

Because of the significant gap in light- and heavy-duty ZEV infrastructure noted in Chapter 3, CARB staff recommend exempting sales tax on new electric vehicle recharging or fuel cell refueling infrastructure, especially those that will

[322] California Fuel Cell Partnership, 2018. July 2018. "The California Fuel Cell Revolution: A Vision for Advancing Economic, Social, and Environmental Priorities." https://cafcp.org/sites/default/files/CAFCR.pdf.

be installed for public use, as a way to encourage its installation. A sales tax exemption on ZEV infrastructure components will allow private and public funding for ZEV infrastructure to be maximized.

e. Require charging infrastructure at both new and existing State facilities where feasible.

CARB staff recommend requiring State facilities to install charging infrastructure to serve the public and State employees to use ZEVs. Additionally, the State's fleet should lead by example. DGS should establish feasibility criteria. For locations where DGS determines it is not feasible to install charging infrastructure, they should publicly disclose via a letter to the Secretary of Government Operations Agency (GovOps) the reason.

f. Provide CEC with additional funding for the deployment of light- and heavy-duty ZEV infrastructure within and near low-income and disadvantaged communities and schools.

By supporting cleaner trucks and buses operating in the communities, ZEV infrastructure for heavy-duty buses and trucks, including for transport refrigeration units, at warehouses, grocery stores, truck stops, ports, and rail, in disadvantaged communities would provide air quality benefits where they are needed most. Light-duty vehicle charging is also a barrier for households that cannot afford to install level 2 home charging, or face other barriers such as landlord resistance or lack of off-street parking. Recognizing that work pursuant to Senate Bill 1000[323] is underway, and that several existing State agency programs, such as the CEC's California Electric Vehicle Infrastructure Project (CALeVIP), contain provisions targeted to benefit disadvantaged communities, CARB staff recommend providing additional funding to locate ZEV refueling facilities within and near low- and moderate-income and disadvantaged communities to maximize the health benefits and accessibility of clean transportation options in these communities. This would include activities to address barriers for residents of multi-unit dwellings and affordable housing complexes to access refueling infrastructure, such as installing infrastructure at nearby, off-site locations that can be easily accessible to all.

Schools have limited budgets for expenditures for transporting students and many of the underfunded schools also have the oldest, dirtiest school buses. Additional funding for CEC targeted for fueling zero-emission school buses, in coordination with the incentive programs designed for zero-emission buses themselves, will facilitate replacement of polluting diesel school buses with zero-emission technology.

g. Direct CEC and CPUC to identify investment priorities for ZEV infrastructure to serve high-mileage fleets and build the business case for ZEV infrastructure.

[323] Lara, Chapter 368, Statutes of 2018.

Because high-mileage fleets, such as ride-hailing services, transit, delivery vehicles, and heavy-duty applications have the potential to reduce more GHG and criteria air pollutants through ZEVs, CARB staff recommend that CEC and CPUC examine investment priorities and support ZEV infrastructure assets that reduce the cost of ZEV infrastructure, including by lowering the cost of upstream transmission and distribution system upgrades (e.g., transformers) that may be needed to accommodate large-scale deployments of high-mileage or heavy-duty vehicles. Furthermore, the business case for ZEV infrastructure needs to be assessed.

h. Increase CEC and Caltrans funding for state-of-the-art ZEV regional readiness planning and implementation, including engagement with local jurisdictions.

Regional readiness plans enable communities to plan for and efficiently deploy infrastructure that supports electric and fuel cell vehicles, permitting procedures, and other supportive policies that enable successful support of ZEVs within a region. CARB staff recommend increasing support of CEC's ZEV regional readiness planning and implementation grants and similar grants from Caltrans that take into account newer vehicle and infrastructure technology, the evolution of mobility, an integrated approach to light-, medium- and heavy-duty applications. This recommendation includes support to involve local communities in the development and implementation of transportation planning efforts. These plans should also be rewarded with streamlined grant requirements for implementation funding.

i. Expand focus of transportation funding to reflect ZEV infrastructure needs at seaports and freight distribution facilities.

Statutory support for developing key ZEV infrastructure projects will help enable adoption and operation of zero-emission technologies along major freight corridors, ports, freight distribution centers, and hubs, per the 2018 ZEV Action Plan Priorities Update.[324] For example, when improving a conventional roadway in these freight areas, an adjacent zero-emission truck parking and refueling facility should also be installed to support transportation electrification in freight.

j. Direct the Electric Program Investment Charge (EPIC) programs, implemented by the CEC and the investor-owned utilities, to include research and development into next-generation ZEV infrastructure technologies and operational strategies, including a focus on growing ZEVs in disadvantaged communities.

Newer technologies and strategies, such as wireless charging, ultrafast charging stations, and vehicle-to-grid integration, have potential to increase convenience of refueling ZEVs, thereby helping to grow the ZEV market. CARB staff encourage long-term research and development (R&D) in the next-generation of

[324] Governor's Interagency Working Group on Zero-Emission Vehicles, 2018.

ZEV refueling infrastructure technologies and operational strategies in order to facilitate the ease and speed of refueling ZEVs. CARB staff recommend increasing funding for EPIC for R&D for next-generation technologies that can reduce the refueling time and increase the convenience of ZEVs, such as, wireless charging, ultrafast charging, and portable stations. Future operational strategies may be able to reduce the fixed cost of installing ZEV infrastructure and minimize the cost of electricity.

4) Local policies

Local governments currently do not have explicit authority or a uniform statutory framework to implement policies such as zero-emission zones or road usage- or emissions-based pricing, but these policies are likely to yield substantial local air quality benefits,[325] could create new local revenue, and would send a strong signal about the future of ZEVs. These policies should be developed in the context of the local government's general plan. Local governments play a critical role in preparing their communities for ZEVs, and in motivating their community members to opt for ZEVs.[326] Therefore, CARB staff suggest the following three actions:

a. Provide explicit authority to local jurisdictions to create zero-emission zones.

Statute allowing for the creation of zero-emission zones would support ZEV market growth. CARB staff recommend enabling local jurisdictions to create zero-emission zones[327] either where only ZEVs are allowed to operate or access without fees. These should be designed with equity considerations and to minimize the exposure of sensitive populations to air pollution. The 2028 Olympics in Los Angeles would be an opportunity to show the world what is possible.[328] These zones could be at the city-level involving all vehicles or focused on encouraging the adoption of zero-emission delivery trucks through localized green loading zones that preferentially allow zero-emission deliveries or green logistics zones that restrict internal combustion delivery trucks at certain times and locations such as those in effect in Shenzhen, China.[329] Furthermore, ports and other freight facilities could also establish fast green lanes for zero-emission trucks during peak hours that provide "front-of-the-line" access as a motivation for encouraging early ZEV adoption.

