DOCKETED	
Docket Number:	20-IEPR-01
Project Title:	General/Scope
TN #:	237268
Document Title:	Final 2020 Integrated Energy Policy Report Update Volume I Blue Skies, Clean Transportation
Description:	Final 2020 Integrated Energy Policy Report Update Volume I: Blue Skies, Clean Transportation
Filer:	Raquel Kravitz
Organization:	California Energy Commission
Submitter Role:	Commission Staff
Submission Date:	3/23/2021 9:57:54 AM
Docketed Date:	3/23/2021

CALIFORNIA
ENERGY COMMISSION

California Energy Commission

COMMISSION REPORT

Final 2020 Integrated Energy Policy Report Update

Volume I: Blue Skies, Clean Transportation

Gavin Newsom, Governor
March 2021 | CEC-100-2020-001-V1-CMF

California Energy Commission

David Hochschild
Chair

Janea A. Scott
Vice Chair Emeritus

Commissioners
Karen Douglas, J.D.
Siva Gunda
J. Andrew McAllister, Ph.D.
Patty Monahan

Stephanie Bailey
Jane Berner
Michael Comiter
Quentin Gee, Ph.D.
Jim McKinney
Tim Olson
Primary Authors

Raquel Kravitz
Project Manager

Heather Raitt
Program Manager

Drew Bohan
Executive Director

ACKNOWLEDGEMENTS

Matt Alexander
Rosemary Avalos
Jonathan Bobadilla
Lindsay Buckley
Chris Compoginis
Denise Costa
Noel Crisostomo
Ben De Alba
Maggie Deng
Pam Doughman
Noemi Gallardo
Tami Haas
Andrew Hom
Madison Jarvis
Elizabeth John
Jeffrey Lu
Dorothy Murimi
Patty Pham
Raja Ramesh
Hannon Rasool
Harrison Reynolds
Jana Romero
Gordon Schremp
Raj Singh
Charles Smith
Michelle Vater
Susan Wilhelm
Taiying Zhang

ABSTRACT

The *2020 Integrated Energy Policy Report Update* provides the results of the California Energy Commission's assessments of a variety of energy issues facing California. Many of these issues will require action if the state is to meet its climate, energy, air quality, and other environmental goals while maintaining reliability and controlling costs.

This year, 2020, was unprecedented as the state continues to face the impacts and repercussions of several events including the COVID-19 pandemic, electricity outages, and statewide wildfires. In response to these challenging events, the *2020 Integrated Energy Policy Report Update* covers a broad range of topics, including transportation, microgrids, and the *California Energy Demand Forecast*.

Keywords: transportation, zero-emission vehicles, plug-in electric vehicles, fuel cell electric vehicles, charging infrastructure, electric vehicle, resiliency, disadvantaged communities, equity, biofuels, hydrogen, Clean Transportation Program

Please use the following citation for this report:

Gee, Quentin, Stephanie Bailey, Jane Berner, Michael Comiter, Jim McKinney, and Tim Olson. 2021. *Final 2020 Integrated Energy Policy Report Update*. California Energy Commission. Publication Number: CEC-100-2020-001-V1-CMF.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

Page

EXECUTIVE SUMMARY

Introduction

The year 2020 brought many challenges but also hopes for a better future. The *2020 Integrated Energy Policy Report (IEPR) Update* identifies actions the state and others can take to ensure a clean, affordable, and reliable energy system. California's innovative energy policies strengthen energy resiliency, reduce greenhouse gas (GHG) emissions that cause climate change, improve air quality, and contribute to a more equitable future.

The *2020 IEPR Update* is divided into three parts:

- Volume I focuses on California's transportation future and the transition to zero-emission vehicles (ZEVs).
- Volume II examines microgrids, lessons learned from a decade of state-supported research, and stakeholder feedback on the potential of microgrids to contribute to a clean and resilient energy system.
- Volume III reports on California's energy demand outlook, updated to reflect the global pandemic and help plan for a growth in zero-emission plug in electric vehicles.

Other Key Energy Planning Efforts

The California Energy Commission (CEC), California Public Utilities Commission (CPUC), and the California Independent System Operator are working to ensure grid reliability in response to increasingly severe events related to climate change, such as the extended heat wave experienced in August 2020 that led to rotating power outages. Grid reliability will be further discussed in the *2021 IEPR*. (For more information on corrective actions the agencies are taking to address the August rolling outages, see the Final Root Cause Analysis, Mid-August 2020 Heat Storm. http://www.caiso.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf.) For the longer term, the CEC is working with the CPUC and the California Air Resources Board (CARB) to plan for transforming the state's electric system to 100 percent renewable and zero-carbon by 2045, as directed by Senate Bill 100 (de León, Chapter 312, Statutes of 2018). (For information, see the CEC's SB 100 web page. https://www.energy.ca.gov/sb100.)

Blue Skies, Clean Transportation

While Californians will remember 2020 for the devastating impacts of COVID-19 and the worst season of destructive wildfires in recorded history, one of the few benefits of the shutdown was better air quality. As traffic dwindled because of the stay-at-home order in late March and early April, Los Angeles experienced blue skies and was ranked one of the cleanest cities in the world. But as traffic returned to normal and wildfires raged, the state's air quality plummeted. Transportation-related pollution is the state's number one source of harmful diesel particulates, smog-forming nitrogen oxides, and GHG emissions, and higher temperatures caused by transportation and other sources of GHGs are exacerbating the problem of wildfires.

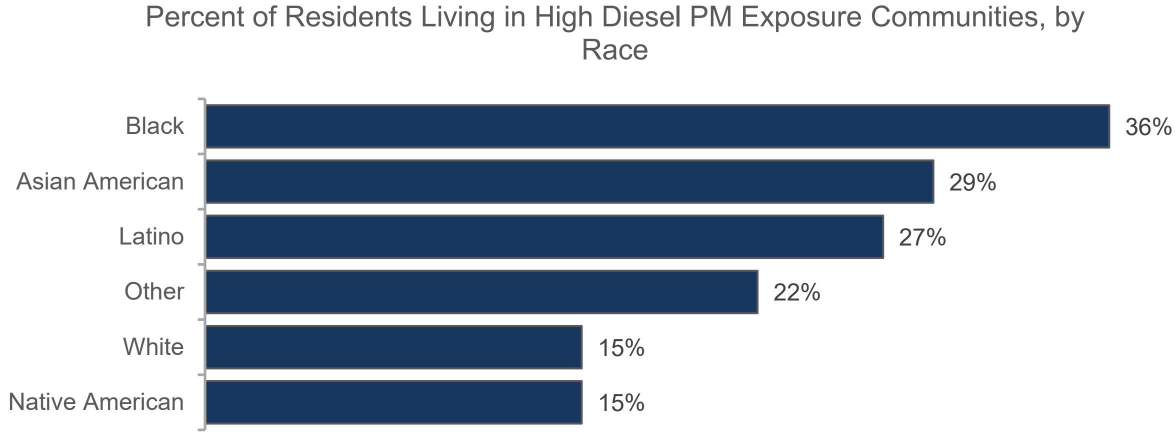
To address these challenges, the state is doubling down to accelerate ZEV deployment. On September 23, 2020, Governor Gavin Newsom signed Executive Order N-79-20, setting a 100 percent ZEV target for new passenger vehicle sales by 2035 and 100 percent ZEV operations target for medium- and heavy-duty vehicles in the state by 2045. Global ZEV sales, especially battery-electric, are growing, and prices are falling as the market scales, accelerating the timeline for ZEVs to achieve cost-parity with internal combustion engine vehicles. Opportunities also exist for streamlining the charging and hydrogen refueling infrastructure for ZEVs, helping reduce costs for refueling.

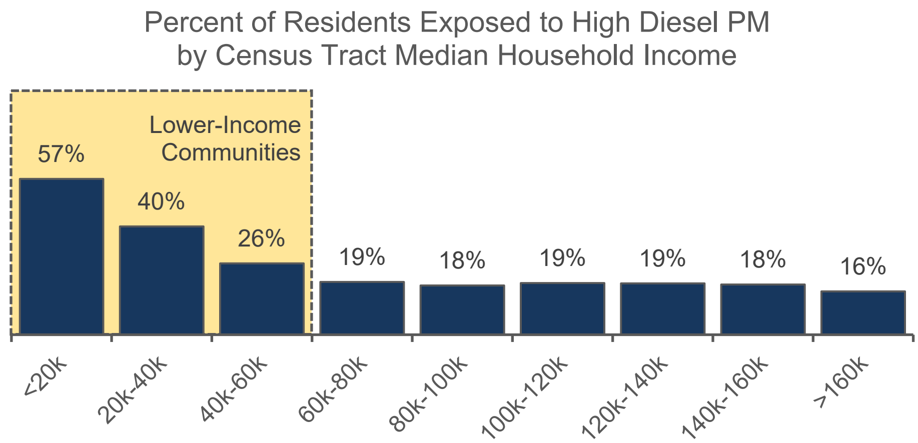
Transitioning to a ZEV future will improve public health, reduce transportation costs for Californians, expand economic development and create jobs, and, with the right planning, improve the reliability of the electric grid. At the same time, the state must ensure access to clean mobility options to ensure low-income and disadvantaged communities benefit from this transition.

Transportation Pollution and Disparate Impacts

While all Californians will benefit from the transition to ZEVs, those who stand to benefit most are those disproportionately impacted by transportation-related pollution. For example, medium- and heavy-duty vehicles (which include vehicles such as school buses and garbage trucks) are the largest source of diesel particulate matter, the leading contributing factor to cancer caused by air pollution. Furthermore, residents living in low-income and disadvantaged communities are exposed to higher levels of transportation-related toxic diesel particulate matter (Figure ES-1). According to a November 2020 study by Harvard researchers, Californians exposed to the most air pollution are more than twice as likely to die from COVID-19 as those living in communities with clean air.

Figure ES-1: Disparities in Transportation-Related Pollution Exposure by Race and Income

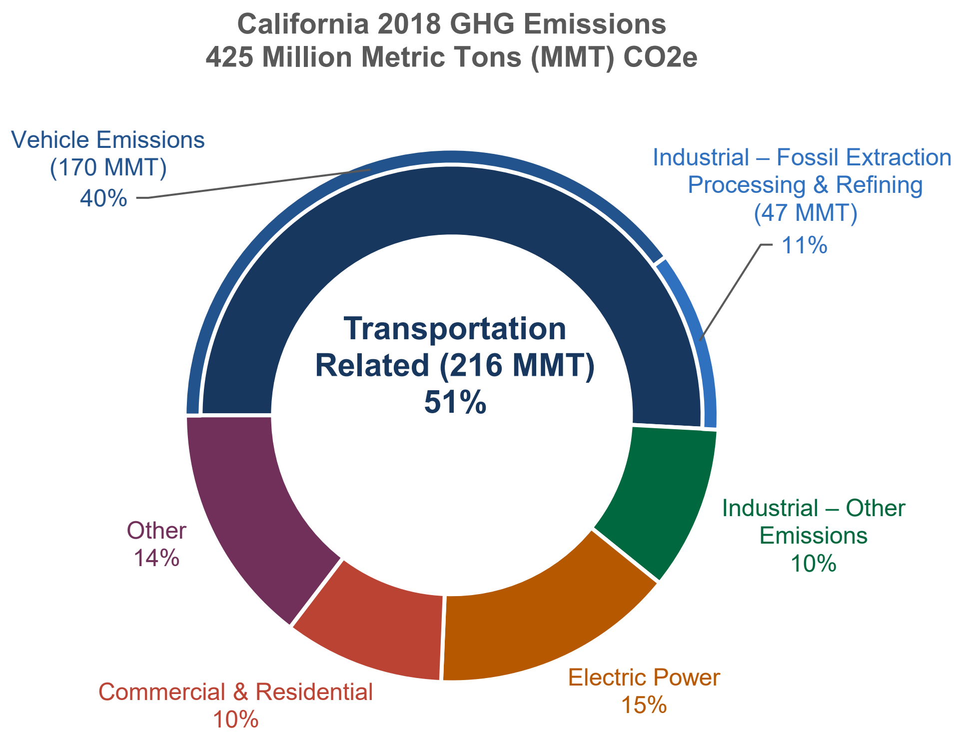




Credit: CEC analysis of census and CalEnviroScreen data (Note: "High Diesel PM Exposure" communities are census tracts that score in the highest 75th percentile of census tracts for diesel particulate matter. The vast majority [90 percent] of diesel PM emissions come from vehicles.)

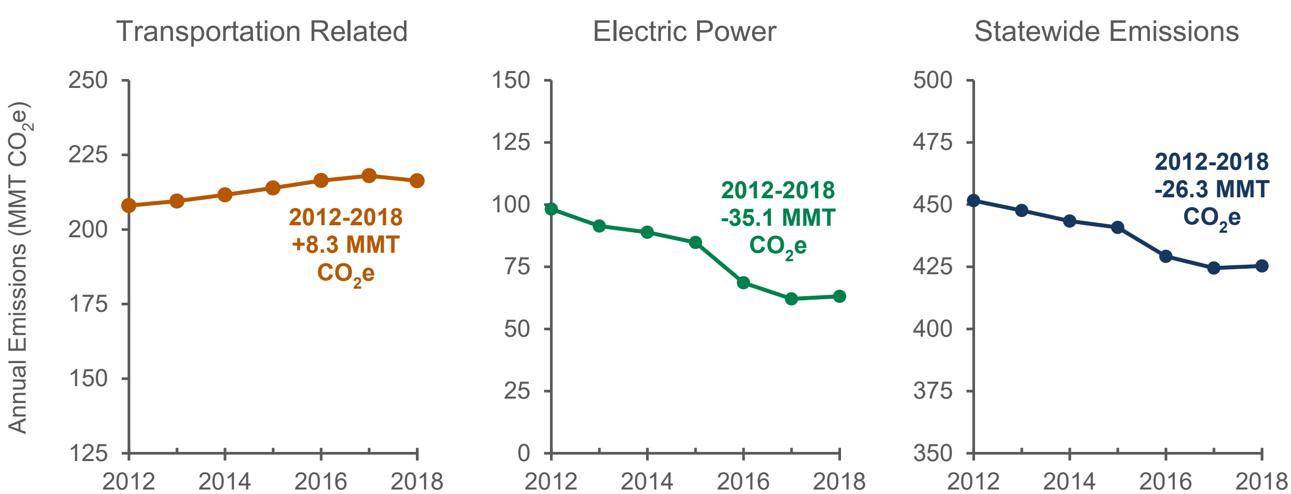
Transportation remains a key focus in the state's efforts to address climate change. The state is making important reductions in GHG emissions, largely from the electricity sector, as electricity generated from renewable energy resources like solar and wind increases and displaces fossil fuel-based electricity generation. By contrast, emissions from vehicles and fuel production have risen since 2012 (although there was a slight drop in emissions in 2018) and comprise more than half of the state's GHG emissions. (See Figures ES-2 and ES-3.)

Figure ES-2: Transportation-Related Emissions Account for More Than Half of the State's GHG Emissions



Credit: CARB 2018 GHG Inventory

Figure ES-3: GHG Emissions From Transportation Have Increased in Recent Years, Despite Declines in Electric Power and Overall Statewide Emissions



Credit: CARB 2018 GHG Inventory

While specific solutions to reduce air pollution and GHG emissions from vehicles will likely evolve as the economy responds to the pandemic-induced recession and as technologies improve, several overarching recommendations are clear:

- A zero-emission transportation system, including battery-electric and hydrogen fuel cell electric vehicles, is necessary for the health of the state's residents and environment.
- Building out a standardized ZEV charging infrastructure and hydrogen fueling infrastructure will be critical to market growth and achieving statewide vehicle and climate goals.
- Continued state support for infrastructure buildout, coupled with leveraging private investment, is needed until the market can achieve self-sufficiency.
- The state must expand access and prioritize clean transportation benefits in the most impacted communities to address disparate impacts of transportation pollution.
- Battery-electric vehicle charging must be aligned with grid needs to help integrate renewables and add resiliency to the grid.

Disruptive Changes to Mobility and Economic Growth

A new series of technologies have begun to emerge in recent years to alter radically the transportation landscape: electrified transportation, autonomous vehicles, and shared mobility services. These have been termed the "Three Revolutions" in transportation. While these exciting changes present a tremendous opportunity, they also come with potential drawbacks.

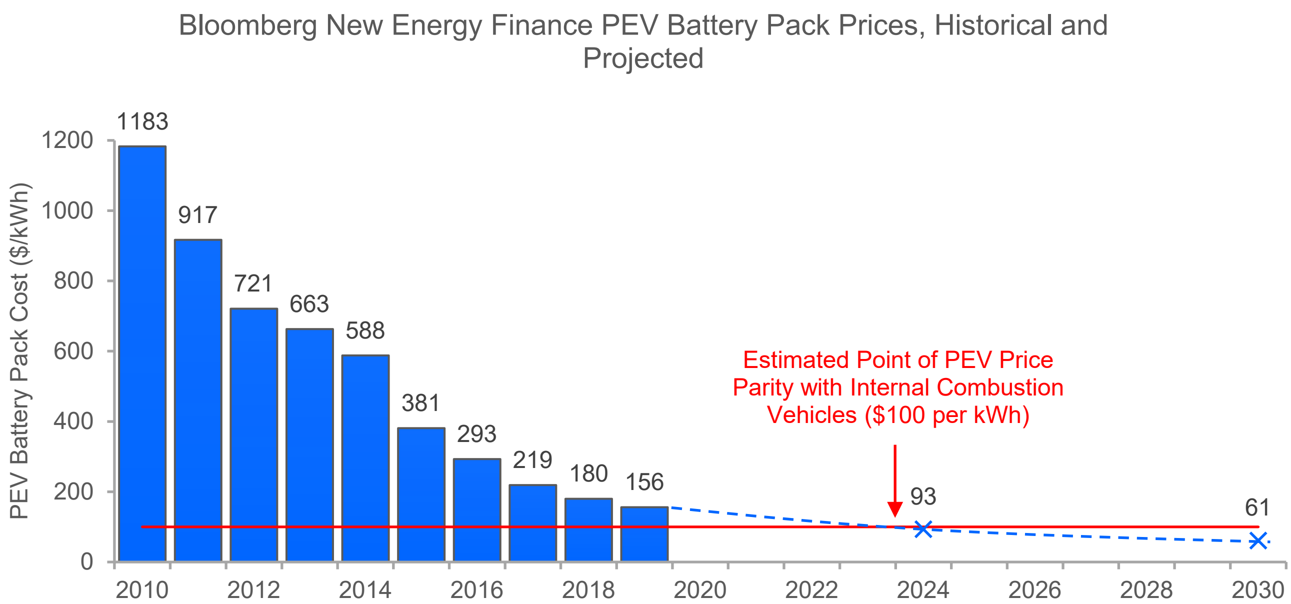
In a "Blue Skies" scenario, transportation accessibility increases for all communities, renewably powered electric transportation reduces pollution, and integration with other transit modes reduces congestion. Done right, this type of scenario can be the basis of additional economic growth of up to $134 billion per year, as estimated in an economic forecast by NEXT 10. However, in a "Dirty Skies" scenario, technologies grow without a broad electrified energy vision and leadership, leading to additional congestion, more fossil fuel-powered vehicles, pollution from dirty electricity sources, and more car dependence due to disorganized transportation services.

In addition to hosting the largest ZEV market in the country, California is the epicenter of the three revolutions. The state is in a unique position to make clean transportation a significant portion of its economy. A 2021 CALSTART survey of the electric vehicle and equipment supply chain in California showed at least 70,000 direct jobs. The same study identified more than 360 unique companies involved in the ZEV supply chain in California. The electric vehicle and equipment manufacturing supply chain comprises hundreds of unique companies. With this initial advantage, there is a substantial opportunity for California to support this industry and become a leader in the export of its products, knowledge, and services, all while ensuring growth of well-paying jobs for residents. Care must be taken to ensure that low-income and disadvantaged communities share in these potential benefits of the three revolutions.

Plug-In Electric Vehicles (PEVs): Innovation, Decreasing Costs, and Market Growth

The light-duty plug-in electric vehicle (PEV) market has surpassed expectations of analysts from even just a few years prior. In China and Europe, PEV sales doubled between 2017 and 2019. This remarkable growth is primarily the result of strong government policies and rapidly decreasing costs for components, especially batteries. Since 2010, prices for lithium-ion battery packs have decreased by nearly 90 percent, with an additional 40 percent decline expected from 2019 to 2024. (See Figure ES-4.) With these continued price declines on the horizon, expert analysts from multiple organizations expect price parity with conventional vehicles within the next five years or sooner, making PEVs a competitive option for many looking to purchase new vehicles. Reduced initial cost, coupled with lower fueling and maintenance costs, will mean more money in Californians' pockets, more than $1,000 per year due to fueling and maintenance savings alone.

Figure ES-4: Battery Prices Experiencing Rapid Declines, With Continued Declines Expected Through 2030



Credit: Bloomberg New Energy Finance

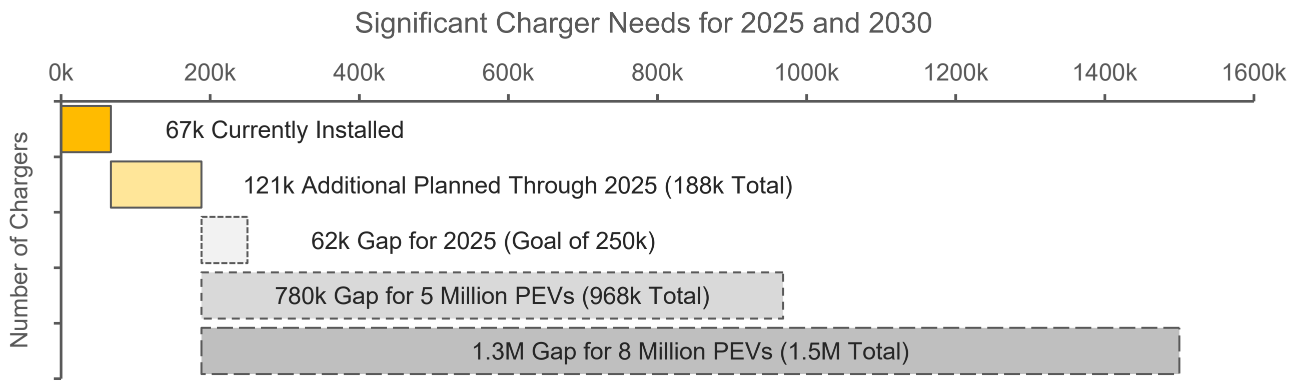
Success in the light-duty PEV market has set the stage for transitioning medium- and heavy-duty vehicles. This sector is poised for rapid growth, in part due to strong state policies and programs. The CEC's bulk purchases of battery-electric school buses have bolstered higher levels of production, contributing to a nearly 50 percent price reduction in the last four years. Prices for PEVs used for freight and buses are also declining, making the total cost of ownership (including maintenance and fuel) cost-competitive with fossil-fueled vehicles in several use cases now, and potentially all by 2030. Continued cost declines will make them the preferred option for many fleet operators.

Meeting the goals in Executive Order N-79-20 will require continued programs and policies supporting the deployment of ZEV infrastructure and vehicles (passenger, medium- and heavy-duty, and off-road), supportive electric utility rates, and additional investment in fueling infrastructure. State and private sector investments are necessary to support a rapid scale-up of vehicle electrification. Investments need to be responsive to the rapidly evolving market conditions and increase equitable access of benefits. The goal is to foster a self-sustaining market that does not rely on public funding for ZEVs.

Charging Infrastructure: Key to PEV Market Growth and an Opportunity for the Grid

One of the leading challenges to address for accelerated market penetration of all PEVs is to ensure a widespread, reliable, and easy-to-use network of charging infrastructure. Statewide goals for PEVs will require many more public and shared chargers. Figure ES-5 shows the current and planned charger infrastructure through 2025 and highlights the gap between the 2025 goal and the gap for a 5 million ZEV scenario in 2030. Meeting Executive Order N-79-20 will require scaling up sales through 2035, resulting in up to 8 million ZEVs on the road by 2030, making the charging infrastructure need even greater.

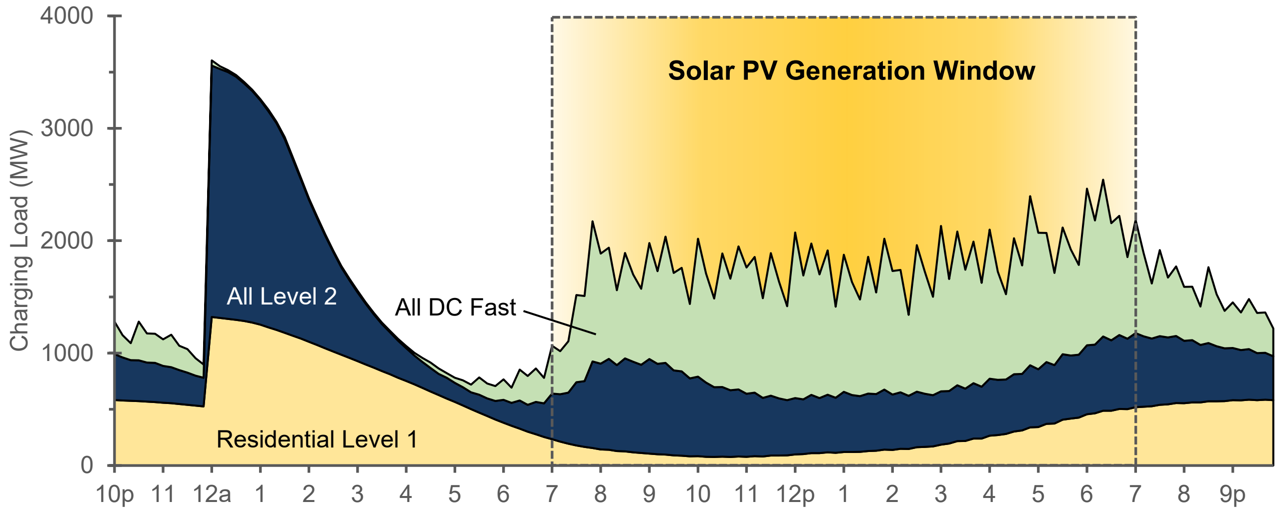
Figure ES-5: Gaps in the Chargers Necessary for Additional PEVs on the Road



Credit: CEC

Uniform charger standards will be key to accelerating station deployment and making charging simple for drivers. Furthermore, incentives and policies will be necessary to help manage charging patterns to benefit the grid, including vehicle-grid integration (VGI, which enables electric vehicles to be responsive to grid needs while meeting consumer charging needs). (See Figure ES-6.) Early research suggests that vehicle-grid integration may enhance grid reliability and reduce the cost of supplying electricity to all consumers. Large-scale charging, however, may compound problems if consumers charge their vehicles when grid operators have less renewable energy available to meet demand or if there is a large amount of demand for other electricity services. Finally, while at-home charging is convenient, it is not accessible for all, especially residents of multiunit dwellings. Programs and policies directed to these challenges and opportunities should be a state priority.

Figure ES-6: Managing Charging Impacts on the Grid for Maximizing Renewable Energy Use Will Be Important as the PEV Market Grows



Credit: National Renewable Energy Laboratory

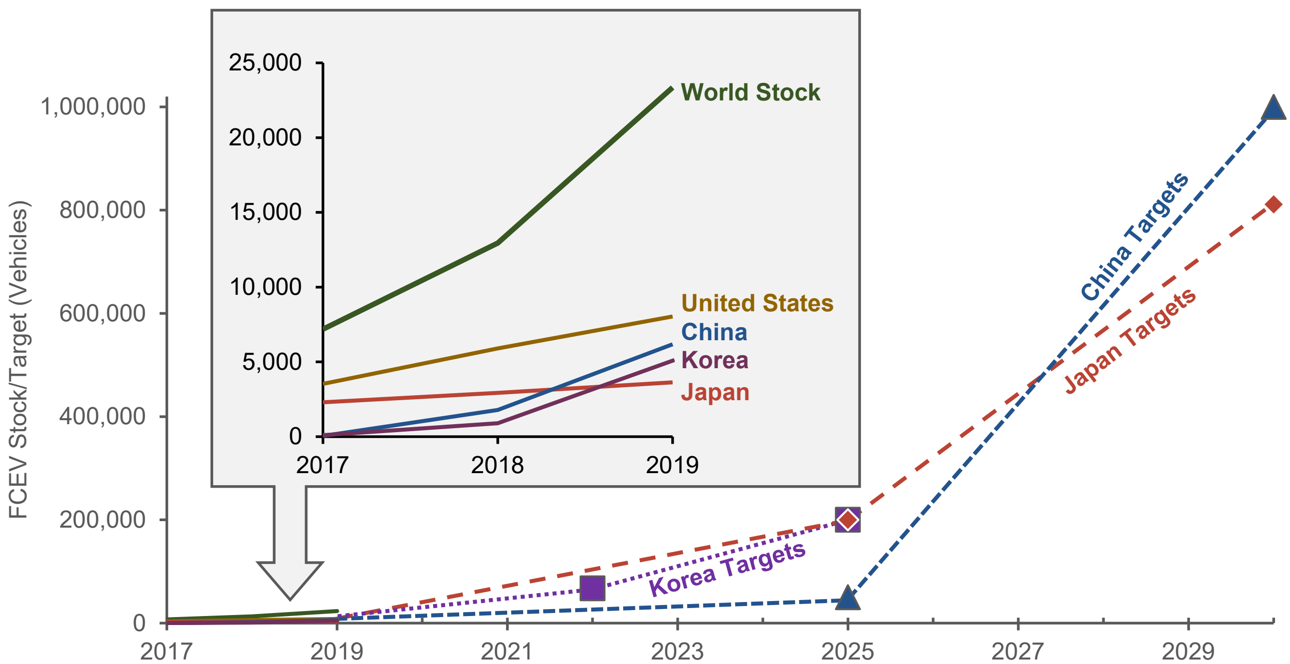
New regulatory and funding mechanisms should be examined to encourage private-sector investments in charging infrastructure, especially those in disadvantaged or low-income communities. Disadvantaged communities are defined by the California Environmental Protection Agency as the top 25 percent of census tracts most impacted by pollution. Low-income communities are defined by the California Department of Housing and Community Development as those communities at or below 80 percent of the statewide median income. Public investment across communities is critical but on its own will not be sufficient to meet the infrastructure build out requirements needed to support California's goals, especially the 2035 goal of 100 percent ZEV sales. Exploration of new business models and programs will be key steps in the next few years, laying the groundwork for rapid electrification of transportation and the benefits that come with it.

Fuel Cells and Hydrogen: Global Investment, Decreasing Costs

Fuel cell electric vehicles (FCEVs) are at a more nascent stage than battery-electric vehicles, but there are growing investments in hydrogen fueling and vehicle deployment. Given the fast refueling and longer ranges, FCEVs offer advantages over battery-electric vehicles that could be particularly important for medium- and heavy-duty applications, including long-distance freight and transit buses. California continues to make progress in building out hydrogen refueling infrastructure. As of December 2020, 179 stations were either in operation or planned for operation. Achieving the goal of 200 stations established by Executive Order B-48-18 will allow the state to satisfy the fueling needs of more than 100,000 light-duty FCEVs. Another potential market growth opportunity is the stacking benefit of fuel cells, which allows production of similar fuel cell stacks across vehicle sizes. For example, Toyota's Class 8 semitruck uses two fuel cell stacks from its light-duty Mirai. Production of the same fuel cell stacks across all vehicle sizes allows economies of scale that may contribute to faster price declines than would otherwise be expected.

Global investment in hydrogen and national FCEV goals in Japan, China, and Korea also bolster the case for fuel cells. Leading economies have made investments that will contribute to a broader hydrogen energy ecosystem, opening the door for economies of scale that could drive down costs and allow FCEVs to play a key role in the ZEV transition. Because hydrogen can be generated with renewable energy and electrolyzers, FCEVs are well-positioned to use renewable hydrogen rather than fossil-derived hydrogen. (See Figure ES-7.)

Figure ES-7: Global Goals for FCEVs Show the Potential for High Market Growth in FCEVs



Credit: International Energy Agency (IEA)

The state should continue to support FCEV commercialization and hydrogen infrastructure build-out to ensure there are ZEV options to meet different user needs. The medium-duty, heavy-duty, and off-road sectors should be priority focus areas, given the urgent need to reduce harmful emissions for these vehicles and the advantages that FCEVs may offer over battery-electric in certain applications.

ZEVs and Energy Resilience

The unprecedented number of wildfires across more than 4 million acres in Northern, Central, and Southern California is putting some grid infrastructure in a precarious position. As a result of public safety power shutoffs (PSPS) to reduce wildfire risk in some areas, many Californians are interested in purchasing generators and backup batteries for their homes or other buildings. ZEVS can help meet this need as they are fundamentally energy storage devices. A battery or fuel cell can provide power to the wheels of the vehicle or to a home or business. Community-scale solutions that take advantage of larger battery resources, such as school buses, are also worth exploring. The right equipment and grid safety precautions are necessary, but this energy resiliency opportunity is one that the state should embrace.

Of course, when the power is out, neither conventional combustion vehicles nor ZEVs can be refueled unless there is a backup source of energy to pump fuel or charge a battery. So, while ZEVs are a source of energy resiliency, they eventually need resilient refueling infrastructure. Fortunately, batteries and onsite renewable generation tied to charging infrastructure offer this resiliency potential. These technologies can also provide critical services to communities in the event of power outages as well as general beneficial energy services when the grid is functioning.

Low-Carbon Fuels and Near-Zero-Emission Vehicles May Be Useful in Some Contexts

Although ZEVs represent a revolutionary opportunity to transform transportation, it will take 15–25 years to transition most fleets, and some transportation modes may be more difficult to electrify. During this ZEV ramp up, low-carbon liquid fuels and other low-emission fuels can be blended with or substitute for petroleum. State policies and incentives should prioritize low-carbon liquid fuels for sectors that are the hardest to electrify, such as long-distance aviation. While air travel is generally the purview of the federal government, California's sustainable aviation fuel can earn credits from CARB's Low Carbon Fuels Standard. The state should, however, keep careful attention directed to carbon accounting and other sustainability metrics.

In the shorter term, renewable gas may also have a place in reducing pollution, such as smog-forming nitrogen oxides. California has seen a rapid expansion of renewable gas facilities in the state, potentially comprising the energy potential for about 25 percent or more of the state's diesel fuel supply. However, renewable gas is primarily composed of methane, and because methane is a potent GHG with 25 times the warming potential of carbon dioxide, the state must balance the benefits of renewable gas against the impacts of methane leakage.

Moving Forward

Putting the pieces in place to enable the rapid market expansion of ZEVs will be challenging but offers the potential of tremendous rewards. Careful attention to building and properly aligning infrastructure, incentives, equity, and the grid can help the state meet its energy and climate goals with benefits for all Californians. Zero-emission transportation is fundamental to a carbon-neutral economy and the health of all Californians. In planning to maximize the benefits of clean transportation for all residents, California can be a leader in developing a cleaner, healthier, and more equitable future.

CHAPTER 1: Today's Transportation Trends

2020: A Year of Unprecedented Challenges

How COVID-19, Climate Change, and Air Pollution Created the Perfect Storm

Californians will remember 2020 for the devastating impacts of COVID-19 and the worst season of destructive wildfires in recorded history. What residents may not realize is the link between the pandemic, massive wildfires, and the pollutants coming from the state's transportation system.

New research finds that COVID-19 death risk is higher for communities with long-term average exposure to fine particulate matter (PM2.5). Harvard University researchers found that an increase of just 1 microgram of PM2.5 per cubic meter of air in a community was associated with an 11 percent increase in death rate from COVID-19.[1] The most polluted disadvantaged communities in California have average PM2.5 levels as high as 20 micrograms per cubic meter, resulting in a potential 220 percent increase in COVID-19 death rate risk for people living in such communities.

The COVID-19 pandemic is having a disproportionate impact on people living in disadvantaged communities. Long-term exposure to air pollutants has created a preexisting medical condition for many residents in these communities, which are often adjacent to major transportation

1 Wu, Xiao, Rachel C Nethery, M Benjamin Sabath, Danielle Braun, and Francesca Dominici. "Air Pollution and COVID-19 Mortality in the United States: Strengths and Limitations of an Ecological Regression Analysis." *Science Advances*. November 4, 2020. https://efiling.energy.ca.gov/GetDocument.aspx?tn=235571&DocumentContentId=68508.

See also Michael Petroni et al. "Hazardous Air Pollutant Exposure as a Contributing Factor to COVID-19 Mortality in the United States." *Environmental Research Letters*. September 11, 2020. https://iopscience.iop.org/article/10.1088/1748-9326/abaf86.

The Harvard study accounted for 20 potentially confounding factors (for example, age or smoking) and was consistent with other studies showing a connection between air pollution and respiratory infection death rates.

corridors.[2] Disadvantaged communities are in part defined by their exposure to air pollutants, and transportation emissions are a leading source of air pollution in the state, especially oxides of nitrogen (NOx) and PM2.5.[3] Annually, Californians' exposure to PM2.5 results in 5,400 premature deaths due to cardiopulmonary causes, 2,800 hospitalizations for cardiovascular and respiratory diseases, and 6,700 emergency room visits for asthma.[4] As a respiratory disease, COVID-19 has impacted many Californians already suffering from impaired lung function.

The massive wildfires of 2020 are symptomatic of Earth's changing climate. Droughts and high summer temperatures resulted in forests that were dry, stressed, and ready to ignite. Unprecedented lightning storms in August produced more than 12,000 lightning strikes, sparking more than 300 fires in just three days — including the largest wildfires in state history.[5] More than 4.1 million acres burned from August through October 2020,[6] representing 1 out of every 25 acres in the Golden State. The particulate-heavy smoke from the fires exacerbated public health by adding additional stress to the lung health of vulnerable populations already exposed to unsafe levels of vehicle pollution and at high risk of exposure to COVID-19.[7]

Transportation is a significant source of the greenhouse gas (GHG) emissions linked to the disruptive impacts of climate change, especially in California. Emissions from vehicle tailpipes alone represent nearly 40 percent of the state's GHG emissions. When fuel consumption,

---

2 *Strategies to Reduce Air Pollution Exposure Near High-Volume Roadways*. Technical Advisory from the California Air Resources Board's (CARB's) Research Division. CARB 2017. Pp. 12-14. https://ww3.arb.ca.gov/ch/rd_technical_advisory_final.pdf.

3 Ibid.

4 CARB. 2020. Mobile Source Strategy, "Vision for Clean Air. 2020 Progress Report." https://ww3.arb.ca.gov/planning/sip/2020mss/pres_marwbnr.pdf.

5 ABC News. "More than 1 Million Acres Burned as California Fire Fighters Brace for New Lightning Storm." ABC News Website. August 23, 2020. https://abcnews.go.com/ABCNews/million-acres-burned-california-firefighters-brace-lightning-storm/story?id=72551511.

6 California Department of Forestry and Fire Protection (CAL FIRE). 2020. "California Statewide Fire Summary October 21, 2020." https://www.fire.ca.gov/daily-wildfire-report/.

7 Ibid. Toxic pollutants from the burning of more than 10,000 structures add to the public health impacts of the 2020 wildfires.

petroleum processing, and petroleum extraction are combined, transportation-related emissions total more than 50 percent of all state GHG emissions.

The unprecedented events of 2020 demonstrate the urgent need to dramatically reduce carbon dioxide (CO_2) and criteria pollutants from California's cars and trucks. Climate scientists have predicted for years what the potential impacts *could* be; 2020 shows what they *will* be.

In light of the issues described above, the *2020 Integrated Energy Policy Report Update* (*2020 IEPR Update*) *Volume I* examines California's progress and challenges in reducing transportation emissions through electrification and the use of low-carbon fuels, with an emphasis on equity. Despite substantial investments from California's clean transportation programs, many disadvantaged communities are suffering disproportionate public health and economic impacts from the 2020 crises, indicating the need for substantial, ongoing investments to reduce the transportation emissions impacting all Californians. The *2020 IEPR Update* also identifies the COVID-19-related impacts to California's transportation systems, including drivers, transit systems, trucking companies, and transportation networking companies (TNCs).

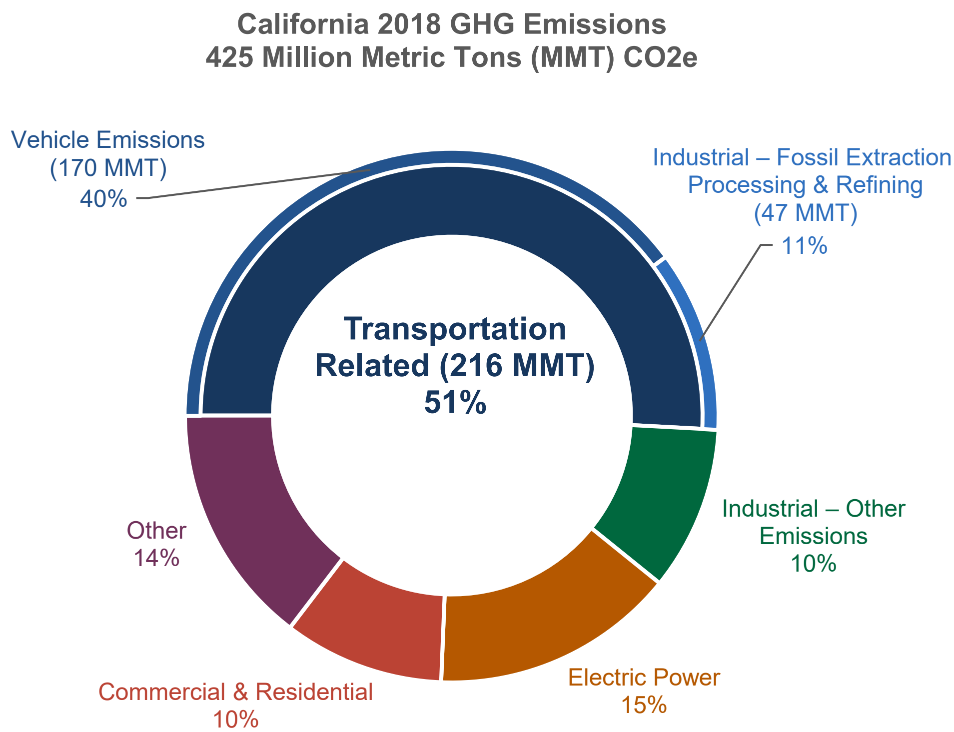
GHGs and Criteria Pollutant Emissions

Transportation comprises half of all California's GHG emissions when accounting for the emissions from transportation fuel production and combustion in vehicles. Figure 1 shows the major categories of emissions and highlights contributions from all transportation-related activities in the state. The data are from the California Air Resource Board's (CARB's) GHG Inventory, with *transportation-related* emissions presented as a combination of tailpipe emissions from vehicles and industrial emissions associated with fossil fuel production. The industrial emissions associated with fossil fuel production combine CARB's subcategories of GHG emissions from refineries and oil and fossil gas extraction.[8]

8 2020. California Greenhouse Gas Emission Inventory - 2020 Edition. https://www.arb.ca.gov/cc/inventory/data/data.htm.

