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California Energy Commission

COMMISSION REPORT

Draft 2020 Integrated Energy Policy Report Update

Volume I: Blue Skies, Clean Transportation

Gavin Newsom, Governor

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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, has been unprecedented as the state continues to face the impacts and repercussions of multiple catastrophic events including the COVID-19 pandemic, electricity outages, and statewide wildfires. In addition to these devastating events, the *2020 Integrated Energy Policy Report Update* covers a broad range of topics, including transportation, microgrids, and the *California Energy Demand Forecast*.

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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 1 focuses on California's transportation future and the transition to zero-emission vehicles (ZEVs). As California works to reimagine its energy system, it is transforming the state's transportation system to one that is based on the use of zero-emission vehicles.
- Volume 2 examines microgrids, exploring how they can contribute to a more resilient energy system.
- Volume 3 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 [Preliminary Root Cause Analysis, Mid-August 2020 Heat Storm](http://www.aiso.com/Documents/Preliminary-Root-Cause-Analysis-Rotating-Outages-August-2020.pdf). <http://www.aiso.com/Documents/Preliminary-Root-Cause-Analysis-Rotating-Outages-August-2020.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). <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 shut-down was better air quality. As traffic dwindled due to 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.

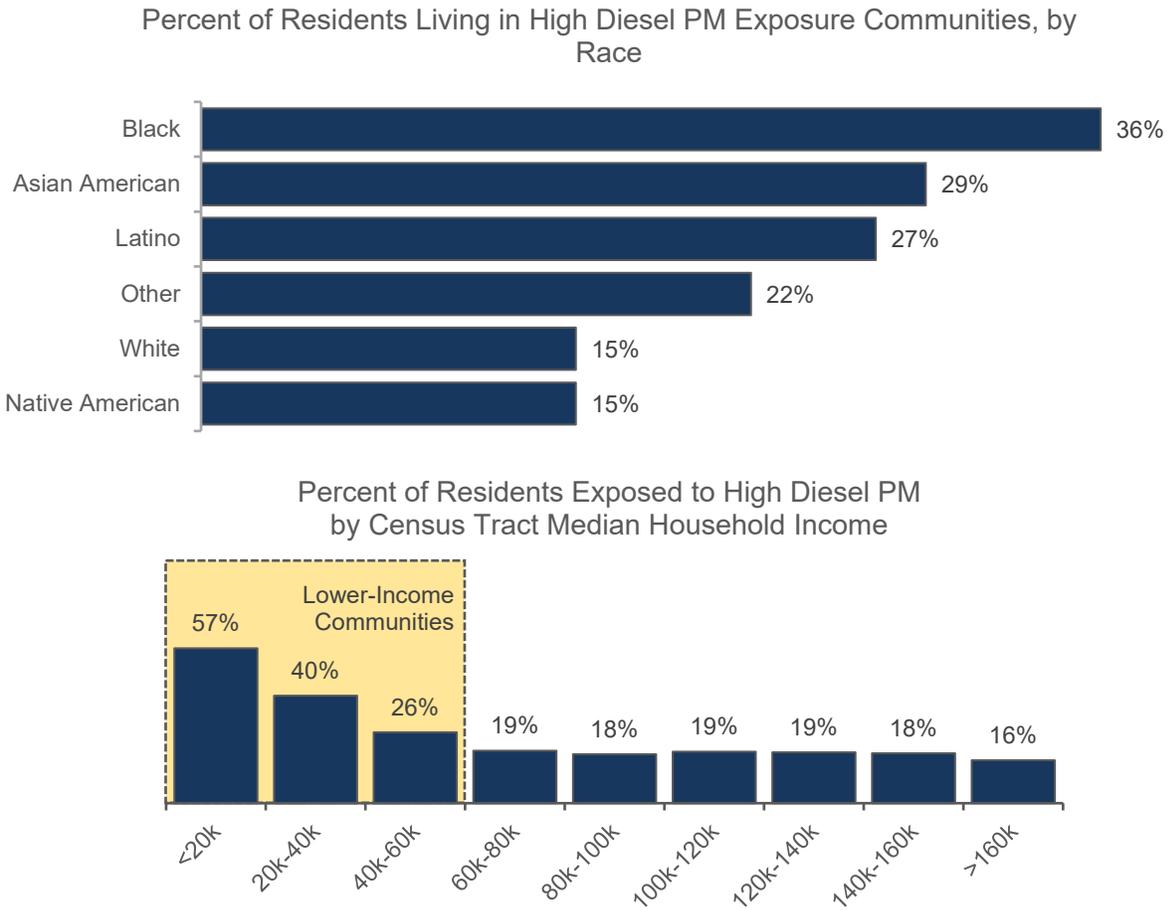
To address these challenges, the state is doubling down to accelerate ZEV deployment. On September 23, 2020, Governor Gavin Newsom signed Executive Order N-79-20, setting a 100 percent ZEV target for new passenger vehicle sales by 2035 and 100 percent ZEV operations target for medium- and heavy-duty 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 grid resilience. 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 includes 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). Tragically, 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.