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[325] Simeonava, et al., 2018. National Bureau of Economic Research Working Paper Series. March 2018. "Congestion Pricing, Air Pollution and Children's Health." https://www.nber.org/papers/w24410.pdf.

[326] Governor's Office of Planning and Research, 2013. "Zero-Emission Vehicles in California: Community Readiness Guidebook." http://opr.ca.gov/docs/ZEV_Guidebook.pdf.

[327] Defined by a set geographical boundary that can go into effect at different at specific times and/or days of the week.

[328] Walford, 2018. August 7. 2019. "Goals for 2028 – The Transportation Group Committed to Cleaner Air During LA Olympics." https://www.autofutures.tv/2019/08/07/cleaner-air-during-la-olympics/. Accessed August 15, 2019.

[329] Crow, et al., 2019. Rocky Mountain Institute. July 2019. "A New EV Horizon: Insights from Shenzhen's Path to Global Leadership in Electric Logistics Vehicles." https://rmi.org/wp-content/uploads/2019/06/a-new-ev-horizon.pdf.

b. Provide explicit authority to local governments to implement equitable pricing mechanisms that favor pooling and ZEVs in a way that meets the mobility needs of priority populations.

Pricing mechanisms support multiple State goals, including accelerating the ZEV market. CARB staff recommend enabling local governments to implement pricing mechanisms that reduce vehicle miles traveled (VMT), increase pooling or sharing of vehicle trips, favor ZEVs, and meet the mobility needs of low- and moderate-income and disadvantaged communities. The pricing mechanisms that can be implemented at the local level include congestion pricing, cordon pricing, or operating fees on new mobility services, which would create new revenue to address regional mobility needs. This recommendation includes a requirement that these pricing mechanisms be designed and implemented in a way that minimizes negative impacts and maximizes benefits to low- and moderate-income households and disadvantaged communities. For example, the revenue source could be used to enhance public transportation or vehicle scrap and replace programs, and exemptions could be granted for priority populations. In contrast, the current system of free roads disproportionately burdens lower-income communities while benefiting the more affluent.[330] In order to design a successful program, California can draw upon various examples implemented or planned worldwide that would minimize adverse equity impacts, including New York, Chicago, London, Paris, Stockholm, Oslo, and Singapore.[331, 332]

c. Incentivize local governments to develop local ZEV readiness plans and implement policies to encourage the use of ZEVs, such as preferential or discounted parking programs and curbside charging.

Regional readiness plans enable communities to plan for and efficiently deploy ZEV infrastructure, permitting procedures, and other supportive policies that enable successful support of ZEVs within a region. Local governments also have the ability to implement other policies that favor ZEVs, for example by providing curbside charging and parking-related incentives such as free or discounted parking for ZEVs or by locating ZEV parking spaces in desirable locations.

5) Fleet adoption

As a wider array of ZEVs and PHEVs becomes available, light-, medium-, and heavy-duty commercial fleets of all types will have more opportunities to adopt and use them,

[330] Manville and Goldman, 2017. March 24, 2017. "Would Congestion Pricing Harm the Poor? Do Free Roads Help the Poor?" Journal of Planning Education and Research. Volume 38, Issue 3, Pages 329-344. https://doi.org/10.1177%2F0739456X17696944

[331] DuPuls, et al., 2019. National League of Cities. "Making Space: Congestion Pricing in Cities." https://www.nlc.org/sites/default/files/2019-08/CSAR_ConjestionPricingReport_Final.pdf.

[332] Ecola and Light, 2009. RAND Technical Report. "Equity and congestion pricing: A Review of the Evidence." https://www.rand.org/pubs/technical_reports/TR680.html.

with the potential to rapidly expand both market growth and consumer awareness of ZEVs and zero-emission miles.

a. **Direct CARB to adopt zero-emission mileage requirements in all high-mileage and new mobility fleets (such as carsharing), while ensuring that these requirements also aim to minimize vehicle miles traveled overall (e.g., by building connections to transit and active transportation wherever possible, similar to SB 1014).[333]**

   High mileage vehicles, such as those used for carsharing and delivery fleets, emit more GHGs and criteria air pollutants because each vehicle is driven much more than average. The only related CARB effort in the light-duty sector has been the development of the Clean Miles Standard,[334] in response to SB 1014, which will require TNCs to decrease their carbon dioxide emissions per passenger mile over time and meet zero-emission mile targets. CARB plans to develop the ZEV Truck Regulation[335] for medium- and heavy-duty fleets. CARB staff recommend requiring a minimum percentage of zero-emission miles in other types of high-mileage and new mobility light-duty applications, such as carsharing, taxis, on-demand delivery services, and driverless vehicles. Because these vehicles have high mileage and thus have the ability to reduce a greater amount of GHG and criteria pollutant emissions compared to a privately owned vehicle, targeting high mileage new mobility vehicles would result in more emissions savings. This recommendation is aligned with the principles outlined by the Multi-Agency Workgroup on Automated Vehicle Deployment for Healthy and Sustainable Communities.[336]

b. **Direct the Department of General Services (DGS) to track vehicle usage and establish zero-emission VMT targets for the State's fleet, and set ZEV targets for other vehicles used by the State (e.g., rental cars and new mobility services used for State employee travel).**

   California is leading by example by requiring all new non-public safety sedans purchased by State agencies to be ZEVs. California should continue leading by example setting a zero-emission VMT target in order to ensure these vehicles are actually utilized. Replacing gasoline and diesel miles with zero-emission miles supports the underlying State air quality and climate goals. Because California recently selected a vendor as its single vehicle telematics provider,[337] CARB staff recommend that the Department of General Services (DGS) take advantage of the data obtained from logging in-use vehicles across California's

[333] Skinner, Chapter 369, Statues of 2018.

[334] See Appendix B for a description and status of the Clean Miles Standard.

[335] See Appendix B for a description and status of the ZEV Truck Regulation.

[336] California Multi-Agency Workgroup on AV Deployment for Healthy and Sustainable Communities, 2018. "Automated Vehicle Principles for Healthy and Sustainable Communities." http://opr.ca.gov/docs/20181115-California_Automated_Vehicle_Principles_for_Healthy_and_Sustainable_Communities.pdf.