For the *2020 IEPR Update*, the CEC is using the terms "pipeline gas," "fossil gas," or simply "gas" where past IEPRs typically used the term "natural gas." Similarly, in this report the CEC refers to "renewable gas" instead of "renewable natural gas."

Figure 1: More Than Half of the State's GHG Emissions Come from Transportation



Data Source: CARB 2018 GHG Inventory

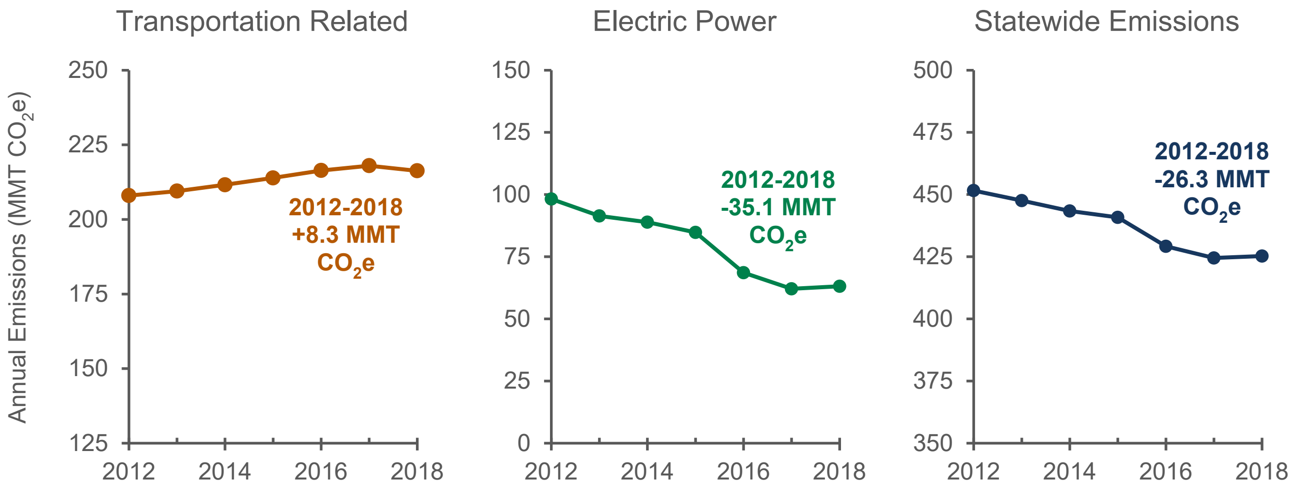
California has made good progress in reducing total GHG emissions, including cutting electricity sector emissions by almost half in the last 10 years. Emissions from the transportation sector, though, have *increased* by 5 percent from 2012 to 2018[9] (Figure 2) because of the historic growth in vehicle miles traveled (up 14 percent between 2011 and 2017[10]) and trends in vehicle ownership (for example, preference for less efficient vehicles such as pickup trucks and sport utility vehicles). Under CARB's 2030 Climate Change Scoping Plan, which identifies the most efficient path toward economywide GHG reduction targets,

9 CARB. 2019. *California Greenhouse Gas Emissions for 2000 to 2017*. https://www.arb.ca.gov/cc/inventory/pubs/reports/2000_2017/ghg_inventory_trends_00-17.pdf.

10 California Department of Transportation. 2020. *California Transportation Plan 2050*. Public Review Draft. August 2020. https://ctp2050.com/wp-content/uploads/2020/08/CTP2050-Transportation-Plan-Draft-1.pdf.

California will need to decrease transportation GHGs by 63 million metric tons, or 37 percent from 2018 levels.[11]

Figure 2: California GHG Emissions (2012–2018): Transportation Related, Electricity, and Statewide



Data Source: CARB 2018 GHG Inventory

The transportation sector is a leading source of air pollutants, with mobile sources responsible for nearly 80 percent of NO_x and 90 percent of diesel PM.[12] CARB estimates that attaining federal air quality standards in 2023 and 2031 for the South Coast air basin will require a 70 percent reduction of 2016 levels of smog-forming emissions by 2023, rising to a total 80 percent reduction by 2031.[13]

The South Coast Air Basin and San Joaquin Valley continue to suffer from the worst air quality in the nation. These are the only two air basins in the United States classified as "extreme

---

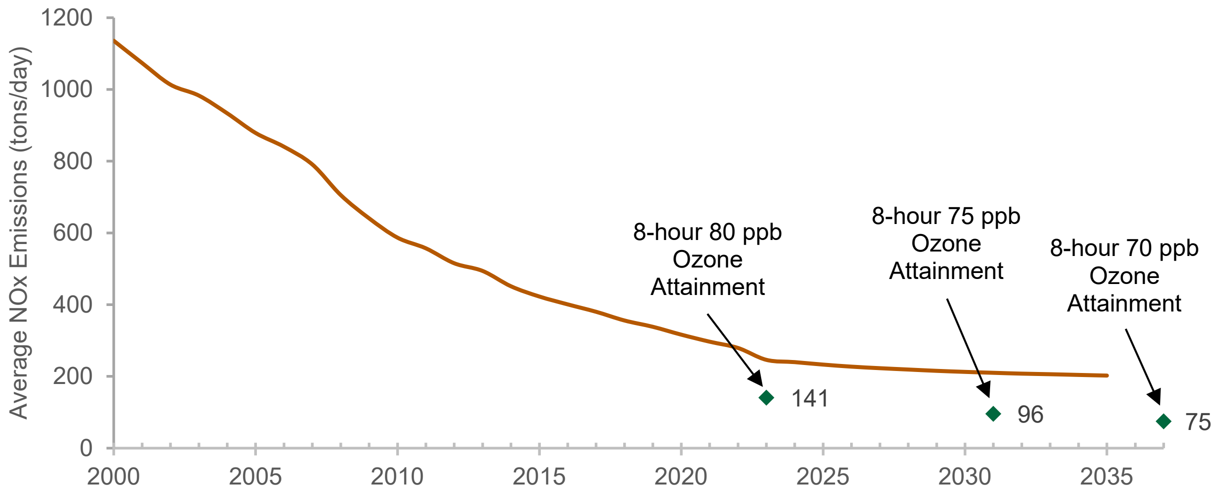
11 *CARB 2017 Climate Change Scoping Plan: The Strategy for Achieving California's 2030 Greenhouse Gas Target.* The scoping plan has a goal of 107 MMT from vehicle emissions, or what CARB terms "transportation." The CEC's analysis presented in Figures 1 and 2 considers transportation-related emissions more broadly to include oil extraction and processing. https://ww2.arb.ca.gov/sites/default/files/classic//cc/scopingplan/scoping_plan_2017.pdf.

12 CARB. 2016. *2016 Mobile Source Strategy*. https://ww3.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf.

13 Ibid.

nonattainment" with federal ozone standards.[14] One-third of the state's total population lives in areas that exceed federal ozone and particulate standards.

Figure 3: NOx Reductions Needed in South Coast Air Quality Management District (AQMD) to Comply with Federal Clean Air Act Standards



Data Source: South Coast 2016 Air Quality Management Plan

Figure 3 shows the gap between NO_x emissions in the South Coast Air Basin and the expected emissions needed to attain compliance with the 2023, 2031, and 2037 federal air quality standards. The line represents actual and anticipated NO_x emissions in tons per day, and the green diamonds represent NO_x emissions estimated necessary to attain specific federally mandated NO_x concentrations.[15] While substantial progress is being made, projected NO_x emissions result in concentrations that are well above the 2023 standard of 80 parts per billion (ppb).

Medium- and Heavy-Duty Vehicles

Heavy-duty (HD) trucks are an essential part of California's economy. They move produce from fields to processing plants to grocery store shelves. They deliver goods from the ports of Los Angeles, Long Beach, Oakland, and San Diego to inland warehouses and then to

14 Ibid.

15 The carrying capacity of 70 TPD in 2037 is based on the preliminary assessment using the modeling done for the 75-ppb ozone standard.

distribution centers in California and across the country. Medium-duty (MD) trucks, such as package delivery vans, perform an equally essential function moving goods from distribution centers to retail stores and homes, or what is termed *last-mile delivery*. This function is especially true as online retailers and on-demand delivery services proliferate during the COVID-19 pandemic.

MD and HD trucks are classified as Class 3 to Class 8 depending on size and cargo capacity. These trucks range from 10,000 pounds gross vehicle weight rating (GVWR) to 80,000 pounds GVWR. Nearly all trucks in these class ranges are powered by diesel or pipeline gas and emit tailpipe emissions in local neighborhoods. Some smaller Class 3 package delivery vans run on gasoline. These various trucks have low fuel economy and travel many more miles per year than passenger vehicles.

Although MD and HD vehicles are a small portion of California's registered vehicle stock, they are responsible for a disproportionate amount of fossil fuel use and emissions. There are 31 million vehicles registered in California, 1 million of which are trucks. Those trucks represent only 3 percent of vehicles in the state but are responsible for nearly 21 percent of on-road GHG emissions, 71 percent of on-road NOx emissions, and 98 percent of on-road diesel $PM_{2.5}$ emissions.[16] Viewed from a different metric, trucks accounted for 1 percent of all vehicle trips but 6 percent of vehicle miles traveled (VMT).[17] CARB classifies diesel particulate emissions as "carcinogenic toxic air contaminants," with diesel engine emissions responsible for 70 percent of the state's estimated known cancer risk attributable to toxic air contaminants.[18] Emissions from this small percentage of the state's total vehicle fleet cause greater public health risks than the emissions from the other 30 million cars, SUVs, and pickup trucks on the road.

California's capacity to regulate MD and HD trucks is further complicated by the large numbers of trucks that are registered out-of-state that operate on California roadways. Roughly one-third of the Class 7 and 8 tractors operating in California were purchased out of state and are subject to less stringent NOx regulations than trucks registered in California, creating two levels of NOx regulation for trucks operating in California. These HD out-of-state trucks

---

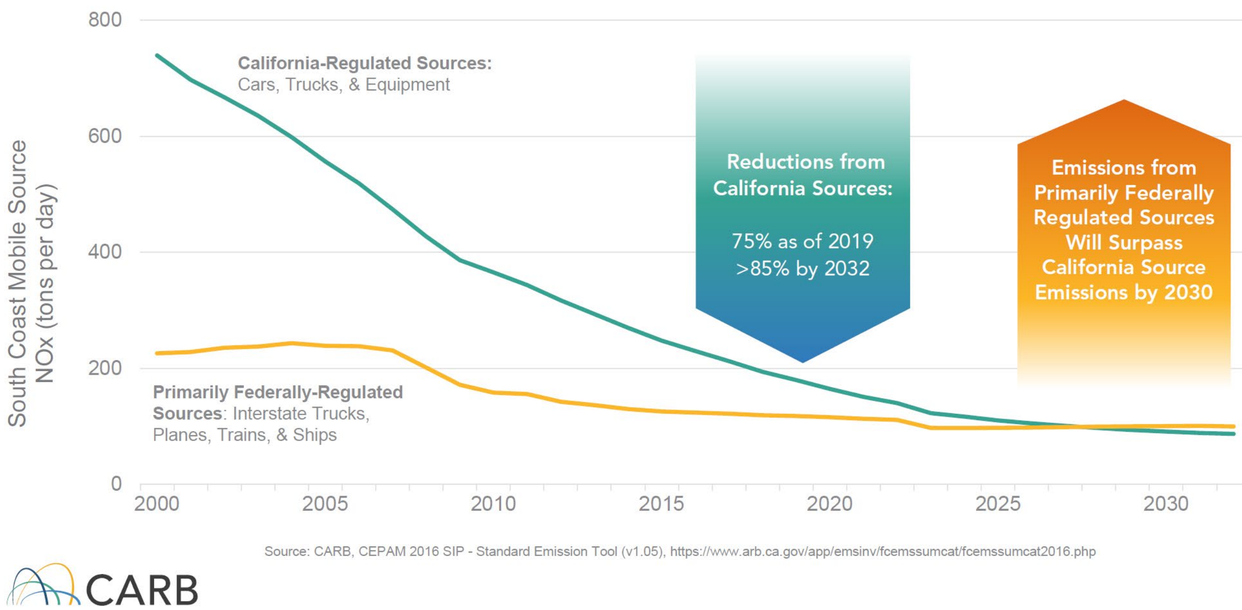
16 CARB. *2020 Mobile Source Strategy*. Workshop Discussion Draft. September 30, 2020. https://ww2.arb.ca.gov/sites/default/files/2020-09/Workshop_Discussion_Draft_2020_Mobile_Source_Strategy.pdf.

17 California Department of Transportation. 2020.

18 CARB. "Summary: Diesel Particulate Matter Health Impacts." https://ww2.arb.ca.gov/resources/summary-diesel-particulate-matter-health-impacts.

account for 50 percent of truck VMT as well.[19] California has adopted stringent policies to manage vehicles under its control, but the state cannot meet federal NO_x air quality standards without a federal low-NO_x vehicle standard.[20] See Figure 4.

Figure 4: Federally Regulated Sources Will Soon Become the Major Source of NO_x Pollution in California



Source: CARB 2020 Mobile Source Strategy

California moved dramatically further in reducing MD and HD vehicle emissions when CARB adopted the Advanced Clean Truck Regulation (ACT) in June 2020. The ACT is modeled after the ZEV Regulation that CARB adopted for light-duty vehicles. Starting in 2024, the ACT will require truck manufacturers to sell an increasing proportion of zero-emission trucks in California. This is the first such regulation in the world. Truck and bus manufacturers selling in California will earn deficits based on the total number of trucks sold. These deficits must be balanced with ZEV credits. ZEV credits can be acquired by manufacturing and selling ZEVs or by purchasing credits from original equipment manufacturers (OEMs) that have sold a higher proportion of ZEVs and earned excess credits. The number of credits required increases each

19 CARB. *2016 Mobile Source Strategy*. https://ww3.arb.ca.gov/planning/sip/2016sip/2016mobsrc.pdf. p. 77.

20 CARB. *2020 Mobile Source Strategy*. March 25, 2020 Public Webinar. https://ww3.arb.ca.gov/planning/sip/2020mss/pres_marwbnr.pdf.

year after 2024 as a proportion of an OEM's sales. The ACT regulation will be applied broadly, affecting all trucks between Class 2b (large pickups) and Class 8. By 2035, 75 percent of Classes 4 to 8 straight trucks and 40 percent of Classes 7 and 8 tractors sold in California must be zero-emission trucks.[21]

CARB is also developing a new regulation known as the Heavy-Duty Engine and Vehicle Omnibus Regulation — also called the HD Omnibus Regulation — that will codify the current optional low-NO_x standard for heavy-duty trucks of 0.02 grams per brake horsepower-hour (g/bhp-hr) as a regulatory standard. This new standard is 90 percent lower than the current standard of 0.2 g/bph-hr. This new regulatory standard is expected to reduce NOx emissions by 50 percent, eliminating 52 tons per day by 2031. It is a critical element of the *2016 Mobile Source Strategy* in that it will force down NO_x emissions from diesel trucks as the ACT regulation is implemented.[22]

Transit and school buses are generally classified as HD Classes 7 and 8 vehicles. California has more than 29,000 school buses, two-thirds of which are powered with diesel fuel. Diesel emissions affect the respiratory health of sensitive populations, such as school-age children. California also has 12,000 transit buses across 200 public transit districts. The large urban fleets tend to be fueled by pipeline gas. With the adoption of the Innovative Clean Transit (ICT) regulation in 2018, large urban transit districts will need to have 25 percent of new bus acquisitions be zero-emissions buses by 2023, rising to 100 percent in 2029. Full electrification of the transit bus fleet by 2040 is the goal.[23] As with the ACT, CARB states that the ICT regulation "is essential for California to meet its long-term air quality and climate protection goals. The proposed ICT regulation reduces GHG, PM, and NO_x emissions, which will result in health benefits for individuals and communities in California. The value of these health benefits

21 CARB. *Initial Statement of Reasons for the Proposed Advanced Clean Trucks Regulation*. October 22, 2019. https://ww3.arb.ca.gov/regact/2019/act2019/isor.pdf.

22 CARB. "Proposed Amendments to the Exhaust Emissions Standards and Test Procedures for 2024 and Subsequent Model Year Heavy-Duty Engines and Vehicles." Initial Statement of Reasons. June 23, 2020. https://ww3.arb.ca.gov/regact/2020/hdomnibuslownox/isor.pdf.

23 CARB. Initial Statement of Reasons for the Innovative Clean Transit Regulation. Public Hearing before the Air Resources Board. September 27, 2018. https://ww3.arb.ca.gov/regact/2018/ict2018/isor.pdf?_ga=2.234292958.178464358.1599585982-1771686935.1580939935.

are due to fewer instances of premature mortality, fewer hospital and emergency room visits, and fewer lost days of school and work."[24]

Passenger Vehicles

Light-duty (LD) passenger vehicles account for 70 percent of transportation-related GHG emissions, and emissions have been generally increasing since 2013.[25] The leading contributors to GHG emissions from transportation are the increase in Californians driving more miles and the trend in consumer preferences for larger vehicles.

Consumer preferences for larger vehicles are reshaping auto markets around the world. Globally, sport utility vehicles (SUVs) accounted for 40 percent of new car sales in 2019, up from 18 percent in 2010.[26] New vehicle sales in California show a similar trend as SUV sales surged to 35 percent of total LD sales in 2019, up from about 20 percent in 2010.[27] One of the factors for this surge in SUV sales is the popularity of smaller SUVs known as "crossovers" such as the Honda CRV and Toyota RAV4,[28] although most of these SUV crossovers are classified as passenger vehicles and have comparable emissions to large passenger vehicles. Larger SUVs and pickups are regulated as light trucks and have a higher emissions profile. These preferences for SUVs come at the expense of passenger sedans, which accounted for

---

24 CARB. "Public Hearing to Consider the Proposed Innovative Clean Transit Regulation. Staff Report: Initial Statement of Reasons." August 7, 2018.

CARB. Staff Report: Initial Statement of Reasons. Public Hearing to Consider the Proposed Innovative Clean Transit Regulation, A Replacement of the Fleet Rule for Transit Agencies. August 7, 2018. https://ww3.arb.ca.gov/regact/2018/ict2018/isor.pdf?_ga=2.169040873.933544004.1601307160-1771686935.1580939935.

25 CARB. 2019. *California Greenhouse Gas Emissions for 2000 to 2017*. https://www.arb.ca.gov/cc/inventory/pubs/reports/2000_2017/ghg_inventory_trends_00-17.pdf.

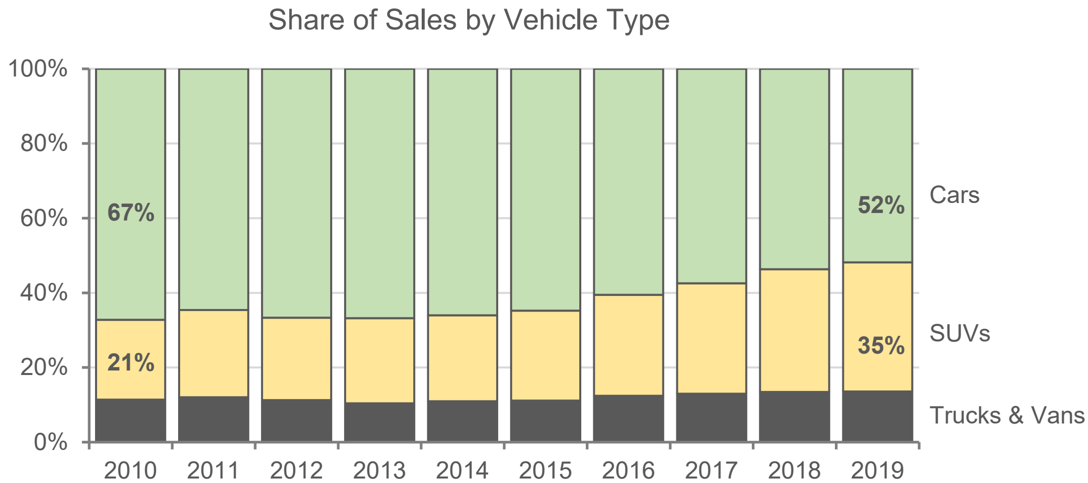
26 Paoli, Leonardo. "Trends in Larger Vehicles." Presentation at the June 11, 2020, IEPR workshop on Transportation Trends and Light-Duty ZEV Market Update. https://efiling.energy.ca.gov/GetDocument.aspx?tn=233408&DocumentContentId=65923.

27 Gage, Jesse. "Light-Duty Vehicle Trends Heavier, Yet More Efficient." Presentation at the June 11, 2020, IEPR workshop on Transportation Trends and Light-Duty ZEV Market Update. https://efiling.energy.ca.gov/GetDocument.aspx?tn=233411&DocumentContentId=65925.

28 Alfred Artis comments. June 11, 2020, IEPR workshop on Transportation Trends and Light-Duty ZEV Market Update transcript. pp. 46-50. https://efiling.energy.ca.gov/GetDocument.aspx?tn=234186&DocumentContentId=67034.

half of new car sales in 2019, down from two-thirds in 2010. As a proxy for this larger vehicle preference, vehicle curb weight can be a useful metric.[29] Figure 5 shows this trend over time. The result is that the average curb weight of internal combustion engine (ICE) vehicles sold in 2019 is about 175 pounds greater than the average curb weight of vehicles sold in 2010.

Figure 5: SUVs Have Increased as a Portion of California's Total Sales in the Last Decade



Credit: CEC Staff based on DMV Data

Consumer preferences for larger vehicles with larger, more powerful engines results in higher fuel use.[30] This higher fuel usage per mile driven results in higher emissions of criteria pollutants and CO_2 emissions. However, the emissions increase for battery-electric vehicles

29 Vehicle curb weight does not capture all the fuel economy impacts associated with larger vehicles. For example, a larger frontal area may have a larger impact on vehicle fuel economy. However, vehicle weight does correlate with vehicle size, including frontal area. This analysis, consistent with the International Energy Agency's approach, is useful to present a general picture of the trends and the potential implications.

30 In some cases, automakers use engine and other vehicle efficiency gains to offset the larger vehicle weight or more aggressive engines. However, if the same efficiency gains occurred without increasing vehicle weight or increasing aggressive acceleration profiles, the vehicle would have better fuel economy.

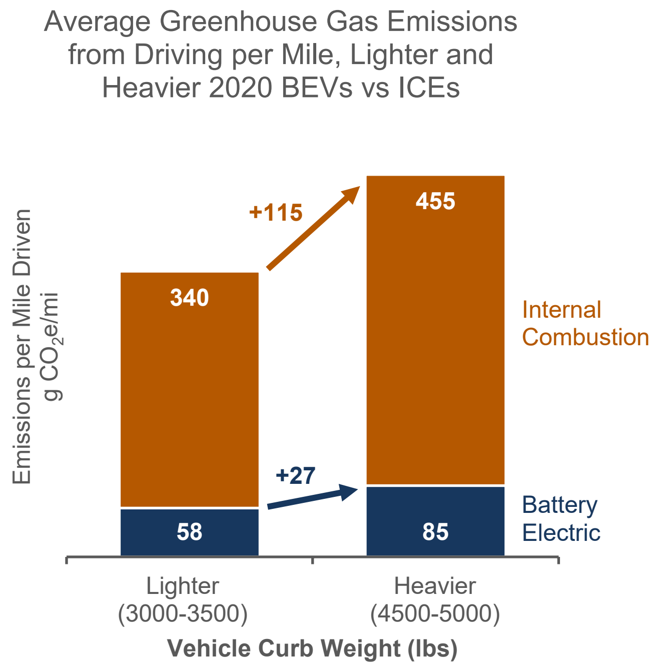
(BEVs) is not as sensitive to increases in vehicle weight.[31] (See Figure 6 below.[32]) As consumers opt for larger vehicles, including SUVs and crossovers, ensuring more BEV options becomes especially important for minimizing emissions.

31 A BEV with a similar size and body style to an internal combustion engine (ICE) vehicle tends to weigh more than the similar ICE vehicle. However, this additional weight does not add significantly to the emissions from driving the BEV. There are not sufficient data on heavy FCEVs to make a comparison due to limited models available.

32 This staff analysis of 2020 California available vehicle models is similar to IEA's European analysis, presented by Leonardo Paoli at the June 11, 2020, IEPR Workshop on Transportation Trends and Light-Duty ZEV Market Update. Figure modified to group vehicle weight categories ("Trends in Larger Vehicles." p. 4. https://efiling.energy.ca.gov/GetDocument.aspx?tn=233408&DocumentContentId=65923.)

Figure 6 does not represent a life-cycle assessment of a vehicle's complete emissions over its lifetime, only the emissions associated with driving. Plug-in electric vehicles (PEVs) have more GHG associated with their production than ICE vehicles. Despite this "upstream" GHG disadvantage, longer expected lifespans of PEVs due to higher reliability may offset this drawback. For example, if a PEV has 25 percent higher upstream GHG footprint but lasts 25 percent longer than a typical internal combustion vehicle, then the upstream GHG emissions of a PEV would not differ from internal combustion vehicles. Second-life uses of vehicle batteries may also offset the initial GHG associated with the energy required to manufacture the battery. See Chapter 6 for more information on second-life batteries.

Figure 6: GHG Emissions for Vehicles are the Most Problematic for Larger Combustion Vehicles



Credit: CEC staff based on California DMV data

Vehicle Miles Traveled are Increasing

Californians are also driving more miles each year, despite state efforts to reduce daily mileage. Solo trips traveling long distances between suburban housing, job centers, retail centers, grocery stores, and other key destinations typify the high levels of VMT. Cars are essential for most Californians to accomplish daily necessities. The chronic shortage of affordable housing in California exacerbates the trend toward longer, solo commutes.[33] The rise of e-commerce has also contributed to higher VMT, as more packages need to be delivered the "last mile." High VMT creates congestion on freeways and urban corridors, resulting in increased emissions, more accidents, and economic losses from lost work time,

33 California Air Resources Board. *2018 Progress Report*. California Sustainable Communities and Climate Protection Act. November 2018. https://ww2.arb.ca.gov/sites/default/files/2018-11/Final2018Report_SB150_112618_02_Report.pdf.

and missed delivery schedules. Congested freeways with high volumes of idling diesel trucks, a common occurrence on the Interstate 710 freeway in Los Angeles (Figure 7), contribute to already dangerous levels of NO_x and $PM_{2.5}$ emissions that impact the public health of local communities.

Figure 7: Congested Truck Traffic on the I-710 Corridor in Southern California

Photo Credit: Physicians for Social Responsibility.

Nationally, VMT increased continuously over the past 50 years until the 2008 Great Recession. As the economy recovered, VMT resumed a steady increase until the COVID-19 pandemic of early 2020. On a per capita basis, the United States had roughly 5,400 VMT per person in 1971 and 9,900 VMT per person in 2019, a nearly doubling of VMT per person in the last 50 years.[34] Per capita VMT in California is also increasing, along with per capita GHG emissions in the transportation sector, despite increases in fuel efficiency and decreases in the carbon content of fuel.[35]

---

34 VMT data from Elliot Martin, Ph. D. University of California, Berkeley. Transportation Sustainability Research Center. "Trends in Policy Considerations of VMT in Mid-2020." Presentation at June 12, 2020 IEPR Workshop on VMT.

Population data from U.S. Census Bureau.

35 CARB. 2018 Progress Report. California Sustainable Communities and Climate Protection Act.

California has worked to reduce VMT for light-duty cars and trucks through the passage of legislation including Senate Bill 375 (Steinberg, Chapter 728, Statutes of 2008), the Sustainable Communities and Climate Protection Act of 2008. SB 375 directed the state's 18 metropolitan planning organizations to create sustainable community strategies to reduce GHG emissions from passenger vehicles through more coordinated land use and transportation planning. The Legislature acted again in 2017 and passed Senate Bill 150 (Allen, Chapter 646, Statutes of 2017), which directed CARB to assess the progress in meeting the VMT reduction targets of the sustainable community strategies. However, the SB 150 report found that "California is not on track to meet the [GHG] reductions expected under SB 375 for 2020, with emissions from statewide passenger vehicle travel per capita increasing and going in the wrong direction." Further, CARB found that the state will not meet its 2030 carbon reduction goals without reducing VMT and associated vehicle emissions.[36] CARB's *2020 Mobile Source Strategy* indicates that a 25 percent reduction in VMT is needed to meet the 2035 Scoping Plan scenario target, with additional VMT reductions needed to meet the 2045 carbon neutrality goal.[37]

More recently, The Governor's Office of Planning and Research (OPR) released new California Environmental Quality Act (CEQA) guidelines that enact Senate Bill 743 (Steinberg, Chapter 386, Statutes of 2013) and change how local lead agencies measure transportation impacts from new developments. Beginning in July 2020, local lead agencies were required to assess changes in VMT, rather than "level of service," to identify potentially significant transportation impacts.[38]

Strategies to reduce VMT include increasing the use of mass transit, carpooling, and micromobility or active transportation modes such as walking, bicycling, and scootering.[39] Moreover, targeted use of shared rides and other TNC services may serve as a "last mile" complement to increased use of mass transit. However, these strategies are often undermined as local and regional land-use authorities struggle to colocate jobs, housing, and other

---

36 Ibid.

37 CARB. *2020 Mobile Source Strategy Draft*. p. 132. https://ww2.arb.ca.gov/sites/default/files/2020-11/Draft_2020_Mobile_Source_Strategy.pdf.

38 Governor's Office of Planning and Research. "Transportation Impacts (SB 743)," OPR web page, accessed November 13, 2020. https://opr.ca.gov/ceqa/updates/sb-743/.

39 Marco Anderson, Chris Lepe, and Jeanie Ward Waller comments. June 12, 2020, IEPR workshop on Transportation Trends and Light-Duty ZEV Market Update transcript. pp. 36–37, 44–48, and 54–56. https://efiling.energy.ca.gov/GetDocument.aspx?tn=234188&DocumentContentId=67033.

essential services, which would reduce solo travel by car. One potential strategy to reduce long commutes and VMT could be to continue the work-from-home policies necessitated by COVID-19. See the section on telework below.

Disproportionate Impacts on Disadvantaged and Low-Income Communities

California's disadvantaged and low-income communities continue to be disproportionately impacted by air pollution, with transportation-sector emissions serving as a major source. As mentioned above, disadvantaged communities are in part defined by air pollution exposure. Transportation pollution and other exposures are incorporated by census tract into a mapping tool, CalEnviroScreen 3.0. Diesel PM is a useful indicator of overall transportation pollution exposure, as the vast majority comes from vehicles. Census tracts with "high diesel PM exposure" are defined as in the 75th percentile or higher of exposure to diesel PM. In disadvantaged communities, 43 percent of residents are exposed to high levels of diesel PM.[40]

Environmental justice plays a role in exposure to diesel PM. Figure 8 displays the percentage of residents exposed to high levels of diesel PM by race. A large percentage of Black, Asian American, and Latino residents live in census tracts with high exposures, about twice the proportion of white residents. High exposures are associated with dense urban areas that are near freight corridors. These disproportionate exposure levels are a symptom of systemic racism, whereby people of color are concentrated in neighborhoods that have been disempowered, both politically and financially. The Native American exposure quotient for diesel PM is relatively low on the figure, primarily because most tribal lands in California are in rural parts of the state away from major transportations corridors. Although most California Native Americans now live outside tribal lands, current data show relatively lower diesel PM exposure rates compared to other urban ethnic groups in California. Southern California tribes in San Diego, Imperial, and Riverside counties tend to have higher exposure levels to transportation related diesel PM.[41]

---

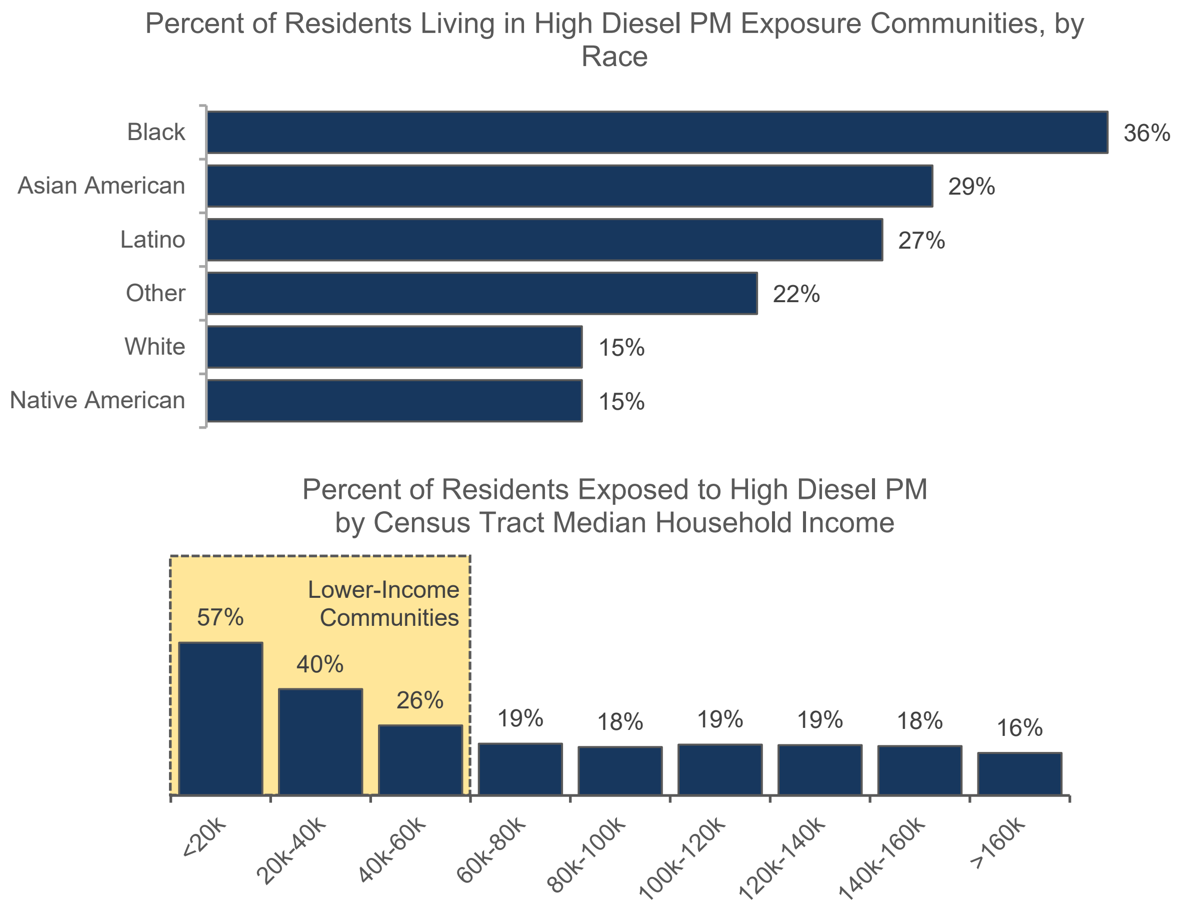
40 CEC staff calculation. Data for these calculations from additional materials from the Office of Environmental Health and Hazard Assessment web page. https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-30.

41 U.S. Environmental Protection Agency, Region 9. Office of Air Quality Analysis. Map of California Tribal Lands and Reservations. https://www3.epa.gov/region9/air/maps/ca_tribe.html.

PM exposure is a public health concern for California tribes, but the PM sources affecting Native Americans tend to come from wildfire smoke, wood fire smoke, and older, diesel-fueled school buses. See for example *National*

Household income also plays a large role in the likelihood of exposure to high levels of diesel PM. Figure 8 also displays the percentage of residents living in census tracts with high diesel PM exposure, categorized by the median income of the census tracts. Residents in low-income communities are much more likely to be exposed to high levels of diesel PM, among other pollutants.

Figure 8: Systemic Racism and Income Play a Large Role in the Likelihood of Living in a Community with High Diesel PM Exposure



Credit: CEC analysis of census and CalEnviroScreen 3.0 data

Tribal Air Association: Status of Tribal Air Report. June 2020. https://7vv.611.myftpupload.com/wp-content/uploads/2020/06/2020-NTAA-Status-of-Tribal-Air-Report.pdf.

CalEnviroScreen Data Source. https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-30.

Because race, air pollution, and COVID-19 risk are all interrelated, the disproportionate racial impacts of COVID-19 demand attention. Nationally, according to U.S. census data, Black Americans make up 13.4 percent of the nation's population but represent 22 percent of COVID-19 related fatalities. Black Californians comprise 4 percent of the COVID-19 cases and 7 percent of fatalities.[42]

In California, Latino communities are suffering the worst of the COVID-19 impacts. Latinos comprise 39 percent of the state's population but account for 60 percent of total cases and nearly 50 percent of fatalities (almost 9,000 through November 16, 2020).[43] Researchers at the University of California, Los Angeles, Center for the Study of Latino Health and Culture have further analyzed COVID-19 data and found that Latino "essential workers," including truck and bus drivers, are bearing the worst of the COVID impacts.[44]

COVID-19 Impacts on Transportation

Significant Short-term Impacts

In addition to the disproportionate public health impacts from COVID-19, the pandemic continues to have major and unanticipated impacts on all aspects of California's transportation system. The first several months of shelter-in-place resulted in a dramatic reduction in VMT, with corollary reductions in fuel use and vehicle emissions. Residents of large urban regions like Los Angeles gained a glimpse into a clean air future when reduced vehicle emissions from electrification, cleaner engines, and lower VMT will eliminate the veil of smog and reveal its skylines and blue skies, such as in this spring 2020 photo of Downtown Los Angeles, compared to a months-long ozone pollution streak in 2018. (See Figure 9.)

42 California Department of Public Health. COVID-19 Race and Ethnicity Data. Daily updated data as of November 16, 2020, accessed on November 18, 2020. https://www.cdph.ca.gov/Programs/CID/DCDC/Pages/COVID-19/Race-Ethnicity.aspx. Docketed record available at https://efiling.energy.ca.gov/GetDocument.aspx?tn=235663&DocumentContentId=68607.

43 Ibid.

44 Hayes-Bautista, David and Paul Hsu. University of California, Los Angeles. Center for the Study of Latino Health and Culture. 2020. "COVID-19-Associated Deaths in Working-Age Latino Adults." https://ph.ucla.edu/sites/default/files/attachments/Report-8-COVID-19_Associated_Deaths_in_Working_Age_Latino_Adults_08272020.pdf.

Figure 9: Downtown Los Angeles, April 2020 and June 2018

Photo Credits: Twitter/@MikeSington, April 6, 2020, (left, https://www.timesunion.com/news/article/clean-clear-air-Los-Angeles-photos-coronanvirus-15204855.php) Wally Skalij/Los Angeles Times, June 2020 (right, https://www.latimes.com/local/lanow/la-me-smog-streak-20180921-story.html)

California's March 19, 2020, stay-at-home order resulted in an unprecedented drop in travel across all modes, with an accompanying drop in fuel demand. Demand for gasoline decreased 45 percent in April 2020 — the lowest demand level since 1968.[45] Fuel production dropped in response, with steep declines in sales of gasoline, diesel, and jet fuel.[46] Refinery utilization rates fell by 56 percent, the lowest in 40 years.[47] Retail gasoline prices also dropped sharply, dipping to a low of $2.50 per gallon in May 2020.[48] The steep drop in fuel sales led to layoffs and refinery closures. Chevron announced in May 2020 that it would reduce its 45,000 global

45 Schremp, Gordon. "Transportation Fuel Trends, Refinery and Market Changes, and Expanded Use of Renewables." CEC. Presentation to Bay Area Air Quality Management District Board of Directors. September 16, 2020.

46 CEC's Energy Insights web page. https://www.energy.ca.gov/data-reports/energy-insights.

47 CEC 2020. Gordon Schremp.

48 CEC. "Petroleum Watch- June 2020." https://www.energy.ca.gov/sites/default/files/2020-06/Petroleum_Watch-June_2020_ADA.pdf.

workforce by 15 percent, including staff cuts at its Richmond refinery complex.[49] In March 2020, Marathon Petroleum announced the permanent closure of its Martinez refinery, which employed more than 700 workers.[50] Phillips 66 announced in August 2020 that it would close its Santa Maria refinery in 2023 and convert its Rodeo refinery to an 800-million-gallon renewable fuels refinery. Four other refineries in the United States and Canada halted production, two of them permanently. California refineries are meeting diesel fuel demand by shifting some refining capacity from jet fuel to diesel, and by increasing imports of renewable diesel. Additional production from underused Southern California refineries, plus Northwest imports, is ensuring reliable supplies of gasoline.[51]

In response to lower travel demand and the economic impacts from COVID-19, the global vehicle market has contracted. The International Energy Agency (IEA) found that the global passenger vehicle sales could contract 15 percent this year compared to 2019 levels. However, sales of used internal combustion engine vehicles are increasing in the United States as consumers seek alternatives to public transit and ride-hailing services.[52] Globally, and in California, electric vehicle sales continue to grow as a proportion of total passenger vehicle sales despite the pandemic.[53]

As the widespread lockdowns kept many home, effects were particularly noticeable in the transportation sector, including transit. California's public transit agencies saw a dramatic decrease in ridership and revenue, pushing more than 85 local public transit agencies to

---

49 DiFeliciantonio, Chase. "Chevron to Cut up to 15 Percent of Global Workforce." *San Francisco Chronicle*. May 27, 2020. https://www.sfchronicle.com/business/article/Chevron-to-cut-up-to-15-of-global-workforce-15299120.php.