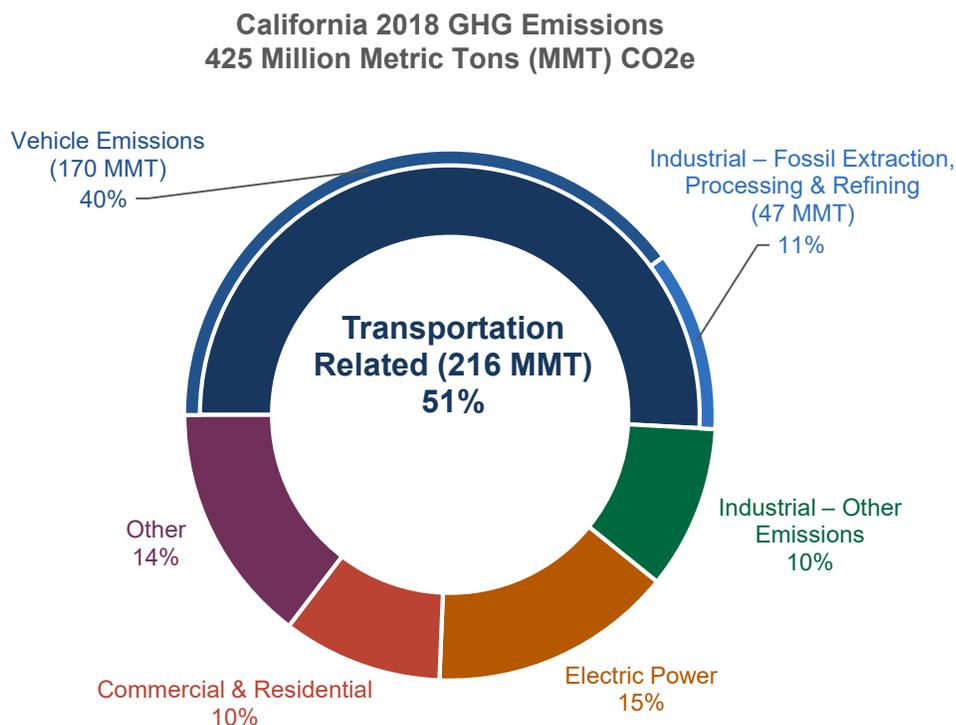
Figure ES-1: Disparities in Transportation-Related Pollution Exposure by Race and Income



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.)

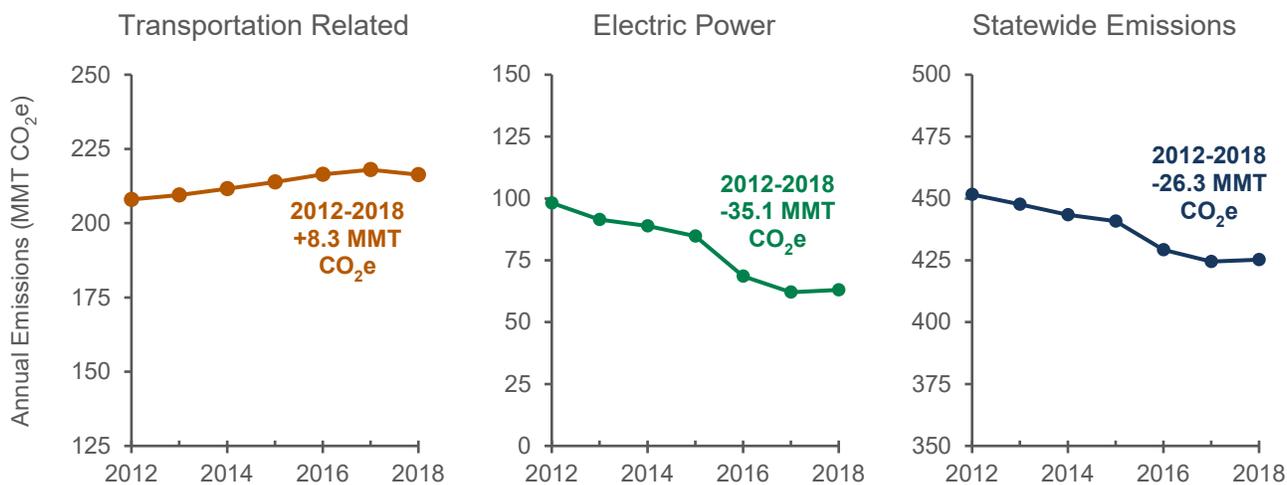
Transportation remains a key focus in the state’s efforts to address climate change. The state is making important reductions in greenhouse gas (GHG) emissions, largely from the electricity sector, as renewable electricity generation increases and displaces fossil fuel-based electricity generation. By 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. 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.