[337] Geotab, 2019. Press Release. May 15, 2019. "Geotab Selected as Sole Telematics Provider by the State of California." https://www.geotab.com/press-release/california-contract-win/. Accessed July 1, 2019.

light-, medium-, and heavy-duty fleet to help meet State goals. Specifically, data collected and analyzed through the vendor could identify opportunities to decrease overall VMT and increase zero-emission VMT. In the longer-term, CARB staff recommend directing DGS to set VMT and zero-emission-VMT targets for the State's fleet based on the data logged and the availability of ZEVs to meet the operational needs of the State fleet.

Additionally, CARB staff recommend directing DGS to set ZEV targets for light-, medium-, and heavy-duty vehicles contracted by the State. This includes vehicle purchases, long-term leases and rentals, as well as short-term rentals and new mobility services used during State employee travel. In addition, CARB staff encourage DGS to institute a "ZEV first" requirement for car rentals, when vehicles available meet the needs of the rental agency. These new actions would build upon existing State directives regarding State agency fleet electric vehicle purchases[338, 339, 340, 341, 342, 343] and would help to further accelerate the ZEV market in order to meet the air quality and climate goals.

With respect to State employee travel, CARB staff first recommend increasing the travel lodging rates to allow employees to stay as close as possible to the travel event location. This would result in reduced VMT during travel by not needing to rent or use a vehicle to reach the travel event location.

c. Establish ZEV targets for other government fleets as ZEV models become available to meet their needs.

Local governments should also lead by example, and prepare for the increasing number of ZEVs in their jurisdictions. CARB staff recommend setting a minimum percentage ZEV requirement for local jurisdiction's light-, medium-, and heavy-duty fleets, and in particular the higher usage vehicles within those fleets, as ZEVs become available to meet their needs. This is already required for public transit agencies through the Innovative Clean Transit regulation.

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[338] SB 498 (Skinner, Chapter 628, Statutes of 2017) also requires the purchase of at least 50 percent light-duty ZEV purchases for the State fleet beginning in 2024-2025 and every year thereafter.

[339] DGG, 2016. State Administrative Manual Management Memo 16-07. December 2, 2016. "Zero-Emission Vehicle Purchasing and Electric Vehicle Service Equipment Infrastructure Requirements." https://www.dgs.ca.gov/-/media/Divisions/OSPPR/Memos/MM16_07.ashx.

[340] Executive Order B-18-12 orders that State agencies identify and pursue opportunities to provide electric vehicle charging stations, and accommodate future charging infrastructure demand, at employee parking facilities in new and existing buildings. https://www.ca.gov/archive/gov39/2012/04/25/news17508/index.html. Accessed July 1, 2019.

[341] Executive Order B-16-12 set a minimum light-duty ZEV purchase requirement for the State fleet of at least 10 percent by 2015 and 25 percent by 2020. https://www.ca.gov/archive/gov39/2012/03/23/news17472/index.html. Accessed July 1, 2019.

[342] AB 739 (Chau, Chapter 639, Statutes of 2017) calls for 30 percent of all new medium- and heavy-duty state vehicle purchases to be ZEVs by 2030.

[343] Executive Order N-19-19. September 20, 2019. https://www.gov.ca.gov/wp-content/uploads/2019/09/9.20.19-Climate-EO-N-19-19.pdf.

6) Outreach and education

Low ZEV awareness has been identified as a main barrier to ZEV adoption,[344, 345] *and ongoing efforts lack sufficient resources to scale up.*

a. **Create a State "Electricity Rate" Ombudsperson to provide expertise to fleets that are transitioning to ZEVs.**

Electricity costs for transportation electrification are difficult to predict and can be higher than gasoline or diesel depending on the electricity rate a fleet is enrolled in through their local utility and their charging behavior, especially for commercial entities.[346, 347] CARB staff recommend funding a position that can help fleets understand their electricity bill, optimize their charging behavior, and identify other strategies to maximize ZEV fuel cost savings due to complex electricity rate structures and demand charges.[348]

b. **Increase funding for existing and new programs for ZEV consumer and fleet outreach and education campaigns to build awareness and dispel misconceptions about ZEVs, including for priority populations and heavy-duty fleet operators.**

CARB staff recommend increased funding for efforts that grow ZEV awareness and understanding. Multiple studies have found that ZEV awareness is low, thus limiting market growth.[349] If consumers and fleet operators do not know about these vehicles, or are misinformed about ZEVs, they will not buy or lease them. There are ongoing efforts focused on ZEV educational campaigns, such as the DriveClean website,[350] the Clean Vehicle Rebate Project outreach,[351] ride-and-drives, and more recently, Veloz's Statewide consumer awareness campaign,[352] but these have been small scale due to limited resources. CARB staff also recommend seeking investments from the private sector to support these efforts. Additionally, CARB staff recommend piloting out-of-the-box efforts, such as incentivizing light- and heavy-duty driver education facilities to train future drivers using ZEVs to increase awareness and familiarity with the technology, which could be a powerful outreach campaign.

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[344] Kurani, et al., 2016. Final Report. March, 2016. "New Car Buyers' Valuation of Zero-Emission Vehicles: California" https://ww3.arb.ca.gov/research/single-project.php?row_id=65166.

[345] Turrentine, et al., 2018.

[346] Nicholas, 2018.

[347] Lee and Clark, 2018.

[348] Because demand charges are based on the maximum load, rather than the average, they penalize short bursts of high power demanded from charging electric vehicles, especially with the faster chargers. Demand charges favor consistent loads, even if high.

[349] Turrentine, et al., 2018.

[350] CARB. "DriveClean." https://www.driveclean.ca.gov/. Accessed August 1, 2019.

[351] See https://cleanvehiclerebate.org/eng/ev and https://cleanvehiclerebate.org/eng/local-events-and-workshops.