50 Goldberg, Ted. "Shutdown of Marathon's Martinez Refinery Prompts Calls for 'Just Transition' for Oil Workers." KQED Radio News. August 3, 2020. https://www.kqed.org/news/11831607/shutdown-of-marathons-martinez-refinery-prompts-calls-for-just-transition-for-oil-workers.

51 CEC 2020. Gordon Schremp.

52 Boudette, Neal E. "Looking to Buy a Used Car in the Pandemic? So is Everyone Else." *New York Times*. September 7, 2020. https://www.nytimes.com/2020/09/07/business/used-cars-pandemic.html?searchResultPosition=1.

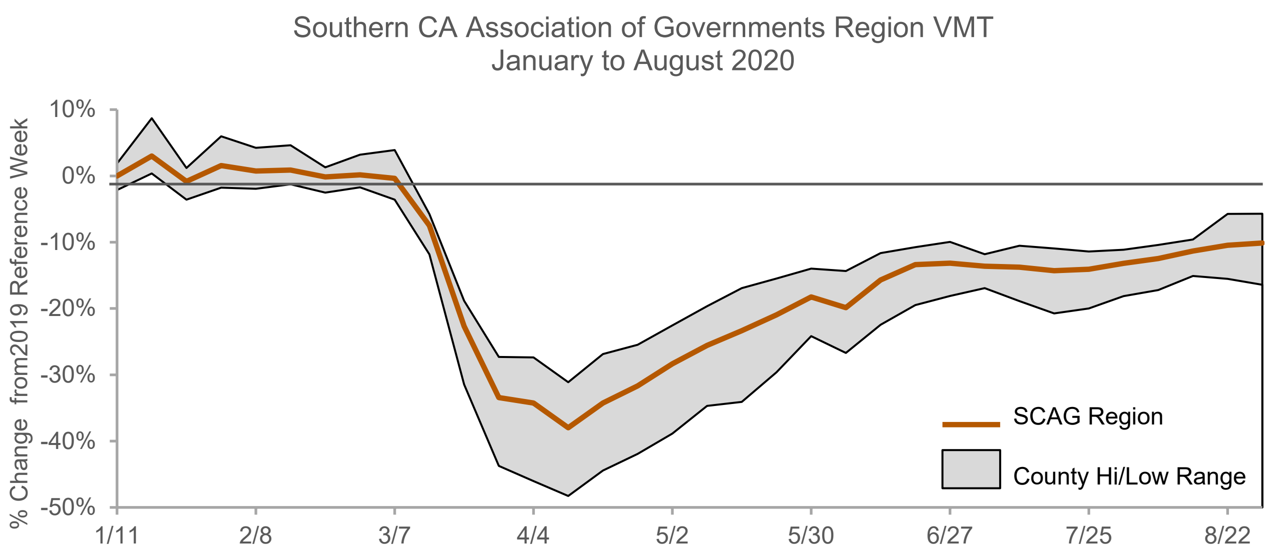
53 IEA press release. "Electric Car Sales This Year Resist COVID-19's Blow to Global Car Market." June 15, 2020. https://www.iea.org/news/electric-car-sales-this-year-resist-covid-19-s-blow-to-global-car-market.

Data for California's ZEV trends is available using the CEC's interactive ZEV Dashboard web page. https://www.energy.ca.gov/data-reports/energy-insights/zero-emission-vehicle-and-charger-statistics.

request more than $3 billion in funding relief from the state to prevent permanent service reductions. For example, Metrolink ridership in Los Angeles is 80 percent below average, while the LA Metro bus system is 75 percent below average. In Northern California, the BART system is 88 percent below the ridership average. AC Transit ridership in the East Bay is down 72 percent. Each of these transit systems is experiencing severe revenue shortfalls. AC Transit is losing revenues of nearly $1 million a week, with BART losing $9 million per week.[54]

Figure 10 shows VMT trends in Southern California, where VMT dropped by 40 percent in April 2020. This chart uses a seven-day moving average. In August, Southern California VMT rebounded to 10 percent below pre-pandemic levels.

Figure 10: Percentage Change in Seven-Day Moving Average VMT in Southern California (Using January 2020 as a Benchmark)



Data Source: Southern California Association of Governments

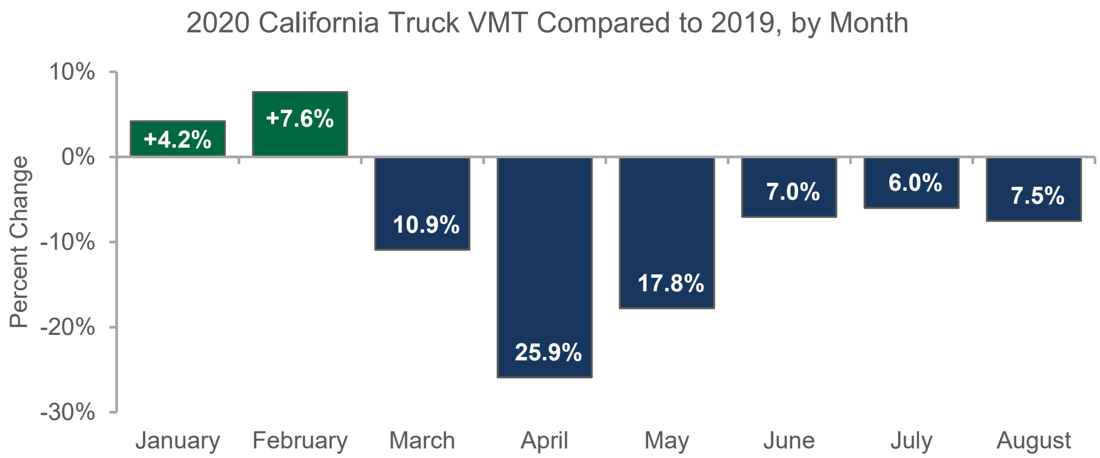
Freight and truck VMT in California increased steadily before the COVID-19 pandemic and declined sharply during the early months of the pandemic. Figure 11 compares VMT changes from a year ago, displayed by month. Consistent with the growth of California's economy, annual truck VMT grew from 85 million to 98 million miles between 2014 and 2018, a 15 percent growth rate. Despite the recent decline, long-term truck VMT could increase to 119

---

54 California Transit Association. "Transit Watch: Public Transit in Crisis." November 23, 2020. https://caltransit.org/news-publications/our-newsroom/transit-watch/.

million by 2040. Truck VMT in urban areas is also increasing rapidly, up 17 percent since 2015, with e-commerce as a key contributor.[55] These state-level trends track generally with national VMT trends, which show a 17 percent increase in urban truck-related VMT through 2018.[56]

Figure 11: California Truck VMT Has Been Impacted by COVID-19



Data Source: Miguel Jaller, Sustainable Freight Research Center, University of California, Davis

Nationally, the COVID-19 pandemic and economic contraction resulted in a 17 percent decrease in truck VMT. In California, the reductions in truck VMT have been more modest, dropping 12.5 percent since the start of the pandemic.[57] Truck VMT is expected to increase as the economy recovers.

Larger, well-established and well-capitalized auto and truck companies regard the pandemic as disruptive in the short term but do not see long-term impacts on their electrification goals. At the June 11, 2020, IEPR workshop on Trends in Vehicle Sizes, Cynthia Williams, global sustainability director for Ford Motor Company, stated that Ford had the resources and intends

---

55 California Department of Transportation. *2020 Freight Mobility Plan*. https://dot.ca.gov/-/media/dot-media/programs/transportation-planning/documents/cfmp-2020-final/final-cfmp-2020-chapters-1-to-6-remediated-a11y.pdf.

56 American Transportation Research Institute. *E-Commerce Impacts on the Trucking Industry*. https://truckingresearch.org/wp-content/uploads/2019/02/ATRI-Impacts-of-E-Commerce-on-Trucking-02-2019.pdf.

57 "COVID-19's Impact on Freight: An Analysis of Long-Haul Freight Movement during a Pandemic." INRX Research. April 2020.

to stay the course on ZEV development through the pandemic.[58] Major HD truck OEMs, such as Daimler, PACCAR, and Volvo, are reporting steep sales declines through the second quarter of 2020.[59] Class 8 tractor sales have been especially affected, with a 47 percent drop in global sales. Volvo reported a 46 percent decrease in global truck sales, including a 31 percent decline in Class 8 tractor sales. Daimler truck sales are down 34 percent. Navistar's truck sales declined by 31 percent, while PACCAR, maker of the Peterbilt and Kenworth lines, saw a 50 percent drop in sales, from $6.6 billion in 2019 to just $3 billion through the second quarter of 2020. Volvo, PACCAR, and Mack Trucks closed their North American manufacturing plants for weeks in April, and Volvo and Mack have announced layoffs.[60] These drops in sales are due to declines in demand and problems with global supply chains.

These economic impacts underscore not only the challenge of funding clean transportation initiatives during a public health emergency, but the need to continue to support and fund clean transportation. Transit and school districts will have much less capacity to finance ZEV buses and their charging infrastructure. Private companies and trucking fleets may have less access to capital for ZEV fleet expansion. As noted, California government agencies will have lower funding levels for incentive programs. Funding is critical to reducing disproportionate air pollution impacts as well as strengthening California's recovery efforts by reinvesting in clean and equitable transportation.

The Age of Telework

Although there was a rapid early decrease in VMT, the long-term consequences of the pandemic on transportation fuel use and emissions are uncertain. Many businesses whose operations were compatible with telecommuting have widely adapted to public health guidelines to ensure safe operations by allowing employees telework in place of their normal commute. This adaptation may be a permanent paradigm shift for some workplaces even after

58 Williams, Cynthia. Ford Motor Company. Presentation at the June 11, 2020, IEPR Workshop on Light-Duty ZEV Update and Trends in Larger Vehicles. https://efiling.energy.ca.gov/getdocument.aspx?tn=233407.

59 "Truck Makers Hit Hard by COVID-19 Fallout." *Triad Business Journal*. May 2020. https://www.bizjournals.com/triad/news/2020/05/26/triad-truck-makers-hit-hard-by-covid-19-fallout.html.

60 "Major OEMs Second Quarter Reports Reflect Continued Impact of COVID-19." TheTrucker.com. July 27, 2020. https://www.thetrucker.com/trucking-news/business/major-oems-second-quarter-reports-reflect-continued-impact-of-covid-19.

it is considered safe to return to work.[61] This paradigm shift has had significant short-term effects on local emissions, but longer-term trends and impacts are uncertain. UC Riverside researchers estimate a 2.4 percent reduction in long-term total GHG emissions in California, since only work-related commutes are expected to see lasting reductions.[62]

Moreover, the emission reductions from telework may be diminished due to countervailing fears of viral spread on public transit systems and ride-hailing services, which in turn cause greater use of single-occupancy vehicle travel.

New research from the UC Davis Institute for Transportation Studies indicates that the benefits of telecommuting may be limited to office professionals who can work from home and are not shared equitably with people working in trades, services, or agricultural sectors who may be classified as "essential workers."[63] Almost all "essential worker" classifications have been tied to jobs that cannot engage in telework, exacerbating existing inequities in the workplace. At the national level, the United States Bureau of Labor Statistics indicates that just 20 percent of Black Americans and 16 percent of Latino or Hispanic Americans have jobs suitable for teleworking, while 37 percent of Asian-Americans and 30 percent of white Americans have telework-compatible jobs.[64]

---

61 Guynn, Jessica. "How Would You Like to Work From Home 'Forever'? Twitter is Encouraging Employees to Do So." *USA Today*. May 12, 2020. https://www.usatoday.com/story/tech/2020/05/12/twitter-work-from-home-forever/3118879001/.

62 Bond, Victoria Pike. "Pandemic Driving Reductions Won't Reduce Greenhouse Gas Emissions Much." UC Riverside News web page. August 4, 2020. https://news.ucr.edu/articles/2020/08/04/pandemic-driving-reductions-wont-reduce-greenhouse-gas-emissions-much.

UC Riverside School of Business. "COVID-19, Commuting, and Clean Air: A Look at Pandemic-Era Mobility and Transportation Emissions in California." July 2020. https://ucreconomicforecast.org/wp-content/uploads/2020/08/Mobility_Emissions_COVID19_CEFD_White_Paper_August_2020.pdf.

63 Matson, Grant et al. "Longitudinal Analysis of COVID-19 Impacts on Mobility: An Early Snapshot of the Emerging 2 Changes in Travel Behavior," University of California, Davis, Institute for Transportation Studies. Pre-publication draft shared by author.

64 Curry, Melanie. "What Benefits Telecommuting May Bring Are Still Very Much Unknown." StreetsBlogCal. August 4, 2020. https://cal.streetsblog.org/2020/08/04/what-benefits-telecommuting-may-bring-are-still-very-much-unknown/.

Setting a Course for Zero Emissions

To meet California's ambitious clean transportation goals, the state has developed goals and milestones to outline its mission to decarbonize the transportation sector and provide global leadership in clean transportation policy.

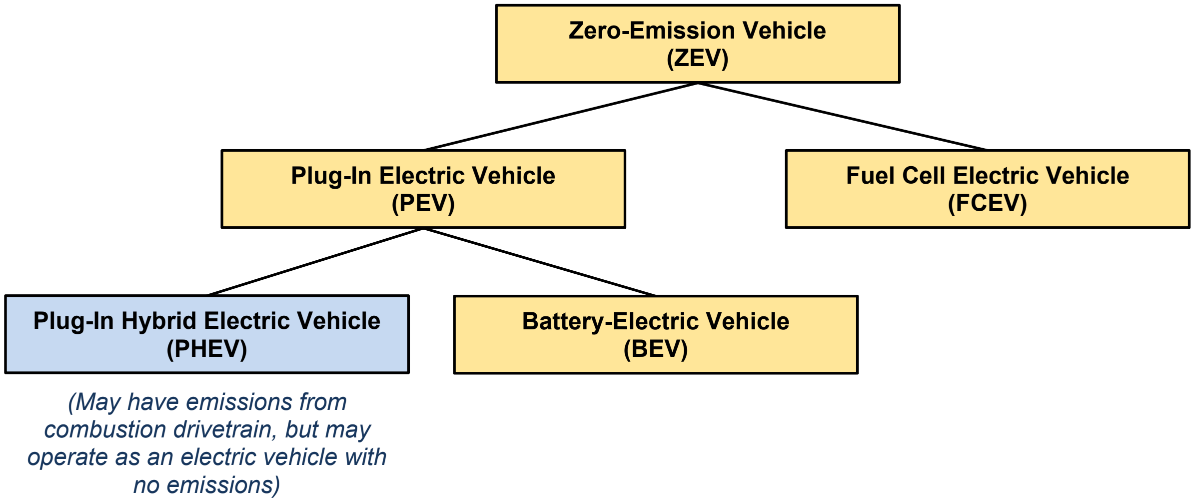
Some opportunities for reducing emissions from transportation can focus on improving the efficiency of the current vehicle stock. Replacement tires are a notable contributor to GHG emissions from transportation. Low-rolling resistance tires are often found in new cars, but replacements do not always have this feature. Increasing the market uptake of low-rolling resistance tires in the replacement tire market is expected to improve the fuel economy of internal combustion engine (ICE) vehicles as well as allow for longer ranges for ZEVs, resulting in net savings for consumers and substantial declines in emissions.[65]

Major changes to transportation emissions will require a focus on future vehicle deployment. In this regard, ZEVs are necessary to meet the state's goal of carbon neutrality by 2045 as set by Executive Order B-55-18.[66] Other laws and executive orders support this goal, including Executive Order N-79-20, which sets a 100 percent ZEV target for new passenger vehicle sales by 2035 and a 100 percent ZEV operations target for MD and HD vehicles in the state by 2045. A variety of zero-emission vehicle types are available to fill this need. Figure 12 below provides a visual categorization of ZEVs.

65 Natural Resources Canada. 2018. Market Analysis Report for Passenger Car Replacement Tires in Canada. https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/resource-library/market-analysis-report-passenger-car-replacement-tires-canada/21805.

66 Executive Order B-55-18. https://www.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf.

Figure 12: Categories of ZEVs



Credit: CEC

California needs focused attention on transportation policies and regulations, as they are crucial to accelerating the transformation of the transportation sector to ZEVs. Moreover, these initiatives contribute to a reliable network of charging infrastructure and hydrogen fueling stations and ultimately improved public health. Further, even when all new passenger cars sold in 2035 are ZEVs,[67] it will take a long time to transform the vehicle fleet. Nearly 15 percent of the passenger vehicle stock will be gasoline-powered in 2045, by which time California must achieve carbon neutrality to help prevent the worst impacts of climate change.[68] VMT reduction must be a part of the state's strategy to reduce transportation emissions. To ensure these changes meet the needs of all Californians, equity must also be a cornerstone in the state's clean energy policies, with engagement from regional and local stakeholders throughout this transportation revolution.

Table 1 summarizes the major California policies and milestones for reducing GHG emissions, reducing criteria pollutant emissions and increasing ZEV deployment within the state.

67 CARB treats PHEVs as separate from ZEVs. As of 2020, the CEC has treated PHEVs as a category of ZEV.

68 CARB. 2020 Mobile Source Strategy. Discussion Draft. p. 59. https://ww2.arb.ca.gov/sites/default/files/2020-11/Draft_2020_Mobile_Source_Strategy.pdf.

Table 1: GHG, Fuel, and Air Quality Goals and Milestones

Policy Origin	Objectives	Goals and Milestones
Senate Bill 32	Reduce GHGs	➢ Reduce GHG emissions to 40 percent below 1990 levels by 2030
Senate Bill 375	Reduce GHGs, Reduce VMT	➢ Directed the state metropolitan planning organizations to create strategies to reduce VMT and carbon emissions
Low Carbon Fuel Standard	Reduce GHGs	➢ Reduce carbon intensity of transportation fuels in California by 20 percent by 2030 ➢ Increase ZEV Infrastructure
ZEV Regulation	Increase ZEVs, Reduce Criteria Pollutants, Reduce GHGs	➢ Increase the deployment of plug-in hybrid, battery, and fuel cell electric vehicles
Executive Order B-16-2012	Increase ZEVs and ZEV infrastructure	➢ Reduce GHG emissions from the transportation sector to 80 percent below 1990 levels by 2050 ➢ Infrastructure to accommodate 1 million electric vehicles by 2020 ➢ 1.5 million electric vehicles by 2025
Executive Order B-48-18	Increase ZEVs and ZEV Infrastructure	➢ 5 million ZEVs by 2030 ➢ 250,000 electric vehicle chargers, including 10,000 direct current fast chargers, and 200 hydrogen refueling stations by 2025
Executive Order B-55-18	GHG Reduction	➢ Achieve carbon neutrality by 2045 and negative emissions thereafter
Innovative Clean Transit Rule	Increase ZEVs, Reduce Criteria Pollutants, Reduce GHGs	➢ 100 percent of all new transit buses will be zero-emission by 2029; all operating buses will be zero-emission by 2040
Advanced Clean Truck Rule	Increase ZEVs, Reduce Criteria Pollutants, Reduce GHGs	➢ 55 percent of Class 2b-3 truck sales, 75 percent of Class 4-8 straight truck sales, and 40 percent of truck tractor sales must be zero-emission trucks/chassis by 2035
Executive Order N-79-20	Increase ZEVs and ZEV Infrastructure, Reduce GHGs	➢ 100 percent of new passenger vehicle sales must be zero emission by 2035 ➢ Where feasible, 100 percent medium- and heavy-duty ZEVs operating in the state by 2045, and by 2035 for drayage trucks and off-road vehicles and equipment

Credit: CEC

To advance the policy initiatives above, state agencies such as the CEC, CARB, and the California Public Utilities Commission (CPUC), as well as regional agencies like the air quality management districts, administer various grant and funding opportunities or enable programs that support the transition to ZEVs. These agency programs support the investment in research, development, demonstration, and market assistance to promote zero-emission transportation technologies, infrastructure, equity, workforce development, and manufacturing. The Clean Transportation Program, established by Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007), is one such program. The Clean Transportation Program is administered by the CEC and has funded nearly $900 million through September 2020 to various projects and initiatives to help the state meet its clean energy and climate goals.[69]

The Electric Program Investment Charge (EPIC) is another funding program dedicated to clean energy research administered mainly by the CEC, with 20 percent of funds being managed by the three largest investor-owned utilities: Pacific Gas and Electric Company (PG&E), San Diego Gas & Electric Company (SDG&E), and Southern California Edison Company (SCE). EPIC provides more than $130 million annually to various clean energy opportunities, including transportation electrification.[70] In 2019, the program provided $33 million in funding toward transportation electrification, with another $23 million drawn from match and leveraged funding toward projects on advanced battery development, EV deployment tools, and vehicle-grid integration.[71]

Other state agency programs play a large role in providing incentives for clean transportation development and commercial deployment. CARB's funding for clean transportation peaked in fiscal year (FY) 2017–2018 at $560 million with a mix of cap-and-trade proceeds and Air Quality Improvement Program (AQIP) funds, declining to about $450 million annually for the next two fiscal years.[72] The FY 2020–2021 funding plan includes just $28.6 million authorized to date in AQIP funding. The Governor's proposed 2021–2022 budget recommends $465 million in cap-and-trade funding to support deployment of zero-emission vehicles.[73] This proposed funding will need to be authorized by the State Legislature before the start of the

---

69 For a more detailed accounting of Clean Transportation Program investments, see the 2020–2023 Clean Transportation Investment Plan. https://efiling.energy.ca.gov/getdocument.aspx?tn=235807

70 Electric Program Investment Charge web page. https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program.

71 Doughman, Pamela. 2020. *Electric Program Investment Charge 2019 Annual Report*. California Energy Commission. Publication Number: CEC-500-2020-009-CMF. https://ww2.energy.ca.gov/2020publications/CEC-500-2020-009/CEC-500-2020-009-CMF.pdf.

72 CARB. Discussion Document. Fiscal Year 2020-2021 Funding Plan for Clean Transportation Incentives. September 29, 2020. https://ww2.arb.ca.gov/sites/default/files/2020-09/fy2021_fp_dis.

Note that these figures do not include CARB's more traditional funding programs such, as Carl Moyer and the Community Air Protection Program.

73 State of California. 2021–2022 Governor's Budget. Budget Summary Chapters, Climate Change. January 8, 2021. http://www.ebudget.ca.gov/budget/2021-22/#/BudgetSummary.

2021–2022 Fiscal Year. Among its other incentive programs, CARB administers two popular programs that provide purchase subsidies for zero- and low-emission cars, trucks, and buses. The Clean Vehicle Rebate Project provides incentive funding for passenger vehicles, and the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project provides incentive funding for MD and HD buses and trucks. Both programs are oversubscribed, showing the ongoing demand and need for program funding.[74]

CARB administers a suite of programs targeting low-income and disadvantaged communities called Clean Transportation Equity Investments. Programs like Clean Cars 4 All and the Enhanced Fleet Modernization Program are designed to provide additional incentive support to low-income consumers to encourage retirement and scrappage of older, high-polluting internal combustion engine vehicles and purchase of new or used ZEVs. These programs are also funded by cap-and-trade auction proceeds, for which Fiscal Year 2020–2021 funding has not yet been approved.[75]

Recommendations

- **The state should invest in additional research to understand the trends more thoroughly toward and potential for enduring changes in travel behavior.** The sharp drops in vehicle miles traveled from the early months of the COVID-19 pandemic provided a unique opportunity to assess the potential for dramatic changes in travel behavior and travel energy demand.
- **State agencies, local jurisdictions, and, where possible, private businesses should evaluate and consider instituting telecommuting options for their workforces to help reduce vehicle miles traveled.** In particular, the California Air Resources Board (CARB) should evaluate telecommuting programs as potential transportation control measures for reducing criteria emissions.
- **To achieve the target of 100 percent zero-emission vehicle (ZEV) sales of light-duty passenger vehicles by 2035, the state needs to ensure that there is a full range of ZEV models to meet consumer preferences, particularly for larger vehicles like sport utility vehicles, minivans, and pickups.** CARB should consider regulatory and incentive approaches to encourage the availability of larger passenger ZEV

74 CARB. 2020. The Fiscal Year 2020-2021 Funding Plan for Clean Transportation Incentives. Staff Discussion Draft. September 19, 2020. https://ww2.arb.ca.gov/sites/default/files/2020-09/fy2021_fp_discussion_document_0.pdf.

75 State of California. 2021–2022 Governor's Budget. Budget Summary Chapters, Climate Change. January 8, 2021. http://www.ebudget.ca.gov/budget/2021-22/#/BudgetSummary.

models to align with trends in consumer preferences. The state should ensure that critical purchase incentive programs run by CARB and the air districts are sufficiently funded to meet the sharp increases in ZEV sales needed to meet the 2035 target.

- **California must do more to engage and understand the local mobility and clean transportation needs of low-income and disadvantaged communities throughout the state and tailor state programs appropriately to meet those needs.** It is essential that state and regional agencies expand direct collaboration with communities to better partner, listen, and understand their needs and then design programs to address these barriers. Testimony from members of the Disadvantaged Communities Advisory Group (DACAG), established by Senate Bill 350, identified the need to develop additional approaches and best practices to identify community benefits, advance equity, and expand inclusion.
- **The state should explore all opportunities to reduce oxides of nitrogen (NOx) emissions from medium-duty (MD) and heavy-duty (HD) vehicles that are registered outside California but operate within the state.** California has NOx attainment challenges that are driven by emissions that are predominantly from sources where the U.S. Environmental Protection Agency is the primary regulator.

CHAPTER 2
The Road Ahead: Disruptive Changes to Mobility and Economic Growth

Three Revolutions: Electrification, Automation, and Shared Mobility Services

A series of new technologies — electrified transportation, vehicle automation, and shared mobility services — are converging to create potentially disruptive changes in the transportation system. Professor Daniel Sperling at the University of California, Davis (UC Davis), Institute for Transportation Studies identifies these technology trends as the "Three Revolutions." If these three interdependent trends evolve in accordance with a best-case scenario, California could foster more sustainable and equitable transportation systems while reducing transportation greenhouse gas (GHG) emissions by 80 percent. To the contrary, if these three trends are not strategically managed by governments and other key stakeholders, they could exacerbate many of the state's most serious transportation issues, including increases in vehicle miles traveled (VMT), congestion, fuel use, and vehicle emissions.[76]

The best-case "Blue Skies Scenario" denotes a future with economic benefits from lower transportation costs, reduced reliance on vehicles, reduced transportation emissions, and more efficient transportation systems. This scenario is achieved through the increased use of zero-emission vehicles, vehicle automation, the support of micromobility options, and improved shared ride-hailing services.

The worst-case "Dirty Skies Scenario" denotes a future suffering from higher levels of VMT and roadway congestion, increased use of fossil fuels, and corresponding increases in GHG and criteria pollutants. In this scenario, autonomous "ghost vehicles" (empty driverless cars) that clog urban streets, noncoordinated use of electric chargers that disrupt grid efficiency, and disparities in mobility services increase. Furthermore, accessibility to clean transportation jobs in disadvantaged and low-income communities remain limited.

---

76 Sperling, Daniel. University of California, Davis, Institute for Transportation Studies. *Three Revolutions: Steering Automated, Shared and Electric Vehicles to a Better Future*. Island Press. 2018.

Figure 13: Future Mobility Scenarios for Three Revolutions

Credit: Based on graphic developed by UC Davis Institute for Transportation Studies

Transportation Electrification

Vehicle markets, within the state and globally, have increasingly made electric vehicles available for consumers. The market share of fuel cell and battery-electric vehicles has grown and will continue to grow as the technology and infrastructure develop. These two technologies and related infrastructure are key to moving toward the "Blue Skies" scenario as they provide a clean alternative for conventional internal combustion engine (ICE) vehicles. Government incentives and regulations support transportation electrification to aid this transition, especially to avoid added emissions from ICE vehicles in shared mobility and vehicle automation.

Chapters 3 through 6 of this report prominently discuss vehicle electrification.

Shared Mobility and Ride-Hailing

As a result of increased municipal public-private partnerships and the rise of shared mobility applications, various forms of shared mobility have seen continued growth.[77] As one of the

77 Shaheen, Susan, Ph.D. et al. U.C. Berkeley Institute for Transportation Studies. UCCONNECT. "Future of Mobility White Paper." 2018. https://escholarship.org/uc/item/68g2h1qv.

lowest GHG options for mobility, shared-mobility options such as bike and scooter share, in addition to mass transit and active transit, are critical for supporting this growth and are key to achieving the Blue Skies scenario. Another part of this paradigm shift has been the growth of ride-hailing.

Before the COVID-19 pandemic, the use of ride-hailing services offered by Uber and Lyft had been growing rapidly for more than a decade. Globally, Uber accumulated more than 10 billion trips through 2018, while Lyft generated 1 billion trips.[78] In the United States, nearly half of urban millennials have Uber on their smartphones.[79] These companies are outcompeting traditional taxi services. For example, in San Francisco, ride-hailing trips outnumber taxi trips by a factor of 12 to 1.[80] These high use levels in urban areas indicate the improvement to personal mobility brought through these services. Collectively, however, the growing use of these services has translated to increases in VMT and congestion. With COVID-19, pooled ridesharing has seen a sharp decline, and how quickly this market will recover after the pandemic is not clear.

General ride-hailing service trends illustrate the challenges of the Dirty Skies Scenario. According to research from the Union of Concerned Scientists, private trips in fossil-fueled ride-hailing vehicles generate nearly 50 percent more GHG emissions than comparable trips in privately owned vehicles. This increase is primarily due to "deadheading," or the empty miles of ride-hailing drivers without a passenger in the car, which increase VMT and GHG emissions associated with the passenger's trip.[81] Even more concerning is the increased use of ride-hailing that displaces micromobility and active transportation, such as walking, bicycling, and scootering. Recent research from UC Davis shows that, while use of ride-hailing services displaces private vehicle use in urban areas, use of these services has also displaced walking and biking by 60 percent and transit use by 70 percent. Including deadheading and the ride-

---

78 Presentation by Giovanni Circella, Ph.D. "Opportunities and Challenges for the 3 Transportation Revolutions." July 16, 2020, IEPR Workshop on the 3 Revolutions. https://efiling.energy.ca.gov/getdocument.aspx?tn=233864.

79 Ibid.

80 Don Anair et al. "Ride-Hailing's Climate Risks: Steering a Growing Industry Towards a Clean Transportation Future." Union of Concerned Scientists. 2020. https://www.ucsusa.org/sites/default/files/2020-02/Ride-Hailing%27s-Climate-Risks.pdf.

81 Ibid.

hailing displacement of other transportation modes increases total GHG emissions by 69 percent.[82]

For consumers who prefer ride-hailing, electrification and increased use of pooled or shared trips are the lowest GHG options. Trips in electrified ride-hailing vehicles generate 53 percent fewer GHG emissions than fossil-fuel vehicles. When electrification is combined with shared or pooled ridesharing, emissions are reduced by 68 percent.[83] At present, electrification rates are very low, with estimated use of EVs for ride-hailing at less than 1 percent.[84]

The Legislature enacted Senate Bill 1014 (Skinner, Chapter 369, Statutes of 2018), which directs the California Air Resources Board (CARB) to adopt and the California Public Utilities Commission (CPUC) to enforce targets for GHG emissions in grams of carbon dioxide (CO_2) per passenger miles traveled and for electric VMT (eVMT) by 2021. One goal of this legislation is to encourage shared ride-hailing services or pooled transportation network companies (TNCs) to use driving best practices such as supporting active transport and first- and last-mile access to complement the use of mass transit and reduce VMT. TNCs, such as Uber and Lyft, will develop two-year implementation plans by 2022 and begin implementation and compliance by 2023.[85] CARB will consider proposed eVMT targets in spring 2021.

Lyft announced in June 2020 that it was committing to electrifying 100 percent of its fleet by 2030.[86] Uber announced in September 2020 that it would commit to electrifying its urban fleets in the United States, Canada, and Europe by 2030 and committed to full global electrification by 2040.[87]

---

82 Ibid.

83 Ibid.

84 Fleming, Kelly, and Mollie Cohen-D'Agostino. "Policy Pathways to TNC Electrification in California." UC Davis Institute for Transportation Studies. National Center for Sustainable Transportation Issue Paper. May 2020. https://policyinstitute.ucdavis.edu/wp-content/uploads/TNC-Electrification_May2020-v2.pdf.

85 CARB. 2019. Senate Bill 1014 Clean Miles Standard. *2018 Base-Year Emissions Inventory Report*. https://ww2.arb.ca.gov/sites/default/files/2019-12/SB%201014%20-%20Base%20year%20Emissions%20Inventory_December_2019.pdf.

86 Lyft. "Leading the Transition to Zero Emissions: Our Commitment to 100% Electric Vehicles by 2030." Lyft Blog. June 17, 2020. https://www.lyft.com/blog/posts/leading-the-transition-to-zero-emissions.

87 Khosrowshahi, Dara. "Driving a Green Economy." Uber Newsroom. September 8, 2020. https://www.uber.com/newsroom/driving-a-green-recovery/.

Automation

The technical development and eventual sales of automated vehicles (AVs) may be the most disruptive trend of the Three Revolutions. AVs have the potential to radically change the way vehicles are used for mobility. With the adoption of significant, vision-driven policy drivers, AVs can substantially improve the efficiency of transportation, including reduced VMT and emissions, improved safety, improved convenience for travelers, and improved equity outcomes. Without such policy safeguards, the "Dirty Skies" scenario of higher VMT, more congestion, increased emissions, and growing marginalization of disadvantaged communities becomes more likely.[88]

Researchers anticipate that AVs could become commercially available between 2025 and 2035.[89] The California Department of Motor Vehicles (DMV) began providing permits for AV testing in 2014 through its Autonomous Vehicle Tester Program to enable AV research and development. As of January 2021, the California DMV has provided 57 manufacturers autonomous vehicle testing permits (with a driver), with six holding permits for driverless testing.[90]

As of November 2020, the CPUC developed regulations for AV use in California through its Order Instituting Rulemaking on Regulations Relating to Passenger Carriers, Ridesharing, and New Online Enabled Transportation Services.[91] This regulation would establish two autonomous vehicle programs that allow companies to charge fares for providing passenger service and shared rides. Permit holders for either the "Drivered Autonomous Vehicle

---

88 Governor's Office of Planning and Research. Statement on Automated Vehicles. OPR Website. https://opr.ca.gov/planning/transportation/automated-vehicles.html.

89 Rodier, Caroline, Ph.D. UC Davis Institute for Transportation Studies. National Center for Sustainable Transportation White Paper. "Travel Effects and Associated Greenhouse Gas Emissions from Autonomous Vehicles." 2018. https://escholarship.org/uc/item/9g12v6r0.

90 DMV webpage. "Autonomous Vehicle Testing Permit Holders." Accessed November 16, 2020. https://www.dmv.ca.gov/portal/vehicle-industry-services/autonomous-vehicles/autonomous-vehicle-testing-permit-holders/.

91 CPUC. Order Instituting Rulemaking on Regulations Relating to Passenger Carriers, Ridesharing, and New Online-Enabled Transportation Services. CPUC Rulemaking 12-12-011.

Deployment Program" or the "Driverless Autonomous Vehicle Deployment Program" have requirements including data reporting and safety planning.[92]

The CPUC establishes four main goals for these programs:

1. Protect passenger safety.
2. Expand the benefits of AV technologies to all of California's communities.
3. Improve transportation options for all, particularly for disadvantaged communities and low-income communities.
4. Reduce GHG emissions, criteria air pollutants, and toxic air contaminants, particularly in disadvantaged communities.

California: An Epicenter of the Three Revolutions

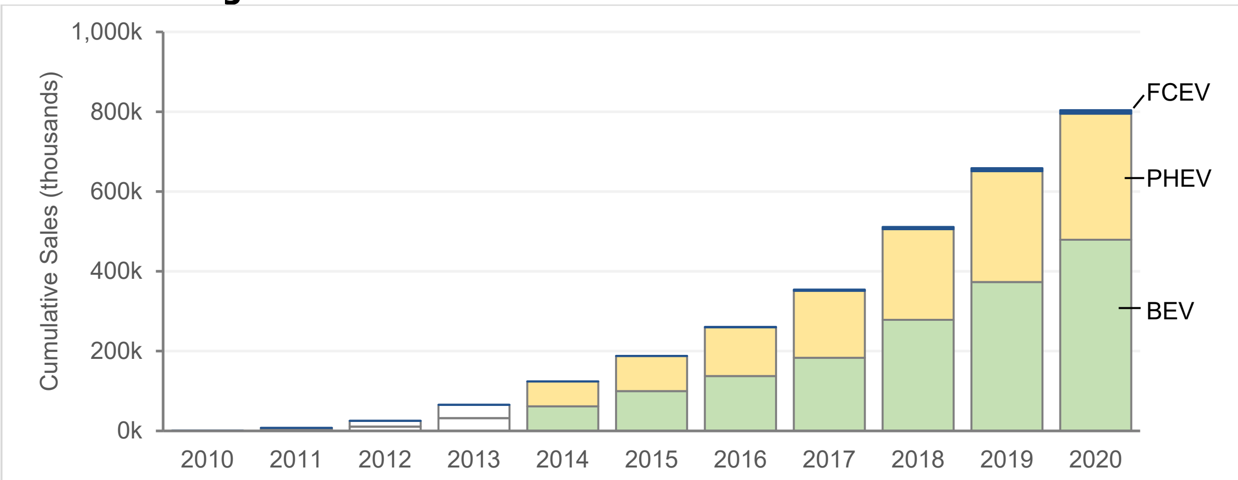
If California were a country, it would be the third-largest market for ZEVs in the world, after China and the United States as a whole. As of December 2020, Californians have cumulatively purchased more than 800,000 ZEVs (as shown in Figure 14),[93] while ZEV sales in the rest of the United States totaled roughly 980,000.[94] Sales of ZEVs in California have steadily increased since 2010 and comprised 8 percent of the new light-duty vehicle market in 2020. See Chapters 3 and 5 for a discussion of battery-electric and fuel cell electric vehicle sales trends.

92 CPUC. Order Instituting Rulemaking on Regulations Relating to Passenger Carriers, Ridesharing, and New Online-Enabled Transportation Services. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M351/K407/351407361.pdf.

93 California ZEV sales data are based upon CEC analysis of data from the California Department of Motor Vehicles. Accessed December 1, 2020. https://www.energy.ca.gov/data-reports/energy-insights/zero-emission-vehicle-and-charger-statistics.

94 Link to California and United States electric car sales data on Veloz's web page. https://www.veloz.org/wp-content/uploads/2021/02/Q4_2020_Dashboard_PEV_Sales_veloz.pdf.

Figure 14: Cumulative Sales of New ZEVs in California



Source: CEC ZEV Dashboard

California companies are also global leaders for the three Revolutions. A CALSTART study estimates that the ZEV industry in California employs roughly 70,000 people.[95] Taking a broader view of the electric vehicle (EV) "ecosystem," including categories such as professional services and construction, the Los Angeles County Economic Development Corporation estimates 276,000 EV-related or supporting jobs.[96] The CALSTART study also identifies more than 360 unique companies in at least 419 different locations involved in the ZEV supply chain in California. With electric vehicles as the number one export in 2020 for the entire state, ZEVs are an increasing share of the state's economy.[97] CEC staff have also identified 34 ZEV and electric vehicle service equipment (EVSE) manufacturers, which have a combined market capitalization of over $500 billion.

In addition to the direct ZEV economic ecosystem, there are the benefits from increasing ZEV use. The lower operating costs of ZEVs save money for drivers, and the use of electricity as a fuel redirects economic activity to more in-state services, bolstering the statewide economy

---

95 CALSTART. 2021. *CALSTART's California ZEV Job Study*. https://calstart.org/wp-content/uploads/2021/02/CA-ZEV-Jobs-Study-Final-0203.pdf.

96 Markle, Lawren. *LAEDC Report: California and SoCal EV Industry is Growing, Giving Region Global Competitive Advantage*. Los Angeles County Economic Development Corporation web page. March 1, 2020. https://laedc.org/2020/03/01/laedc-ev-industry-report/.

97 US Census Bureau. 2021. State Exports from California. https://www.census.gov/foreign-trade/statistics/state/data/ca.html.

and reducing dependence on oil imports. A recent economic forecast on the benefits of widespread transportation electrification from NEXT 10 finds that California's Gross State Product could grow over a baseline scenario by an additional $82 billion to $134 billion by 2030, resulting in an additional 394,000 to 530,000 jobs from the stronger economy.[98]

Two of the biggest global TNCs, Lyft and Uber, are headquartered in California. These companies have changed the landscape of transportation and the reliance on vehicle ownership, with opportunities for fleet automation and electrification in the future. As noted earlier, both companies have committed to electrifying their U.S. operations by 2030, and CARB is developing the Clean Miles Standard regulation that will set targets that TNCs must meet to reduce GHGs and, over time, electrify their fleets.

Two California-based companies that are integrating all three revolutions from the get-go are Cruise and Zoox. The once Californian start-up, Cruise is developing in each of the areas of the three revolutions and seeks to release a fleet of autonomous EVs and shuttles for ride-hailing. General Motors plans to contribute $20 billion to Cruise's autonomous and EV programs, and Cruise is waiting for approval of a 2018 request from the National Highway Traffic Safety Administration to launch its "fleet of vehicles without steering wheels or pedals."[99] Similarly, Zoox is a Californian start-up focusing on developing autonomous electrified mobility with more than 1,000 employees.[100] Zoox was recently acquired by Amazon to reduce the company's overall carbon footprint, suggesting a push to automize product deliveries. How Zoox will do so remains uncertain, given its stated focus on the "autonomous ride-hailing experience."[101] Companies like these have the potential to push the envelope for the role of future autonomous transportation, particularly in the ride-hailing and logistics spaces, where operations provide a good opportunity for the use of artificial intelligence.

98 Next 10. 2020. *Clean Transportation: An Economic Assessment of More Inclusive Vehicle Electrification in California*. https://www.next10.org/sites/default/files/2020-01/clean-transportation-ev-benefits-final.pdf.