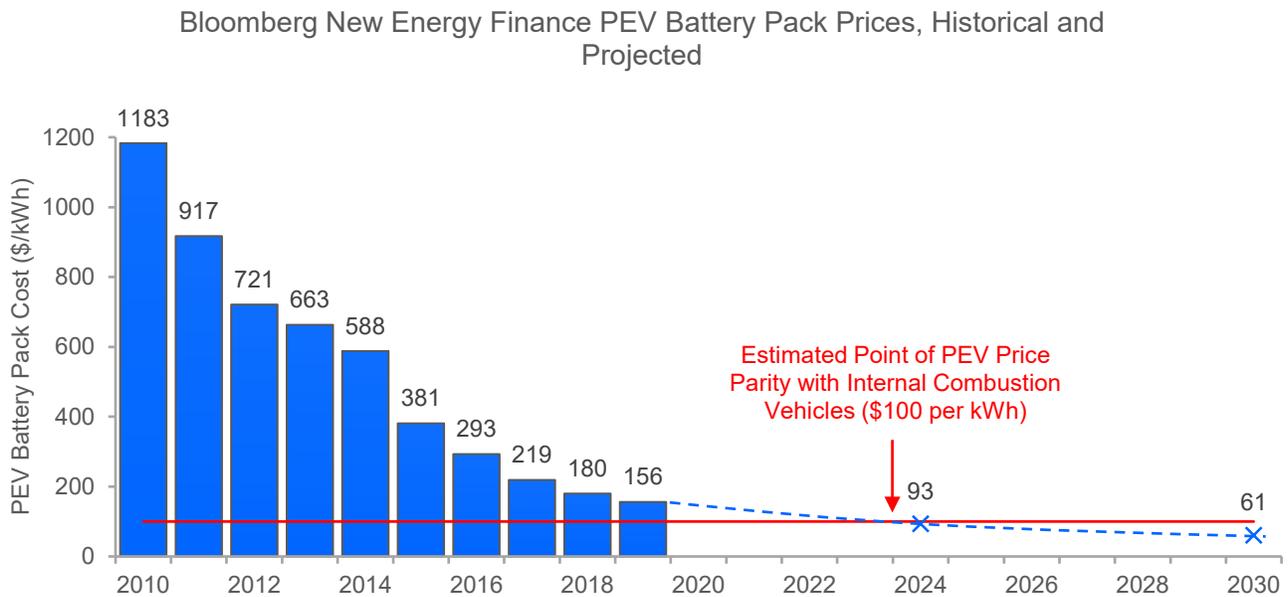
In addition to hosting the largest ZEV market in the country, California is the epicenter of the three revolutions. The state is in a unique position to make clean transportation a significant portion of its economy. Current estimates of the jobs in the electric vehicle ecosystem — the network of key services in the industry supporting electric vehicles — is 276,000 workers, more than a third of the more than 700,000 jobs in the state's automotive sector. The electric vehicle ecosystem is spread across a wide array of sectors, including manufacturing, technology, research, utility, and others. 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 several major economies, market penetration of PEV sales has nearly doubled in the last two years. 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, over \$1,000.