[352] Veloz, 2019. "Electric For All." https://www.veloz.org/initiatives/electric-for-all/. Accessed August 15, 2019.

c. **Fund training for local government inspection, building, and planning officials, and builders, about ZEVs and ZEV infrastructure to achieve ZEV infrastructure permit streamlining for light- and heavy-duty applications.** Installation of infrastructure is taking longer to build out in California than in other states due in part to slow permitting processes. ZEV infrastructure permitting timeliness and complexity is a barrier despite the requirement for local jurisdictions to streamline permitting pursuant to AB 1236,[353] which requires all cities and counties to develop an expedited, streamlined permitting process for all levels of electric vehicle charging stations. Outreach to permitting officials and builders regarding siting and permit review best practices would speed up and reduce the cost of ZEV infrastructure installations for both light-duty and heavy-duty applications.[354] CARB staff recommend funding to help facilitate ZEV infrastructure permit streamlining per Assembly Bill 1236. In conversations with local jurisdictions, many have mentioned they have not complied with AB 1236 due to limited resources.[355] This recommended funding would also include instruction for local government inspection, building, planning, and permitting staff on zero-emission vehicles and infrastructure in order to help facilitate quicker resolution of permits. Additionally, this permit streamlining process and training should be expanded to include hydrogen stations as well. Finally, this recommendation includes training for residential and commercial developers and builders to increase their understanding of ZEV infrastructure, CALGreen building code requirements, California Building Code accessibility requirements, and the permitting process.

d. **Provide funding for CARB to establish partnerships with manufacturers and the academic community to foster experimentation and innovation.**

CARB staff recommend funding for CARB to pilot how partnerships with industry and the academic community could help grow the ZEV market. For example, the funds could be used to fund innovative pilots to accelerate commercialization and deployment of ZEVs. Research into sustainable business models for ZEV manufacturers and charging/fueling, ZEV opportunities in the freight sector, and strategies to ensure California's policies are exportable to other jurisdictions and will help California build a sustainable ZEV market and ensure that the State remains at the leading edge of the ZEV transition. These partnerships could create a public forum for sharing lessons learned from adopting zero-emission technology across the heavy-duty applications.

[353] Chiu, Chapter 598, Statutes of 2015.

[354] GO-Biz's Electric Vehicle Charging Station Permitting Guidebook provides a foundational outreach document: http://businessportal.ca.gov/wp-content/uploads/2019/07/GoBIZ-EVCharging-Guidebook.pdf.

[355] In July 2019, GO-Biz initiated a formal evaluation of compliance with AB 1236, and the effort continues.

7) Workforce development

The ZEV transition will require a growing workforce that can manufacture, repair, and support zero-emission vehicles and infrastructure to support job creation and business development. Both the Cap-and-Trade Auction Proceeds Third Investment Plan[356] and CARB staff's report that identified barriers that low-income Californians face in accessing zero-emission transportation options[357] highlighted the importance of workforce training, especially within disadvantaged and low-income communities, to enable the transition to a low carbon economy and zero-emission transportation.

a. **Increase investment in existing California Workforce Development Board (CWDB) and Employment Training Panel (ETP) programs that target occupation and skill gaps and promote job preparation through partnerships between educational institutions and ZEV-related employers.**

   Growing a strong ZEV workforce requires that professional development, training, and apprenticeships match occupation gaps and lead to employment. This investment is particularly critical for priority populations. CARB staff recommend funding for CWDB to build partnerships between ZEV-related industries and educational institutions, aligned with the High Road Training Partnerships (HRTP) initiative.[358] These partnerships would then identify the expected occupation and skill gaps in order to determine the appropriate ways to prepare the needed workforce through professional development, training, pre-apprenticeships, and apprenticeships. CARB staff additionally recommend additional funding for ETP to implement a deliberative workforce development effort targeted to disadvantaged communities. This effort would include curriculum development and vocational instruction focused on developing the skills identified by ZEV-related industry training partnerships.

b. **Fund CWDB to conduct research on the net job benefits from public investments in zero-emission vehicles and infrastructure and identify strategies to ensure the quality and accessibility of these jobs.**

   Transitioning the transportation sector to zero-emission will create jobs associated with low carbon transportation but more information on the net flow of jobs between economic sectors is needed to ensure that California's economy remains strong. CARB staff recommend funding research through CWDB to analyze the number, type, and quality of jobs resulting from the

[356] California Department of Finance and CARB, 2019. January 2019. "Cap-and-Trade Auction Proceeds Third Investment Plan: Fiscal Years 2019-20 through 2021-22." https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/2019_thirdinvestmentplan_final_021519.pdf.

[357] CARB, 2018a.

[358] CWDB's High Road Training Partnerships (HRTP) initiative invests in labor market intermediaries that help convene employers and workers, by industry and within a specific region, to: 1) address the critical skill issues emerging as every industry faces the challenges of climate change and environmental sustainability, 2) increase the capacity of firms and workers to adapt and compete in a carbon-constrained economy, and 3) help California communities prosper by creating accessible local pathways into safer, healthier, and more highly skilled jobs.

transportation electrification projects funded through public and utility ratepayer investments. Furthermore, this study should also identify and examine strategies that public agencies can take in order to ensure that public funds are creating or supporting, and increasing access to high quality jobs; the CEC demonstrated one such strategy, by incorporating information about employee work environment, policies, and practices[359] into their scoring criteria for a zero-emission school bus solicitation.[360] Furthermore, a more general and holistic study is also needed to determine the overall impact of the transition of the transportation sector to zero-emission technology on the economy and jobs.

8) Program flexibility

Agencies administering ZEV programs need flexibility and longer expenditure deadlines for funding to respond to the rapidly evolving ZEV market, keep programs streamlined and easy to access and understand by consumers, support ZEV development especially in the earliest stages of commercialization, and respond to needs from priority populations.

a. Remove statutory barriers that inhibit consumers' ability to access ZEV incentives.

Competing priorities for incentive programs often lead to complexity; for example, rebate income caps introduce complexity that prevents the rebates from being provided at the point-of-sale without burdensome pre-qualification. Simplification of programs would increase program effectiveness. CARB staff recommend minimizing program complexity so that administering agencies can design and implement programs that consumers and fleet operators can readily understand and access while still meeting the State's goal.

b. Remove statutory barriers that limit ZEV program adaptability.

Many existing ZEV programs have specific requirements that become outdated as the ZEV market matures, hindering their ability to respond to the emerging market. More flexibility in funding program requirements would allow investments to shift toward the emerging technologies that will continue to accelerate the ZEV transition. CARB staff recommend allowing discretion and flexibility when agencies develop and implement programs aligned with State goals. This discretion and flexibility to make changes to ZEV programs in real-time would allow agencies to respond to a maturing ZEV market and other external factors. This would help CARB and other administering agencies create innovative solutions to simplify and streamline ZEV programs for consumers and fleet operators while still meeting the program's goals. Removing program

[359] This includes information on the wages, benefits, hours worked, and opportunities for training and upward mobility.