99 Hall, Kalea. "GM's Cruise 'Making Progress' on Self-Drive Technology." *The Detroit News*. June 16, 2020. https://www.detroitnews.com/story/business/autos/general-motors/2020/06/16/gms-cruise-making-progress-self-drive-technology/3197539001/.

100 Schubarth, Cromwell. "Amazon Primed to Hit Brakes on $1.3B Zoox Purchase if Too Many Employees Bail." Silicon Valley Business Journal. July 9, 2020. https://www.bizjournals.com/sanjose/news/2020/07/09/amazon-zoox-purchase-terms-employee-stock-options.html.

101 Osborne, Charlie. "Amazon Acquires Self-Driving Startup Zoox." ZD Net. June 26, 2020. https://www.zdnet.com/article/amazon-to-pay-over-1-billion-to-secure-self-driving-startup-zoox-report/.

As California sets more aggressive targets to electrify transportation and reduce VMT, it will increase the incentive for companies in California and beyond to help the state reach the "blue skies" scenario of reduced emissions, better livability in cities, and reduced congestion.

Economic Recovery and ZEV Workforce Opportunities

In the midst and aftermath of the COVID-19 pandemic, zero-emission mobility can play a key role in California's economic recovery and development. The burgeoning ZEV industry creates an opportunity for "high-road jobs" and economic recovery for the state.[102] For example, a 2018 report from the Luskin Center for Innovation at the University of California, Los Angeles, modeled the job benefits of the state's $2.2 billion in climate investments between 2013 and 2016. The study found that the $2.2 billion directly supported 19,700 jobs and indirectly supported an additional 55,900 jobs from the private sector's $6.4 billion in matching investments. The study estimates nearly 9 new jobs per each million invested, plus nearly 25 additional jobs from induced private-sector investments.[103]

California must deploy additional ZEV infrastructure to support its ZEV and clean air goals. The build-out of infrastructure creates good jobs and is fundamental to the longer-term transition to an electrified fleet. Moreover, other employment opportunities are available for building, maintaining, and repairing ZEVs and associated infrastructure. The workforce for an electrified transportation economy includes a diverse set of roles with varying levels of education, training, and experience. Many occupations will require specialized training or work experience, particularly in manufacturing, electrical contracting, and maintenance.

In accordance with Assembly Bill 398 (Garcia, Chapter 135, Statutes of 2017), the California Workforce Development Board commissioned the Center for Labor Research and Education at the University of California, Berkeley, to study labor in the green economy.[104] The report assesses the range of job classifications, skill sets, salaries, and working conditions in the green energy and green transportation sectors of the state's economy. It provides a detailed

---

102 "High-road jobs" are discussed in the UC Berkeley Center for Labor Research's report *Putting California on the High Road: A Jobs and Climate Action Plan for 2030*. The report describes these jobs as those that offer family-supporting wages, employer-provided benefits, a voice for workers, and opportunities for advancement. (https://laborcenter.berkeley.edu/wp-content/uploads/2020/09/Putting-California-on-the-High-Road.pdf.)

103 University of California, Los Angeles. Luskin Policy Center for Innovation. 2018. *Employment Benefits from California Climate Investments and Co-Investments*. https://innovation.luskin.ucla.edu/wp-content/uploads/2019/03/Employment_Benefits_from_CA_Climate_Investments_and_Co-investments.pdf

104 University of California, Berkeley. Center for Labor Research and Education. *Putting California on the High Road: A Jobs and Climate Action Plan for 2030*. June 2020. https://laborcenter.berkeley.edu/wp-content/uploads/2020/09/Putting-California-on-the-High-Road.pdf.

roadmap and recommendations for creating better working conditions, higher compensation, and a more equitable workforce for the state's burgeoning green economy. The report identifies four key goals:

- Create high-quality jobs.
- Prepare workers with the skills needed to adapt to and master new ZEV technologies.
- Broaden career opportunities for workers in disadvantaged communities.
- Support workers in fossil fuel industries whose jobs are at risk with retraining for high quality jobs to promote a just transition.

The report finds that the quality of jobs created in the ZEV manufacturing sector has been mixed. Some companies offer prevailing wages, benefits, and healthy work environments, while other manufacturers have been reported for violations of wage, health and safety, and worker protection rules. The report finds that unionization correlates with higher job quality and salaries, such as at ZEV and rail manufacturing plants.

The report also stresses the need to offer incentives for "high-road" job creation in the ZEV industry, where employers seek to be competitive by investing in their workforce (for example, through wage standards, training, or work standards), while promoting equity. Specifically, workforce training should allow individuals to attain high-wage jobs that allow them to support their families, while boosting the local economy, particularly for low-income and disadvantaged communities.

The AB 398 report provides a series of recommendations on how to leverage the state's substantial green transportation and energy investments to improve job quality, working conditions, wage and benefit levels, training, and equity of opportunity with disadvantaged members of the workforce. Some of the key strategies[105] recommended in the report include the following:

- Expand the use of community workforce agreements, which have been used successfully in the solar power industry.
- Leverage clean transportation investments to require prevailing wages, compliance with employment law, and health and safety standards.
- Partner with employers to develop high-value training and apprenticeship programs that prepare workers for green careers, rather than a job that may or may not endure.

---

105 Zabin, Carol. 2020. *Putting California on the High Road: A Jobs and Climate Action Plan for 2030*. University of California, Berkeley Labor Center. https://laborcenter.berkeley.edu/putting-california-on-the-high-road-a-jobs-and-climate-action-plan-for-2030/.

- Expand inclusion of disadvantaged workers into "family-supporting, career-track jobs."

Lastly, the AB 398 report recommends strategies and plans to ensure a "just transition" for workers in fossil fuel industries whose jobs may be eliminated during the transition to a green transportation economy. Ensuring these workers have access to education and job opportunities for a clean energy economy is a high priority for the report.

There must be a focus on offering incentives for high-road job creation in the ZEV industry, where employers seek to be competitive by investing in their workforce (through wage standards, training, work standards, and so forth), while promoting equity.[106] Specifically, workforce training should allow individuals to attain high-wage jobs that allows them to support their families while boosting the local economy, particularly for low-income and disadvantaged communities.

There are opportunities to incorporate equity and recovery for all communities and foster greater workforce development as the three revolutions expand. On August 19, 2020, the CEC hosted an IEPR workshop to explore where gaps in clean transportation equity and workforce exist and potential solutions for closing them, while supporting economic recovery.[107] The workshop discussion pointed out that one of the worst effects of the pandemic has been the creation of a new pipeline of impoverished Californians that are now trying to rebuild their lives.[108] This effect has been especially true for those in disadvantaged communities and minority communities. Two further takeaways from the workshop were the need for new approaches to meet the needs of disadvantaged communities and promote awareness of and opportunities for clean technologies and jobs.

Solutions for recovery and development in disadvantaged communities must not use a one-size-fits-all approach. There should be flexible planning and ground-level problem solving that work with local stakeholders to better understand the local context. Moreover, the new paradigm of developing zero-emission mobility and workforce development is more than just providing resources or more zero-emission vehicle technologies. It also must address any shortages in local education and increase awareness of opportunities as the industry continues to grow. This new model requires collaboration with local communities that values equity in

106 Ibid.

107 August 19, 2020, IEPR Workshop in Clean Transportation Equity, Jobs, and Economic Recovery. Materials can be found on the CEC web page. https://www.energy.ca.gov/event/workshop/2020-08/session-1-clean-transportation-equity-jobs-and-economic-recovery.

108 Ibid.

scaling ZEVs. More effort should be placed in establishing local partnerships and a pathway for the growing zero-emission mobility job market.[109]

In addition to supporting ZEV market development, more investment is needed to support the ZEV job market. Accordingly, the CEC adjusted its most recent Clean Transportation Program Investment Plan to earmark $10 million to fund "Recovery and Reinvestment." This funding allocation is focused on economic recovery and resiliency in response to COVID-19 impacts and on leveraging public and private capital to promote job creation.[110]

109 Ibid.

110 CEC web page for the 2020–2021 Investment Plan Update Proceeding. https://www.energy.ca.gov/programs-and-topics/programs/clean-transportation-program/clean-transportation-program-investment-5.

KIGT and Workforce Training

Another key piece for bringing clean transportation jobs to communities most in need is through job training and workforce reentry. One example of a company that supports this effort is KIGT, a vertically integrated, smart-charging station manufacturer for EVs, with the goal of bringing EV job opportunities to low-income and disadvantaged people and those who were incarcerated. Collaborating with the Los Angeles Cleantech Incubator, KIGT launched the Electric Vehicle Network Technician Program to provide students from underserved communities with "job training and job placement opportunities in the Electric Vehicle Charging Industry," including individuals that have been recently incarcerated.[111] This program connects individuals to opportunities to make a living and become part of the growing EV industry. Further efforts like this are important for a more equitable path to economic recovery.

KIGT also highlights the innovative work supported through two CEC-funded initiatives: CalTestBed, a voucher program that connects entrepreneurs to a statewide network of testing facilities; and Cleantech San Diego, a member of the CEC's regional energy innovation network that provides key resources, mentoring, and services to entrepreneurs.

At the state level, California passed Assembly Bill 841 (Ting, Chapter 372, Statutes of 2020), which continues funding the Electric Vehicle Infrastructure Training Program (EVITP). This program provides a comprehensive curriculum to train and certify installers for ZEV infrastructure. This bill also increases the need for EVITP certification for state-funded or approved installation projects.[112]

---

111 KIGT web page on the Electric Vehicle Network Technician Training Fellowship Program. https://www.kigtinc.com/single-post/2020/01/22/Electric-Vehicle-Network-Technician-EVNT-Training-Fellowship-Program.

112 Assembly Bill 841 (Ting, Chapter 372, Statutes of 2020). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200AB841.

Taking Advantage of In-State Raw Materials for ZEV Battery Manufacturing

A ZEV-related opportunity for economic development lies in California's emerging lithium extraction industry. The state is home to vast lithium deposits and could meet a significant portion of the world's lithium demand. As the global demand for lithium has grown because of the transition away from fossil fuels and toward batteries for energy storage, harnessing this natural capital to power a carbon-neutral economy and job growth holds promise for economic development. According to the National Renewable Energy Laboratory, the Imperial Valley alone may have the potential for $860 million in annual revenues, leading many to dub the location "Lithium Valley."[113] To invest in this opportunity, through its EPIC research program, the CEC has granted nearly $8 million to support lithium extraction technologies using the lithium-rich geothermal brine from geothermal power generation.[114] Furthermore, to assess the social, economic, and environmental consequences of this industry, the California Legislature passed Assembly Bill 1657 (Garcia, Chapter 127, Statutes of 2020). This legislation designates the CEC to establish a blue-ribbon commission on lithium extraction in California.[115]

Recommendations

- **The California Energy Commission (CEC) should monitor and assess the energy and emissions effects of the three revolutions in California.** This assessment should be incorporated into the CEC's transportation energy forecasts and energy demand scenarios. See the *2020 Integrated Energy Policy Report Update, Volume III* on forecasting for more information on plans to assess the three revolutions as part of future work.
- **The state should ensure that autonomous vehicle technology and services minimize emissions, promote cost savings, and benefits disadvantaged communities.** This recommendation would require deploying more electric vehicles, sizing vehicles appropriately, developing best practices for vehicle operation, and addressing community input.
- **In consultation with the Governor's Office for Business and Development, the CEC should support the zero-emission vehicle (ZEV) industry and ZEV**

---

113 CEC press release. "Geothermal, Lithium Recovery Projects Get Boost From California Energy Commission." May 13, 2020. https://www.energy.ca.gov/news/2020-05/geothermal-lithium-recovery-projects-get-boost-california-energy-commission.

114 CEC web page for Business Meetings. https://www.energy.ca.gov/proceedings/business-meetings.

115 Assembly Bill 1657 (Garcia, Chapter 127, Statutes of 2020). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200AB1657.

infrastructure supply chains in the state. This recommendation will include workforce training targeted for electric vehicle industry needs to increase clean transportation job opportunities for disadvantaged and low-income communities.

CHAPTER 3
Plug-in Electric Vehicles (PEVs): Innovation, Decreasing Costs, and Market Growth

Light-Duty PEV Sector on the Rise

Global Industry Outlook is Positive, but More State Policy Innovation is Necessary

In early 2021, vehicle manufacturers and state and federal policy makers demonstrated a greater commitment to a ZEV future. General Motors (GM) announced a goal of phasing out all internal combustion engine (ICE) vehicle production in favor of zero-emission vehicles (ZEVs) by 2035.[116] Ford announced that it will double its investments in EVs to $22 billion by 2025.[117] Shortly before GM and Ford made these production goal announcements, Massachusetts announced a plan to achieve 100 percent new ZEV sales by 2035 in alignment with California's Executive Order N-79-20.[118] President Joseph Biden issued an executive order mandating that the federal government purchase ZEVs for its various fleets, including the U.S. Postal Service.[119] These announcements and policy shifts emerged from the background of exponential growth in ZEV production and technological advancement in the last decade.

Several market analysts highlighted the growth in the PEV market at the June 11, 2020, Integrated Energy Policy Report (IEPR) workshop on the status of light-duty ZEV markets. Globally, cumulative ZEV sales more than doubled from 3 million to nearly 7 million between

---

116 Boudette, Neal E., and Coral Davenport. "G.M. Will Sell Only Zero-Emission Vehicles by 2035." *New York Times*. January 28, 2021. https://www.nytimes.com/2021/01/28/business/gm-zero-emission-vehicles.html.

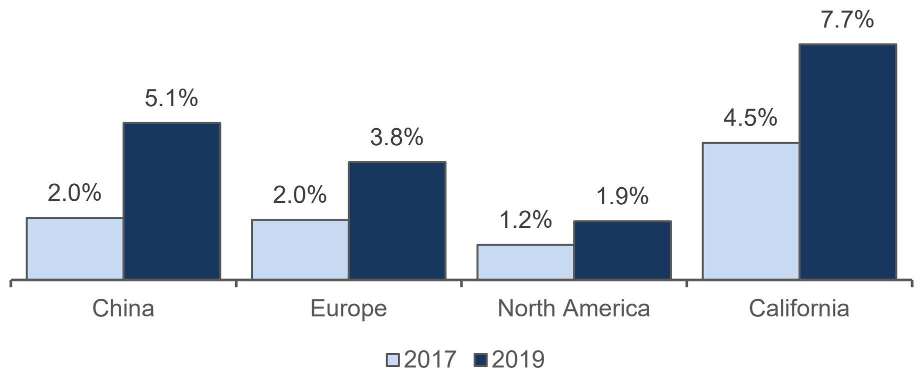
117 Klayman, Ben, and Paul Lienert. "Ford Boosts Investment Plan for EVs and Self Driving Vehicles, Reports Loss." Reuters.com. February 4, 2021. https://www.reuters.com/article/us-ford-motor-results/ford-boosts-investment-plan-for-evs-and-self-driving-vehicles-reports-loss-idUSKBN2A42VN.

118 Choi, Joseph. "Massachusetts to Require 100 Percent of Car Sales to be Electric by 2035." *The Hill*. January 5, 2021. https://thehill.com/policy/energy-environment/532684-massachusetts-to-require-100-percent-of-car-sales-to-be.

119 Executive Order on Tackling the Climate Crisis at Home and Abroad. January 27, 2021. https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/.

2017 and 2019. Market penetration of ZEVs also increased in large economies, with ZEVs as a percentage of total passenger vehicle sales increasing. See Figure 15 for a comparison. Norway is another interesting case study of ZEV market penetration. Although it had a small number of total new vehicles sold in 2019, roughly 42 percent were battery-electric, doubling from the country's 2017 sales.[120]

Figure 15: Light-Duty PEV Sales as a Percentage of Total Sales in Large Economic Regions, 2017–2019



Sources: Bloomberg New Energy Finance (BNEF), California New Car Dealers Association, California Energy Commission (CEC) Staff

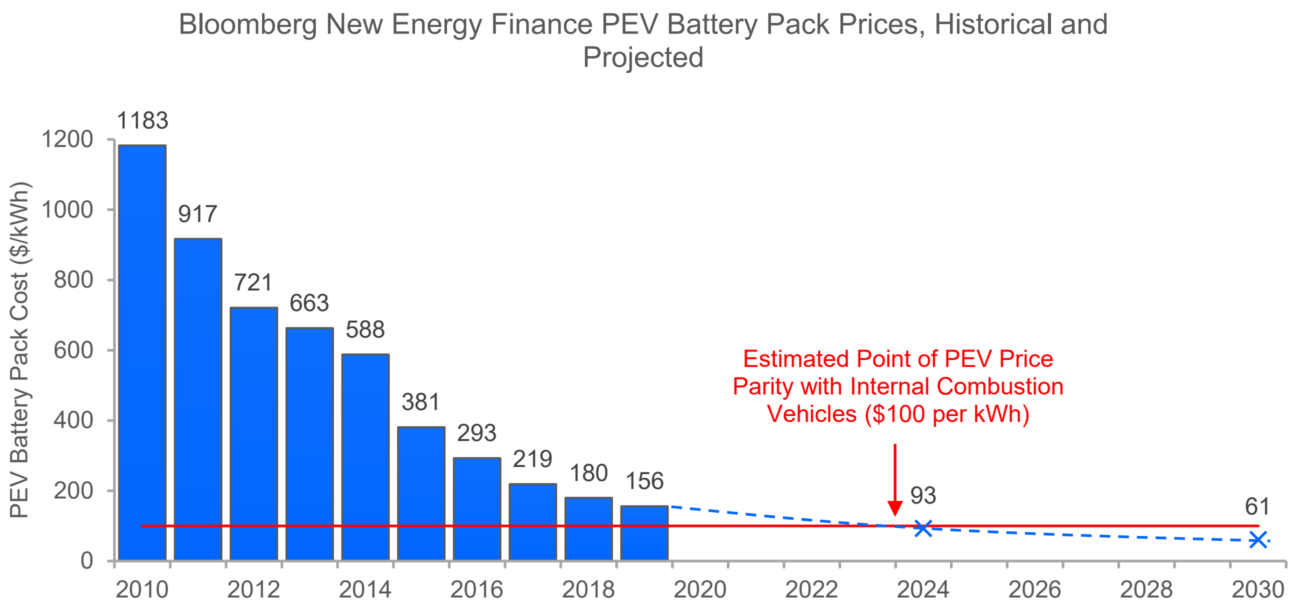
Battery prices are a leading contributor to PEV costs, as batteries are the highest cost element of battery-electric vehicle (BEV) manufacturing (roughly 40 percent) and a significant cost of plug-in hybrid electric vehicle (PHEV) manufacturing. Recent estimates from BNEF indicate that battery prices in 2020 have fallen by nearly 90 percent since 2010. By 2024, BNEF projects that they will drop another 40 percent below today's prices (Figure 16).[121]

---

120 Norway reported 142,381 total cars sold in 2019, with 60,345 of them being ZEVs. Almost all ZEVs were battery-electric vehicles. 2019 sales are available at https://ofv.no/bilsalget/bilsalget-i-2019. The 2017 sales are available at https://ofv.no/bilsalget/bilsalget-i-2017.

121 Presentation by Nicholas Albanese. BloombergNEF. "Electric Vehicle Outlook 2020." June 11, 2020, IEPR workshop on Light-Duty ZEV Update and Trends in Larger Vehicles. https://efiling.energy.ca.gov/getdocument.aspx?tn=233410.

Figure 16: BNEF PEV Battery Cost Declines



Data Source: BNEF

While the upfront cost of a ZEV can be a challenge for some consumers in the new vehicle market, the decline in battery prices will have a significant effect on the affordability of new BEVs. Beginning in 2022, BNEF projects that passenger BEVs will approach price parity with ICE-powered large sedans and sport utility vehicles (SUVs), followed by price parity in 2024 for small and medium cars. With price parity, consumers may take further notice of the savings for the total cost of car ownership, which can keep more money in their pockets each year. A recent BEV ownership cost assessment by *Consumer Reports* concludes that fuel and maintenance benefits of electric vehicles can save Californians $889 to $1,471 per year in fuel and $240 to $540 per year in maintenance.[122]

The BNEF projection is slightly more optimistic than the International Council on Clean Transportation (ICCT) analysis from a year prior, which anticipates BEV parity beginning in

---

122 Harto, Chris. "Electric Vehicle Ownership Costs: Today's Electric Vehicles Offer Big Savings for Consumers." *Consumer Reports*. October 2020. https://advocacy.consumerreports.org/wp-content/uploads/2020/10/EV-Ownership-Cost-Final-Report-1.pdf.

2024.[123] ICCT also analyzes PHEVs but does not expect them to experience the same price declines as BEVs. This expectation is due to the higher cost of having both ICE and electric drivetrains, which may limit PHEV market share in the long run. Range and convenient refueling benefits from PHEVs make them a preference among some consumers. As BEV ranges and charging infrastructure increase, so may BEV appeal. Chapter 4 discusses the challenge of charging infrastructure for drivers.

With rapidly declining vehicle prices and related lower ownership costs, BNEF expects U.S. sales of PEVs to grow as well, with 2020 to 2030 total sales to be roughly 16.4 million.[124] Guidehouse Insights consultants[125] project a similar 19.5 million PEVs for all of North America.[126] If California maintains 46 percent of national PEV sales or even reduces its share to 36 percent of national sales, these projections suggest 9 million to 6 million total PEVs sold in California between 2020 and 2030. Both BNEF and Guidehouse analyses account for some uncertainty with the COVID-19 economic impacts, anticipating growth to return around mid-to-late 2021. These market analyses also assume continued ZEV policy support from several directions, including programs such as infrastructure investments, vehicle incentives, and regulations (such as CARB's ZEV rule through 2025). However, model results beyond 2025 are based primarily on general economic models that focus on vehicle prices. The Executive Order N-79-20 goal of 100 percent ZEV sales by 2035 will play an additional role as policies to achieve the goal will likely result in stronger regulations and continued incentives.

While workshop presenters expected sales in the United States to increase dramatically in the next 10 years, they did expect sales growth in other countries to be higher due to more aggressive near-term policies. For instance, China and the European Union are expected to

---

123 Albanese, Nicholas. BloombergNEF. "Electric Vehicle Outlook 2020." Presentation at the June 11, 2020, IEPR workshop on Light-Duty ZEV Update and Trends in Larger Vehicles. https://efiling.energy.ca.gov/getdocument.aspx?tn=233410.

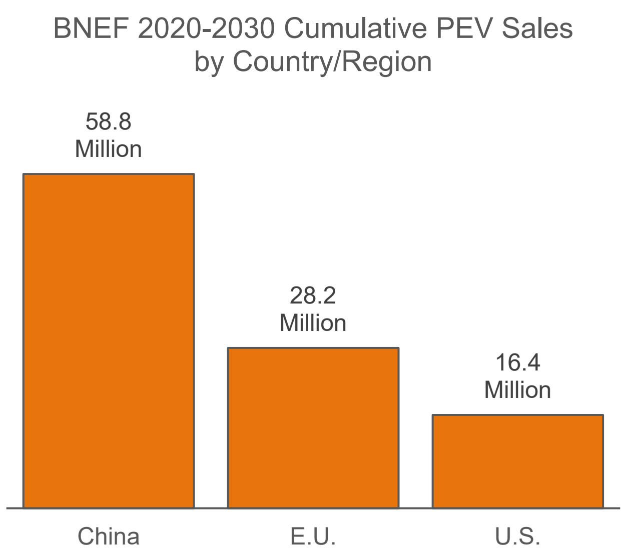
124 Ibid.

125 Guidehouse Insights is a consulting firm that previously was named Navigant.

126 Chawan, Ajay. Guidehouse Insights. "IEPR Workshop Transportation Trends and ZEV Market Update". Presentation at the June 11, 2020, IEPR workshop on Light-Duty ZEV Update and Trends in Larger Vehicles. https://efiling.energy.ca.gov/GetDocument.aspx?tn=233401&DocumentContentId=65917.

have substantially more total sales from 2020 to 2030 compared to the United States.[127] Figure 17 compares BNEF's estimate of cumulative sales for China, the European Union (EU), and the United States. Given the economic benefits of ZEVs compared to ICEs, lackluster market penetration in the United States may result in lower economic benefits for the country. In contrast to BNEF's analysis, a recent International Energy Agency (IEA) assessment suggests that current U.S. policies are not sufficient to achieve this level of cumulative sales.[128] BNEF and IEA's assessments do not consider California's new 2035 100 percent light-duty ZEV sales goal, other state and national policies, or recent original equipment manufacturer (OEM) announcements for ZEV sales discussed above. If other states establish similar goals to California's 2035 ZEV sales goal, market momentum in the United States will change from these projections.

Figure 17: Comparison of China, EU, and United States PEV Sales From 2020 to 2030



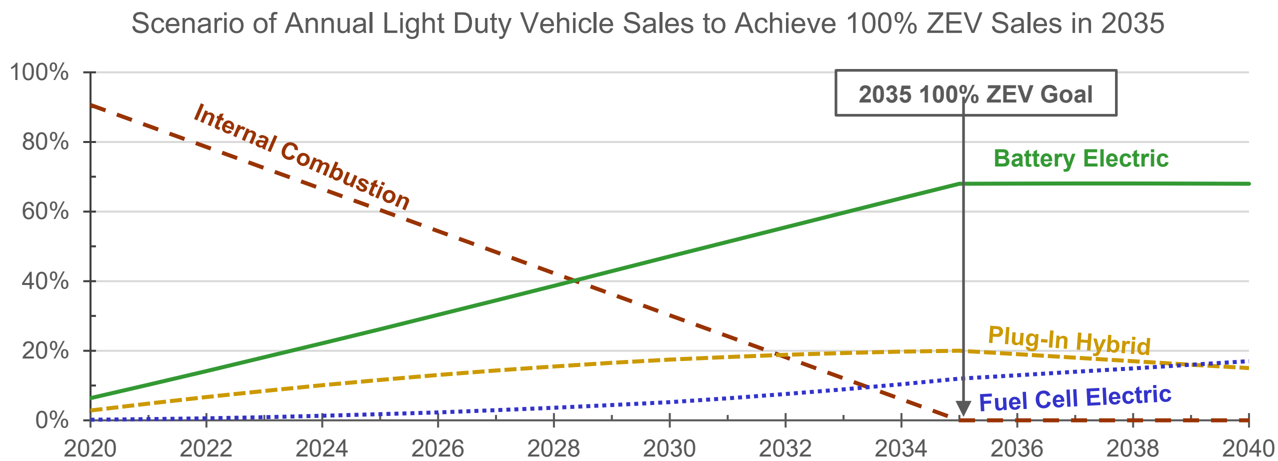
Data Source: BNEF

127 Albanese, Nicholas. BNEF. "Electric Vehicle Outlook 2020." Presentation at the June 11, 2020, IEPR workshop on Light-Duty ZEV Update and Trends in Larger Vehicles. https://efiling.energy.ca.gov/getdocument.aspx?tn=233410.

128 IEA. 2020. Global EV Outlook. p. 155. https://www.iea.org/reports/global-ev-outlook-2020.

The IEA's sustainable development scenario differs from California's goals. While the IEA sustainable development scenario calls for net-zero emissions by 2070, California's Executive Order B-55-18 calls on the state to achieve carbon neutrality by 2045.[129] To contribute to this goal, the 100 percent LD ZEV goal established by Executive Order N-79-20 will play a key role.[130] For reference, achieving 100 percent LD ZEV sales by 2035 in CARB's draft *2020 Mobile Source Strategy* scenario requires a dramatic increase in ZEV market penetration, including 70 percent of sales by 2030, as shown in Figure 18. Figure 18 also shows the sales scenario of the Mobile Source Strategy through 2050, with specific market penetration of BEVs, FCEVs, and PHEVs. Achieving the Mobile Source Strategy scenario would mean a statewide ZEV stock of 8 million in 2030. The strategy anticipates, however, that even if 100 percent of all new LD sales in 2035 are ZEVs, the market trajectory will not be enough to have a complete LD ZEV stock by 2045.[131]

Figure 18: CARB's Scenario for ZEV Market Penetration of ZEV Sales Shows an Accelerated Need for ZEVs to Achieve 100 Percent of Sales by 2035



Data source: CARB Mobile Source Strategy

129 Executive Order B-55-18. https://www.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf.

130 Executive Order N-79-20. https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-text.pdf.

131 CARB. *2020 Mobile Source Strategy Draft.* November 24, 2020. https://ww2.arb.ca.gov/sites/default/files/2020-11/Draft_2020_Mobile_Source_Strategy.pdf. pp. 57-60.

PHEVs, which can burn gasoline, pose a challenge to the 2045 carbon neutrality goal because of the potential use of petroleum fuel combustion. These vehicles have strong sales in the used car market. However, given the dual-drivetrain cost challenges of PHEVs described above, purchase prices may shift consumer preferences toward BEVs.

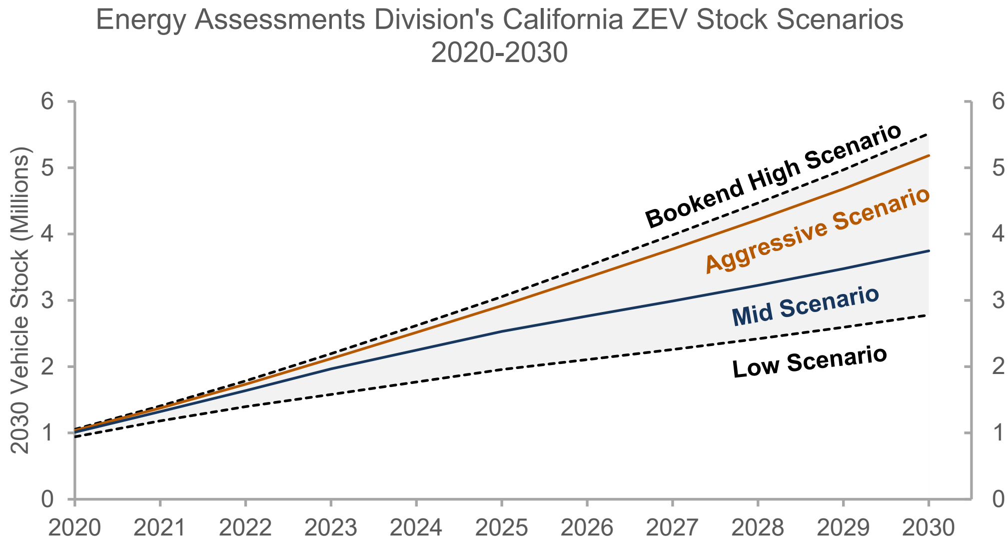
The CEC's Energy Assessments Division (EAD) forecasts California's 2030 on-road passenger ZEV stock to be lower than the market analyst forecasts and CARB's scenario for approaching carbon neutrality. (See Figure 19.) The model for this forecast is based on consumer choice preferences with sensitivities to factors such as vehicle prices, vehicle range, fuel cost, demographic changes, and incentives to establish what may occur under current market and regulatory conditions. For example, the low, mid, and high scenarios assume state rebates only through 2025, whereas the aggressive and bookend scenarios assume continued rebates through 2030. With this bottom-up structure, the model does not direct outcomes based on policy goals, such as the ZEV regulation or the new Executive Order N-79-20.[132] For this reason, it contrasts with CARB's scenario, which is based on market penetration levels needed to achieve specific state goals. The EAD model also provides a contrast to the work of market analysts, which anticipate more aggressive battery price declines and do not integrate consumer preferences.

The various results from EAD and other market scenarios and forecasts show the potential for a dramatic tipping point in the LD ZEV market but also reveal that high ZEV sales are not guaranteed, especially without strong leadership. Achieving the state's ZEV sales goals and long-term climate goals requires more aggressive policies. Other impacts to electricity demand may unfold as a result as well, especially if more aggressive action results in higher sales. The CEC recognizes that this difference between the forecasts and long-term policy goals need to be trued up. The CEC continues to work with the CPUC on refinements necessary to the forecast to support the infrastructure investments. For more information on PEV charging impacts, see Chapter 4 of Volume I of the *2020 IEPR Update* on Charging Infrastructure, as well as Volume III.

---

132 The inputs for the forecast were finalized in late summer 2020, before developments such as Governor Newsom's Executive Order N-79-20 calling for 100 percent new passenger car and truck sales be zero-emission by 2035, the change in federal administration, or the OEM announcements noted at the opening of the chapter. These and other policy and market developments will be factored into the next forecast being developed in the *2021 IEPR*.

Figure 19: EAD's Projection of Passenger PEV Vehicle Stock Under Various Scenarios



Credit: CEC

Consumer and Manufacturer Interest is High, but Consumers Are Not Fully Committed to ZEVs

Other factors in the growing market worth highlighting are vehicle model availability and increased consumer interest and perceptions. BNEF highlights the increase in PEV vehicle makes and models, with more than 500 PEV models available globally by 2022. During the June 11, 2020, IEPR workshop on transportation trends and light-duty ZEV market update, the Ford Motor Company reaffirmed its commitment to its plans for a new electric vehicle model rollout despite setbacks from the COVID-19 crisis.[133] The company affirmed that it had sufficient capital to maintain technology rollout, highlighting its new Ford Mach-E crossover SUV released in late 2020. In 2022, Ford is planning to release a new BEV F-150, which is particularly significant given that the Ford F-series trucks have been the best-selling vehicle in the United States for the past 38 years.

Consumer perceptions also remain optimistic on electric vehicles. In 2019, a Harris poll for Volvo found that 74 percent of American drivers believe that electric cars are "the future of transportation" and that the long-term savings on gasoline outweigh the higher upfront

133 June 11, 2020, IEPR Workshop on Transportation Trends and Light-Duty ZEV Market Update transcript. https://efiling.energy.ca.gov/GetDocument.aspx?tn=234186&DocumentContentId=67034.

cost.[134] These beliefs are not merely passive acknowledgments. Drivers also have an interest in electric vehicles, with a *Consumer Reports* and Union of Concerned Scientists 2019 survey showing that 63 percent of respondents have some interest in EVs, and 31 percent are considering one for their next purchase. Moreover, the survey found that people who identify as people of color are more likely to consider buying an electric car than all prospective buyers combined. However, only 5 percent of prospective car buyers were "definitely" going to purchase a ZEV.[135] This finding may suggest that, while there is acknowledgement of an electric future, it will not come in the next few years without active state policies, incentives, and access to infrastructure. Finally, Americans nationwide exhibit a strong desire for enhanced policy support for transportation electrification. A June 2020 Yale University and George Mason University survey found 73 percent of respondents support stronger vehicle efficiency standards, 70 percent supported an expansion of federal EV tax incentives, and 65 percent support government support of additional PEV charging infrastructure.[136]

Limited Access for Disadvantaged Communities and Low-Income Households

Disadvantaged and low-income communities have less access to ZEVs and ZEV infrastructure (see chapter 4 for a discussion of charging infrastructure challenges) than other communities. A recent study out of the University of California, Los Angeles, finds that zip codes with high California EnviroScreen percentile scores (census tracts in zip codes are used to define disadvantaged communities) have lower rates of electric vehicle adoption.[137] The researchers suggest that this disproportionate benefit is the result of a policy structure that allows wealthier households to take advantage of programs and have more access to ZEVs. With these sorts of concerns in mind, California has already passed Senate Bill 350 (De León, Chapter 547, Statutes of 2015), which led to program changes that were not considered

134 Volvo press release. "Poll finds Americans Feel Electric Vehicled are the Future of Driving." https://www.media.volvocars.com/us/en-us/media/pressreleases/248305/poll-finds-americans-feel-electric-vehicles-are-the-future-of-driving.

135 *Consumer Reports* press release. "New Survey Shows Strong Support for Electric Vehicles Across Economic Spectrum." July 18, 2019. https://advocacy.consumerreports.org/press_release/evsurvey2019/.

136 Yale Program on Climate Change Communication press release. "New Poll: Voters Support Stimulus for Clean Energy, Not Fossil Fuels." June 29, 2020. https://climatecommunication.yale.edu/news-events/new-poll-voters-support-stimulus-for-clean-energy-not-fossil-fuels/.

137 Fournier, Eric Daniel, Robert Cudd, Felicia Federico, and Stephanie Pincetl. 2020. "On Energy Sufficiency and the Need for New Policies to Combat Growing Inequities in the Residential Energy Sector." *Elementa Science Anthology*. https://www.elementascience.org/article/10.1525/elementa.419/.

directly in the study.[138] These include increased rebate amounts for low-income buyers, allowing rebate and grant incentive stacking, additional incentives for used vehicles providing clean mobility options (for example, car sharing or ride share), and developing a one-stop shop to streamline low-income consumer access to incentives. However, additional policy adjustments may be able to expand access more equitably as costs decline and the market grows.

The June 11, 2020, IEPR workshop included a panel on enhancing equitable access to light-duty ZEVs. Panelists emphasized the importance of prioritizing environmental justice communities, especially because these communities are disproportionately exposed to industrial pollution sources or transportation pollution, or both. Moreover, many individuals living in these communities have been categorized as "essential workers" in light of the COVID-19 crisis.[139] Panelists encouraged a broader look at transportation accessibility beyond vehicle ownership, including transit and other programs, such as ZEV carsharing and ridesharing services. Ridesharing programs were an important highlight, with the City of Huron's "Green Raiteros" program providing mobility services in electric vehicles to residents of rural areas.[140]

A consistent theme from environmental justice advocates has been the critical need for effective engagement with communities for improving clean transportation programs. Participants on panels from several workshops highlighted the importance of direct collaboration with communities to partner, regularly listen, and understand their needs, and then design programs to address the barriers they face.[141] Panelists encouraged a broader look at transportation accessibility beyond vehicle ownership, including transit and other programs, such as ZEV carsharing and ridesharing services. For example, the City of Huron's

138 More information on the recommendations that came out of SB 350 is available in the CEC's *Low Income Barriers Study, Part B: Overcoming Barriers to Clean Transportation Access for Low Income Residents.* https://ww2.arb.ca.gov/our-work/programs/accessible-clean-transportation-options-sb-350.

139 Leon, Rey. June 11, 2020, IEPR Workshop on Transportation Trends and Light-Duty ZEV Market Update transcript. https://efiling.energy.ca.gov/GetDocument.aspx?tn=234187&DocumentContentId=67035.

140 Ibid.

141 See transcripts for the June 11, 2020, IEPR workshop on ZEV Affordability and Equitable Access (https://efiling.energy.ca.gov/GetDocument.aspx?tn=234187&DocumentContentId=67035), the August 4, 2020, IEPR workshop on PEV Charging Infrastructure (https://efiling.energy.ca.gov/GetDocument.aspx?tn=235912&DocumentContentId=68870), and the August 19, 2020, IEPR workshop on Clean Transportation, Equity, Jobs, and Recovery (https://efiling.energy.ca.gov/GetDocument.aspx?tn=235112&DocumentContentId=67987).

"Green Raiteros" program[142] uses shared electric vehicles to take community members to doctor's appointments and other important services. The program builds off a long-standing informal system of "raiteros," people with cars who would provide rides for other community members. An agricultural community in Fresno County ranked one of the poorest cities in the state, Huron's residents are primarily Latino and low-income. Green Raiteros rides are chauffeured by volunteers and are charged on a sliding scale based on income and trip length.

The state has several incentives to help low-income residents purchase an EV and a charger, but it is challenging to navigate the nuances of each program, including eligibility requirements and application processes. Access Clean California (formerly known as One-Stop Shop) is a one-stop shop designed to streamline access to clean energy, transportation, and other related consumer-based incentives. The goal is to increase awareness for low-income residents and expand existing outreach and education on clean transportation and mobility options. In partnership with CARB, the Greenlining Institute, and a network of program administrators and outreach partners, GRID Alternatives is piloting Access Clean California for lower-income residents to access CARB light-duty equity programs (Clean Vehicle Assistance Program, Clean Cars 4 All, CVRP, and clean mobility options) and provide support for coordinating and streamlining community-based outreach targeted toward low-income populations. CARB intends the pilot to be the first step toward the broader vision of the program to encompass all climate incentives for low-income consumers.

Panelists at the June 11, 2020, IEPR workshop also emphasized the extent to which residents in disadvantaged communities deserved the best technologies when it comes to ZEV access, including incentives for individual vehicle ownership, but also for community-owned-and-managed ridesharing programs.[143] For instance, the California Environmental Justice Alliance stated that disadvantaged communities bear the brunt of the environmental harms from transportation pollution, so promoting access to high-quality, environmentally friendly technologies is a part of ensuring justice.[144] As costs continue to decline across the passenger

---

142 EVgo press release. "Green Raiteros Connects Rural Californians to Vital Services." https://www.evgo.com/about/news/green-raiteros-connects-rural-californians-vital-services/#:~:text=The%20Green%20Raiteros%20program%20connects,to%20and%20from%20critical%20services.

143 Leon, Rey. June 11, 2020, IEPR Workshop on Transportation Trends and Light-Duty ZEV Market Update transcript. https://efiling.energy.ca.gov/GetDocument.aspx?tn=234187&DocumentContentId=67035.

144 Torres, Jose. California Environmental Justice Alliance. June 11, 2020, IEPR Workshop on Transportation Trends and Light-Duty ZEV Market Update transcript. https://efiling.energy.ca.gov/GetDocument.aspx?tn=234187&DocumentContentId=67035.

vehicle ZEV market, maintaining strong vehicle incentives for disadvantaged and low-income communities should remain a priority, even if incentives for higher-income families phase out.