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



Credit: Bloomberg New Energy Finance

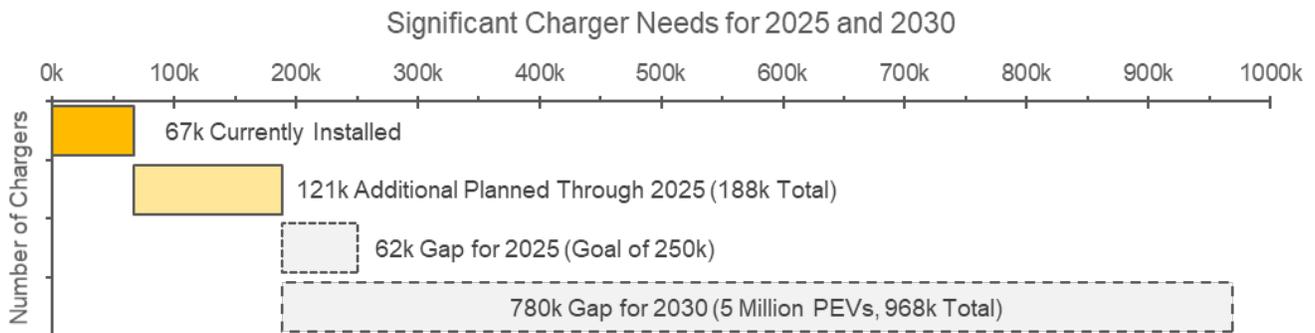
Success in the light-duty PEV market has set the stage for transitioning medium- and heavy-duty vehicles. This sector is poised for rapid growth, in part due to strong state policies and programs. The California Energy Commission’s (CEC’s) bulk purchases of battery-electric school buses have bolstered 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 rapidly declining, making the total cost of ownership (including maintenance and fuel) cost-competitive with fossil-fueled vehicles in several use cases now, and likely all by 2025. 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 ZEVs (passenger, medium- and heavy-duty, and off-road), a new approach to 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 to 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. Currently, 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 up to 8 million ZEVs by 2030, making the charging infrastructure need even greater.

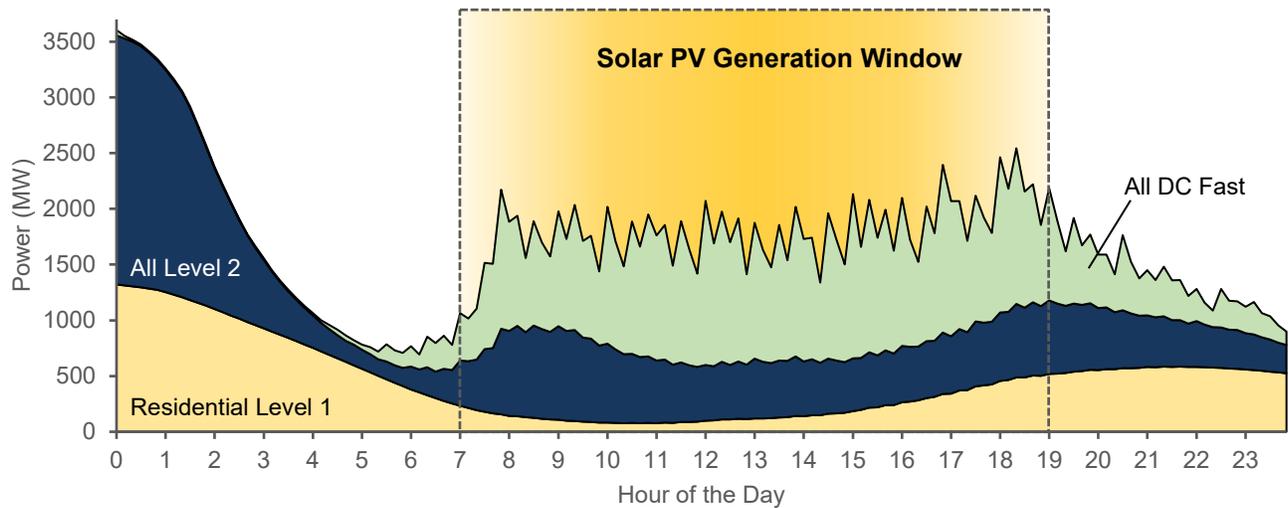
Figure ES-5: Gaps in the Chargers Necessary for Additional PEVs on the Road



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 grid congestion. 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