[360] CEC, 2019. "GFO-18-604 - Establish Bulk Purchase Pricing for Electric School Buses." https://www.energy.ca.gov/solicitations/2018-12/gfo-18-604-establish-bulk-purchase-pricing-electric-school-buses. Accessed Aug 15, 2019.

requirements set in statute to fund specific zero-emission and low carbon technologies at certain amounts would give the administering agencies the added flexibility to allocate the total funds based on the current state of the ZEV market, technology, and the deployment of ZEV infrastructure in order to maximize the air quality and climate benefits.

c. Continue to provide four years as the funding liquidation deadline especially for technology demonstration projects, pilots, and programs that include ZEV refueling infrastructure.

CARB staff recommend continued extension of the liquidation deadlines for Clean Transportation Incentives from two years to liquidate to four, as was done in the 2019-2020 budget, in order to ensure sufficient time for program completion—especially for technology demonstration projects, pilots, and programs that include ZEV infrastructure since building these pre-commercial vehicles and designing and installing ZEV infrastructure is a multiyear process. These projects have lengthy permitting and CEQA review processes, in addition to the complex vehicle manufacturing and installation of ZEV infrastructure that are difficult to complete in two years, as allowed by the budgets prior to 2019-2020; for demonstration projects this leaves little time for data collection and reporting. This recommendation would make funding deadlines consistent with similar technology demonstration programs administered by CEC[361] that allow four years to liquidate.

[361] These CEC programs are the Clean Transportation Program, also known as the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP); the Electric Program Investment Charge Program (EPIC); and the Food Production Incentive Program.

CHAPTER 9: RECOMMENDATIONS FOR FLEETS TO INCREASE ZEVS

SB 498 also directed CARB to include recommendations on how vehicle fleet operators can increase the number of ZEVs in vehicle fleet use. For the purposes of SB 498, fleets are defined as ten or more vehicles under common ownership or operation. However, the recommendations outlined below apply to smaller fleets. These recommendations are for steps that owners and operators of light-, medium-, heavy-duty fleets as well as mixed fleets should take to increase the number of ZEVs, which may reduce their operating costs. These recommendations were developed by reviewing available resources.[362, 363, 364, 365, 366, 367, 368, 369, 370, 371] California, along with Oregon, Washington, and British Columbia have created West Coast Electric Fleets[372] as a clearinghouse of resources that fleets can utilize to increase ZEV usage by public and private fleets. In addition, CARB is currently funding a research study that, among other tasks, will create a guidance document for heavy-duty fleets looking to switch to alternative fuels;[373] this document is expected to be available in 2020. CARB staff recommends fleets do the following:

[362] Natural Resources Canada, 2018. "Greening Government Fleets: A Helpful Guide to Understanding Best Practices." https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/transportation/NRCan_GreeningGovFleets_e.pdf.
[363] GreenBiz, 2018. "Curve Ahead: The Future of Commercial Fleet Electrification." https://sustainability.ups.com/media/UPS_GreenBiz_Whitepaper_v2.pdf.
[364] Lee and Clark, 2018.
[365] Lutsey and Nicholas, 2019. ICCT Working Paper. April, 2019. "Update on Electric Vehicle Costs in the United States through 2030." https://theicct.org/sites/default/files/publications/EV_cost_2020_2030_20190401.pdf.
[366] Li, et al., 2019. World Resources Institute. "How to Enable Electric Bus Adoption in Cities Worldwide." https://wriorg.s3.amazonaws.com/s3fs-public/how-to-enable-electric-bus-adoption-cities-worldwide.pdf.
[367] Sclar, et al., 2019. World Resources Institute. "Barriers to Adopting Electric Buses." https://wriorg.s3.amazonaws.com/s3fs-public/barriers-to-adopting-electric-buses.pdf.
[368] Meroux and Tal, 2018. April 3, 2018. "Policies to Maximize Fuel Economy of Plug-in Hybrids in a Rental Fleet." SAE Technical Paper 2018-01-0670. https://doi.org/10.4271/2018-01-0670.
[369] Foellmer, 2019. NAFA Webinar. June 5, 2019. "The Electrification Checklist." https://www.youtube.com/watch?v=2pDMV-66RwU.
[370] West Coast Electric Fleets, 2019. "Webinars" http://www.westcoastelectricfleets.com/business-case-for-fleet-electrification/. Accessed August 1, 2019.
[371] CSE, 2019. "Clean Vehicle Rebate Project." YouTube Channel. https://www.youtube.com/channel/UCY4k_1fFRLbkZ0sb5amstpw.
[372] West Coast Electric Fleets, 2019. "West Coast Electric Fleets." http://www.westcoastelectricfleets.com/. Accessed August 15, 2019.
[373] Samuelson, 2019. "The Optimal Route for a Clean Heavy Duty Sector in California." https://ww3.arb.ca.gov/research/single-project.php?row_id=65448.

Battery Electric Vehicle Charging Infrastructure

Charging infrastructure: includes the "make-ready" components that support EV charging including the electrical infrastructure from the utility-side (e.g. transformer and distribution circuit) to the customer-side connecting the vehicle (electrical panel, conduit, and wiring) to the EVSE.

Electric vehicle supply equipment (EVSE): equipment that interconnects the alternating current from the electricity grid to the electric vehicle to allow charging.

There are three types of plugs for charging vehicles:

Level 1: uses a standard 120 volt electrical outlet; adds 2-5 miles of range per hour of charging.

Level 2: uses a 240 or 208 volt plug; adds 10-20 miles of range per hour of charging.

DC Fast Charger: uses a 408 volt plug and requires specialized, high-powered equipment and be supported by vehicle; adds 60-80 miles of range per 20 minutes of charging.