Nearly 75 percent of lower-income families (the bottom 40 percent of incomes) purchase used vehicles instead of leasing or buying new ones, compared to about 55 percent of higher-income families (the top 20 percent of incomes).[145] Given this tendency, incentives in this market can be useful as well to increase ZEV access for all Californians, with an emphasis on equity. Programs such as CARB's Clean Vehicle Assistance Program and Clean Cars 4 All, as well as some local utility and other programs, exist to provide additional support for the purchase of a used PEV. However, panelists in the ZEV affordability and accessibility panel listed several concerns that may need to be addressed to ensure this market is viable. Concerns include charging infrastructure availability in the community, the reliability of the battery of the used vehicle, and the availability of EV mechanics in the area.[146] Even an average long-term benefit perception can be outweighed by the risk of the high cost of a potential battery failure and limited availability of affordable replacement options. To address these types of concerns, Assembly Bill 193 (Cervantes, Chapter 363, Statutes of 2018) requires CARB to establish a battery assurance project by 2025 to address potential uncertainties in the used BEV market, known as the Zero-Emission Assurance Project. As of mid-November 2020, this project is not funded, but CARB staff continues to research and lay the groundwork for implementation in the future.[147]

Medium- and Heavy-Duty BEVs Poised for Growth

As discussed in Chapter 1, several policies on medium-duty (MD) and heavy-duty (HD) vehicles will transition this sector to electric drivetrains over the next two decades. Policies such as the Advanced Clean Trucks (ACT) rule and Innovative Clean Transit (ICT) rule have sent a powerful signal to the market, resulting in an industry poised for dramatic growth. This section discusses MD and HD BEVs specifically. Additional discussion of MD and HD fuel cell

---

145 Paszkiewicz, Laura. Bureau of Labor Statistics. 2003. "The Cost and Demographics of Vehicle Acquisition." Consumer Expenditure Survey Anthology. https://www.bls.gov/cex/csxanthol03.pdf.

146 Torres, Jose. California Environmental Justice Alliance. June 11, 2020, IEPR Workshop on Transportation Trends and Light-Duty ZEV Market Update transcript. https://efiling.energy.ca.gov/GetDocument.aspx?tn=234187&DocumentContentId=67035.

147 CARB. Proposed Year 2020-2021 Funding Plan for Clean Transportation Incentives. https://ww2.arb.ca.gov/sites/default/files/2020-11/proposed_fy2020-21_fundingplan.pdf.

electric vehicles (FCEVs) is in Chapter 5. This IEPR Update will not discuss electrification of rail, which is another important aspect of transportation.[148]

More MD and HD BEVs Can Improve Air Quality in Disadvantaged Communities, but Inclusion is Key

As discussed in Chapter 1, disadvantaged communities have been the most severely impacted by air pollution, and MD and HD vehicles are a leading source of pollution. Given the additional health and economic impacts from COVID-19, the case for vehicle electrification in these communities is even stronger. ZEVs, including BEVs, emit no toxic pollutants and are quieter, providing an opportunity to improve the conditions in the areas in which they operate.

During the CEC's May 20, 2020, IEPR workshop on MD and HD ZEVs, presenters and panelists highlighted the potential for MD and HD ZEVs (including BEVs) to enhance equity in disadvantaged communities. Speakers from the Greenlining Institute and the Moving Forward Network called specific attention to equity and environmental justice issues in the MD and HD space. They highlighted the need to move beyond Assembly Bill 1550 (Gomez, Chapter 369, Statutes of 2016) to create a broader community engagement process. AB 1550 requires that 25 percent of investments from the state's Greenhouse Gas Reduction Fund (GGRF) be allocated toward projects in disadvantaged communities. However, speakers highlighted the importance of creating a more inclusive approach through broader planning processes rather than focusing on spending targets alone. The Greenlining Institute emphasized that development of metrics to improve equity in communities is not easy and is a process rather than a clearly established indicator.[149]

The Greenlining Institute emphasized the extent to which communities should "help drive the project's direction."[150] A key example highlighted by the Moving Forward Network was the Interstate 710 freeway, a stretch of highway in the Los Angeles region that is the main throughway for the ports of Long Beach and Los Angeles, with many trucks delivering cargo to railyards and warehouses in East Los Angeles. Several groups, including disadvantaged community advocates, propose to make the highway a zero-emissions freight corridor.

---

148 For example, the Caltrain Modernization (CalMod) program seeks to introduce electric trains in the Bay Area. See the CalMod web page (https://calmod.org/) for more information.

149 Román Partida-Lopez comments. May 20, 2020, IEPR workshop on Ports and Off-Road Equipment transcript. pp.28-31. https://efiling.energy.ca.gov/GetDocument.aspx?tn=233610&DocumentContentId=66189.

150 Ibid, p. 5.

Throughout visioning and planning, disadvantaged community advocates seek additional collaboration to ensure a broad range of input.

Trends are Beginning to Move to Match Future Regulations

Major global fleets are committing to electrification, driven by falling battery prices and increased consumer and government pressures to address the problem of global warming. The IKEA Group announced that all customer deliveries and services across operations in 30 countries will use zero-emission vehicle solutions by 2025.[151] Walmart announced a global goal of complete freight operations electrification by 2040.[152] To assess the latest trends, opportunities, and challenges associated with HD ZEVs, the CEC hosted an IEPR Workshop May 20, 2020, on the HD ZEV market status. Panelists included fleet operators, vehicle and original equipment manufacturers (OEMs), community advocates, site operations managers, and government program managers.

Early Adopters of MD and HD BEVs are Optimistic But Identify Needs

Transit agencies and school districts have also begun using battery-electric buses (BEBs) with increasing success. One of the benefits of BEBs is the associated lower maintenance costs. A June 2020 National Renewable Energy Laboratory (NREL) financial analysis shows a break-even payback period of around 3.6 years compared to diesel transit buses, with accruing benefits thereafter.[153] There are sensitivities that can alter this payback, and the analysis includes a grant for the buses, but the continued decline in vehicle costs will improve the economic case over diesel or gas buses.

---

151 Ingka Group press release. "IKEA Retail U.S. Joins New Electric Vehicle Alliance." February 10, 2020. https://www.ingka.com/news/ikea-retail-u-s-joins-new-electric-vehicle-alliance/.

152 Walmart press release. "Walmart's Regenerative Approach: Going Beyond Sustainability." September 21, 2020. https://corporate.walmart.com/newsroom/2020/09/21/walmarts-regenerative-approach-going-beyond-sustainability.

153 Johnson, Caley, Erin Nobler, Leslie Eudy, and Matthew Jeffers. 2020. Financial Analysis of Battery Electric Transit Buses. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-74832. https://www.nrel.gov/docs/fy20osti/74832.pdf.

The NREL analysis finds the 3.6-year payback by assuming a grant of $375,000 per BEB, so the net benefit is the result of a partial subsidy. However, the analysis does not consider the benefits that can accrue from California's Low Carbon Fuel Standard (LCFS). As discussed in the "Making Money Per Mile" section below, LCFS can result in fueling being a source of income rather than a cost. Excluding the direct purchase subsidy but including the LCFS benefits can result in a similar payback period. Vehicle purchase incentives that do exist in California may add onto the net benefit for transit fleets.

On the ground, transit fleet operators cite some remaining challenges for the use of BEBs, mostly in installing charging infrastructure, developing charging plans to reduce fuel costs, and supporting operation schedules, vehicle range, and maintenance training. The Los Angeles Metropolitan Transportation Authority highlighted maintenance training aspects as a potential challenge. Workers that had been recently trained to maintain gas buses now must be retrained to support zero-emission buses, which could include battery-electric and fuel cell buses.[154] Planning is yet another issue to address, as charging infrastructure is an additional logistical matter that large agencies need to balance with several other issues. (More consideration of charging infrastructure is in Chapter 4.) However, lower operating costs of BEBs are appealing for the long run.

The workshop highlighted several examples of MD and HD BEB early adoption strategies, spurred by enhanced incentives and programs. Panelists from the Lion Electric Company and A-Z Bus Sales discussed the latest in battery-electric school buses. The Lion Electric Company pointed out that funding programs, such as the CEC's bulk purchases of battery-electric school buses for its school bus replacement program, have bolstered OEM production scaling, contributing to a near 50 percent price reduction of battery-electric school bus prices in the last four years.[155] Continued battery price reductions discussed in the light-duty section above will decrease costs and expand vehicle ranges.

Early adopters in freight transport include several shorter-range duty cycles.[156] During the May 20, 2020, IEPR workshop, Daimler highlighted the key initial strategy for its current freight pilot programs: dedicated, shorter range (up to 200-mile round-trip duty cycles), repeatable routes with a centralized operations hub.[157] These routes take advantage of the limited range of vehicles and charging at a central location. Rivian's comments regarding its recent contract

154 Cris Liban comments. Panel discussion on Heavy-Duty ZEVs at the May 20, 2020, IEPR Workshop on Heavy-Duty ZEV Market Trends transcript. pp. 40-42. https://efiling.energy.ca.gov/GetDocument.aspx?tn=233612&DocumentContentId=66191.

155 Nate Baugio comments. Panel discussion on Heavy-Duty ZEVs at the May 20, 2020, IEPR Workshop on Heavy-Duty ZEV Market Trends transcript. p. 10. https://efiling.energy.ca.gov/GetDocument.aspx?tn=233612&DocumentContentId=66191.

156 Various workshop presenters. May 20, 2020, IEPR workshop on Medium- and Heavy-Duty ZEVs transcript. https://efiling.energy.ca.gov/getdocument.aspx?tn=233611.

157 Voets, Alex. May 20, 2020, IEPR workshop on Medium- and Heavy-Duty ZEVs transcript. https://efiling.energy.ca.gov/getdocument.aspx?tn=233611.

with Amazon for 100,000 MD last-mile delivery vehicles elaborate on this central hub approach.

With a slightly larger set of use cases, Volvo Group discussed its Volvo LIGHTS project (Figure 20), a freight electrification demonstration project coordinated with 15 other groups in Southern California, including CARB. The project has 23 battery-electric HD trucks and 29 onsite electric equipment vehicles at various warehouses. The demonstration involves the inclusion of on-route charging capabilities for the vehicles, expanding the potential beyond a central hub model. A key takeaway for Volvo is the “paradigm shift” of scope in this approach to freight, revealing key interdependencies among fleets, utilities, truck OEMs, and policymakers.

Figure 20: Volvo LIGHTS

Credit: Volvo

Off-road vehicles are another example of early-stage development. DANNAR manufactures a modular off-road vehicle capable of integrating different use-case attachments onto a single wheeled platform that houses between 126 and 504 kilowatt-hours of battery storage. The vehicle can be used in various agricultural, maintenance, depot, and construction activities. It can also function as a mobile power source for various purposes, including municipalities’ public events and, potentially, in cases of power shutoffs.

Figure 21: DANNAR's Mobile Power Station Modular Options Provide Numerous Options to Off-Road Utility Operations

Credit: DANNAR

The nonprofit organization Ceres has established a Corporate EV Alliance of more than 20 companies that are coordinating to provide recommendations for expanding the MD and HD BEV market. In its recent report, Ceres explores recommendations for increasing BEV uptake from the corporate sector.[158] One of Ceres's key recommendations from the panel discussion was for OEMs to provide more MD and HD models for different use cases.

Themes for all MD and HD BEV panelists included charging infrastructure, charging rate design, and equipment interoperability. More discussion of these topics is available in Chapter 4. Notably, the key reason for the interest in charging is that these issues are on the horizon for experts who see the potential for rapidly decreasing TCO, with a potentially dramatic increase in vehicle demand as a result.

---

158 Ceres. 2020. *The Road to Fleet Electrification*. https://www.ceres.org/resources/reports/road-fleet-electrification.

Fleets and Costs: Total Cost of Ownership at Price Parity for Many Duty Cycles

While typical consumer decisions for passenger vehicles involve more than upfront cost or TCO (for example, aesthetics, high acceleration, multiple vehicle uses), many fleet operators are focused on costs, making TCO a priority. BEVs have high upfront cost and require additional costs for in-house charging infrastructure. However, the efficiency advantage of BEVs over diesel and gas engines, as well as the related lower maintenance costs, mean that the entire life-cycle cost of the vehicle is lower for many vehicle types and uses, and by 2030 TCO will be below diesel and gas for almost all uses. CARB analysis shows that a battery-electric Class 8 drayage truck, depending on driving conditions, is 3.2 to 5.5 times more energy-efficient than a similar class diesel truck.[159] Further, because MD and HD vehicles tend to drive much more per year than a passenger vehicle, the increased efficiencies mean that fuel savings add up faster than light-duty BEVs. Continued decreases in battery costs will make the TCO even more advantageous for BEVs. Panelists were quick to highlight this trend and note that the business sector is closely watching and paying attention out of fear of losing out on the significant cost advantages of BEVs.

As discussed in the previous section, a recent analysis from NREL has already shown the TCO advantage (with government incentives) for transit buses, with an average 3.6-year payback period. Other studies in the MD and HD vehicle segment show similar TCO advantages. For instance, the consulting firm ICF conducted a TCO analysis for Class 2b to Class 8 trucks with different drivetrains, finding that TCO is slightly higher for BEVs across classes, but only without considering benefits from incentives and policies.[160] Including incentives and policies reduces TCO below diesel and gas across *all* use cases, including Class 8 tractors. The analysts note that strategic charging can reduce costs even more, although fleet operators may not always be able to optimize freight schedules in this way. ICCT also conducted a TCO analysis in 2019, finding similar results. In its 2020 case, TCO is slightly higher for BEVs but by 2025 will approach parity. However, ICCT did not include policies and incentives.[161]

---

159 CARB. Appendix G: Battery Electric Truck and Bus Energy Efficiency Compared to Conventional Diesel Vehicles. https://ww3.arb.ca.gov/regact/2019/act2019/appg.pdf.

160 ICF. 2019. Comparison of Medium- and Heavy-Duty Technologies in California. https://efiling.energy.ca.gov/GetDocument.aspx?tn=236878&DocumentContentId=70033.

161 Hall, Dale, and Nic Lutsey. 2019. "Estimating the Infrastructure Needs and Costs for the Launch of Zero-Emission Trucks." https://theicct.org/sites/default/files/publications/ICCT_EV_HDVs_Infrastructure_20190809.pdf.

Battery leasing is another option that OEMs are beginning to employ to address costs and increase interest from fleet operators. This business model of integrating the battery cost into the operation of the vehicle can dramatically reduce vehicle upfront costs, ensure battery reliability and longevity, and set up a pipeline for second-life batteries. This option may reduce the BEV upfront cost below that of a comparative diesel vehicle, although charging infrastructure remains an additional consideration for fleet operators. Proterra is providing this option in California for its BEBs.

Incentives and Policies are Critical to Set the Course for the ACT Regulation

The three major policies and programs that contribute to the TCO advantage for BEVs are the Low Carbon Fuel Standard (LCFS), vehicle incentives, and charging infrastructure support. The LCFS policy provides fleet operators with additional revenue for using low-carbon fuels rather than petroleum-based fuels. The lower the carbon footprint associated with the life-cycle production of fuel energy (production, distribution, and usage of the fuel), the greater the earned credit for the fuel user.[162] With existing high renewables on the grid, electricity is at a distinct advantage for this policy and will increase as more renewables are integrated and used for fueling. Because electricity costs already result in lower per-mile driving costs than diesel, the LCFS provides a bonus, in some cases resulting in *positive* fuel revenue for the operator. Vehicle incentives partially address upfront cost barriers of a BEV purchase. The MD and HD operators have several options for vehicle incentives. (See Table 2.) Due to the high levels of oversubscriptions for the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) and the rate at which they fill up, it may be useful to lower the rebate amounts to more equally share the benefits across operators looking to electrify, especially as battery prices decline.

Table 2: Incentive Programs for MD, HD, and Off-Road ZEVs

Program	Currently Funded Amount	Status
Clean Off-Road Equipment Program (CORE)	$44 million	No funds remaining for 2020
HVIP funding for ZEVs	$324 million through August 2020	No funds remaining for 2020

162 The life-cycle assessment for LCFS GHG emissions includes emissions associated with production, distribution, and combustion of the fuel.

Program	Currently Funded Amount	Status
Volkswagen Mitigation Trust Zero-Emission Class 8 Freight and Port Drayage Trucks	$27 million through August 2020	No funds remaining for 2020
Carl Moyer Program[163]	$94 million for FY 19-20	Funds may remain
Community Air Protection Incentives Program	$209 million for FY 19-20	Funds may remain

Credit: CEC

A consistent theme in IEPR workshops discussing MD and HD BEV incentives is the need for a one-stop shop for potential buyers to easily access and apply for all incentives available in their region at once. Panelists noted that this need is especially important for smaller operators, who may not have dedicated staff to understand the program details and processes involved to take advantage of program opportunities.[164]

The LCFS and vehicle incentives build the case for the TCO advantage that MD and HD BEVs have. However, other uncertainties remain. As a new technology, some fleet operators are still apprehensive about issues such as charging infrastructure, workforce training, and vehicle reliability. While OEMs will soon be required to sell more ZEVs in accordance with the ACT regulation, it is important to help build the momentum for a smooth ramp up to the sales requirements in 2024.

163 The Carl Moyer Program and Community Air Protection Incentives Program can provide funds towards several projects, including ZEVs. The determination on whether to fund specific projects is at local discretion.

164 May 20, 2020, IEPR workshop on Medium- and Heavy-Duty ZEVs transcript. https://efiling.energy.ca.gov/getdocument.aspx?tn=233611.

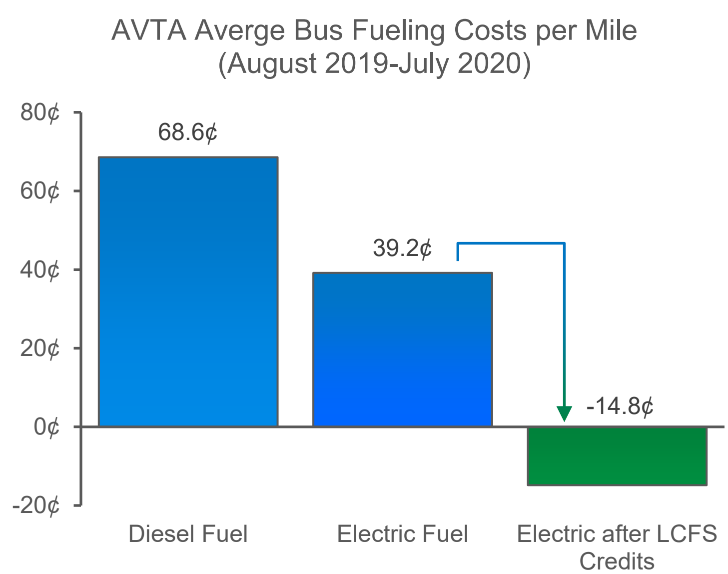
Making Money Per Mile

California's LCFS provides revenue for low carbon-fuels, especially electricity. With an increasingly renewable electricity grid and the option to book and claim zero-emission electricity sources, revenue from these credits may more than offset the cost of the electricity. A key example of this revenue benefit potential comes from the Antelope Valley Transit Authority's BEB system.

Image Credit: AVTA

As Figure 22 below shows, from August 2019 to July 2020, electric fuel cost less than diesel fuel, and the revenue per LCFS credit drops the average cost of driving per mile into the negative, making fuel a source of income for the authority. The Antelope Valley Transit Authority (AVTA) has also experienced higher availability rates for its BEBs. Average availability for BEBs in the fleet was 95 percent from March 2019 to March 2020, whereas average availability for its remaining diesel buses was only 76 percent. In April 2020, AVTA's operations were 100 percent electric.

Figure 22: AVTA LCFS Credits Result in Positive Net Revenue



Credit: AVTA

Recommendations

- **The state should pursue incentives for zero-emission vehicles (off-road, medium- and heavy-duty, and passenger) and infrastructure that are adjusted as costs fall and the market scales up to achieve the goals established by Executive Order N-79-20.** State and private sector investments are necessary to support infrastructure deployment, the scale-up of new vehicle electrification, and the accelerated turnover of fossil fuel vehicles to zero-emission vehicles (ZEVs). Investments should be adjusted over time to match trends in new and used vehicle markets and equitable access to infrastructure and optimize access and benefits for lower-income residents and residents of disadvantaged communities. A longer-term goal should be to align these incentives with the goal of phasing out the need for public funds over time.
- **The California Energy Commission should explore coordination opportunities to integrate its efforts with one-stop-shop projects, such as the California Air Resources Board's Access Clean California.** Lessons here could be learned for implementing medium- and heavy-duty ZEVs as well.
- **The state should explore financing programs that support fleet operators with the acquisition of medium- and heavy-duty ZEVs and the installation of related fueling infrastructure.** Ddirect fiscal incentives are needed to help many types of medium- and heavy-duty vehicles transition toward ZEVs, but the state should explore ways to diversify its financial support to meet the needs of all fleet operators. The low total cost of ownership and payback periods for ZEVs in certain applications (such as transit buses) suggest an opportunity to leverage lifetime cost savings to overcome higher upfront costs. The California Infrastructure and Economic Development Bank, through its proposed Climate Catalyst Fund, could administer such financing programs.
- **One-stop shops for medium- and heavy-duty ZEV purchasers, particularly small businesses, are needed.** One-stop shops combining all incentives into one simple accessible process for prospective buyers, including charging incentives, can be effective in helping fleet managers navigate the federal, state, and local programs that are designed to increase accessibility to ZEVs. Potential medium- and heavy-duty ZEV buyers would benefit from centralized, easy-to-access information about how to apply for all incentives available in their region at once.

CHAPTER 4
Charging Infrastructure: Key to Market Growth and an Opportunity for the Grid

California Must Stay Ahead of Charging Demand as the Plug-In Electric Vehicle (PEV) Market Grows

To reach the levels of transportation electrification required by Governor Newsom's Executive Order N-79-20, California will need charging infrastructure that is ubiquitous, easy-to-use, and smartly integrated into the grid. Light-duty charging will need to be tailored to meet the needs of drivers, transportation network companies, and fleets. Doing so can also provide an opportunity to balance out the grid in a way that reduces costs and lowers rates for all electricity users, not just PEV drivers. It is particularly important to ensure that charging infrastructure supports the mobility needs of disadvantaged and low-income communities, and that people living in apartment buildings have convenient access to charging. Charging for medium- and heavy-duty vehicles and off-road equipment must meet specific use-case requirements (such as port drayage or long-haul travel).

Charging infrastructure for passenger vehicles is generally available in three varieties: Level 1, Level 2, and DC fast charging (DCFC).[165] California has roughly half of all passenger PEVs in the United States but only one-quarter of publicly available chargers.[166] But investments by utility ratepayers and private industry are accelerating, fueled in part by the state's commitment to electrifying transportation (Figure 23).[167] Carmakers are partnering with

165 Level 1 charging provides about 4 miles of range per hour of charging. Level 2 typically provides about 35 miles per hour of charging but can range from 12 to 70 miles, depending on the vehicle and charger. DC fast charging also varies by vehicle and charger, with most chargers able to restore a passenger PEV to 80 percent of full range within 30 minutes. New and upcoming DC fast-charging options (some approaching 350 kilowatts) could reduce this to 15 minutes or less, if allowed by the vehicle.

166 Data based on U.S. Department of Energy Alternative Fuels Data Center. "Electric Vehicle Charging Station Locations." Accessed October 20, 2020. https://afdc.energy.gov/fuels/electricity_locations.html#/analyze?fuel=ELEC.

167 Chart developed based on presentation from Gia Brazil-Vacin at the September 25, 2020, IEPR workshop on Approaches to Assessing Funding Program Benefits. "Approaches to Assessing ZEV Funding Program Benefits." https://efiling.energy.ca.gov/GetDocument.aspx?tn=234906&DocumentContentId=67768.

charging providers to make it easier for their customers to access convenient charging. For example, General Motors is partnering with EVgo to expand charging access.[168] Further, VW's newly announced electric ID.4 SUV,[169] Lucid's Air sedan,[170] and the Ford Mach E[171] come with packages of free charging on the Electrify America Network for up to three years. Government also has a significant role to play to leverage private investment to fill gaps and ensure access and benefits for low-income and disadvantaged communities.

---

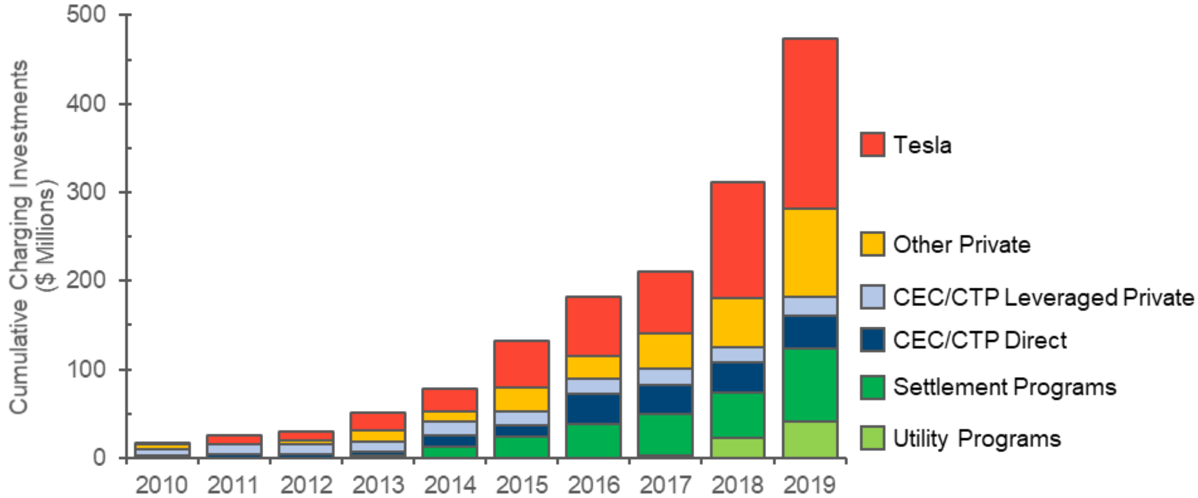
168 General Motors press release. "General Motors and EVgo Aim to Accelerate Widespread EV Adoption by Adding Fast Chargers Nationwide." July 31, 2020. https://media.gm.com/media/us/en/gm/ev.detail.html/content/Pages/news/us/en/2020/jul/0731-evgo.html.

169 Electrify America press release. "Electrify America and Volkswagen of America Announce Agreement Providing Unlimited Charging Plan for Owners of the All-New 2021 VW ID.4 Electric SUV." September 21, 2020. https://media.electrifyamerica.com/en-us/releases/112.

170 Electrify America press release. "Lucid Motors to Provide Customers With Access to Electrify America's Ultra-Fast Charging Network." https://media.electrifyamerica.com/en-us/releases/7.

171 Electrify America press release. "Ford Mustang Mach-E Customers to Receive Up to Five Complimentary 'Fill-Ups' at Electrify America Charging Stations." June 15, 2020. https://media.electrifyamerica.com/en-us/releases/99.

Figure 23: Private Investment in Charging Infrastructure Has Increased Substantially Over the Years, With Leveraged Public Funding and Other Nonprivate Investments



Data Source: Governor's Office of Business and Development

The California Energy Commission (CEC) is responsible for analyzing charging needs. Assembly Bill 2127 (Ting, Chapter 365, Statutes of 2018) requires the CEC to prepare a statewide assessment of the charging infrastructure needed to support widespread transportation electrification. In addition to the ZEV sales goal established by Executive Order N-79-20, the order also requires that this charging assessment be adjusted in accordance with the sales goal. Detailed results of this assessment will be published in the CEC's AB 2127 report, currently in draft phase, but this chapter provides key modeling findings. Senate Bill 1000 (Lara, Chapter 368, Statutes of 2018) directs the CEC to assess potential disproportionate deployment of charging infrastructure and use funding mechanisms available to address the disproportionality. The CEC released the SB 1000 report in December 2020.[172] In addition to exploring the main results of these requirements, this chapter considers other aspects of charging for large-scale ZEV adoption (including PEVs) consistent with state goals and policies.

Meeting the 2025 PEV Charger Goal

Executive Order B-48-18 requires the state to work with the private sector and all appropriate levels of government to install 250,000 PEV chargers by 2025, including 10,000 DCFC

---

172 Hoang, Tiffany. *California Electric Vehicle Infrastructure Deployment Assessment: Senate Bill 1000 Report*. California Energy Commission. Publication Number: CEC-600-2020-009. https://efiling.energy.ca.gov/GetDocument.aspx?tn=236189&DocumentContentId=69167.

chargers. This goal does not include private chargers at single-family homes. Rather, it covers publicly accessible charging (for example, grocery stores, public parks) and private-shared charging, such as charging available at multiunit dwellings (MUDs). As of January 4, 2021, there are about 64,000 L2 chargers in public or private-shared spaces and about 6,000 DCFCs. The CEC's latest survey of existing and planned chargers shows that the state is roughly 62,000 chargers short of the 2025 goal, as depicted in Figure 24 below.[173] However, this modeled gap does not account for private investments in charging infrastructure that may be made without support from CEC, utility, or settlement funds.

Meeting the 2030 PEV Goal

Thoughtful charger deployment is a significant undertaking that demands careful attention to driver behavior, equity, varying duty cycles and vehicle classes, the local geography, grid capacity and resiliency, and technical standards. To optimize infrastructure buildout with public dollars and make private investment easier, the CEC coordinates detailed assessments of charging infrastructure needs. CEC staff has worked with modelers, sister agencies, and stakeholders to expand and improve charging assessments. These partners include the California Public Utilities Commission (CPUC), the California Air Resources Board (CARB), the National Renewable Energy Laboratory (NREL), the University of California Davis Institute for Transportation Studies, Lawrence Berkeley National Laboratory (LBNL), and Stanford University. During the August 4 and 6, 2020, Integrated Energy Policy Report (IEPR) workshop on charging infrastructure, modelers discussed a wide range of ways BEVs are used. See Table 3 for a description of models from the workshop.

Table 3: Charging Infrastructure Models and Descriptions Considered in the August 4 and August 6, 2020, IEPR Workshop on Charging Infrastructure

Charging Infrastructure Model	Description
EVI-Pro 2	Updated assessment from EVI-Pro for LD PEVs. Includes potential for mitigation policies, additional vehicles, and DCFC use.
EVI-Pro Road Trip	Assesses LD DCFC charging needs and impacts from interregional long-distance travel (>100 miles).

173 CEC 2020-2023 Clean Transportation Program Investment Plan. For more information, see the *Clean Transportation Program Investment Plans web page*. https://www.energy.ca.gov/programs-and-topics/programs/clean-transportation-program/clean-transportation-program-investment.

HEVI-LOAD[174]	Assesses charging load for various regions associated with medium- and heavy-duty vehicles across several vehicle functions and sizes.
EDGE	Analyzes electric vehicle supply equipment (EVSE) deployment and grid capacity for regions in the state using EVI-Pro and HEVI-LOAD. Can integrate with LD and MD/HD needs assessments.
SPEECh	Customizable and rapid sensitivity analysis available for various infrastructure planning users in any region.
WIRED	Models LD load profiles associated with rider services with transportation network companies

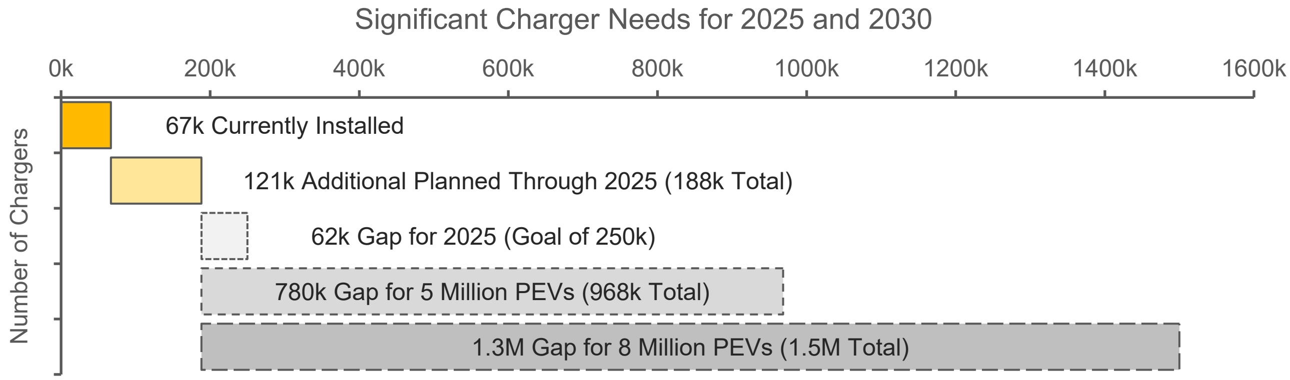
Source: CEC staff

One key takeaway from the overall modeling conversation is that charging infrastructure needs will continue to grow past 2025, and quickly. Preliminary modeling suggests that the state's 2030 goal of 5 million ZEVs, if they are all or mostly PEVs, will require close to 1 million public or private-shared chargers (Figure 24), almost four times the 2025 goal.[175] With the 2035 goal of 100 percent in-state LD ZEV sales established by Executive Order N-79-20, cumulative sales in 2030 will need to ramp up to properly build momentum by 2035. This will require more than the established goal of 5 million ZEVs on the road, making the charging need even larger. Under the nearly 8 million ZEV 2030 scenario provided in CARB's Mobile Source Strategy draft, charger needs could exceed 1.5 million.

174 The HEVI-LOAD model was formerly known as "HEVI-Pro."

175 Preliminary results from EVI-Pro 2 presented in August 2020 assume that roughly 82 percent of PEVs have access to home charging in 2030. NREL. Presentation on Electric Vehicle Infrastructure Projection Tool. August 2020. https://efiling.energy.ca.gov/getdocument.aspx?tn=234215.

Figure 24: Charger Needs for 5 Million Light-Duty PEVs, Including Chargers for Road Trips



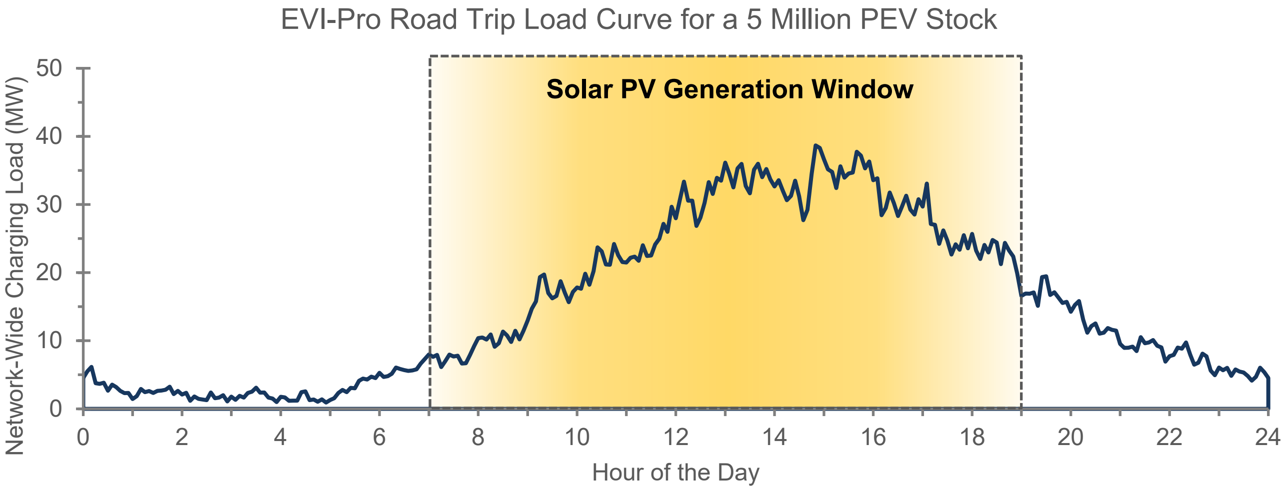
Credit: CEC

Preparing for Charging Loads in 2030

For light-duty vehicles, research suggests that current grid infrastructure and daily load profiles may work well with only a small subset of unmanaged charging behaviors. (See Volume III of the *2020 IEPR Update* for exploratory scenarios of PEV charging in terms of greenhouse gas [GHG] emissions and load shape.) For example, charging needs for long-distance, interregional road trips (greater than 100 miles) coincide with the high solar generation window. (See Figure 25 on EVI-Pro RoadTrip's average daily results.)[176]

176 Chart developed by CEC staff, using data presented by Dong-Yeon Lee with NREL at the August 6, 2020, IEPR workshop on PEV Charging Infrastructure. "DC Fast Charging Infrastructure for Electrified Road Trips." https://efiling.energy.ca.gov/GetDocument.aspx?tn=234213&DocumentContentId=67049.

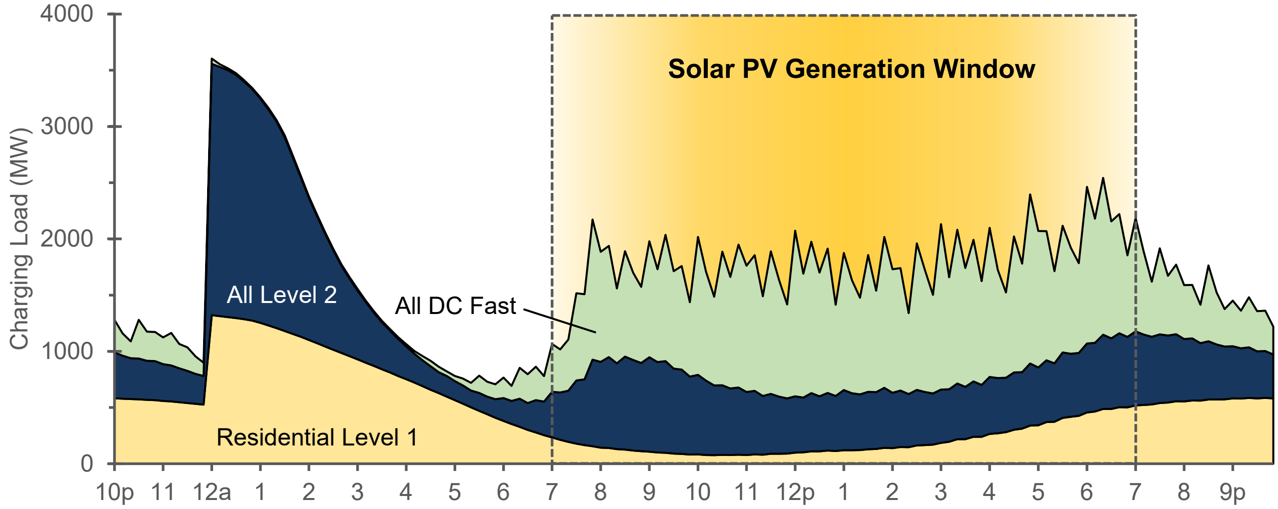
Figure 25: EVI-Pro Road Trip Charging Load Modeling Shows Partial Alignment with Solar Generation on a Typical Day in 2030



Data Source: National Renewable Energy Laboratory

Although charging from road trips work well with the grid, charging load for PEVs across major use cases is somewhat out of alignment with solar generation and overlaps with early evening nontransportation electricity demand. Load patterns may have rapid shifts in demand at night. Figure 26 below shows the main EVI-Pro 2 modeling scenario with about 5 million PEVs on a typical weekday. Influencing much of this load pattern is time-of-use (TOU) pricing. TOU assigns different electricity rates depending on the time, encouraging consumer to charge at different points of the day. Current TOU structures encourage PEV drivers to charge from 12:00 a.m. to around 6:00 a.m. Of note is the near instantaneous demand spike of nearly 2500 megawatts at 12:00 a.m.

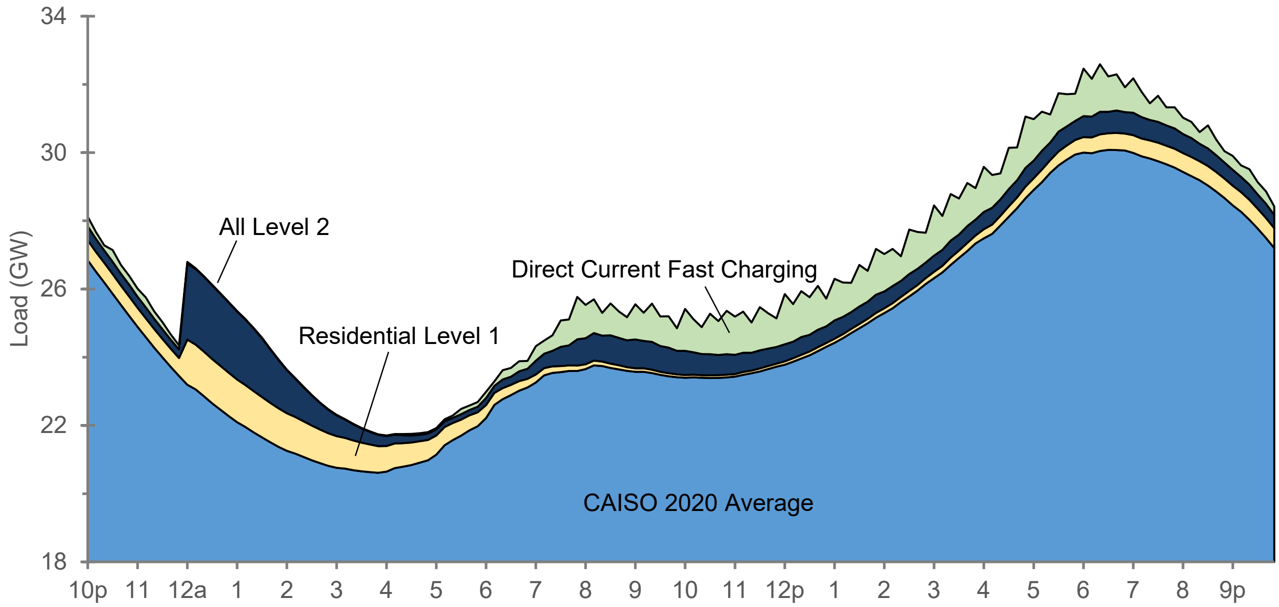
Figure 26: Load Profile for a Typical Weekday for EVI-Pro 2 With 5 Million PEVs



Data Source: National Renewable Energy Laboratory

To provide additional context for Figure 26, adding its load onto a typical grid load may be useful. In Figure 27 below, the EVI-Pro 2 load model and RoadTrip model are stacked on top of the average 2020 10-minute load from the California Independent System Operator (California ISO). Because 2030's California ISO load will likely be different from 2020's, this conceptual exercise only shows only that the net-load impact from a 12:00 a.m. timer spike would not likely pose a supply challenge for the state's grid as a whole. However, localized impacts may still be at risk, and these could become a challenge, especially as more ZEVs are integrated into the grid. For example, the coincidence of charging clustered in neighborhoods may cause voltage issues or overload secondary transformers. The CEC's Assembly Bill 2127 report will explore models that attempt to align generation to maximize with solar and consider local grid impact mitigation strategies.