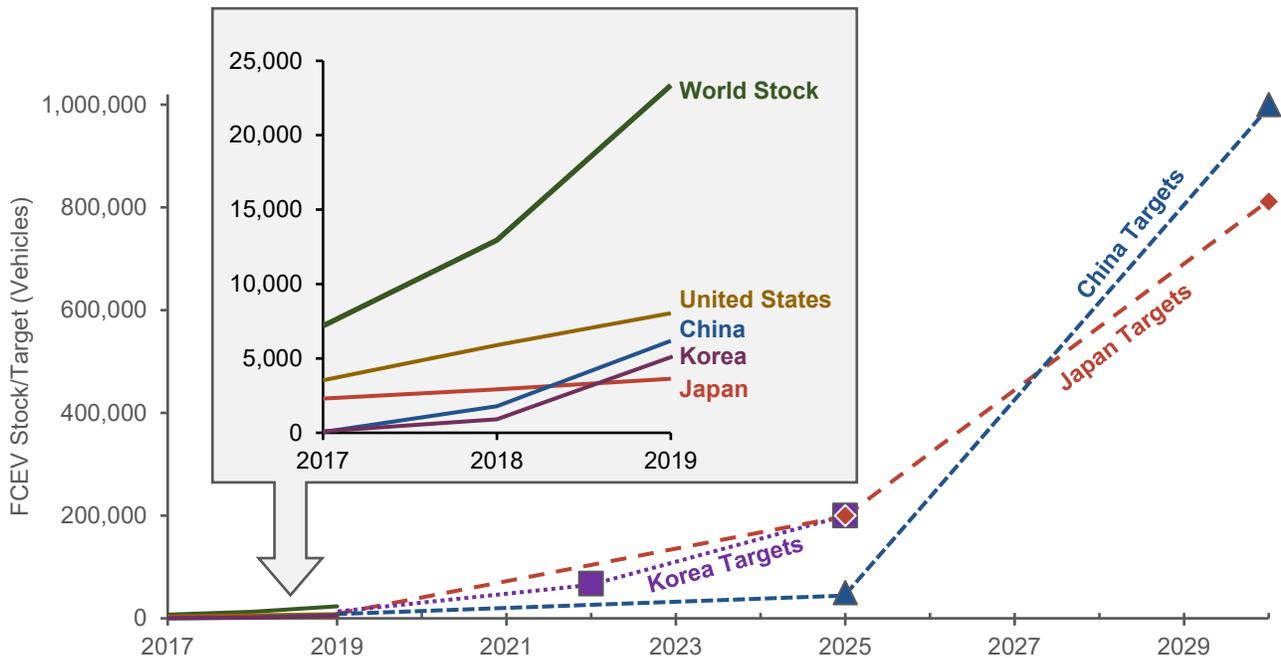
New regulatory and funding mechanisms are needed to encourage private-sector investments in charging infrastructure, especially those in disadvantaged or low-income communities. Disadvantaged communities are defined by the California Environmental Protection Agency as the top 25 percent of census tracts 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 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 November 2020, 173 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 and China 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: 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 these 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 shutoff events 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, PEVs and FCEVs are not an unlimited supply of energy, and each must eventually be refueled, especially if used to help power a resident's home. While a PSPS can reduce the ability for any vehicle to refuel, including power losses at gasoline stations, charging infrastructure can include battery systems and on-site renewable generation to provide resilient energy and charging services in the event of a power loss. These technologies provide several opportunities (backup, charging, grid services) for those that use them. The resiliency they offer beyond typical gasoline stations should be considered in the charging infrastructure build-out.

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

Although ZEVs represent a revolutionary opportunity to transform transportation, reduce GHG emissions and health-related air pollution, lower refueling costs, and support the efficient use of the electricity grid, some transportation modes may be difficult to electrify. 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 nitrogen oxides, until the state achieves a full transition to ZEVs. 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, because methane is a potent GHG at 25 times the warming potential of carbon dioxide, the state must balance the benefits of renewable diesel against the impacts of methane (a potent GHG) 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 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 over 10,000 structures adds 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 (CO₂) 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 multiple COVID-19-related impacts to California's transportation systems, including drivers, transit systems, trucking companies, and transportation networking companies (TNCs).