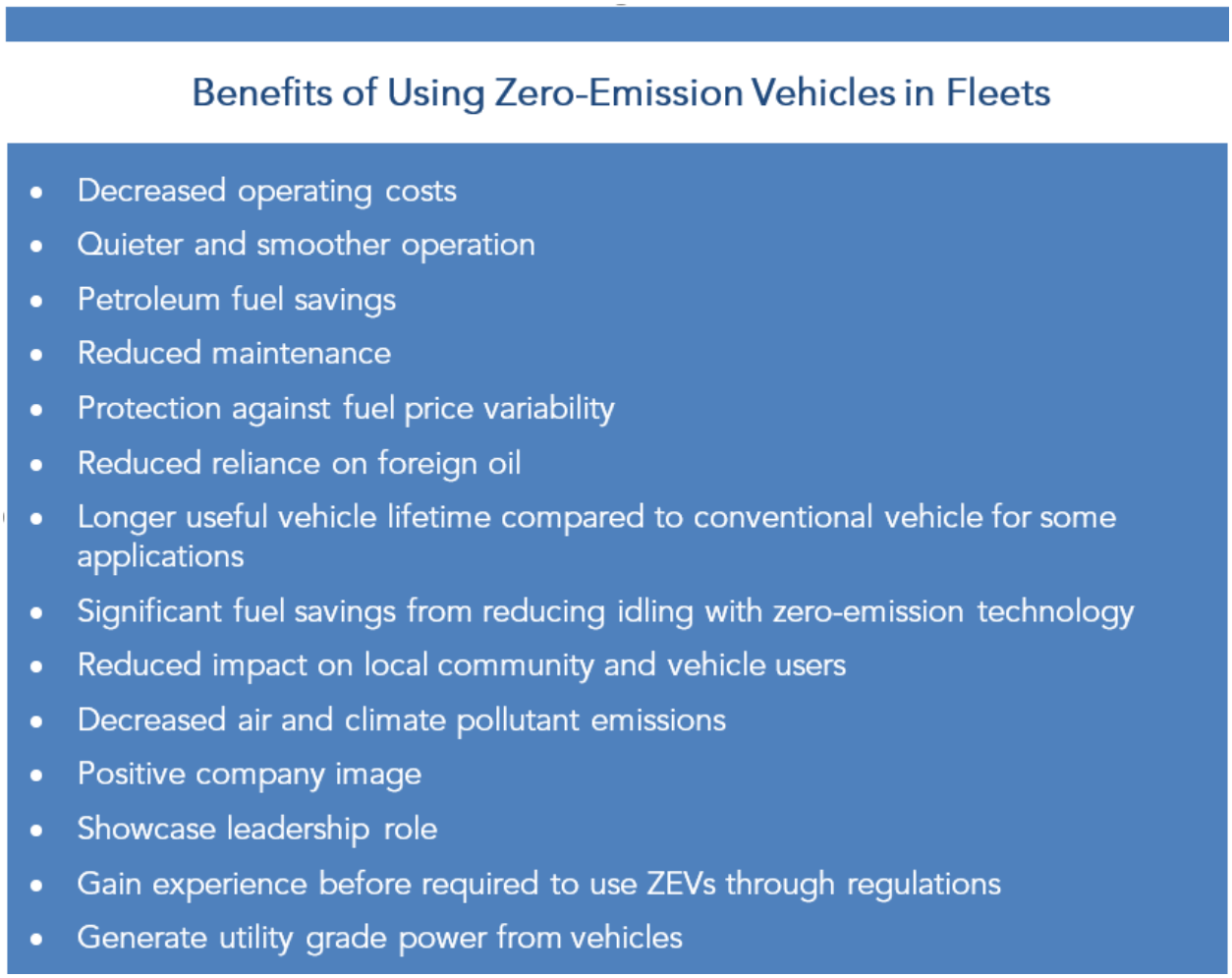
1) Assess fleet needs

a. Assess current baseline of fleet vehicle usage, fuel consumption, maintenance, and costs.

The first step in the process is to assess the current fleet vehicle usage and fuel consumption baseline for comparison with any alternatives. Vehicle usage refers to average daily miles driven, maximum daily miles driven, annual miles traveled, and the temporal pattern of vehicle operation and non-operation. The non-operation pattern is useful for figuring out if the vehicle is parked long enough to charge. Ideally, vehicle usage can be determined per individual vehicle, but the next best thing is to understand the vehicle usage per vehicle type, per route, or per application. The fleet vehicle usage can be easily tracked through a data logging or telematics device, a smart telephone application,[374] or by the built-in telematics capability available in some vehicles. In addition, identify the most important vehicle performance characteristics per vehicle application. Through this assessment, identify potential good candidate routes or applications that can be served by ZEVs. To get the most out of the ZEVs, these vehicles should be placed in routes or applications where they can fully utilize the vehicle range to maximize the fuel savings.

[374] Such as My Green Car, available at https://mygreencar.com/.

The fuel consumption of the current fleet should also be tallied by the same vehicle break down as utilized for the vehicle usage. This can be done by 1) tracking the number of gallons of fuels used, if fleet has dedicated fueling infrastructure, 2) checking with the fuel card provider as this is typically a service provided, if fleet uses such a service, or 3) summing the fueling receipts.



b. Assess future fleet needs

Beyond knowing the expected fleet turnover, fleets should do their best to estimate their future needs. How will the fleet needs evolve over time? Is there a reason to expect the fleet must drive more or less? Will more or fewer vehicles be needed? Will a different vehicle utility be required? Taking time to assess future fleet needs is important in planning for success, regardless of which vehicle technology is utilized.

2) Research zero-emission options

a. Learn about zero-emission choices

Before choosing what vehicles to purchase or lease, learn about the latest ZEV offerings since choices are rapidly multiplying across the light-, medium-, and

heavy-duty applications. As the ZEV market matures, the variety in ZEV body styles and platforms continues to expand, supporting more zero-emission technologies used in diverse vocations. While most fleets zero-emission range requirements can be met with fuel cell technology, the electric range of plug-in electric vehicles also continues to expand, facilitating more integration of both plug-and fuel cell powered ZEVs throughout the fleet. In addition to learning about the vehicles, it is also important to test drive them using your fleet's drive cycle.

Barriers to Zero-Emission Vehicle Adoption by Fleets

- Higher upfront vehicle costs
- Lack of charging or fueling infrastructure
- No ZEVs available for specific applications
- Current vehicles available may not meet operational needs
- Confusing or unknown fueling costs
- Rigid procurement requirements, especially for public fleets
- Increased time for building certain ZEV medium- and heavy-duty vehicles
- Reluctance to change
- Vehicle manufacturer instability
- Discomfort with new technologies
- Too complicated
- Unknown residual value

A fundamental benefit of ZEVs is low operating and maintenance costs compared to conventional vehicles.[375] This is due to reduced maintenance needs from having fewer moving parts and from cheaper fuel cost per mile. However, because the upfront costs of new ZEVs is still higher than conventional vehicles, costs should be analyzed per the total cost of ownership. Fleet operators should also investigate used ZEVs. For some fleet applications, a used or repowered ZEV may meet the needs at a reduced upfront cost compared to a new ZEV.