Figure 27: EVI-Pro 2 2030 5 Million PEV Charging Scenario with California ISO 2020 Average Grid Load

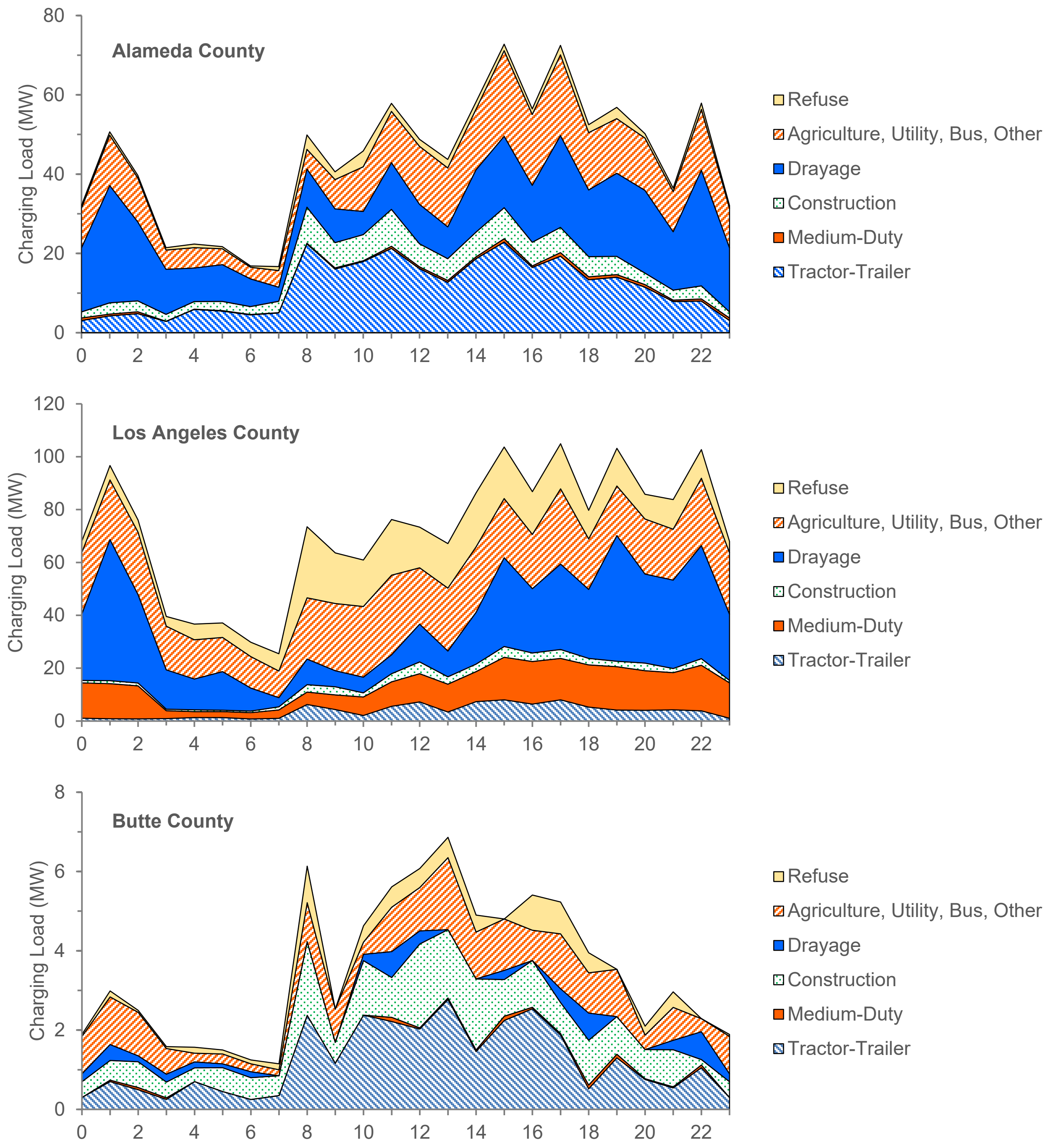


Data Source: CEC staff, NREL, and California ISO

At a local level, more detailed model results will be critical for planning entities to prepare for growing PEV adoption and charging demand, as the geography and local use cases differ from one region to another. For example, the HEVI-LOAD model can generate illustrative charging load profiles on a county-by-county basis. (See Figure 28.)[177] Preliminary results from HEVI-LOAD indicate that the bulk of MD/HD vehicle charging generally occurs during the day.

177 Charts developed by CEC staff, using data presented by Bin Wang with LBNL at the August 6, 2020, IEPR workshop on PEV Charging Infrastructure. "Medium- and Heavy-Duty Electric Vehicle Infrastructure Projections (HEVI-Pro)." https://efiling.energy.ca.gov/GetDocument.aspx?tn=234209&DocumentContentId=67048.

Figure 28: HEVI-LOAD Modeling Shows Dramatically Different Use Cases and Loads for Different Counties



Data Source: Lawrence Berkeley National Laboratory

Overall, buildout and grid mitigation will require incentives, rate structures, new business models, advanced technologies, and other policy tools to encourage and enable the optimal integration of vehicles and the grid. These options closely tie into vehicle-grid integration, discussed below.

Standardization and Interoperability

Standardization of charging connectors is another aspect to effective charging infrastructure build-out. For any technology adoption trend, there is a balance between unique market approaches and unified movement forward. Moving forward quickly on a single approach without an opportunity for the market to select better solutions can lead to inefficient technology lock-in. However, at some point, increased market penetration beyond enthusiasts requires simplicity and ease of use. Furthermore, having additional connector types to accommodate various vehicle requirements at chargers increases costs for EVSPs. Thus, connector standardization, especially in the MD and HD sector, should be a high priority.

For the LD market, there are three main connector standards: combined charging system (CCS), CHAdeMO (a DC charging standard for electric vehicles), and Tesla's propriety system. Other than Tesla, all LD vehicle OEMs have signaled their intention to standardize around CCS for future vehicle models. For the MD and HD PEV market, many manufacturers continue to use proprietary connectors that are not interoperable between different vehicles. As highlighted by BNSF Railway, the various unique changing connectors, even from within a specific vehicle OEM, is a common frustration among vehicle operators.[178] Several MD and HD OEMs are beginning to adopt standardized charging connectors for their vehicles. However, many standards designed specifically for MD and HD applications remain under development, including the Society of Automotive Engineers standards for wireless and pantograph charging, as well as CharIN's conductive Megawatt Charging System.[179] Regardless of when MD and HD vehicle manufacturers converge on connector design, continued fragmentation in the market may confuse consumers and means that chargers used today may not be as useful in later years. Given the limited time and funds to scale charging infrastructure across the state, the CEC, in coordination with CARB, must leverage appropriate policy tools to foster connector standardization among manufacturers as soon as possible.

Identifying and Addressing "Soft Costs"

During a June 22 and 24, 2020, IEPR workshop on funding charging infrastructure, many panelists spoke about the costs of charging infrastructure. Electrify America highlighted a recent report from the Rocky Mountain Institute (RMI) that explores the various costs

---

178 Amanda Marruffo comments. May 20, 2020, IEPR workshop on Heavy-Duty ZEVS: Ports and Off-Road Equipment transcript. pp. 84–85. https://efiling.energy.ca.gov/GetDocument.aspx?tn=233610&DocumentContentId=66189.

179 National Renewable Energy Laboratory, "NREL-Hosted Event Supports Industry Development of Megawatt Charging System Connectors," October 12, 2020. Available at https://www.nrel.gov/news/program/2020/nrel-hosted-event-supports-industry-development-megawatt-charging-system-connectors.html.

associated with charging infrastructure.[180] While costs for charging components are expected to decrease with economies of scale, "soft costs" remain a significant challenge. Soft costs for charging infrastructure include site "future-proofing,"[181] easement processes, interconnection to the grid, compliance with varying codes across jurisdictions, and cost delays in permitting. These costs remain some of the largest and most unpredictable factors for electric vehicle service providers (EVSPs) in charger deployment. RMI points out that soft costs for charging infrastructure are lower in Europe, so best practices and common barriers across regions merit additional consideration. Development of policies and programs to reduce these costs should be a key action moving forward.

Equity Should be a Prominent Factor in Developing Infrastructure Priorities

Establishing priorities for charging infrastructure requires deep equity considerations. During several 2020 IEPR workshops, stakeholders identified PEV and PEV charging access as a key priority for disadvantaged communities. Interest in ZEVs is high across people of varying incomes and explicitly expressed among stakeholder voices in disadvantaged communities.[182] However, there is a consistent perception that charging will be difficult and expensive. A common concern from many stakeholders was accessibility of charging for residents who live in MUDs.[183] As discussed below, charging access for MUD residents is often unavailable.

In accordance with Senate Bill 1000 (Lara, Chapter 368, Statutes of 2018), CEC analysis of public charging distribution across communities of different income levels also shows a disparity of infrastructure. Low-income census tracts have a 20 percent lower L2 charging port

---

180 Rocky Mountain Institute. "Reducing Charging Infrastructure Costs." January 16, 2020. https://rmi.org/the-hidden-costs-of-ev-charging-infrastructure/.

181 "Future proofing" is the process of trying to predict future events and developing methods to minimize the stress of future events.

182 Various presenter comments. June 11, 2020, IEPR workshop on ZEV Affordability and Equitable Access transcript. https://efiling.energy.ca.gov/GetDocument.aspx?tn=234187&DocumentContentId=67035.

183 Ibid.

Various presenter comments. August 4, 2020, IEPR workshop on Engaging Communities for Charging Infrastructure Needs transcript.

density than high-income tracts.[184] While this difference is somewhat modest, the need for public charging in lower-income communities will be higher with similar levels of PEV ownership. Creative state policies and business models will need to address the unique challenge of ensuring equitable charging access across communities.

Other challenges remain for the affordability of PEVs for people who live in disadvantaged communities. A simple way to understand the cost benefits of PEVs is to provide an equivalent gasoline price for a typical EV (about 3.5 miles per kWh) versus a typical ICE vehicle (about 28 MPG). When charging from home and taking advantage of utility charging programs, the equivalent gasoline price for a PEV can be less than $1 per gallon. However, depending on the price and type of public charging (for example, L2 vs. DCFC), the equivalent gasoline price may sometimes approximate the current gasoline costs. Some creative public charging business models may be able to keep the cost to charge very low by putting charging within a value-added framework for commercial real estate. However, it is not a guarantee that residents in disadvantaged and low-income communities, especially those who live in multiunit dwellings, will be able to take advantage of the lowest costs for charging.

To maximize the benefits of PEVs in disadvantaged communities, stronger incentives will be necessary. During the June 11, 2020, IEPR workshop on the status of LD ZEV markets, stakeholders expressed the need for the state to provide charging subsidies for low-income families or those without access to home charging.[185] The subsidies could be analogous to the state's California Alternate Rates for Energy (CARE) program, although not necessarily ratepayer-funded, and integrated with EVSPs across a wide range of public or private-shared charging stations, possibly with enhanced incentives to integrate with renewables.[186]

Residents of disadvantaged communities also face a series of other unique mobility and infrastructure challenges that require a deeper level of engagement to ensure community acceptance and integration within the community.[187] For example, car-sharing programs in

---

184 Hoang, Tiffany. "SB 1000 Electric Vehicle Charging Infrastructure Deployment Assessment." Presentation at the August 4, 2020, IEPR workshop on Plug-In Electric Vehicle Charging Infrastructure. https://efiling.energy.ca.gov/getdocument.aspx?tn=234182.

185 Leon, Rey. June 11, 2020, IEPR Workshop on Transportation Trends and Light-Duty ZEV Market Update transcript. https://efiling.energy.ca.gov/GetDocument.aspx?tn=234187&DocumentContentId=67035.

186 CEC Chair David Hochschild comments. June 11, 2020, IEPR workshop on Transportation Trends and Light-Duty ZEV Market Update transcript. p. 56. https://efiling.energy.ca.gov/GetDocument.aspx?tn=234187&DocumentContentId=67035.

187 See transcript for the May 20, 2020, IEPR workshop on Medium- and Heavy-Duty ZEVs (https://efiling.energy.ca.gov/getdocument.aspx?tn=233611), the June 11, 2020, IEPR workshop on

communities may have charging infrastructure that also serves the public. Collaboration with community stakeholders and municipal organizations on implementing various programs and associated infrastructure for several purposes will be key. The CEC and its partnering organizations should engage the community at the beginning and throughout program development, listen to the needs of local communities, and work to develop relationships with community representatives. This engagement is necessary to developing effective planning that can best attain meaningful charging infrastructure goals in disadvantaged communities.

Opportunities for Multiunit Dwellings

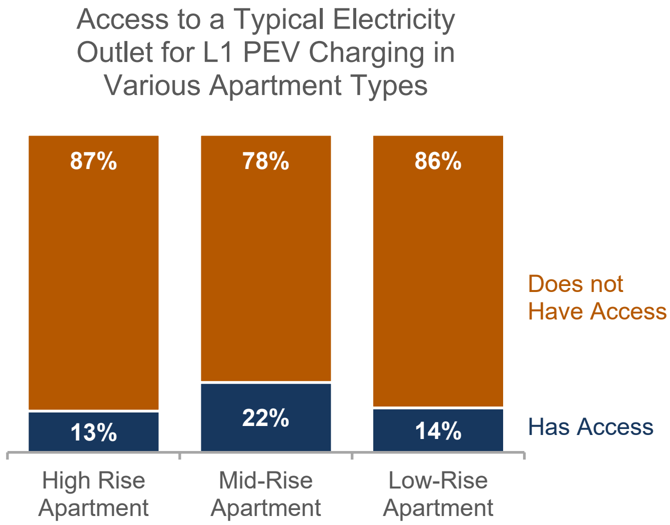
Not all drivers have access to home charging options, especially those that live in multiunit dwellings (MUDs). Roughly 3 million of the 13 million total households in the state are low-income renters, many of whom live in MUDs.[188] Recent CEC/NREL analysis estimates that only about one in seven MUD units in California has access to L1 charging.[189] (See Figure 29.) The factors that limit at-home charging vary, but to account for these limitations, widespread charging access will need to increase for those that do not have direct charging access: MUDs, workplaces, and public locations. New construction of MUDs under new building codes will require readiness for electric vehicles, but significant gaps remain for existing MUDs. Low-cost solutions for these Californians, potentially incorporating additional energy services, should garner increasing attention from the state. (See Chapter 6 for a discussion of MUDs, charging, and energy resilience.)

Transportation Trends and Light-Duty ZEV Market Update transcript (https://efiling.energy.ca.gov/GetDocument.aspx?tn=234187&DocumentContentId=67035), and the August 4, 2020, IEPR workshop on Engaging Communities for Charging Infrastructure Needs transcript (https://efiling.energy.ca.gov/GetDocument.aspx?tn=235912&DocumentContentId=68870).

188 Estimate provided by written public comments from Grid Alternatives, the Greenlining Institute, Ecology Action, and the Union of Concerned Scientists. https://efiling.energy.ca.gov/GetDocument.aspx?tn=236507&DocumentContentId=69504.

189 L1, or Level 1, charging is charging from a typical 110-volt household outlet. Typical L1 charging can add about 4 miles of range per hour to a PEV.

Figure 29: Vehicle Access to Standard Outlets in MUDs is Lacking



Credit: CEC

Innovative models for bringing widespread and low-cost charging services to residents of MUDs exist and can offer additional benefits beyond the charging service itself. For example, Powertree Services works with MUDs to provide charging, building battery backup, and rooftop PV in one agreement. One case study involves an apartment complex in San Francisco to establish 2 of 14 garages in the complex for electric charging services. With solar PV already on the roof, Powertree installed the charging system in the garages, a 48-kilowatt-hour (kWh) battery backup system, and high-speed internet for apartment residents. Residents and nonresidents can subscribe to the service for access to the garages for unlimited charging.

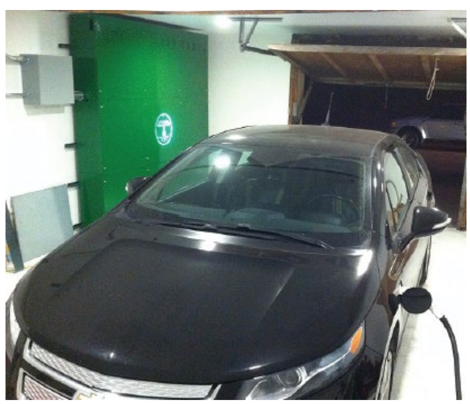


Image Credit: Powertree Services

Powertree pays rent to the complex owner for the two garages, shares a portion of charging revenue, and guarantees residents a 10 percent lower electricity service cost than the utility due to the distributed energy resource system. Apartment residents can opt-in to solar cost savings with a supplemental agreement. The battery backup in the system reduces the overall load of the complex and provides the building with auxiliary energy resiliency in cases of power loss. The system installation avoided costly power upgrades for the additional PEV charging load by using the battery and solar PV system.

During the CEC's June 24, 2020, IEPR workshop on scaling charging infrastructure, Powertree noted that housing unit renters represent an increasing proportion of the population. According to Powertree, services that integrate solar PV, onsite battery storage, and PEV charging are worth up to $598 billion in the MUD market. With the right incentives, regulatory framework, and cost-savings guarantees to residents, business models that move beyond selling electricity alone may offer a distinct advantage in providing a valuable service to MUD residents.

Medium- and Heavy-Duty Vehicles Have Distinct Charging Needs

MD and HD PEVs require more energy per mile and have duty cycles different from LD PEVs, so developing the charging infrastructure for these vehicles will be more complicated and expensive. A recent conceptual report for the West Coast Clean Transit Initiative assumes 350 kW charging rates for MD and a 2 MW charging rate for HD vehicles. An example site with ten 2 MW chargers may require a dedicated substation that more than doubles the price of the site.[190] These types of upgrades to transmission and distribution are more likely given the higher power demands for these vehicles, higher parking densities in lots, and charging needs at warehouses.[191] Fleet operators also have concerns about having reliable and widespread access to charging on the road, especially if space is limited at fleet operator sites. Planning charging infrastructure for off-road environments introduces additional complexities given the broad range of vehicle uses and often-inflexible operating patterns.

Moving from a Public and Utility-Dependent Funding Model to Market Sustainability

Today's Market Depends on a Mix of Public, Utility, and Private Investments

Existing investments in charging infrastructure are largely from state and ratepayer funds, as well as funds from settlements between state agencies and the companies NRG and Volkswagen. While some programs provide incentives for private individuals' charging equipment at home, most large programs support public charging infrastructure, such as grocery stores, or private-shared charging in MUDs and workplaces. Funding is managed at multiple levels, including municipalities, statewide government programs and affiliate

190 West Coast Clean Transit. 2020. *West Coast Clean Transit Corridor Initiative*. https://www.westcoastcleantransit.com/. p. 40.

191 Steve Campbell comments. May 20, 2020, IEPR workshop on Medium- and Heavy-Duty ZEVs transcript. pp. 10–13. https://efiling.energy.ca.gov/GetDocument.aspx?tn=233611&DocumentContentId=66190.

organizations, and different investor-owned utility (IOU) and publicly owned utility (POU) programs. Major funding programs include the following:

- **California Electric Vehicle Infrastructure Project (CALeVIP):** Created by the CEC's Clean Transportation Program, CALeVIP offers incentives for publicly available charging projects and is implemented by the Center for Sustainable Energy. Existing projects as of January 2021 have been funded at $157.2 million, including $32.3 million in matching partner funding. For 2020–2021, an additional $61.1 million is planned, bringing the Clean Transportation Program's investment up to $186 million. Additional funding from partnerships, such as local jurisdictions, will leverage these funds further.[192]
- **CARB/Volkswagen Settlement:** Volkswagen's subsidiary Electrify America plans to spend $800 million from 2017 to 2026 on ZEV infrastructure, education, and access. For its second of four cycles (Q3 2019 to Q4 2021), Electrify America plans to spend $153 million of $200 million on infrastructure alone, with an emphasis on DCFC charging stations for metro communities and highways and regional routes.[193]
- **CPUC IOU Programs:** The CPUC has approved IOU transportation electrification investments from Pacific Gas and Electric Company, Southern California Edison, and San Diego Gas & Electric Company of more than $1.4 billion. More than $700 million of the approved funding is dedicated for MD and HD charging infrastructure.[194] These programs represent the largest portion of charging infrastructure investments in the state.

---

192 Fauble, Brian. "CALeVIP." Presentation at the June 24, 2020, IEPR workshop on Vehicle-Grid Integration and Charging Infrastructure Funding. https://efiling.energy.ca.gov/GetDocument.aspx?tn=233633&DocumentContentId=66218.

193 Electrify America. 2018. *California ZEV Investment Plan: Cycle 2*. https://www.electrifyamerica.com/assets/pdf/Cycle%202%20California%20ZEV%20Investment%20Plan.3e6ce81a.pdf.

194 Sisto, Carrie. "CPUC Transportation Electrification and Vehicle-Grid Integration Programs." Presentation at the June 24, 2020, IEPR workshop on Vehicle-Grid Integration and Charging Infrastructure Funding. https://efiling.energy.ca.gov/GetDocument.aspx?tn=233625&DocumentContentId=66203.

- **CPUC/NRG Settlement:** In 2012, NRG and the CPUC agreed to NRG spending $102.5 million on charging infrastructure. NRG's subsidiary EVGo has implemented and completed the plan as of January 2020, with a full review currently in development.[195]

Average total costs per L2 or DCFC connector vary among different funding programs. Comparison of installation effectiveness and sharing of best practices may be useful as these programs continue to build out. This level of comparison and coordination will also require additional cost transparency across funding programs to make adequate comparisons, identify leverage points for reducing average installation costs, and improve planning. CEC staff recommends additional coordination among different funding programs and an assessment of different funding models that could further leverage these dollars for rapid infrastructure buildout.

Steps to Create a Sustainable Market Without Public Funding

Given the dramatic increase in charging infrastructure necessary for the 2030 and 2035 goals, current funding levels are insufficient. NRG settlement funds have been spent, and the Volkswagen settlement will be spent by 2026, potentially putting additional pressure on public and ratepayer funding to achieve targets.

Economies of scale for hardware and soft cost streamlining can help reduce costs per connector. However, these reductions are not sufficient on their own for the buildout necessary for all vehicle classes and ZEV goals given current funding structures. Fortunately, as more PEVs are on the road, the business case for charging infrastructure increases as well. Ultimately, demand for charging solutions will make infrastructure profitable, and the challenge of meeting continually increasing buildout targets will need to transition to the private sector. The CEC has several recommendations moving forward with the transition to a business case that is well planned to minimize costs to drivers and maintains equitable access for all Californians, as discussed in the sections below.

Identify the Role of Utilities' Investments in Supporting Charging Infrastructure

In 2014, the CPUC overturned a blanket prohibition against electric utility ownership of PEV charging infrastructure on the basis of competitive limitation.[196] The competitive limitation could occur as a result of IOU charging infrastructure programs using ratepayer funds to create an unfair advantage against private charging companies. The ruling gave IOUs an

---

195 CPUC. 2020. CPUC/NRG Settlement Agreement. https://www.cpuc.ca.gov/General.aspx?id=5936.

196 CPUC. 2014. Decision 14-12-079.
https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M143/K682/143682372.PDF.

opportunity for case-specific CPUC approval of IOU charging infrastructure programs. The case-by-case approach is assessed on the potential risk for competitive limitation. In addition, the CPUC's staff draft *Transportation Electrification Framework* identifies the appropriate role of the IOUs in transportation electrification as an area for consideration.[197] The draft framework describes the need for the utilities to assess the market maturity of transportation electrification segments (for example, on deployment level, cost compared to conventional options, and progress addressing market barriers) to identify how the utility would propose an investment as a necessary intervention. The framework also highlights the importance of public-private partnerships to improve cofunding and increase capacity to build charging infrastructure while reducing ratepayer burdens. After several workshops and comments, final decisions on the framework are pending.

Assembly Bill 841 (Ting, Chapter 372, Statutes of 2020) presents an opportunity to encourage the effective deployment of infrastructure build-out and to make the utility-side portion of the infrastructure a core utility role to support transportation electrification for all Californians. By mid-2021, the CPUC is directed to approve a utility tariff or rule that authorizes IOUs to design and dispatch electric distribution infrastructure for separately metered charging on the utility side of the customer's meter.[198] The costs are tracked in a memorandum account and would be recovered in the utilities' subsequent general rate case, meaning ratepayers contribute to those parts of PEV charging infrastructure buildout.[199] While AB 841 provides new opportunities for rapid infrastructure buildout, safeguards built into the tariff or rule will help lead to optimal investments in infrastructure. For example, some charging projects could place higher costs on infrastructure buildout that the IOU must cover.

An example of how this could happen may be helpful. In this example, a charging installer seeks to build a set of chargers at a site to supply enough energy for a specific number of PEVs per year. Each project option provides the same level of charging service but utility costs vary.

---

197 See the CPUC's *Transportation Electrification Framework* (https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442463904) or the CPUC's web page on zero-emission vehicles (www.cpuc.ca.gov/zev).

198 Public Utilities Code Section 740.19 defines this as "poles, vaults, service drops, transformers, mounting pads, trenching, conduit, wire, cable, meters, other equipment as necessary, and associated engineering and civil construction work."

199 Public Utilities Code 740.19.

- Option A requires in-front-of-the-meter (utility side) line capacity upgrades of $150,000 and behind-the-meter charger installation costs of $250,000. In-front-of-the-meter upgrade activities and costs are managed by the IOU, with costs ultimately paid by ratepayers through the IOU general rate case. The total project cost is $400,000, but the site host pays only $250,000.
- In option B, the developer uses onsite battery storage to minimize line upgrades and other utility-side costs, so the utility's in-front-of-the-meter costs are $100,000 (compared to $150,000 in option A). The site host is responsible for the cost of the battery installation ($50,000) and charger installation ($250,000). In this scenario, the total project cost is the same as option A, but the site host would have to pay $300,000 for the batteries, chargers, and behind-the-meter installation work. In addition to the site host having a preference against this option, option A has the potential to place more costs onto ratepayers.

These options are illustrative and not guaranteed to happen in this manner or cost under AB 841.[200] Real-world variations in project costs can differ substantially, meaning that sometimes battery systems may cost more or vice-versa. Battery systems may also offer benefits that may be appealing to site hosts or IOUs, such as reducing demand charges or peak load grid stress. In January 2021, the CPUC solicited comments on the interpretation of AB 841 implementation for submission in February 2021.[201] Underlying this call for comments is the California Public Utilities Code requirement that transportation electrification programs "minimize overall costs and maximize overall benefits" and that programs are "in the interests of [utility] ratepayers."[202] The CPUC's request will be crucial in helping IOUs and charging companies work together to identify roles and minimize the overall costs associated with EV charging buildout while ensuring ratepayer benefits. The CEC anticipates that thoughtful implementation of AB 841 will continue to improve IOU and charging companies' innovative solutions to charging needs while minimizing costs for drivers and ratepayers.

200 For instance, FreeWire's July 15, 2020, written comments on the *2020 IEPR Update* point out that their Mobi charger does not qualify for charging infrastructure programs or state rebates. https://efiling.energy.ca.gov/GetDocument.aspx?tn=233891&DocumentContentId=66672.

201 Rechtschaffen, Clifford. 2021. Assigned Commissioner's Ruling Regarding Implementation of Assembly Bill 841. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M360/K524/360524015.PDF.

202 California Public Utilities Code, Section 740.12. https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?sectionNum=740.12.&lawCode=PUC.

Create Market Opportunities for Accelerating Charging Infrastructure and Vehicle-Grid Integration (VGI)

With increasing private sector interest in charging infrastructure technology,[203] it is critical to recognize the potential for various solutions enabled by project developers. For example, VGI solutions can create benefits for renewables penetration and vehicle owners. During the June 22 and 24, 2020, IEPR workshops on charging and VGI funding, panelists presented a series of funding and business models to develop charging infrastructure. Panelists also presented several challenges to current funding models of charging infrastructure. For example, funding programs often serve charging electricity demands by providing infrastructure to serve the maximum potential power need at the site. For example, if eight 10-kW chargers are placed at a location, the infrastructure build-out will accommodate 80 kW plus a margin. By contrast, some charging options are independent of the grid, and others specifically target low grid impacts with behind-the-meter storage.[204] The potential for these to reduce high make-ready costs (or the upfront costs to ensure electrical infrastructure is present to allow for charging), minimize grid load, and provide additional energy resiliency (see Chapter 7) is promising. However, some current funding programs have not included certified hardware with these capabilities on lists of eligible equipment.[205] A focus on meeting energy demands created by transportation electrification, rather than necessarily increasing the power capacity of the grid

---

203 Root, Al. "Is There Enough Electricity to Charge EVs? Yes. Here's Who Will Charge Them." *Barrons*. November 14, 2020. https://www.barrons.com/articles/theres-enough-electricity-in-the-world-for-electric-vehicles-heres-who-will-charge-them-51605368406.

204 Monbouquette, Marc. EnelX. "Attracting Private Capital + New Business Models for EV Charging Infrastructure." Presentation at the June 24, 2020, IEPR Workshop on Vehicle-Grid Integration and Charging Infrastructure Funding. https://efiling.energy.ca.gov/getdocument.aspx?tn=233634.

Shah, Rajiv. FreeWire. "Charging Infrastructure Simplified." Presentation at the June 24, 2020, IEPR Workshop on Vehicle-Grid Integration and Charging Infrastructure Funding. https://efiling.energy.ca.gov/getdocument.aspx?tn=233618.

205 Public comments from FreeWire, Nuvve, Enel X, and BEAM expressed concern about their charging hardware and/or business models are often ineligible for state or IOU funding programs.

FreeWire. https://efiling.energy.ca.gov/GetDocument.aspx?tn=236500&DocumentContentId=69497.

Nuvve and Enel X. https://efiling.energy.ca.gov/GetDocument.aspx?tn=236504&DocumentContentId=69500.

BEAM. https://efiling.energy.ca.gov/GetDocument.aspx?tn=236489&DocumentContentId=69485.

or onsite transportation electrification infrastructure, may help the charging infrastructure market value all options more successfully.[206]

Accumulating several collocated projects that manage the associated load and, in turn, defer service upgrades with high levels of certainty could avoid or defer larger distribution capacity upgrades, such as substations. While it may be difficult to assess the precise benefits and needs in each region, the scenarios suggesting the need for 8 million PEVs on the road by 2030 reveal the need for careful consideration of the potential impacts, benefits, and regulatory needs.

Private Investment Must be Supported by Regulatory and Financial Streamlining

In addition to existing state and utility charging infrastructure programs, there are several opportunities for innovative solutions to charging infrastructure that are not part of major charging funding programs. Continuing with existing charging funding programs alone may not be enough to build the charging infrastructure needed to achieve state goals and could lead to missed opportunities, such as VGI benefits and optimal alignment with renewable electricity.

Some existing regulations already target charging infrastructure deployment and use without directly funding chargers themselves. For example, CARB's Low Carbon Fuel Standard (LCFS) enables utilities and, in some cases, the owner of the charger to claim credits for dispensing electricity as a fuel. The LCFS also contains provisions providing capacity credits for new fast charger deployments,[207] as well as incremental fuel credits to encourage smart charging.[208]

Other options outside current funding programs and regulations present an opportunity for charging buildout. During the June 24, 2020, IEPR workshop on charging funding, Cambridge Capital presented a business model based on "non-wires" distributed solar and storage at

---

206 Comments of FreeWire and Nuvve to the June 24 IEPR Workshop on Vehicle-Grid Integration and Charging Infrastructure Funding. https://efiling.energy.ca.gov/getdocument.aspx?tn=233891 and https://efiling.energy.ca.gov/getdocument.aspx?tn=233895.

207 Section 95486.2 of the Low Carbon Fuel Standard describes capacity credits for new fast charger deployments, which decrease as use of the charger increases. https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf.

208 Section 95486.1 of the Low Carbon Fuel Standard describes credits for fuel delivery, including incremental credits that offer incentives for smart charging when electricity carbon intensity is low. https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf.

commercial and industrial sites.[209] This model could help support infrastructure deployment by lowering demand charges, addressing grid impacts, shortening project development cycle, and simplifying permitting to reduce overhead. Cambridge Capital recommends that the CEC and developers use equity finance approaches and project aggregation early in the development phase. With this early-stage financing, it concludes that this investment strategy could leverage up to 40 times the initial investments.

Similar approaches to maximizing behind-the-meter capacity (such as coordinating distributed generation and energy efficiency deployments simultaneously with charging) could minimize total costs for charging infrastructure deployment. With this potential, new regulatory and funding mechanisms may help spur private investment, ensure buildout to meet demand, and ensure low costs for all Californians, especially those in disadvantaged or low-income communities.

Maximizing Charger Benefits at the Lowest Cost Will Spur Private Investment

The CEC recently made its first steps on developing and presenting a possible new approach to funding charging infrastructure which considers factors such as location, charging capability, and cost-effectiveness. In workshops on June 24 and August 4, 2020, CEC staff presented a potential funding pathway to leverage funds currently used for charging infrastructure.[210] This concept[211] would create a holistic way to assess the market for charging infrastructure, invest in charging infrastructure, and deliver projects more consistently across the state.

The concept would introduce a measure of the cost to enable charging capability through the investment of public funding, which could serve as the basis for market competition for diverse charging solutions. It relies on the concept of the "avoided cost of charging," the difference between the cost that a customer would pay in a noncompetitive process and the lowest cost-set of alternative proposals bid in an auction to serve the same customer. Efforts to explore innovative models received supportive comments from the public. However, other stakeholders

209 Rangarajan, Anand. Cambridge Capital. "Financing EV Charging Infrastructure in California." Presentation at the June 24, 2020, IEPR Workshop on Vehicle-Grid Integration and Charging Infrastructure Funding. https://efiling.energy.ca.gov/getdocument.aspx?tn=233621.

210 Crisostomo, Noel. "Lessons Learned From Electricity Policy for Transportation Electrification." Presentation at the June 24, 2020, IEPR workshop. https://efiling.energy.ca.gov/getdocument.aspx?tn=233635.

Crisostomo, Noel. 2020. "Assembly Bill 2127 Charging Infrastructure: Other Programs to Accelerate EV Adoption." Presentation at the August 4, 2020, IEPR workshop. https://efiling.energy.ca.gov/getdocument.aspx?tn=234173.

211 Formerly known as the Transportation Electrification Regulatory Policies Act (TERPA).

believed the concept needed clarity and additional deliberation and generally urged caution. Additional exploration of the potential and limitations of the concept with workshops and additional input from stakeholders is necessary.

This concept would allow for a multistep process that works roughly as follows:

- The CEC and program administrators assess and confirm energy needs associated with achieving an electric transportation target within a given region and identify locally appropriate projects.
- Administrators hold a reverse auction, where EVSPs bid on developing projects that contribute toward the assessed energy needs and compete with others in providing the lowest-cost services. EVSP bids are rank-ordered up to the quantity of transport electricity required to quantify the total cost of meeting the charging demand.
- The CEC and administrators budget public investment according to the needs of the region.
- The CEC makes awards to EVSPs.
- The utility supports installations by serving the required electric load and offers economic rates.

Under this approach, acquiring the funding for charging infrastructure does not require a specific business model approach or form of infrastructure (beyond minimum quality and technical standards). Rather, the EVSPs are assessed primarily on the public investment the EVSPs need to viably serve their charging project and enable electric miles. This approach can create an option for new charging business models, complementing existing programs such as CALeVIP. Stated simply, the EVSP is offered incentives to bring the greatest amount of private funding in developing projects that are bid into the auction to reduce costs. This model can leverage public, ratepayer, and other existing funding sources in a way that can potentially open new private investment channels.

Effective Vehicle-Grid Integration Can Improve Energy Access for Transportation and the Grid

With the growing number of PEVs in California, charging needs create additional demand for grid electricity. However, over the past decade, wind generation in California has more than doubled, and utility-scale solar generation has grown more than 35 times over, with generation at times exceeding demand.[212] This growth in renewable energy generation has resulted in increasing amounts of energy curtailment, the reduction of renewable electricity output due to overgeneration risk at specific times in specific parts of the state. Curtailment typically happens during peak solar generation times. Senate Bill 100 (De León, Chapter 312, Statutes of 2018) also requires 60 percent renewable electricity by 2030. Approaches to managing increasing renewables on the grid are in order. For PEVs, encouraging charging during peak renewable generation, particularly for vehicles that are already parked and plugged-in midday, will maximize the economic, climate, and clean air benefits of EVs. It will also help ensure that drivers and fleet operators have simple and reliable access to the energy they need to power their vehicles. These benefits can be accomplished with VGI.

Vehicle-Grid Integration

VGI is a suite of technological and economic solutions that alter the timing, location, and rate of charging and discharging of PEVs. Effective implementation of VGI goes hand in hand with continued growth in renewables while ensuring reliable energy for mobility.

A major shift in thinking with VGI is that PEVs are not merely a source of additional electricity demand, but are distributed energy resources. Understood this way, having enough PEVs integrated with the grid can enhance grid resiliency, reduce additional infrastructure costs, and avoid renewable electricity curtailment.[213] While PEVs typically need the grid to recharge, they can often do so in a dynamically responsive way without affecting the driver. With the appropriate design and integration, they can put energy back onto the grid when needed if it suits the owner.

VGI strategies can be categorized based on the direction and target of electricity flow (see the VGI Working Group Glossary of Terms[214]):

- *V1G* (or managed, controlled, or "smart" charging) involves controlled ramping-up or ramping-down of chargers of an individual or several PEVs.

---

212 Staff analysis of data from Energy Information Administration's Electricity Data Browser. https://www.eia.gov/electricity/data/browser/.

213 Piero, Jacqueline. Nuvve. "Reframing EVs as DER." Presentation at the June 24, 2020, IEPR Workshop on Vehicle-Grid Integration and Charging Infrastructure Funding. https://efiling.energy.ca.gov/GetDocument.aspx?tn=233573&DocumentContentId=66117.

214 VGI Working Group Glossary of Terms. https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442455744.

- *V2G* involves controlled (dis)charging of energy from an individual or several PEVs to facility circuits connected to the electric power system.
- *V2X* involves controlled discharging of energy from an individual or several PEVs to buildings, homes, or other loads that may be temporarily islanded or disconnected from the electric power system.

Potential Benefits of VGI

The simplest form of VGI is time-of-use (TOU) pricing. PEV driver responses to current TOU rate structures may provide a net benefit to the grid by increasing grid load at the times that best align with the price signal. This simple VGI tactic has some limitations in the long run. As the number of PEVs increase, demand spikes may also increase if price-responsive drivers have their vehicles on simple timers. As shown in Figure 27, current TOU load modeling shows a near-instantaneous spike at 12:00 a.m. of nearly 2,500 megawatts under a 5 million PEV scenario.

The more sophisticated VGI practice of smart charging (V1G) can help the grid reduce operating costs, ease demand fluctuations, and reduce curtailment of renewable energy. Smart charging involves user participation in a utility or third-party program that remotely controls the charging process but enables the user to specify needs (for example, ensuring 100 percent charge by 8 a.m.). Under a 5 million PEV modeling scenario, researchers from University of California, Berkeley, found a net grid benefit of $125 to $140 per year per EV with smart charging. This benefit would amount to a nearly 10 percent reduction in grid wholesale operating costs compared to unmanaged charging, potentially benefitting all electricity users, even those that do not drive a PEV.[215]

One of the main ways that smart charging can create net benefits is by using energy that would otherwise be curtailed. The same UC Berkeley study found that smart charging in a 5 million PEV scenario resulted in a potential 40 percent reduction in renewables curtailment. This reduction would likely be even greater as the state produces more renewable energy and has more PEVs on the road.[216] Charging "happy hours" that have very low cost or even free

---

215 Szinai, Julia. "Reducing CA's Grid Operating Costs and Renewable Curtailment With Electric Vehicle Charge Management." Presentation at the June 24, 2020, IEPR Workshop on Vehicle-Grid Integration and Charging Infrastructure Funding. https://efiling.energy.ca.gov/GetDocument.aspx?tn=233574&DocumentContentId=66118.

216 Ibid.

charging for drivers could create additional incentives to pursue charging at specific times and locations to maximize the benefits of renewables and reduce curtailment.

Studies considering V2G show the potential for even more benefit to the grid than V1G. A recent study from Lawrence Livermore National Laboratory analyzes potential benefits from BEVs engaging in smart charging when prices are low and selling back via V2G during high demand can yield $243 to $1,380 in potential net benefit per year for an LD BEV.[217] Transferring this value to the owner could make his or her vehicle a source of income while enhancing grid reliability, with no significant impact to his or her mobility.

CEC-funded efforts have shown the potential for VGI in larger vehicles, particularly school buses. With specialized rates, electric school buses can flexibly charge and reduce demand charges, as well as offset TOU electricity use at the school site (V2B) during the summer, when bus operations are on a reduced schedule. The results suggest that VGI can save or offset $2,052 per EV bus in electricity costs annually.[218] Additional grid services, integration with solar PV on site, and usage at other times throughout the year could increase this benefit.

Another benefit of VGI is the ability of vehicles to serve as sources of resiliency in case of power loss at a home or other location. See Chapter 6 on ZEV resiliency for more information.

Battery cycling degradation is sometimes mentioned as a concern for VGI, but several studies and real-world experience show that this is exaggerated. Indeed, the opposite may be true. Without VGI, owners may try to keep the battery in a high state of charge, which is more harmful to the battery in the long term than cycling[219] within defined ranges.[220] One recent study found that a smart VGI model could enhance battery life compared to drivers that charge to 100 percent every night, with a smart VGI algorithm reducing battery capacity fade by 9.1 percent.[221]

---

217 Donadee et al. 2019. Potential Benefits of Vehicle-to-Grid Technology in California: High Value for Capabilities Beyond One-Way Managed Charging. https://www.osti.gov/biblio/1557041.

218 ARV-13-011. Report to be published before adoption of the *2020 IEPR Update*.

219 Battery *cycling* refers to the process of fully charging the battery and then dispatching that power as required in a load.

220 Guo, Jingli, Jin Yang, Zhengyu Lin, Clara Serrano, and Ana Maria Cortes. 2019. "Impact Analysis of V2G Services on EV Battery Degradation: A Review." IEEE. https://ieeexplore.ieee.org/document/8810982.

221 Uddin, Kotub, Tim Jackson, Widanalage D. Widanage, Gael Chouchelamane, Paul A. Jennings, and James Marco. 2017. "On the Possibility of Extending the Lifetime of Lithium-Ion Batteries Through Optimal V2G

During the July 15, 2020, IEPR workshop on ZEV resiliency, panelists noted that batteries, when charged and discharged within specified ranges (for example, 20 to 80 percent state of charge) and kept at moderate temperatures, do not suffer significant degradation. One reason for this is the discharge power. Homes do not draw as much power as accelerating a vehicle and maintaining high speeds. This finding was an important takeaway from Honda's Smart Home pilot project. It was also a key result from a Nuvve pilot project for a frequency regulation pilot in Denmark using Nissan Leafs, which involved significant battery cycling (but within specified charge/discharge parameters).[222] Additional pilot projects can provide more information on battery impacts, but indeed, several bus manufacturers, including both that were awarded under the CEC's Electric School Bus Program, are already commercializing V2G as a standard feature on their vehicles, available nationwide.[223]

Targets for VGI are Essential to Signal for Scale Up

Equipment to manage VGI for home use is cost-competitive with nonnetworked charging equipment,[224] so the major hurdles are consumer acceptance, implementing appropriate capabilities, and an effective regulatory framework to maximize the benefits of VGI. Benefits to consumers should be made clear and easily accessible, and further research must look beyond the direct dollar-value benefits of VGI to ensure an equitable transition to electrified transportation where all Californians can receive these benefits.

Facilitated by an Integrated Vehicle and Smart-Grid System." Science Direct. https://www.sciencedirect.com/science/article/pii/S0360544217306825.

222 July 15, 2020, IEPR workshop on ZEV Resilience and Three Revolutions in Transportation transcript, https://efiling.energy.ca.gov/getdocument.aspx?tn=234949.

223 "Nuvve and Blue Bird Announce Availability of Nationwide Vehicle-to-Grid (V2G) School Bus Offer." September 15, 2020. https://www.prnewswire.com/news-releases/nuvve-and-blue-bird-announce-availability-of-nationwide-vehicle-to-grid-v2g-school-bus-offer-301131309.html

"Nuvve Corporation and Lion Electric Announce Vehicle-to-Grid (V2G) Collaboration." November 19, 2020. https://www.prnewswire.com/news-releases/nuvve-corporation-and-lion-electric-announce-vehicle-to-grid-v2g-collaboration-301177245.html.

224 Noel Crisostomo presentation. "Load Management Rulemaking (19-OIR-01)." January 14, 2020. Slide 6. https://efiling.energy.ca.gov/GetDocument.aspx?tn=231541&DocumentContentId=63354.

Coordinated by Gridworks and including several California state agencies, the VGI Working Group completed a final report on VGI in 2020.[225] The report includes 92 policy recommendations on VGI. The CEC is also working to complete a new VGI roadmap with several recommendations on accelerating VGI, streamlining the many recommendations that have already been offered.[226] The VGI roadmap may have targets and recommendations for VGI implementation moving forward, such as:

1. Manufacturing PEVs that have advanced VGI capability and for the deployment of charging infrastructure that includes open VGI standards
2. Outreach, incentives, and programs for consumers to take advantage of VGI, with prioritization of disadvantaged communities
3. Integration of cost-effective VGI capabilities in general charging infrastructure buildout goals
4. Policy development to encourage customer use of VGI capabilities within various jurisdictions within the state and beyond
5. Continued improvement of charging technology, interoperability, and standardization to maximize bi-directional interconnection capabilities, including for MD and HD BEVs

Recommendations

- **The state should commit to advancing a market for charging, where plug-in technology is interoperable, and vehicle owners can have confidence that the charging technology for any site will work for their vehicle.** Achieving this goal has been slow and challenging with the light-duty vehicle industry, but the market is coalescing around the Combined Charging System as a standard for light-duty vehicle charging infrastructure, with the notable exception of Tesla. The state should learn from experiences in the light-duty sector and move quickly to advance interoperability in the heavy- and medium-duty vehicle sectors.
- **The California Energy Commission (CEC) should collect and analyze the data needed to support charging infrastructure development that minimizes costs and maximizes benefits to the grid.** Vehicle electrification is essential to meeting California's energy and climate goals, and vehicle grid integration is key. Data on charging

225 Gridworks. *Final Report of the California Joint Agencies Vehicle-Grid Integration Working Group*. June 30, 2020. https://gridworks.org/wp-content/uploads/2020/09/GW_VehicleGrid-Integration-Working-Group.pdf.

226 California VGI Roadmap Update web page. https://www.energy.ca.gov/programs-and-topics/programs/california-vehicle-grid-integration-roadmap-update.

sessions, including time- and location-specific charging data from across the state, can support the analytical work necessary to advance effective vehicle grid integration that reduces rates for all ratepayers through more efficient use of fixed grid assets.

- **The CEC, California Public Utilities Commission, utilities, and electric service providers should support market opportunities, incentives, and other mechanisms to better align charging with increasing renewable generation.** Maximizing the use of renewable generation will help optimize the benefits of plug-in electric vehicles and will require planning and incentives, including for vehicle grid integration. Broad support is needed for developing incentives, rate structures, new business models, advanced technologies, and other policy tools to encourage and enable the optimal integration of vehicles and the grid.
- **The CEC should address barriers to charging infrastructure access in low-income and disadvantaged communities.** In addition to its legislatively mandated role in evaluating and deploying proportionate charging infrastructure, the CEC should work with community stakeholders to identify and address barriers to access beyond location. The CEC should also consider subsidies for low-income households for charging infrastructure use comparable to the state's California Alternate Rates for Energy program. Such subsidies could be integrated with electric vehicle service providers across a wide range of public or private shared charging stations, possibly with enhanced incentives to integrate with renewables. Any efforts would need to particularly address opportunities for charging availability at multiunit dwellings and workplaces.
- **The CEC recommends evaluating new regulatory and funding mechanisms to further encourage private sector investments in the charging infrastructure needed to meet demand while ensuring low costs for all Californians, especially those in disadvantaged communities or low-income communities.** Public investment is critical but on its own will not be enough to meet the infrastructure build-out requirements needed to support California's goals, especially the 2035 goal of 100 percent ZEV sales. The CEC should continue to collaborate with the California Governor's Office of Business and Economic Development (GO-Biz) and other agencies to develop and vet innovative proposals to leverage public, ratepayer, and private investments in the widespread and equitable development of charging infrastructure.

CHAPTER 5
Fuel Cells and Hydrogen Have an Important Role to Play

California has Been a Leader on Hydrogen and Fuel Cells

Since the signing of Executive Order S-07-04 by former Governor Arnold Schwarzenegger in 2004, California has led the world in hydrogen and fuel cell market innovation. With the passage of Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) in 2013, the state set an additional ambitious goal of deployed hydrogen fuel stations. As of December 2020, 45 stations are in operation, with another 38 in development and allocated funding for roughly 73 more. Costs and construction time for station installation have declined significantly since the passage of AB 8. As of 2019, California also had more fuel cell electric vehicles (FCEVs) than other large economies, although China and Japan have seen a marked increase in their FCEV stock. With these trends and global momentum to match, fuel cells and the hydrogen that powers them are in a good position to play a large role in the state’s transportation sector.

FCEVs Offer Characteristics That Can Expand the Zero-Emission-Vehicle (ZEV) Market

FCEVs and plug-in electric vehicles (PEVs) have different characteristics that provide each with advantages in certain transportation market segments. FCEVs typically have longer ranges and faster refueling times than battery-electric vehicles (BEVs), which make this technology particularly attractive to customers who must travel long distances, have demanding duty cycles, or need to minimize downtime. By supporting PEVs and FCEVs, California is providing ZEV options that can meet the needs of more people and businesses than one technology alone.

For passenger vehicle applications, the three commercially available FCEVs (Toyota Mirai, Honda Clarity Fuel Cell, and Hyundai Nexo) have ranges of 310 to 380 miles, depending on the driver’s habits. Some users, including taxis and ride-hailing operators, may prefer a ZEV with refueling times similar to gasoline and diesel, rather than the longer recharging times needed for BEVs. One recent demonstration of some of these benefits is StratoShare, a car-sharing program developed by hydrogen infrastructure provider StratosFuel, Inc. Deploying 15 Toyota Mirais in Riverside and San Bernardino Counties, the program focus on students and residents in disadvantaged communities has allowed them to enroll 800 people in need of vehicles with high range.[227] With more widespread deployment, public hydrogen refueling stations can also offer more convenient fueling for Californians who face barriers to accessing PEV chargers, such as those living in multiunit dwellings (MUDs). While passenger FCEVs have these potential benefits over PEVs, FCEV costs remain high, and refueling may face several challenges. For a successful passenger FCEV market, other countries will need to increase sales to build the economies of scale necessary to drive FCEVs costs down.

FCEVs may be particularly important to decarbonize the medium-duty (MD), heavy-duty (HD), and off-road sectors. Hydrogen tends to become more competitive relative to other ZEV technologies as customers' needs require longer duty cycles and covering longer distances, because in these cases range and quicker refueling are of higher value.[228] Material-handling equipment such as fuel cell forklifts are already gaining substantial market penetration because of the good match between the vehicle performance and the needs of many warehouse operations. Fuel cell transit buses are emerging as an early market in the United States and globally (see below), offering a similar experience as diesel buses in terms of range and refueling time. More than 12 years of fuel cell electric bus use in California have proven that the technology is ready and reliable on some urban and suburban transit bus routes. Industry interest in FCEVs is also growing into other MD and HD market segments. For example, Anheuser-Busch has ordered up to 800 fuel cell semitrucks from the Phoenix, Arizona-based Nikola Motor Company. These trucks may travel between 500 and 1,200 miles before a 20-minute refueling is required. A key advantage of fuel cells over battery-electric vehicles in the commercial sector is that the price of electricity can vary dramatically over the day, while the price of hydrogen is stable. This advantage allows businesses the flexibility to refuel throughout the day without worry of high demand charges.

Fuel cell electric trucks tend to weigh less than the battery-electric counterparts and, therefore, can haul heavier loads, giving this technology an advantage for many freight applications. For its Class 8 fuel cell tractor, Toyota simply uses two fuel cell stacks from its light-duty (LD) Mirai FCEV.[229] Other than the fuel stacks, a fuel cell electric truck mostly needs

---

227 Jonathan Palacios-Avila comments. July 2, 2020, IEPR Workshop on Hydrogen and Fuel Cell Electric Vehicle Market Status transcript. https://efiling.energy.ca.gov/getdocument.aspx?tn=234946.

228 Morrison, Geoff, John Stevens, and Fred Joseck. 2018. "Relative Economic Competitiveness of Light-Duty Battery Electric and Fuel Cell Electric Vehicles." *Transportation Research Part C: Emerging Technologies 87* (February): 183–96. https://doi.org/10.1016/j.trc.2018.01.005.

229 James Kast presentation, "Fuel Cell Applications." Department of Energy Truck Targets Workshop. July 30, 2018. Slide 11. https://www.energy.gov/sites/prod/files/2018/08/f54/fcto-truck-workshop-2018-2-kast.pdf.

additional storage for the hydrogen fuel. For example, the Mirai has a 5-kilogram hydrogen fuel tank, while the Class 8 truck will have 70- to 80-kilogram storage capacity. In battery-electric trucks, heavy battery packs can take away from the space and weight available for goods. If fuel cell technology can maintain a competitive advantage to battery technology in size, weight, and performance for many heavy-duty applications, fuel cell electric trucks will play an important role in decarbonizing the freight sector. Cost reductions in fuel cells and hydrogen fuel are also key to this success. As global volumes of fuel cell production increase, LD and HD fuel cell applications will experience cost reductions.

Hydrogen refueling infrastructure also offers a potential cost benefit to transit agencies or businesses looking to convert an entire fleet of vehicles to zero emissions. Installing a hydrogen refueling station for a demonstration of a few FCEVs is relatively expensive compared to the more modular charging infrastructure needed for a BEV demonstration. This large capital requirement can make it financially difficult to support an FCEV demonstration. However, as FCEV fleet sizes increase, a single fueling station can continue to refuel them with no or minimal expansion. This presents an advantage over charging infrastructure for HD BEVs, which can require expensive upgrades with higher power demand. Therefore, hydrogen refueling can have advantages in supporting the quick scale-up of fleets to zero emission and offer the potential for infrastructure sharing between different fleet customers to use the full capacity of a station. Hydrogen also poses other potential advantages related to energy resiliency given concerns with power outages. For more information, see Chapter 6.

California is Working to Overcome Barriers to FCEV Commercialization

Today's FCEV market faces several barriers, including a lack of infrastructure for light-duty and MD/HD vehicles, higher vehicle cost, lack of model availability, and higher cost of hydrogen (particularly green hydrogen).

California is working to overcome these barriers through a combination of public and private investment. The CEC's Clean Transportation Program supports the development of public hydrogen refueling stations for light-duty and MD/HD vehicles. (See below for more detail on hydrogen infrastructure build-out.) CARB's Low Carbon Fuel Standard Hydrogen Refueling Infrastructure program helps address the chicken-and-egg problem between vehicles and supporting infrastructure, providing credits based on station capacity rather than fuel delivered. CARB's Clean Vehicle Rebate Project and Clean Cars 4 All program provide incentives for LD FCEV purchases or leases.[230] Its Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) provides grants for MD and HD FCEVs. Light-duty FCEV manufacturers have also offered fueling incentives to attract customers in California. Typically, the FCEV passenger vehicle owner or lessor obtains three years of free fuel, or the equivalent of up to $15,000, as part of their purchase/lease agreement. This incentive reduces the barrier of fuel price to consumers, at least in the short run.

Global Investments are Increasing, With Production Costs Expected to Decline as Industry Scales

The international adoption of hydrogen fueling infrastructure is growing, and the global population of LD, MD, and HD FCEVs vehicles is increasing. But to rapidly scale, greater progress is needed on a global scale. Passenger vehicles are sold only in relatively small quantities, as shown in Table 4. Today, there are nearly 9,000 FCEVs in California, and a survey of original equipment manufacturers (OEMs) estimates 48,000 LD FCEVs will be sold in California by 2025. North America is expected to have between 100 and 1,000 MD and HD FCEVs by the same year.

In contrast, Asia dwarfs North America and Europe for adoption goals of fuel cell passenger vehicles, buses, MD trucks, and other non-LD applications.[231] The International Energy Agency (IEA) presented specific FCEV targets in the July 2, 2020, IEPR workshop, shown in Figure 31 below. Some of the most aggressive targets are from Japan, South Korea, and China. By 2025, China has a target of 50,000 commercial vehicles, and Japan and Korea each have goals of 200,000 FCEV deployments.[232] The vehicles deployed through 2025 are expected to be mostly light-duty because of the investments Toyota, Honda, and Hyundai are making in passenger vehicles. However, Tokyo aims to have 100 fuel cell electric buses by 2020 (now 2021) for the Summer Olympics. South Korea is targeting 67,000 FCEVs and 2,000 fuel cell electric buses by

---

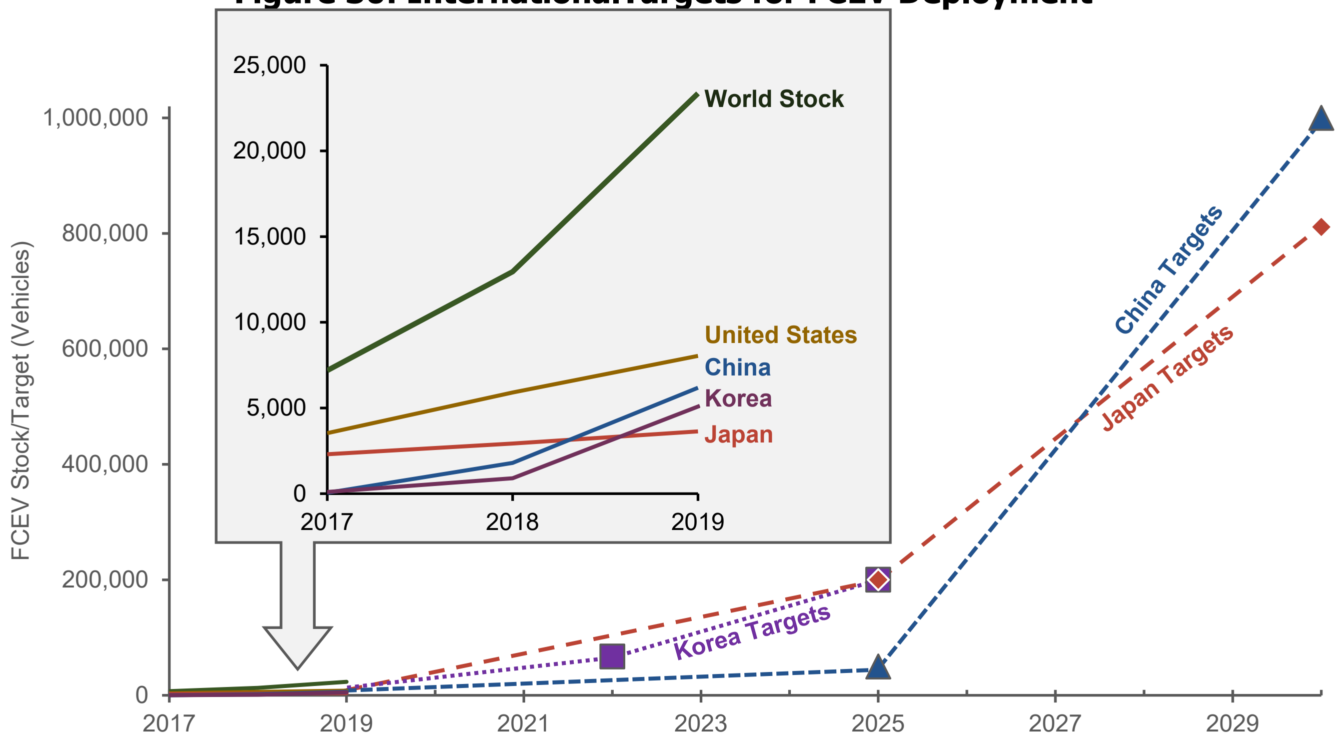
230 The Governor's proposed 2021-2022 budget prioritizes funding for the equity-oriented Clean Cars 4 All program, although some funds remain in CVRP as of February 2021.

231 Other non-light-duty applications include portside equipment, freight applications, commuter rail, trains, and trams.

232 Korean New Deal. July 28, 2020. https://english.moef.go.kr/pc/selectTbPressCenterDtl.do?boardCd=N0001&seq=4948.

2022 and 200,000 by 2025.[233] By 2030, China aims to have 1 million FCEVs by 2030, focused more on MD and HD applications, while Japan has a target of 850,000 FCEVs.

Figure 30: InternationalTargets for FCEV Deployment



Source: IEA

In sum, the IEA estimates that global investment in hydrogen expanded substantially to about $80 billion in 2019, well above investment estimates from earlier years.[234]

233 South Korea Ministry of Economy and Finance press release. "Government Releases an English Booklet on the Korean New Deal." July 28, 2020. http://english.moef.go.kr/pc/selectTbPressCenterDtl.do?boardCd=N0001&seq=4948.

234 Teter, Jacob. "Hydrogen and Fuel Cells Considerations for the California Energy Commission." IEA. Presentation at the July 2, 2020, IEPR workshop on Hydrogen and Fuel Cell Electric Vehicle Market Status. https://efiling.energy.ca.gov/getdocument.aspx?tn=233701.

Hydrogen and Fuel Cell Cost Reductions are Key to Total Cost of Ownership (TCO) Parity

Despite some unique advantages of FCEVs, they are at a TCO disadvantage against diesel and BEVs in terms of vehicle purchase price, although there is a wide range of vehicle purchase prices for BEVs because there are more options and models available than for FCEVs. In many cases, the FCEV OEM gives the lessor of the FCEV a fueling card good for three years of free fuel, or an amount of fuel equivalent to $15,000. Costs for FCEVs continue to decline, and market opportunities are available with effective policy and program support.

Renewable Hydrogen is Necessary, with Costs Continuing to Decline

Just as a plug-in electric vehicle is only as clean as the electricity grid, a hydrogen fuel cell vehicle is only as clean as the hydrogen fuel source. Hydrogen can be sourced in several ways, including fossil fuels, such as petroleum or pipeline gas. Many hydrogen refueling stations in California dispense hydrogen from fossil-based steam reformation, but importantly, they purchase a one-to-one amount of renewable biogas that is injected into the state's pipeline system, effectively making the hydrogen renewable per requirements of the Low Carbon Fuel Standard program.

Fossil-based methods of sourcing hydrogen are not a viable long-term strategy for the state's climate and ZEV goals. There is growing international consensus that only hydrogen produced from renewable sources will be sustainable in the long run.[235] A fossil-based application does not help the state achieve its overall goals. If the hydrogen is renewably produced, however, those goals are readily achievable. One potential source is hydrogen from biomass and municipal solid waste. A recent Lawrence Livermore National Laboratory study finds that using forest biomass, agriculture biomass, or municipal solid waste as a source of hydrogen allows for negative emissions, as carbon dioxide (CO_2) from the feedstock to hydrogen conversion can be easily captured. The report emphasizes that hydrogen production has the greatest potential for negative emissions compared to producing other fuels. This finding is because hydrogen gas is completely separated from the carbon in the feedstock, maximizing CO_2 capture at the point of production.[236]

---

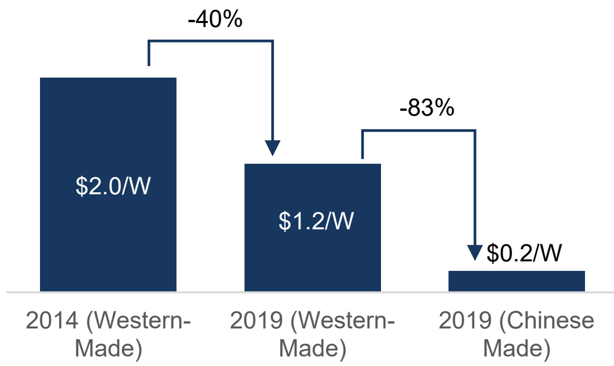
235 As articulated in Germany's *National Hydrogen Strategy*, p. 2. https://www.bmbf.de/files/bmwi_Nationale%20Wasserstoffstrategie_Eng_s01.pdf.

236 Baker, Sarah E., Joshuah K. Stolaroff, George Peridas, Simon H. Pang, Hannah M. Goldstein, Felicia R. Lucci, Wenqin Li, Eric W. Slessarev, Jennifer Pett-Ridge, Frederick J. Ryerson, Jeff L. Wagoner, Whitney Kirkendall, Roger D. Aines, Daniel L. Sanchez, Bodie Cabiyo, Joffre Baker, Sean McCoy, Sam Uden, Ron Runnebaum, Jennifer Wilcox, Peter C. Psarras, Hélène Pilorgé, Noah McQueen, Daniel Maynard, Colin McCormick. *Getting to Neutral:*

Another process for hydrogen production is, from a chemical point of view, the opposite of how a fuel cell operates. By supplying renewable electricity to an electrolyzer, facilities can create renewable hydrogen from water. Further, hydrogen created using renewable-based electricity such as solar and wind can reduce the need to curtail renewable generation. With this relatively simple renewable strategy, the main issue is ensuring that costs are competitive with fossil fuels.

On July 2, 2020, the CEC hosted an IEPR workshop on hydrogen and FCEV market status. The workshop began with a presentation from BNEF highlighting large cost reductions for the supply of renewable hydrogen. For example, alkaline electrolyzer costs in western countries have declined 40 percent in the last five years. Current electrolyzers available in China have been as low as 83 percent lower than current western alkaline electrolyzers. (See Figure 30.[237])

Figure 31: Alkaline Electrolyzer Capital Costs



Source: BNEF

Despite decreased capital costs for electrolyzers, overall levelized costs of renewable hydrogen remain high, but BNEF expects them to be competitive with fossil hydrogen within 10 to 20 years. The cost reductions for hydrogen involve reductions in the capital costs of the electrolyzers, lower-cost renewable electricity inputs, and improvements in the treatment, storage, and delivery of the hydrogen.

Options for Negative Carbon Emissions in California. January 2020. Lawrence Livermore National Laboratory. LLNL-TR-796100. https://www-gs.llnl.gov/content/assets/docs/energy/Getting_to_Neutral.pdf.

237 Xiaoting Wang presentation. "Hydrogen Economy Outlook." Bloomberg New Energy Finance. Presentation at the July 2, 2020, IEPR workshop on Hydrogen and Fuel Cell Electric Vehicle Market Status. https://efiling.energy.ca.gov/getdocument.aspx?tn=233719.

Adding load onto the electricity grid can make the case for electrolyzers more economically challenging as well as difficult for grid operations, so options that minimize baseload electricity use are preferable. One is using the curtailed electricity associated with high solar generation in California during the day. Given that this energy is wasted, using otherwise curtailed electricity may be a low-cost benefit to the grid. However, electrolyzers can operate with a high usage factor throughout the day, so using only curtailed electricity would underuse the capacity, resulting in suboptimal capital expenditures. Thus, a PEV "charging happy hour" approach discussed in Chapter 4 may be a better use of curtailment, as PEVs do not typically charge with DCFC for very long and can be optimally timed to match curtailment without underusage. Another option is potentially to have electrolyzers operate with offshore wind operations, which are expected to have more regular electricity output than solar. One challenge for this option is that the state views potential offshore wind as a source for baseload power, so additional load using this resource may compete with grid needs.

Statewide and Global Actions on Refueling and Vehicles May Improve the TCO Case

The CEC's Clean Transportation Program is providing grant funding to develop hydrogen refueling stations until at least 100 are publicly available, as required by Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013). Executive Order B-48-18 added the goal of 200 stations by 2025, such that FCEVs will have the fueling infrastructure needed to contribute substantial numbers toward the goal of achieving 5 million ZEVs by 2030. As of December 2020, 45 stations are in operation, and the proposed awards under GFO-19-602 are expected to add 111 stations, for a total of 179 stations that are either open or have funding allocated. These developments have contributed to cost reductions for station deployment. Per FCEV enabled with fueling infrastructure, the station cost has decreased by 60 percent from 2016 to 2020.[238] With some station developers indicating the possibility of building stations without grant funding, California may be able to close the gap of 21 stations to reach the 200 stations goal by 2025 (Table 4).

---

238 Baronas, Jean, Gerhard Achtelik, et al. 2020. *Joint Agency Staff Report on Assembly Bill 8: 2020 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California*. California Energy Commission and California Air Resources Board. Publication Number: CEC-600-2020-008. https://ww2.energy.ca.gov/2020publications/CEC-600-2020-008/CEC-600-2020-008.pdf.

Table 4: Progress Toward 200 Hydrogen Stations by 2025 as of December 2020

Category	Hydrogen Refueling Stations
Number of Existing Open Retail	45
Number for Which Funding has Been Allocated	111
Expected From Private Funding	23
Total	**179**
2025 Goal (Executive Order B-48-18)	200
Gap From Goal	**21**

Source: CEC

While Clean Transportation Program investments in publicly available hydrogen refueling stations have thus far primarily aimed to serve the deployment of passenger FCEVs, GFO-19-602 allowed projects to include fueling for commercial fuel cell vehicles and buses as long as they did not diminish the light-duty customer experience. This approach was taken to potentially aid in transitioning California's commercial vehicle and bus fleets to a zero-emission alternative while strengthening the business case for light-duty hydrogen fueling through increased station throughput and opportunities to build multiuse stations with common designs and fuel supply. This strategy also aimed to reduce the costs of hydrogen production and distribution by encouraging greater use of hydrogen-powered commercial fleet vehicles and buses.

Globally, several countries are working to build stations. Table 5 shows the quantity of hydrogen refueling stations as reported on the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) website (except where noted otherwise). These numbers should be considered as "ballpark" in that countries continue to make progress in opening stations, and it is difficult to compile data uniformly (for example, open stations vs. in-development stations).

Table 5: Reported National Quantities of Hydrogen Refueling Stations as of October 2020

Country	Hydrogen Refueling Stations
Japan	143
Germany	76
France	37
China	35
South Korea	34
United Kingdom	13
Canada	9

Country	Hydrogen Refueling Stations
Norway	6
Austria	5
Netherlands	5
Italy	4
Brazil	2
Czech Republic[239]	2
India	2

Source: CEC and IPHE

A common refrain of stakeholders is that the certainty of the CEC's annual Clean Transportation Program funding for hydrogen refueling stations has been key to inducing private sector investment in hydrogen production and the FCEV market. During the CEC's July 2, 2020, workshop on hydrogen and FCEV market status, FirstElement Fuel reported that it has leveraged more than $90 million in private investments and that private investors are working to achieve the scale necessary to support a self-sufficient market.[240]

The global market is changing as well, which will contribute to the fuel production and cell stack volumes that will in turn bring down costs. Several countries — most notably Japan, South Korea, China, Germany, and the Netherlands — have recently established station deployment and FCEV stock goals. Each country has hundreds of planned station deployments through 2030, combined with aggressive vehicle targets in the hundreds of thousands, both of which will contribute to cost reductions. As shown in the previous table, Japan and Germany have been leaders in station development to date. Germany is working to complete 100 public stations serving primarily passenger cars and light commercial vehicles (vans). Starting in 2021, additional stations will be built where there is demand for commercial vehicles and

239 FuelCellsWorks. "ORLEN Invests in the First Hydrogen Stations in the Czech Republic." FuelCellsWorks web page. October 10, 2020. https://fuelcellsworks.com/news/orlen-invests-in-the-first-hydrogen-stations-in-the-czech-republic/.

240 Stephens, Shane. "CEC's Hydrogen Refueling Infrastructure Program Provides Tremendous Value in Delivering Results and Lessons Learned." FirstElement Fuels. Presentation at the July 2, 2020, IEPR workshop on Hydrogen and Fuel Cell Electric Vehicle Market Status. https://efiling.energy.ca.gov/getdocument.aspx?tn=233698.

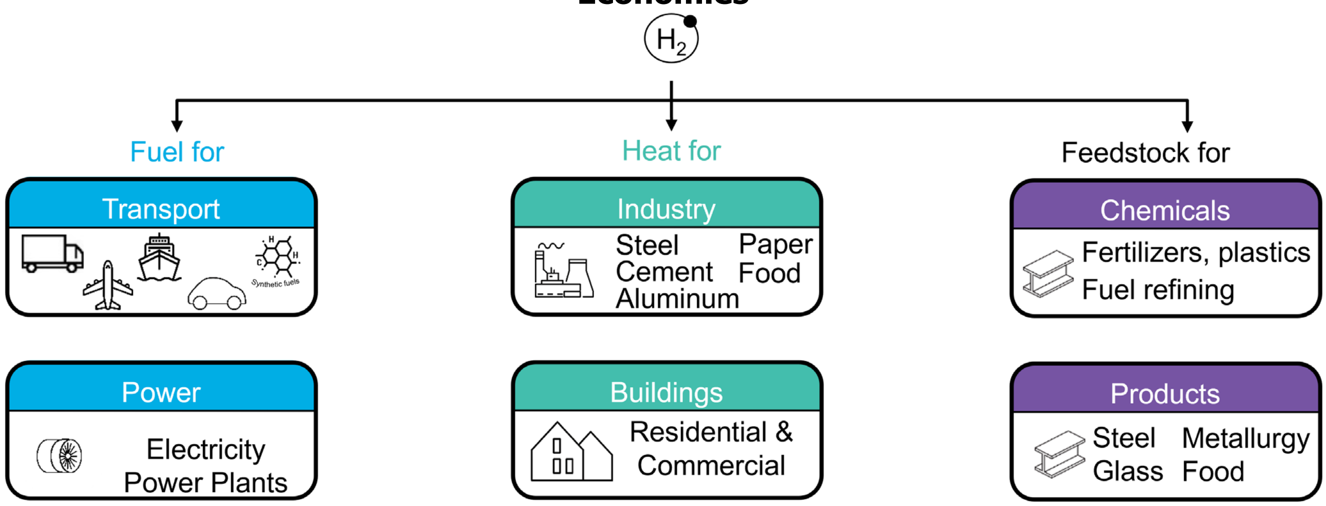
where a station makes sense for a growing network of passenger cars.[241] By 2030, China aims to have 1,000 stations, Japan aims for 900, and South Korea aims for 500.

Opportunities for Hydrogen Go Beyond Fueling Vehicles

Several countries also see a market opportunity to produce and supply hydrogen for end uses including transportation and industrial processes that are difficult to decarbonize. In 2020, several countries announced plans for large investments in hydrogen to support a variety of sectors.

Like the expanded opportunities created by PEVs and vehicle-grid integration across electricity services, hydrogen can connect different systems to reduce greenhouse gas emissions in multiple sectors, especially sectors that are difficult to electrify, such as industry. Hydrogen can play a role in decarbonizing industry and the pipeline gas system and provide seasonal energy storage. Figure 32 illustrates potential roles that hydrogen and renewable hydrogen could play in advanced economies.

Figure 32: Potential Uses of Hydrogen and Renewable Hydrogen in Advanced Economies



Credit: BNEF

Renewable hydrogen can be used to replace fossil gas and coal in many industrial settings where a fuel source is needed to fire boilers or heat materials in industrial processes, such as cement manufacturing or aluminum recycling. Renewable hydrogen can be used to fire combined-cycle gas plants and single-turbine peaking plants for power generation. It can also

241 H2 Mobility web page. https://h2.live/en/h2mobility.

be used as a feedstock in petroleum refining, ammonia and methanol production, and steel manufacturing. These industries will be expensive and technically challenging to decarbonize without renewable hydrogen.[242]

A particularly important hydrogen application could be as a long-term or seasonal storage medium for solar, wind, and other renewable energy resources. With appropriate cost reductions of electrolyzers and renewable electricity to power them, hydrogen can be stored at scale and used for the various applications discussed above.[243] Salt caverns, depleted gas fields, and rock caverns are being investigated as large-scale storage mediums for renewable hydrogen.[244]

Two demonstration projects in California illustrate how hydrogen can be used in integrated grid or fueling projects. The University of California, Irvine, Advanced Power and Energy Program is integrating an electrolyzer and fuel cell into its long-term Smart Grid Demonstration Project to evaluate how well a renewable hydrogen system can perform in capturing and using renewable electricity to stabilize grid functions, capture curtailed renewable electricity, and produce green hydrogen for vehicle fueling.[245]

At the Ports of Los Angeles and Long Beach, Toyota is working with Shell and Kenworth to integrate a 2.3-megawatt fuel cell into a large, $80 million demonstration project for hydrogen-powered trucks and fueling stations. The project would demonstrate a hydrogen-centered "ship-to-store" freight-handling process that includes 10 heavy-duty fuel cell trucks, two hydrogen refueling stations designed for trucks, and hydrogen-fueled drayage and materials handling equipment.[246]

---

242 Hydrogen Council. *Pathways to Hydrogen Competitiveness: A Cost Perspective*. January 20, 2020. https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf.

243 Ibid.

244 Ibid.

245 Razeghi, Ghazal, Jennifer Lee, and Scott Samuelsen. Advanced Power and Energy Program. 2020. *Station Automation and Optimization of Distribution Circuit Operations*. California Energy Commission. Publication Number: CEC-500-2020-022.

246 Port of Los Angeles press release. "Port of Los Angeles Preliminary Awarded $41 Million From California Air Resources Board to Launch Zero Emissions Hydrogen-Fuel-Cell-Electric Freight Project." September 14, 2018. https://www.portoflosangeles.org/references/news_091418_carb_toyota.

Electrolyzed Fueling on Sunshine with SunLine

With more than 1,100 square miles of service area, complicated terrain, and the desert heat, SunLine Transit Agency's buses deal with demanding driving conditions. Many service routes have a daily service distance of 300 miles. With some concerns for the ability for many of these routes to operate with BEBs, the agency's primary zero-emissions focus is on fuel cell electric buses (FCEBs). However, the agency's operations area is far from the standard hydrogen distribution network. This delivery challenge makes onsite hydrogen production a key strategy.

Image Credit: SunLine Transit Agency

SunLine operates an electrolyzer capable of generating up to 900 kg per day of hydrogen, 60 percent powered by solar photovoltaics. Because this generation is more than the current FCEB demand, SunLine plans to expand its refueling station to offer public access for passenger FCEVs. The agency can generate hydrogen using grid power at about $8 per kg, compared to $30 per kilogram to purchase it from a nearby region. Future expansions will involve additional electrolyzers as the FCEB fleet expands, as well as a microgrid to enhance resiliency for the agency.

Recommendations

- **The state should continue investments in fuel cell electric vehicles (FCEVs), infrastructure, and green hydrogen production, with increasing attention to the medium-duty (MD), heavy-duty (HD), and off-road sectors.** The state should continue to support FCEV commercialization and hydrogen infrastructure buildout to ensure that there are ZEV options to meet different user needs. The MD, HD, and off-road sectors should be priority focus areas, given the urgent need to replace diesel with zero emission and the advantages that FCEVs may offer over battery-electric in these applications. The state should also continue to invest in the development of fueling infrastructure for light-duty vehicles in alignment with market growth.
- **The state should collaborate with other countries to accelerate investments and share lessons learned in FCEVs and hydrogen, build the global market, and drive down costs.** This partnership includes deeper collaboration with countries that have committed to hydrogen FCEVs, such as China, Japan, South Korea, and Germany, to better understand market opportunities for light-duty, MD, and HD vehicles, as well as promising opportunities for electrolyzer cost reductions and renewable hydrogen production. This collaboration also includes activating other states and a broader array of countries to support FCEVs, green hydrogen production, and hydrogen infrastructure build-out.

- **The California Energy Commission (CEC) should conduct further research into best practices for producing hydrogen in ways that reduce greenhouse gas emissions and integrate well with the operation of California's electricity grid.** The production of hydrogen is energy-intensive, and the usefulness of hydrogen in helping the state meet its energy and climate goals will depend on how it is produced and how its use integrates with the state's entire energy ecosystem, including transportation. The CEC's Electric Program Investment Charge should continue research to advance hydrogen development in support of California's energy and climate goals.
- **The state should explore broad opportunities for hydrogen. Using hydrogen effectively in different applications will be key to California achieving its climate change goals.** The use of hydrogen in seasonal energy storage systems can outweigh the cost of production. Further, the use in connecting energy systems in various sectors is another opportunity for hydrogen, including industry. Feedstocks for hydrogen production may also integrate with carbon sequestration technologies. Finally, hydrogen can play a role in the state's pipeline gas system. Integrating these broader plans for hydrogen with the plans for the use of hydrogen in transportation can advance the state's efforts to decarbonize the transportation sector.

CHAPTER 6
Zero-Emission Vehicles (ZEVs) Are a Source of Energy Resilience, but Careful Planning is Needed

Energy Resiliency is an Important Consideration

The effects of climate change on California include more extreme and severe drought, heat waves, and wildfires, with far-reaching impacts on health and human safety as well as the economy. To reduce wildfire risk from power lines during dry, windy conditions, unprecedented numbers of Californians were subject to public safety power shutoffs (PSPS) in 2019 that resulted in outages that lasted hours for some people and several days for others. Collectively, millions of Californians lost power during the 2019 fire season because of PSPS events.[247] In September 2020, hundreds of thousands more lost power in another PSPS event, albeit for less time than in 2019.[248] Further, in August 2020, the state grid operator initiated rolling outages to manage high electricity demand during an extreme heat wave that strained electricity supply across the West. The California Independent System Operator, California Public Utilities Commission, and California Energy Commission (CEC) are taking concerted action to strengthen the reliability of the grid given these events.

One solution consumers are increasingly turning to is fossil-powered backup generation, typically fueled with diesel or propane. Such backup power produces air pollution and greenhouse gases and is inconsistent with the state's climate and air quality goals. Demand for fossil-powered backup generators increased as high as 1,400 percent for some installers after the June 2019 PSPS events.[249] Trends in increasing backup power demand are also reflected in higher share prices for companies that manufacture backup generators, with the generator company Generac seeing a 70 percent year-to-date increase in share price as of September

247 For a listing of October 2019 PSPS events, see CPUC's October 2019 PSPS Events web page. https://www.cpuc.ca.gov/Oct2019PSPS/.

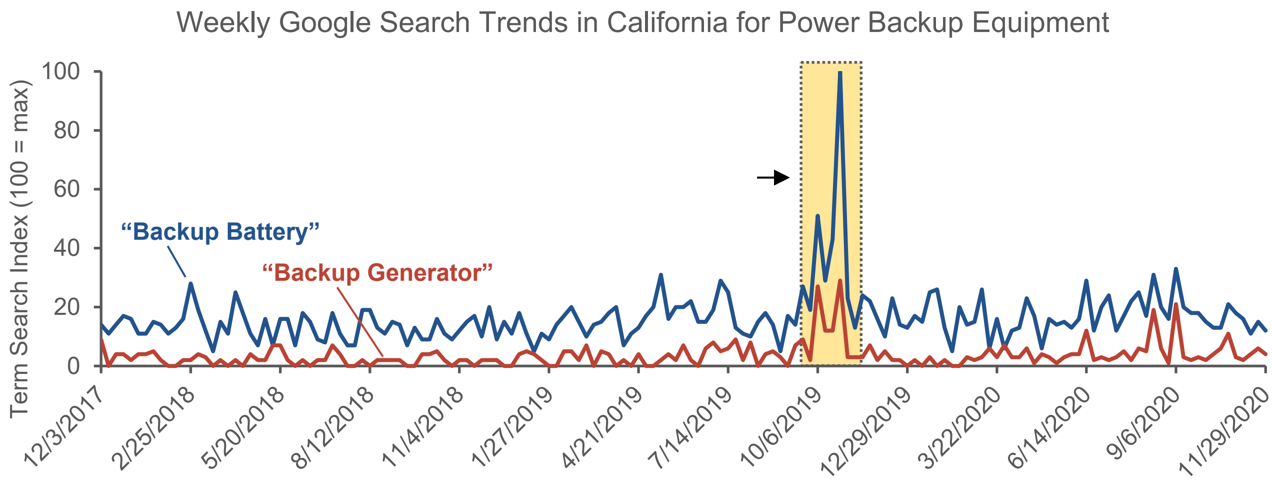
248 Graff, Amy. "Maps: Here's Where PG&E Has Shut Off Power in California." September 8, 2020. SFGATE web page. https://www.sfgate.com/weather/article/map-California-PG-E-power-shut-off-psps-15549633.php.