[375] Hardman, et al., 2018. International EV Policy Council Policy Guide. March 2018. "Driving the Market for Plug-in Vehicles: Developing Charging Infrastructure for Consumers." https://phev.ucdavis.edu/wp-content/uploads/Infrastructure-Policy-Guide-March-2018.pdf.

Because fleet operators must consider refueling their vehicles and not only acquiring them, they should learn about the three charging speeds of plug-in electric vehicles, availability and access to public charging, and costs and options available for installing on-site electric vehicle infrastructure.

With respect to speed, most charging needs can be met with Level 1 or Level 2, with DC fast charging for days when the miles driven exceed the vehicle's electric range. Be aware that not all plug-in electric vehicles are capable of fast charging, and having a vehicle built-in fast charge port is not standard on plug-in electric vehicle models. The majority of plug-in hybrid vehicles are not fast charge capable. Similarly, it is worth getting familiarized with the different costs of refueling, as the potential reduced expenses is a strong motivator for adopting ZEVs.

Installing electric vehicle infrastructure can be a lengthy and costly process through planning, permitting, and construction. When installing charging infrastructure, site operators must ensure that the electrical capacity at the site and the grid can handle the added electrical load. If building or renovating a facility or parking lot, consider installing electric vehicle capable infrastructure that includes the needed panel capacity and conduit, so it is cheaper to install the wiring and electric vehicle supply equipment (EVSE) in the future without having to trench out the area. If constructing new facilities, these should be located close to power stations and designed to maximize electric charging capacity. However, there are other alternatives that provide turnkey electric vehicle infrastructure solutions not permanently connected to the electrical grid or require any construction. For example, there are portable EVSE units[376] and portable integrated EVSE units powered by on-site renewable energy generation.[377] Through "smart" or power management software and hardware, it is also possible to increase the number of EVSE available at sites that already have at least one installed without installing more electric capacity or electrical infrastructure.[378] Smart charging can reduce the cost to expand the number of EVSEs and the demand charges associated with the higher power draws of having multiple independent EVSE charging vehicles simultaneously. Fleet operators also need to consider whether 1) EVSE should be open to the public or kept private for the fleet's needs, 2) the system should be networked or not, and 3) the business case for working with an EVSP. Additionally, it is worth learning about the heavy-duty ZEV infrastructure options available, such as overhead charging, flash charging, etc.

[376] SparkCharge's ultrafast, portable charge is one example: https://sparkcharge.io/.
[377] Envision Solar's Electric Vehicle Autonomous Renewable Charger (EV ARC) is one such example: https://envisionsolar.com/products/ec-arc/.
[378] This approach would limit the amount of power available to charge thus decreasing the charging speed.

For hydrogen-powered fuel cell vehicles, fleet managers should learn about the current[379] and planned[380] hydrogen retail stations, and the typical costs to refuel. Fleet operators can also negotiate set hydrogen fuel prices with fuel providers. If there is sufficient demand for hydrogen fueling, fleet operators should also learn about the process and cost of installing a hydrogen station on site.

b. Explore zero-emission technology incentives and other policies

Because ZEVs may have an initial upfront cost compared to conventional vehicles while the market is still maturing and they require specific refueling infrastructure, seek out information on zero-emission vehicle and infrastructure incentives and grants from federal, state, and local governments, and utilities, and other entities. There are several clearinghouses that compile this information.[381, 382] This includes learning about the Low Carbon Fuel Standard credits for ZEV infrastructure and fuel.[383] In addition, fleet operators should learn about any upcoming or potential local, state, federal ZEV mandates that may affect them.

c. Learn from the ZEV experiences of other fleets

Taking the time to learn from the positive and negative experiences of other fleets using zero-emission technology can yield valuable insights that cannot be learned anywhere else. This can be done by watching webinars on fleet electrification, attending workshops and meetings,[384] and by participating in various fleet managers associations and in ZEV fleet specific groups, such as West Coast Electric Fleets.[385] Developing relationships with other fleet operators and other actors in this space is also worthwhile, as they can help answer questions and help troubleshoot.

3) Collaborate with internal and external stakeholders

a. Engage with internal stakeholders early and often

An essential step before trying to electrify the fleet is to have discussions on using zero-emission technology among internal stakeholders, including drivers, mechanics, procurement staff, internal fleet clients, and senior management. Explain the benefits of using ZEVs in the fleet and barriers to adoption in your specific situation. Understand how the budget may shift internally among different teams or departments. For example, while the fleet team may see fuel

[379] See https://m.cafcp.org/ for current station status.
[380] California Fuel Cell Partnership, 2019. "Station Map." https://cafcp.org/stationmap. Accessed August 15, 2019.
[381] For example, see the Funding Wizard and select the transportation category or use this link directly: https://fundingwizard.arb.ca.gov/search/all?f%5B0%5D=field_category%3A97. Accessed August 15, 2019.
[382] CARB, 2019. "Projects in Action." https://www.arb.ca.gov/msprog/lct/project.htm. Accessed August 15, 2019.
[383] CARB, 2019. Last Updated September 3, 2019. "LCFS ZEV Infrastructure Crediting." https://www.arb.ca.gov/fuels/lcfs/electricity/zev_infrastructure/zev_infrastructure.htm. Accessed August 15, 2019.
[384] Such as the annual Advanced Clean Transportation Expo: https://www.actexpo.com/.
[385] West Coast Electric Fleets: http://www.westcoastelectricfleets.com/.

savings, the facilities team sees a higher electrical bill. Having strong internal buy-in will help in overcoming the barriers.

b. Define motivation for electrifying the fleet

With internal stakeholders, define motivations for electrifying the fleet. It could be a combination of lower total cost of ownership, sustainability goals, building a positive reputation, or satisfying current or potential regulations. Having a clear motivation can help focus actions and build support among internal stakeholders.

c. Build external partnerships

It is never too early to contact your local utility, ZEV industry representatives, and others to build partnerships that can help ensure alignment and success. Perhaps you can work with other partners on a ZEV grant, to share infrastructure, or to troubleshoot. Utilities can help assess and develop charging strategies to fit each fleet and facility needs. They can also explain your local electric rate structures and recommend one for your fleet.