249 Shao, Elena. "Demand for Generators Lights Up as PG&E Power Shutoffs Loom." *San Francisco Chronicle*. June 27, 2019. https://www.sfchronicle.com/business/article/Demand-for-generators-lights-up-as-PG-E-power-14054242.php.

2020.[250] A rapid spike in search engine terms for "backup generator" in California occurred during the major October 2019 PSPS events, with a similar spike in August and September 2020 during several rolling blackouts, wildfire events, as well as smaller PSPS events. Interestingly, the term "backup battery" had a similar spike in search engine interest, averaging three times more search activity than "backup generator." (See Figure 33.[251])

As discussed below, ZEVs can function as a backup generator and provide energy resiliency during a planned or unplanned power shutoff. It is important to bear in mind, however, that ZEVs, backup generators, and microgrids are not a substitute for the investments needed in California's energy grid to address energy reliability more broadly in California.

Figure 33: Timely Interest in Backup Power Reflected in Google Searches



Data Source: Google Trends

250 Bromels, John. "Why Shares of Generac Holdings Jumped More Than 20 Percent in August." *The Motley Fool*. September 9, 2020. https://www.fool.com/investing/2020/09/09/why-shares-of-generac-holdings-jumped-more-than-20/.

251 Data for terms "backup battery" and "backup generator" from Google Trends web page. https://trends.google.com/trends/?geo=US.

ZEVs are a Source of Energy Resilience

During the CEC's July 15, 2020, IEPR workshop on ZEV resilience and the three revolutions in transportation, panelists discussed the opportunities for ZEVs to provide energy resiliency.[252] Batteries and fuel cells produce electric current to power the electric motors that drive the vehicle.[253] Rather than providing electric current to the motors that drive the wheels, this power flow can be directed through the proper equipment (external electric vehicle service equipment, or EVSE) to serve as a power source for devices, or more broadly, for a home or building. With plug-in electric vehicle (PEV) battery energy containing dozens of kilowatt-hours (kWh) and a fuel cell electric vehicle (FCEV) containing similar electrical capacity in the associated hydrogen tank, a ZEV has the equivalent of up to several days' worth of energy use for a typical home.

Given the high levels of energy in ZEVs, there is an opportunity for them to serve as a source of energy resiliency. This is especially due to the inherent mobility of these vehicles and low driving rate. The average passenger vehicle in the United States is parked at home more than 80 percent of the time, and more than 50 percent of vehicles are parked at home even during weekday work hours.[254] As discussed in Chapter 4, grid-integrated PEVs may be understood as distributed energy resources (DERs), not merely sources of grid load. PEVs and FCEVs are effectively DERs, although FCEVs are only a source of electric power, while PEVs can manage charging and serve as a power source.

With larger batteries and larger hydrogen fuel tanks, medium-duty and heavy-duty ZEVs may also be a source of energy resiliency. However, these vehicles have different duty cycles and are often used at a higher rate than passenger vehicles. Opportunities for them still exist, especially for some duty cycles. The CEC is supporting several vehicle-to-grid (V2G) pilot projects to explore the possible timing, costs, and benefits for both daily grid support and electric islanding (providing power for a facility when the grid is down). All buses in the CEC's School Bus Replacement Program have V2G capability and districts may be able to use this feature in the future. The Twin Rivers School District's pilot VGI program in Sacramento

252 July 15, 2020, IEPR workshop on ZEV Resilience and Three Revolutions in Transportation web page. https://www.energy.ca.gov/event/workshop/2020-07/session-1-energy-resilience-and-zevs-workshop-zero-emission-vehicle.

253 Fuel cells power an intermediary battery in the vehicle that can provide power, but the ultimate power source in the vehicle is the fuel cell.

254 National Academy of Sciences 2015. *Overcoming Barriers to Deployment of Plug-in Electric Vehicles*. p. 84. https://www.nap.edu/catalog/21725/overcoming-barriers-to-deployment-of-plug-in-electric-vehicles.

County is evaluating prospects for using buses as mobile power sources for emergency centers or maintaining building functions during power losses.[255]

As more pilot projects show progress, additional standardization and V2G/V2B incentives will be necessary to ensure this becomes an opportunity for Californians. While safety and reliability are priorities for providing energy, panelists mentioned redundant certifications as a key issue. For instance, standard interconnection certification on vehicles may not be necessary if the electric vehicle supply equipment (EVSE) is certified to not operate bidirectionally unless the address where the EVSE is installed is allowed to host a DER. In this circumstance, the EVSE serves as the point of safety, and vehicle original equipment manufacturers (OEMs) can maintain their standard certifications.

The State Needs Resilient Charging Options for PEVs

Power shutoffs can affect the ability of all vehicles to have reliable access to energy. This is true for ZEVs, but also for petroleum vehicles, as gas stations require electricity to operate fuel pumps.[256] ZEVs that could sustain house energy functions for longer than a few days would eventually need to be refueled, so the enhanced resiliency for homes during power shutoffs requires a resilient way to refuel ZEVs for this function and travel. Furthermore, residents in high-fire-risk areas may also be concerned about relying on their vehicles as a source of home energy, as it would reduce the battery charge and range. Residents may also have concerns about the ability to charge along routes to evacuate a given region or at temporary community shelters.

For many PEV drivers, home-mounted solar panels can be a source of power, and rooftop solar will continue to be integrated into new homes. Specialized EVSE is necessary, which allows the home to "island" itself, or disconnect, from the grid. This option can allow a resident to be somewhat or completely self-sufficient under the right circumstances during a sustained power outage.

There are several technologies and charging options that can allow enhanced charging resiliency, especially for light-duty vehicles. Besides home solar photovoltaic systems, several

---

255 Tim Shannon comments. July 15, 2020, IEPR workshop on ZEV Resilience and Three Revolutions in Transportation transcript.
https://efiling.energy.ca.gov/GetDocument.aspx?tn=234949&DocumentContentId=67818.

256 Woodyard, Cindy and Christopher Damien. 2019. "No Traffic Signals, No Gas Stations: How Motorists are Coping With California's Power Outages." *USA Today*. October 10, 2019.
https://www.usatoday.com/story/news/nation/2019/10/10/california-power-outage-how-motorists-and-commuters-coped/3936787002/.

charging companies have chargers that offer unique resiliency advantages. During the July 15, 2020, IEPR workshop on ZEV resilience, two companies — BEAM[257] and FreeWire — explained the options that they offer to provide energy to battery-electric vehicles (BEVs) without the grid.[258]

BEAM offers the EV ARC™, a completely freestanding solar and battery charger designed to fit within a standard parking space. The elevated solar panels provide 4.3 kilowatts (kW) of power, and the battery system can store up to 40 kWh, allowing the station to provide Level 2 charging with no grid connection. In addition to being resilient, the lack of grid interconnection offers other benefits, such avoided wiring, trenching, and other needs that add expense and time to installation. These benefits can speed up installation time and eliminate utility-related energy costs for charging.

Figure 34: BEAM's Grid Independent PEV Charging Station Can Be Moved to Different Locations

Credit: BEAM

The company FreeWire offers a different charging and energy resiliency solution. The company offers two battery-based chargers that are designed to draw lower amounts of

---

257 BEAM was known as Envision Solar during the July 15, 2020, IEPR workshop. The company changed its name in September 2020.

258 July 15, 2020, IEPR workshop on ZEV Resilience and Three Revolutions in Transportation transcript. https://efiling.energy.ca.gov/getdocument.aspx?tn=234949.

power from the grid and store them for faster charging. The company's Boost charger can output up to 120 kW at speedy DCFC levels after charging the internal battery with a typical L2 connection to the grid. The internal battery stores 160 kWh, allowing the charger to charge several vehicles even with power loss. The L2 connection to the grid reduces the make-ready costs and allows the charger to smartly recharge and minimize electricity costs.

BEAM and FreeWire are also capable of supplying backup power to buildings when properly wired. Battery storage for charging and building energy resilience may be an attractive option for residents in MUDs, as already evidenced in the case of Powertree in Chapter 4. With the right planning and design, developers can integrate charging services at MUDs with backup storage and photovoltaic (PV) arrays to supply emergency power functions to residents. This broader energy resiliency approach could be a useful combination for enhancing equity for residents of MUDs. These types of broad resiliency options have also caught the eye of charging companies. Electrify America announced in 2019 that it would install Tesla battery packs to 100 of its DCFC charging stations. While the goal appears to be managing demand charges,[259] similar resiliency options are available with this design.[260]

Other technology options exist at a larger scale. Located in the Humboldt Bay area, the Blue Lake Rancheria microgrid was also a highlight of the July 15 IEPR workshop. During the PSPS events of 2019, the microgrid was able to island, or isolate itself from the rest of the grid, and the associated PV and battery system allowed residents to maintain power. (For more information, see *2020 IEPR Update, Volume II: The Role of Microgrids in California's Clean and Resilient Energy Future.*) The EV charging stations at Blue Lake Rancheria were also capable of providing charging services to EV drivers, some of whom were able to use their car batteries to power refrigerators and freezers.[261]

Transit agencies are especially concerned about battery-electric bus resiliency, as services must remain consistent, and transit agencies are sometimes tasked with responsibilities for evacuation procedures or other emergency response functions in nearby regions. During the July 15 IEPR workshop, panelists discussed these sorts of energy resiliency needs for transit

---

259 "Demand charges" are electric bill charges that are based on the peak electricity usage of a customer.

260 Electrify America press release. "Electrify America Adds Tesla Battery Storage to More Than 100 New Charging Stations." February 4, 2020. https://media.electrifyamerica.com/en-us/releases/48.

261 Ganion, Jana. "Energy Resilience and ZEVs." Presentation at the July 15, 2020, IEPR workshop on ZEV Resilience and Three Revolutions in Transportation. https://efiling.energy.ca.gov/getdocument.aspx?tn=233849.

options as part of "core planning" for transit agencies, especially as fleet electrification grows.[262]

Transit agencies are looking to other options for ensuring resiliency. As transit fleets move to 100 percent electric buses (FCEV or battery-electric), additional options should be broadly considered, including microgrid solutions and onsite storage. AC Transit in Alameda County is also exploring the possibility of using FCEV buses to charge BEV buses, along with a broad array of other resiliency ideas.[263] The California Transit Association also sees resiliency as a key challenge in moving forward and recommends additional support for pilot projects to ensure that the transition to 100 percent ZEV fleets is done without service interruptions for passengers who rely on transit. Developing a long-term resiliency plan is key for these agencies.

One additional contribution to energy resiliency for ZEVs is battery functionality beyond the useful driving life. While battery prices are continuing to decline, used batteries will allow additional opportunities for even lower cost battery use. These "second-life" batteries may be capable of providing an additional 7 to 10 years of service at roughly 75 percent of the original storage and power capacity.[264] CEC analysis from 2017 estimated that by 2030, up to 13,000 megawatt-hours of storage capacity could be made available through second-life battery use of expected vehicle retirements.[265] Several companies intend to take advantage of this potential market, such as ReJoule Energy, RePurpose Energy, and Smartville.[266] CEC's EPIC has provided funding for these California startups to demonstrate different aspects of

262 Callaway, Joe. "Zero-Emission Bus Program." Presentation at the July 15, 2020, IEPR workshop on ZEV Resilience and Three Revolutions in Transportation. https://efiling.energy.ca.gov/getdocument.aspx?tn=233850.

263 Ibid.

264 California Environmental Protection Agency Lithium-Ion Car Battery Recycling Advisory Group web page. https://calepa.ca.gov/climate/lithium-ion-car-battery-recycling-advisory-group/lithium-ion-car-battery-recycling-advisory-group-meeting-materials-11-4-19-background/.

265 Sevier, Isaac, Ignacio Mendez, Eesha Khare, and Ken Rider. 2017. *Preliminary Analysis of Benefits From 5 Million Battery Electric Passenger Vehicles in California*. California Energy Commission. Publication Number: CEC-999-2017-008. https://ww2.energy.ca.gov/2017publications/CEC-999-2017-008/CEC-999-2017-008.pdf.

266 Repurpose Energy focuses on battery systems that incorporate second-life batteries. ReJoule offers improved battery health monitoring in a PEV prior to battery removal. Smartville is developing a system to independently control and monitor the health of batteries using different chemistries.

developing a streamlined second-life battery pathway for the state.[267] While there is potential for this sector, panelists described second-life batteries as a difficult problem, and design for disassembly and repurposing would likely be necessary given the complex differences among different manufacturers' approaches to battery design.

Recommendations

- **The California Energy Commission (CEC), California Public Utilities Commission (CPUC), and California Independent System Operator should continue to work together to ensure that zero-emission vehicles (ZEVs) support energy resiliency in California, including vehicle-grid integration.** Further work is needed to ensure that regulatory requirements, market rules, and charging technology are designed to enable ZEVs to increase energy resiliency (such as drawing energy from a vehicle battery to a home during a power outage). Also, ZEVs need to be able to participate in California's energy system as a distributed energy resource that can enhance grid operations (such as minor changes to vehicle charging in alignment with the needs of the grid and the vehicle owner).
- **The CEC should work with state and local planners to identify strategic ZEV charging and refueling opportunities that are resilient to power outages and natural disasters.** More planning is needed to ensure that charging and refueling are available during emergencies for all drivers, especially those in disadvantaged and low-income communities. Opportunities include backup power and charging integration for resiliency in multiunit dwellings.
- **The CEC should invest in pilot projects for ZEV resiliency for medium- and heavy-duty ZEVs, with a focus on transit.** This support is particularly needed for transit applications to ensure that Californians who rely on public transit will not be subject to service interruptions during the transition to 100 percent zero-emission fleets.
- **The CEC should continue to fund and explore opportunities for second-life batteries and battery recycling.** The ability to repurpose ZEV batteries after the initial use increases the lifetime value of the vehicle, potentially without upfront cost increases, while improving the state's ability to integrate increasing levels of renewable electricity generation.

267 Pyper, Julia. 2020. "Second Life: Carmakers and Storage Startups Get Serious About Reusing Batteries." Greentech Media, June 30, 2020. https://www.greentechmedia.com/articles/read/car-makers-and-startups-get-serious-about-reusing-batteries.

CHAPTER 7
Low-Carbon Fuels and Near-Zero-Emission Vehicles Will Be Useful in Sectors That Are Difficult to Electrify

The Advanced Clean Trucks Rule and Executive Order N-79-20 have established a clear goal of achieving 100 percent electrification for all on-road and many off-road vehicles where feasible. This transition cannot occur immediately, and some sectors will be more difficult to electrify than others. During this ZEV ramp-up, low-carbon liquid fuels and other low-emission fuels may also work in lieu of petroleum. For example, sustainable aviation fuel (SAF), renewable diesel, and renewable gas have lower associated greenhouse gas (GHG) emissions than fossil fuels, and because they are chemically identical to the fossil-based counterparts, they may also serve as a "drop-in" fuel that can be replaced with no changes to engines. As part of a shorter-term strategy, these options may be useful. Given some of the deeper challenges of electrification with some sectors, such as aviation, liquid low-carbon fuels may also be necessary in the long term.

Low-Carbon Liquid Fuels

Two common low-carbon replacements for diesel include biodiesel and renewable diesel. The two terms sound very similar but involve two separate processes. Both use similar renewable feedstocks, but renewable diesel is processed with hydrogen to produce fuels nearly identical to petroleum diesel. Biodiesel can be blended with diesel up to 20 percent but is not similar enough to petroleum diesel for a complete drop-in replacement. Biodiesel and renewable diesel can be blended together in various combinations as well.

Renewable diesel offers the potential of modest criteria pollutant reductions (including 30 percent of PM and 10 percent of oxides of nitrogen [NO_x]) compared to conventional diesel.[268] Biodiesel has the potential to increase NO_x, but these impacts can be addressed under the Alternative Diesel Fuel regulation.[269] Depending on the feedstocks and processes used to produce these liquid fuels, GHG emissions can vary significantly. The biodiesel and renewable

268 CARB. *Staff Report – Multimedia Evaluation of Renewable Diesel*. May 2015. https://ww2.arb.ca.gov/sites/default/files/2018-08/Renewable_Diesel_Multimedia_Evaluation_5-21-15.pdf.

269 Ibid.

diesel fuel credited under the Low Carbon Fuel Standard typically average between two-thirds and three-quarters less GHG emissions relative to conventional diesel.[270]

In 2019, California consumed around 3.8 billion gallons of diesel fuel. About 830 million gallons, 22 percent, were from low-carbon diesel, 618 million gallons of renewable diesel; and 212 million gallons of biodiesel.[271] More than 80 percent of this total is imported from other states and countries, spurred by the value of Low Carbon Fuel Standard (LCFS) credits. A continual growth trend can be expected with possible limitations due to uncertainties with waste-based low-carbon feedstocks.

World Energy has successfully refurbished the Alon petroleum refinery in Paramount (Los Angeles County) to produce renewable diesel and renewable jet fuel, supported in part by the California Energy Commission's (CEC's) Clean Transportation Program.[272] It recently initiated a tenfold plant expansion to increase production.[273] Phillips 66 has announced plans to close its petroleum refinery in Santa Maria and convert its Rodeo petroleum refinery to produce renewable diesel.[274] In addition, Marathon Petroleum idled its Martinez petroleum refinery and is evaluating a shift to produce renewable diesel within one to two years.[275] Global Clean Energy signed an agreement to produce renewable diesel at a converted petroleum refinery in

270 CARB. Low Carbon Fuel Standard Annual and Quarterly Reporting Tool. https://ww3.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm.

271 Ibid.

272 The original funding was for Alt Air, which was eventually acquired by World Energy in 2018. For more information on the CEC's support of this conversion, see https://www.energy.ca.gov/showcase/driving-cleaner-transportation/altair-fuels-renewable-diesel-fuel-project.

273 Gebolys, Gene. "World Energy Conversion Project." Presentation at the July 29, 2020, IEPR workshop on Near-Zero Emission Vehicles and Low-Carbon Fuels. https://efiling.energy.ca.gov/getdocument.aspx?tn=234041.

274 Phillips 66 press release. "Phillips 66 Plans to Transform San Francisco Refinery into World's Largest Renewable Fuels Plant." August 12, 2020. https://investor.phillips66.com/financial-information/news-releases/news-release-details/2020/Phillips-66-Plans-to-Transform-San-Francisco-Refinery-into-Worlds-Largest-Renewable-Fuels-Plant/default.aspx. (As well as CEC staff interview with Phillips 66, August 24, 2020.)

275 Bomgardner, Melody. "California Refiners Shift Production to Renewable Diesel." *Chemical and Engineering News*. August 19, 2020. https://cen.acs.org/energy/biofuels/California-refiners-shift-production-renewable/98/i32.

Bakersfield to deliver fuel to ExxonMobil.[276] The combined conversions and expansions will increase renewable diesel production in California by 1.2 billion gallons per year within the next four years.

California petroleum jet fuel consumption has typically been equal or greater than on-road diesel fuel consumption since 1960.[277] The state has no regulatory ability with GHG emissions from aviation but has recently allowed SAF to qualify for LCFS credits. As a result, airlines have begun using very small amounts of SAF blended with petroleum jet fuel. During the July 29, 2020, IEPR workshop on low-carbon fuels, United Airlines cited consumer pressure and LCFS as major drivers of its recent expansion of SAF use.[278]

Low-carbon liquid fuels can also play a role in reducing the climate impacts of rail travel. The Capitol Corridor Joint Powers Authority is overseeing a renewable diesel pilot program to test the integration of renewable diesel into routes between the Bay Area and Sacramento. Life-cycle carbon emissions from this project are expected to be about one-third that of conventional diesel,[279] with final test results expected in Spring 2021.[280]

Globally, the International Civil Aviation Organization is developing more stringent SAF standards. Currently, 3 of 12 sustainability criteria have been approved, with 9 under consideration. These criteria include several life-cycle environmental, economic, and social impacts. Presenting at the July 29, 2020, IEPR workshop, the Environmental Defense Fund (EDF) pointed out the opportunity for California's LCFS system to build on the work done on

276 ExxonMobil press release. "Exxon Mobil and Global Clean Holdings Sign Agreement for Renewable Diesel." August 11, 2020. https://corporate.exxonmobil.com/News/Newsroom/News-releases/2020/0811_ExxonMobil-and-Global-Clean-Energy-Holdings-sign-agreement-for-renewable-diesel.

277 U.S. Energy Information Administration. State Energy Consumption estimates, 1960–2018. p. 77. (Diesel fuel is categorized as a Distillate Fuel Oil in the analysis presented.) https://www.eia.gov/state/seds/sep_use/notes/use_print.pdf.

278 Robinson, Aaron (with United Airlines). July 29, 2020, IEPR workshop on Near-Zero Emission Vehicles and Low-Carbon Fuels transcript. https://efiling.energy.ca.gov/getdocument.aspx?tn=234943.

279 Capitol Corridor Joint Powers Authority. "CCJPA Eyes Renewable Diesel to Power Trains for a Sustainable Future." Accessed October 22, 2020. https://www.capitolcorridor.org/blogs/get_on_board/ccjpa-tests-renewable-diesel/.

280 Capitol Corridor Joint Powers Authority. "Meeting of Board of Directors." Accessed October 22, 2020. https://www.capitolcorridor.org/wp-content/uploads/2020/09/Sept-16-2020-CCJPA-Board-Meeting_Agenda-Packet-1.pdf.

SAF. For instance, the LCFS considers indirect emissions only from crop-based biofuels, not waste-based biofuels. However, EDF pointed out that using waste streams as feedstocks for fuels may leave out the effects from competing uses of waste feedstocks. For example, using waste beef tallow for SAF that would have been used in cosmetics may result in the cosmetics producer resorting to palm oil, which has high associated GHG emissions and other negative environmental impacts.[281]

Proposed plant conversions and expansions in California will compel a careful look at the feedstock sources not only in California, but throughout the United States and international markets. This examination is because these low-carbon feedstocks are limited in supply, they compete with other uses, and other states' introducing LCFS policies may result in additional competition. Producers are developing new technologies and new supply chains within California borders and other geographic regions to diversify the current waste oil feedstock portfolio and waste residues to include other sources and advanced conversion technologies.[282]

Dimethyl ether (DME) is another fuel that can be produced from various waste streams and renewable feedstocks. DME can serve as a replacement for diesel fuel and has several other uses. The CEC has recently funded a DME project implemented by Oberon fuels to scale up production from its original pilot phase.

The high monetary incentive generated by the LCFS attracts biodiesel imports and creates fierce competition with in-state biodiesel refineries. New Leaf Biofuel discussed this concern in more detail during the July 29, 2020, IEPR workshop on low-carbon fuels.[283] The increased imports driven by the LCFS result in more supply than the market can absorb because the storage and blending infrastructure is insufficient and controlled by a few distributors. The supply glut forces all prices to be deeply discounted to unprofitable levels and results in underutilization of California biodiesel production capacity.

---

281 Petsonk, Annie (with Environmental Defense Fund). July 29, 2020 IEPR workshop on Near-Zero Emission Vehicles and Low-Carbon Fuels transcript. https://efiling.energy.ca.gov/getdocument.aspx?tn=234943.

282 Fulks, Tom, and Michael Coates. Mightycomm Proposed 2020 IEPR Update Liquid Fuels Chapter Parts 1 and 2. Public comments in the IEPR Docket No. 20-IEPR-02. July 28, 2020. https://efiling.energy.ca.gov/GetDocument.aspx?tn=234033&DocumentContentId=66862 and https://efiling.energy.ca.gov/GetDocument.aspx?tn=234034&DocumentContentId=66863.

283 Case, Jennifer. "Biodiesel Infrastructure." Presentation at the July 29, 2020, IEPR workshop on Near-Zero Emission Vehicles and Low-Carbon Fuels. https://efiling.energy.ca.gov/getdocument.aspx?tn=234042.

Renewable Gas and Low-NO_x Engines

Use of biomethane or renewable gas fuel in California's transportation sector has grown significantly to displace an increasing portion of fossil pipeline gas, and the state is poised for significant development of new California-based production plants in several sectors. The CEC expects a continual growth trend because of state and local government incentives, vehicle and engine technology advances, and an existing network of fueling stations located in key areas of the state.

Vehicles in California consumed 179 million diesel gallons equivalent (DGE) of fossil gas and renewable gas. Renewable gas has been directed primarily at vehicle fuels because of the LCFS, comprising 77 percent of the pipeline gas supply for vehicles in 2019.[284] Compared to the 3.8 billion gallons of DGE mentioned above, renewable gas displaced 5 percent of the diesel fuel consumption in trucks.

During the July 29, 2020, IEPR workshop on near-zero-emission vehicles, the environmental consulting firm Gladstein, Neandross, and Associates discussed key statewide trends in renewable gas. Almost all the renewable gas used in 2019 was imported from outside the state. However, more than 100 new biomethane projects have come on-line or are under construction in California, converting dairy and livestock manure, organic food waste, landfill gas, and wastewater biogas and residues to fuel. A survey of state-cofunded biomethane projects indicates that projects currently operating, as well as those under development with permit approval, will result in a cumulative 160 projects operating in California between July 2020 and January 1, 2024.[285] The new growth will increase production with an additional 119 million DGE at an average negative carbon intensity rating, estimated by consultants from Gladstein, Neandross, and Associates to be roughly -102 grams of carbon dioxide equivalent (CO_2e) per megajoule in 2024.[286] Imports of out-of-state biomethane are also expected to grow, stimulated by the value of LCFS credits. As the lead agency on the LCFS, the California Air Resources Board (CARB) regularly evaluates the complex calculations associated with the

---

284 CARB. Low Carbon Fuel Standard Annual and Quarterly Reporting Tool. https://ww3.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm.

285 Gladstein, Cliff. "An Assessment: California's In-State RNG Supply for Transportation, 2020-2024." Presentation at the July 29, 2020, IEPR workshop on Near-Zero Emission Vehicles and Low-Carbon Fuels. https://efiling.energy.ca.gov/getdocument.aspx?tn=234038.

286 Ibid.

standard. Over time, the values associated with emissions that would have otherwise gone into the atmosphere may be adjusted.

Independent studies estimate waste residues from in-state dairies, landfills, food diversion and wastewater treatment plants could be used to produce biomethane in volumes ranging from 750 million to 1.2 billion gallons DGE per year, which would displace 23 percent to 36 percent of the on-road diesel fuel consumption in California.[287]

Vehicles that use renewable gas are an increasing share of HD vehicles in the state.[288] Since 2016, Cummins, Inc. has annually manufactured 7,000 to 8,000 advanced gas engines capable of operating on fossil or renewable gas (6.7-, 8.9-, and 12-liter sizes), and the company has expressed interest in expanding production with additional demand.[289] One unique benefit is that these engines are capable of using renewable gas, which has negative carbon emissions. These engines have been certified by the United States Environmental Protection Agency (U.S. EPA) and CARB as achieving a 90 percent reduction in tailpipe emissions compared to the existing 2010 diesel engine ambient air quality standard.[290] The Cummins engines are the only combustion engines that can meet the U.S. EPA anticipated 2027 standard for low-NO_x tailpipe emission levels. Several truck chassis and cab manufacturers have embedded these engines in new product sales. The cumulative growth of fossil or renewable gas trucks in California

---

287 U.S. Department of Energy. *2016 Billion Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy*. July 2016. https://www.energy.gov/sites/prod/files/2016/12/f34/2016_billion_ton_report_12.2.16_0.pdf.

Jaffe, Amy Myers. *The Feasibility of Renewable Natural Gas as a Large-Scale, Low Carbon Substitute*. UC Davis Institute of Transportation Studies. June 2016. https://ww2.arb.ca.gov/sites/default/files/classic//research/apr/past/13-307.pdf.

Sheehy, Philip, and Jeff Rosenfeld. *Design Principles for a Renewable Gas Standard*. ICF International. February 2017.

288 The CEC's Energy Research and Development Division has contributed to the development of these engines in partnership with Cummins Westport. For example, see CEC's final report on the 12-liter size, ultra-low NOx engine. https://ww2.energy.ca.gov/2019publications/CEC-500-2019-002/CEC-500-2019-002.pdf.

289 Cummins, Inc. written comments submitted to Docket 20-IEPR-01. https://efiling.energy.ca.gov/GetDocument.aspx?tn=236364&DocumentContentId=69359.

290 Swenson, Tom. "Cummins Near-Zero Engines." Presentation at the July 29, 2020 IEPR workshop on Near-Zero Emission Vehicles and Low-Carbon Fuels. https://efiling.energy.ca.gov/GetDocument.aspx?tn=234044&DocumentContentId=66870.

exceeds 20,000 (roughly 4 percent of the truck sector), and new vehicles entering the market have averaged 1,000 vehicles per year for the last three years.[291] Most of these are Class 7 and Class 8 trucks, with notable growth in submarkets, such as long haul, regional haul, waste hauling, port drayage, and package delivery.

While the potential growth of in-state renewable gas fuel production and imports from outside the state is on an upward trend, vehicle product offerings are also growing. However, supply is limited, and costs range from $50,000 to $100,000 more than diesel truck equivalent models. State and local government incentives and programs can help with this cost. Moreover, LCFS credit value sharing between fuel producers and vehicle owners could help cover the cost difference.

As California moves toward zero-emission fuels and transportation, the role of renewable gas as a low-carbon transportation fuel will continue to be a point of debate among stakeholders. Many government and industry groups view renewable gas as a cost-effective method of reducing waste-based methane emissions from dairy and landfill operations while creating a low-carbon transportation fuel for trucks and buses. Some national environmental groups and local environmental justice organizations are concerned that the methane reduction benefits of renewable gas may be overstated, and that government support for such projects can exacerbate the current trends in market consolidation and concentrations of the dairy industry.[292] Expanded, high-volume dairy operations may worsen water and air quality in nearby communities, which are often disadvantaged. Stakeholder discussion at the July 29, 2020, IEPR workshop on renewable gas and low carbon transportation fuels workshop exemplified this debate.

The processing of dairy manure into renewable gas from anaerobic digesters requires sufficient volumes and economies of scale to make the projects cost-effective. One effective strategy has been for dairies to form a "cluster" in which biogas from digesters sited at several farms is combined, upgraded, and injected into a pipeline or used onsite for transportation fuel (also termed "hub and spoke"). This approach allows smaller dairies to achieve improved

---

291 CEC Analysis, 2019 California Fuel Supply Outlook, September 2017 and *2019 Transportation Energy Demand Forecast*, including evaluations of the Department of Motor Vehicles database, *2019 Integrated Energy Policy Report*, February 2020.

Rindt, Craig, et. al. *Natural Gas Vehicle Incentive Program Final Report*. UC Irvine Institute of Transportation Studies. June 2020.

292 Phoebe Seaton comments. July 29, 2020, IEPR workshop on Near-Zero Vehicles and Low-Carbon Fuels transcript. p. 59. https://efiling.energy.ca.gov/GetDocument.aspx?tn=234941&DocumentContentId=67811.

economies of scale and share the expenses of biogas processing and interconnection. It is important not to conflate such digester cluster projects with broader, longstanding market and industry trends toward consolidation into fewer, larger dairies and feedlots. Although interrelated, these are separate. Industry trends toward consolidation are being driven by economic forces including high production costs and fixed, deflated commodity prices. These forces are distinct from the transportation sector and the state's efforts to reduce methane emissions from existing dairy operations.

Senate Bill 1383 (Lara, Chapter 523, Statutes of 2014) sets a target of achieving a 40 percent reduction in statewide methane emissions below 2013 levels by 2030. The bill also directed CARB to convene working groups of four principal agencies[293] and multiple stakeholders to develop strategies to achieve methane emissions reductions. The workgroups conducted 31 public meetings to discuss and debate these issues. Working subgroup 2 on dairy digesters found that dairy digesters "represent a proven and highly cost-effective way of reducing dairy methane emissions in California. Removing barriers to ongoing dairy digester development and improving incentives for ongoing project development is critical to achieving a 40 percent reduction in dairy manure methane emissions," as sought under the state's Short-Lived Climate Pollution (SLCP) Reduction Strategy. The working group findings and recommendations also pointed out that using the cluster model to produce biogas from digesters maximizes biogas outputs and GHG emissions reductions. It also found reductions in some air pollutants, such as ammonia and hydrogen sulfide.[294]

Environmental advocates remain concerned about flush manure management systems at dairy operations, as they are a larger source of manure methane than the dry-managed counterparts or pasture-based operations.[295] The bulk of California's dairies operate as centralized gravity flow of wet manure waste diverted into anaerobic lagoons. A small percentage of California dairies are pasture dairies located mostly on California's Bay Area and north coast, where manure can dry in the field. *Enteric fermentation*, or the breaking down of

---

293 These agencies were CARB, The California Department of Food and Agriculture, the CEC, and the CPUC.

294 CARB. Findings and Recommendations Subgroup 2: Dairy Digesters. SB 1383 Dairy and Livestock Working Group. October 12, 2018. https://ww2.arb.ca.gov/sites/default/files/2020-11/dsg2-final-recs-112618.pdf.

295 United States Environmental Protection Agency. 2019. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017. Chapter 5: Agriculture. https://www.epa.gov/sites/production/files/2019-04/documents/us-ghg-inventory-2019-chapter-5-agriculture.pdf.

Although methane from manure is lower in pasture systems, enteric fermentation may be higher.

substances that takes place in the digestive systems of animals, is a major source of methane emissions no matter how the dairy operation is configured, but these emissions are not a potential source of renewable gas.[296] One avenue of streamlining renewable gas production could be similar to Denmark's approach of centralized facilities that can combine manure and organic waste streams at a lower cost than current operations.[297]

Further, water quality is a concern related to dairy operations, as cow manure is a considerable source of nitrates and salts, which can negatively impact groundwater. During the July 29, 2020, IEPR workshop panel on renewable gas, the Central Valley Regional Water Quality Control Board stated that elevated groundwater nitrate concentrations existed at all monitored dairies.[298] The primary source is applied manure of dairy operations in nearby areas for the production of forage crops. The Central Valley Salinity Alternatives for Long-Term Sustainability program (CV-SALTS) was designed to address salt and nitrate pollution in drinking water. This program requires that all dairy flush operations, including those with digesters, be subject to evaluations during permitting processes, presenting potential challenges to some dairy operations. The CV-SALTS requirements could affect the use of digestate by-products from dairy and livestock manure management operations as land-applied fertilizers, increasing costs for operators who must incorporate other less environmentally problematic strategies to manage the digestate.

Methane leakage from digester covers remains another challenge that merits close attention when considering dairy biogas projects. In 2020, the CEC published *The California Methane Survey*, which quantified point source emissions from more than 272,000 energy-related, livestock, and waste management infrastructure elements in the state, including 443 animal feedlot operations, based on airborne measurements conducted between 2016 and 2018. The

296 CARB. 2016. Short-Lived Climate Pollution Plan, Inventory of California methane sources. For more information see the CARB GHG Short-Lived Climate Pollutant Inventory web page. https://ww2.arb.ca.gov/ghg-slcp-inventory.

297 Biogas Go Global. 2020. Biogas Production: Insights and experiences from the Danish Biogas Sector. https://www.biogasgoglobal.com/Admin/Public/DWSDownload.aspx?File=%2FFiles%2FFiles%2FBiogas-Go-Global%2FResults%2FBIOGAS-PRODUCTION_UK-VERSION_WEB.pdf.

A centralized digester operation may have additional impacts from increased VMT and transportation pollution to areas near the main digester site.

298 Patterson, Doug. "The Central Valley Water Board." Presentation at the July 29, 2020, IEPR workshop on Near-Zero Emission Vehicles and Low-Carbon Fuels. https://efiling.energy.ca.gov/GetDocument.aspx?tn=234043&DocumentContentId=66871.

report concluded that manure management through lagoons and settling ponds generated 26 percent of all California point-source methane emissions. The report also analyzed 25 dairy digesters and found that four exhibited "significant and fairly persistent leakage." The extent of this leakage on a longer-term basis is uncertain, but the survey suggested more rigorous testing near facilities before and after construction to arrive at a better assessment of overall leakage.[299]

GHG emissions, water quality, and other environmental issues related to digester gas are being addressed by CARB, the California Department of Food and Agriculture (CDFA), and the CPUC through various ongoing proceedings.[300] The CEC will closely monitor the outcomes of these efforts and reflect policy findings and outcomes in the CEC's programs.

Recommendations

- **State policies and incentives should prioritize low-carbon liquid fuels for sectors that are the hardest to electrify.** Where electrification is possible and likely, the state should encourage it. These fuels also have the potential for reducing greenhouse gas and criteria pollutant emissions from diesel engines in the existing vehicle fleet as the state transitions to zero-emission vehicles. The state should also explore additional options to emphasize low-carbon fuels for sectors that are the most difficult to electrify, such as aviation.
- **The state should further explore challenges to the Low Carbon Fuel Standard (LCFS) credit system, including indirect effects and other potential benefit gaps.** This exploration includes careful consideration toward feedstocks that compete with other uses and may contribute to emissions from upstream market impacts. The LCFS should also consider potential gaps in carbon accounting from fossil gas and renewable gas operations.

---

299 Duren, Riley, Andrew Thorpe, and Ian McCubbin. 2020. *The California Methane Survey.* California Energy Commission. Publication Number: CEC-500-2020-047.

Airborne measurements provide snapshots in time that, while providing valuable information, do not provide enough information to include in CARB's GHG inventory nor to use in monitoring for regulatory purposes. Such snapshot measurements can identify areas that could benefit from additional research and the identification of individual plumes may assist in emission mitigation.

300 These include CARB's Scoping Plan update expected to be completed in 2021, methane recovery regulations being developed by CARB in consultation with CDFA, CDFA monitoring and reporting on methane capture at projects they funded, and analysis of data from dairy pipeline injection pilot programs funded by the CPUC.

- **The state should closely scrutinize both potential and active renewable gas projects to avoid emissions from leaks, impacts to water quality, and local harm to communities impacted by the operations.**
- **The CEC should explore potential challenges to the biodiesel, renewable diesel, and aviation fuel market, which has experienced a crowding effect from LCFS credits.** The high import rate of these fuels has created instability for in-state producers. Solutions may be able to help encourage local production of fuels to maximize in-state benefits of low-carbon liquid fuels.

Acronyms

ACT	Advanced Clean Trucks
BEB	battery-electric bus
BNEF	Bloomberg New Energy Finance
CALeVIP	California Electric Vehicle Infrastructure Project
CARB	California Air Resources Board
CEC	California Energy Commission
CO_2	carbon dioxide
CPUC	California Public Utilities Commission
CV-SALTS	Central Valley Salinity Alternatives for Long-Term Sustainability
DCFC	direct-current fast charger
DER	distributed energy resource
DGE	diesel gallons equivalent
DME	dimethyl ether
EDF	Environmental Defense Fund
EV	electric vehicle
EVITP	Electric Vehicle Infrastructure Training Program
EVSE	electric vehicle supply equipment
FCEV	fuel-cell electric vehicle
FCEB	fuel-cell electric bus
GVWR	gross vehicle weight rating
ICCT	International Council on Clean Transportation
ICE	internal combustion engine
ICT	Innovative Clean Transit
IEPR	Integrated Energy Policy Report
IOU	investor-owned utility
g/bhp-hr	grams per brake horsepower-hour
GHG	greenhouse gas
HD	heavy-duty

kW	kilowatt
kWh	kilowatt hours
LCFS	Low Carbon Fuel Standard
LD	light-duty
MD	medium-duty
MUD	multiunit dwelling
NREL	National Renewable Energy Laboratory
NOx	oxides of nitrogen
OEM	original equipment manufacturer
OPR	Governor's Office of Planning and Research
PEV	plug-in electric vehicle
POU	publicly owned utility
PM2.5	fine particulate matter
PV	photovoltaic
SAF	sustainable aviation fuel
SUV	sport utility vehicle
TCN	transportation network company
TOU	time of use
VGI	vehicle-grid integration
VMT	vehicle miles traveled
ZEV	zero-emission vehicle

Glossary

Disadvantaged communities are defined by the California Environmental Protection Agency as the top 25 percent of census tracts most impacted by pollution.

Enteric fermentation is the breaking down of substances that takes place in the digestive systems of animals.

For the *2020 IEPR Update*, the CEC is using the terms **gas**, pipeline gas, or fossil gas, where past IEPRs typically used the term "natural gas." Similarly, in this report the CEC refers to "renewable gas" instead of "renewable natural gas."

"High-road jobs" are discussed in the UC Berkeley Center for Labor Research's report *Putting California on the High Road: A Jobs and Climate Action Plan for 2030.* The report describes these jobs as those that offer family-supporting wages, employer-provided benefits, a voice for workers, and opportunities for advancement.

Low-income communities are defined by the California Department of Housing and Community Development as those communities at or below 80 percent of the statewide median income.

A **megajoule** is a unit of work or energy equal to 1 million joules. According to Wikipedia, a *joule* is equal to the energy transferred to an object when a force of one newton acts on that object in the direction of the force's motion through a distance of one meter.

Micromobility is a form of transportation that consists of lightweight mobility devices that are controlled by the operator and powered by either the operator or a small electric motor. They have limited speeds compared to passenger vehicles or motorcycles. For example, these devices include bicycles, electric scooters, e-bikes, and skateboards.

The **Three Revolutions** refer to new technologies — electrified transportation, vehicle automation, and shared mobility services — which are converging to create potentially disruptive changes in the transportation system. If these three interdependent trends evolve in accordance with a best-case scenario, California could foster more sustainable and equitable transportation systems while reducing transportation GHG emissions by 80 percent. (This is known as the "Blue Skies scenario".) To the contrary, if these three trends are not strategically managed by governments and other key stakeholders, they could exacerbate many of the state's most serious transportation issues, including increases in vehicle miles traveled, congestion, fuel use, and vehicle emissions. (This is known as the "Dirty Skies scenario.")

Zero-emission vehicles are those that do not emit exhaust from the onboard source of power. Zero-emission vehicles include plug-in electric vehicles, fuel cell electric vehicles, and battery-electric vehicles. Plug-in hybrid electric vehicles may have emissions from combustion drivetrains but may operate as an electric vehicle with no emissions.