4) Develop and implement a strategic plan to acquire and utilize ZEVs

a. Develop a strategic plan to acquire ZEVs

Once you have the fleet vehicle usage information ready, researched zero-emission vehicles, infrastructure and incentives, identified the specific barriers to ZEV adoption in your fleet, and identified the motivation for moving forward with ZEVs, the next step is to put all this information together to develop a strategic plan. Because every fleet has different needs, budgetary constraints, and their own internal, local, and state policies, it is important to develop a strategic plan that accounts for all of these factors. The plan should include specific details on the items enumerated below that are aligned with your fleet's motivations:

i. *Suitable applications*: which vehicle types, routes or applications are best suited to ZEVs within the fleet

ii. *Suitable ZEVs and manufacturers*: which manufacturers offer ZEVs that support the identified suitable applications based on drive cycle and other performance characteristics; what is the purchase cost and lead time for building these ZEVs; will the manufacturers be around for the long-term

iii. *Refueling*: how, when, and at what cost will these vehicles be fueled; how will the refueling infrastructure be accessed to support the fleet; is it worth negotiating set fuel prices with fuel providers for off-site charging; whether on-site infrastructure will be needed, what type, how much, and at what cost; will this on-site infrastructure be limited to fleet-use only; strategies for compensating employees or contractors for at-home or public charging

iv. *Cost comparison*: what is the estimated total cost of ownership for the ZEVs compared to conventional vehicles; what types of incentives are available

v. *Paying for vehicles*: what is your fleet's budget; identify strategies to reduce cost (incentives, bulk purchasing, renting, leasing, etc.) working within your budget, is it better to purchase or lease;

vi. *Servicing vehicles*: how will these vehicles be serviced and maintained and by whom; what is the warranty of these vehicles and what is requirement to keeping warranty valid

vii. *Key performance indicators*: establish key performance indicators and tracking strategies to know ahead of time how success will be measured

viii. *Training*: what training is needed for vehicle drivers, service technicians, and others to support successful deployment and tracking of key performance indicators

ix. *Overcoming barriers*: what steps can be taken to surmount the barriers identified

x. *Return on investment*: what is the expected return on investment

xi. *Timeline*: develop a timeline of actions. For example, ensure ZEVs delivery is synchronized with refueling and charging infrastructure availability.

xii. *Reassess*: periodically reassess based on changing needs, changes in local and state policies, costs, maturing ZEV market, etc.

Start simple with a small scale pilot to gain experience with ZEVs and to ensure they satisfy the fleet's need before acquiring more. Based on the lessons learned during the initial ZEV experience, update the strategic plan, the cost analysis and move forward from there.

There are existing resources and tools that can be leveraged to develop the strategic plan. The Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) tool allows light-, medium-, and heavy-duty fleet managers to estimate petroleum use, greenhouse gas and air pollutant emissions, and to compare the total cost of ownership of ZEVs to conventional vehicles.[386] The EV SmartFleets Fleet Procurement Analysis Tool compares light-duty vehicle procurements side-by-side on a cost-per-mile basis and analyzes cash flows and location-specific lifecycle emissions.[387] The Battery-Electric Truck

[386] Available at: https://greet.es.anl.gov/afleet_tool.
[387] Available at: https://www.atlasevhub.com/materials/fleet-procurement-analysis-tool/.

and Bus Charging Cost Calculator estimates annual electricity cost for battery electric truck and bus deployments at a utility meter.[388]

It is also worth investigating the option of participating in bulk or aggregate purchase agreements to minimize the upfront cost of ZEVs. California has several State procurement contracts for zero-emission light-, medium-, and heavy-duty vehicles and charging infrastructure that public agencies throughout the State can also use.[389] California is also setting up a Statewide contract for electric buses.[390] Similarly, cities[391] across the United States leveraged their collective buying power to accelerate the conversion of public fleets to ZEVs through the Climate Mayors Electric Vehicle Purchasing Collaborative.[392] This collaborative provides a turnkey procurement portal that U.S. cities, counties, state governments and public universities can use to acquire light-duty ZEVs and charging infrastructure. Other purchasing agreements can also be setup following previous successful examples.[393] Besides purchasing agreements, state or local government agencies can get help financing their ZEVs.[394]

b. Implement your strategic plan

Once the strategic plan has been developed, put it into action. Know that the plan should be a living document that evolves with lessons learned and as ZEV technology matures. With internal consensus built around ZEVs and external relationships built with fleet managers and other actors in the space, you are now prepared to overcome challenges to implementation.

c. Assess and make corrections

Continue to assess the vehicle usage of the ZEVs in your fleet. Are they performing as expected? Are they being fueled appropriately? Have your fleet's needs changed? Also, solicit feedback from the vehicle operators and users to ensure you know of issues early and can take corrective measures, such as training, providing refueling instructions in the vehicle, educating on charging etiquette, etc.

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[388] Available at: https://ww2.arb.ca.gov/resources/documents/battery-electric-truck-and-bus-charging-cost-calculator.

[389] Go to https://www.caleprocure.ca.gov/pages/LPASearch/lpa-search.aspx and type "fleet vehicle" or "EVSE" to find the current contracts.

[390] https://www.dgs.ca.gov/PD/Announcements/Release-of-Request-for-Proposal-for-Zero-Emission-Buses.

[391] With the goal of helping to maintain the U.S. commitment to the Paris Climate Agreement.

[392] https://driveevfleets.org/.

[393] See for example: https://www.georgetownclimate.org/files/report/Capturing-the-Federal-EV-Tax-Credit-for-Public-Fleets%20-%20Case%20Study.pdf.

[394] For example, through the Golden State Financial Marketplace (GS $Mart), which works with a pool of prequalified lenders that offer the most competitive, tax-exempt interest rates https://www.dgs.ca.gov/PD/Resources/Page-Content/Procurement-Division-Resources-List-Folder/GS-$Mart-Frequently-Asked-Questions.

5) Share your ZEV fleet experiences

a. Let your constituents know about your ZEVs

Based on your fleet's motivations for pursuing ZEVs, promote these vehicles within the community where the fleet operates and beyond. This can be done by identifying the vehicles themselves as zero-emission through decals or other physical markers or labels. In addition, you can use traditional press coverage, newsletters, and social media to get the word out.

b. Contribute your ZEV experience to the general knowledge

Help other fleets by sharing your ZEV experiences. Write up a case study on your ZEV experience. Provide a talk or webinar on the lessons learned from your fleet's experience. Let folks know whether your fleet's zero-emission vehicles and infrastructure are meeting your needs, what you would have done differently in hindsight, and what the cost impact has been on the fleet.

Overall, because ZEVs are still relatively new, there remains a learning process and common barriers, but these obstacles are surmountable. Fleets interested in transitioning to ZEV technology have a growing number of resources available to assist them.