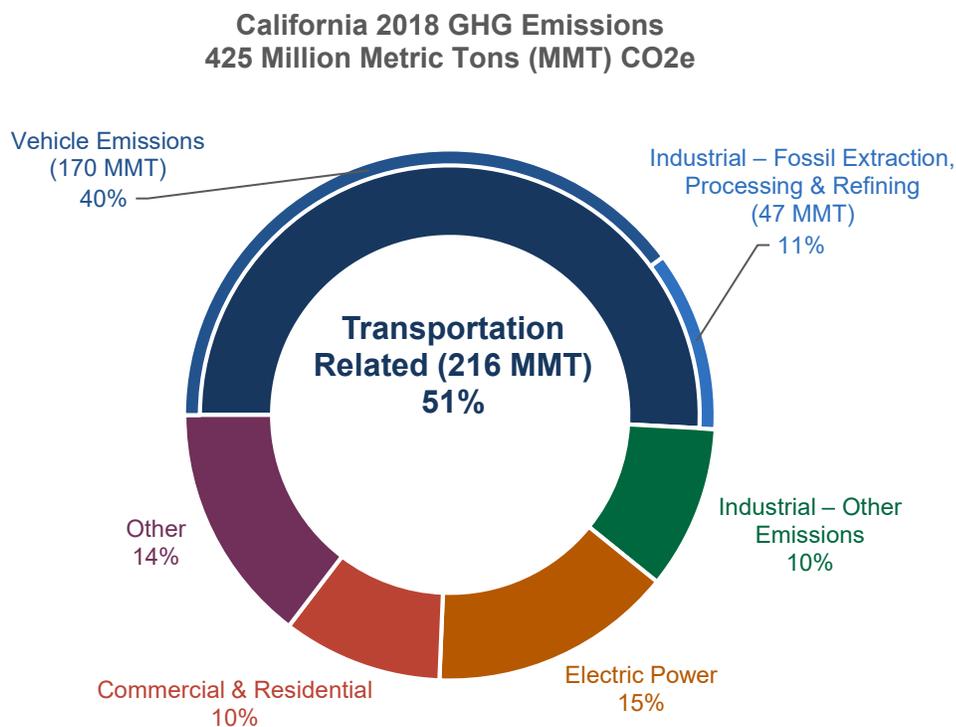
GHGs and Criteria Pollutant Emissions

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).
<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

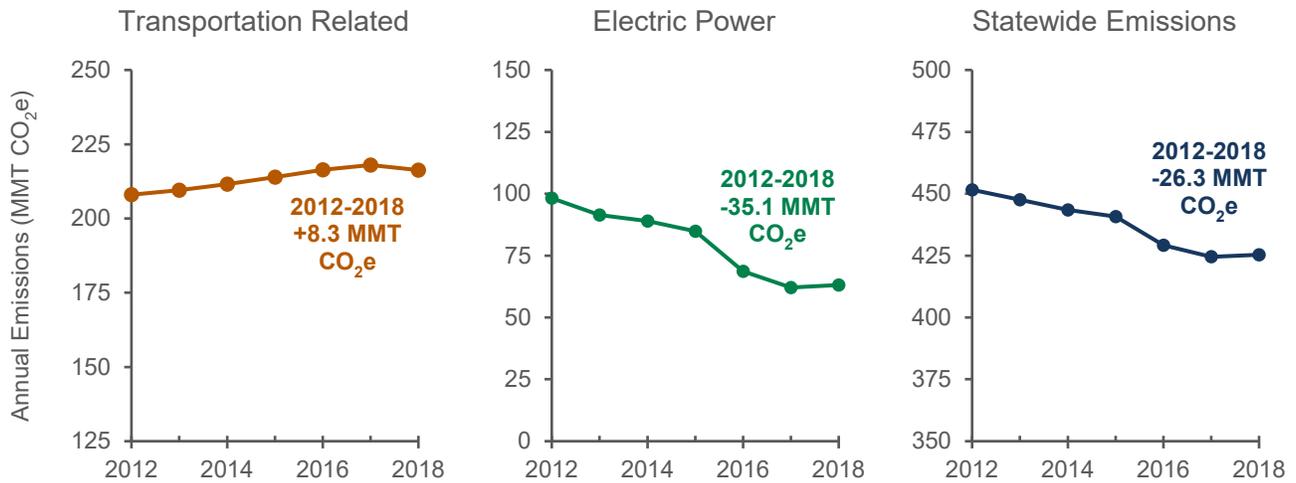
California has made good progress in reducing total GHG emissions, including cutting electricity sector emissions by almost half in the last 10 years. Emissions from the transportation sector, though, have *increased* by 5 percent from 2012 to 2018⁹ (Figure 2) because of the historic growth in vehicle miles traveled (up 14 percent between 2011 and 2017¹⁰) 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 towards 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).
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](https://ctp2050.com/wp-content/uploads/2020/08/CTP2050-Transportation-Plan-Draft-1.pdf).
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 NOx 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

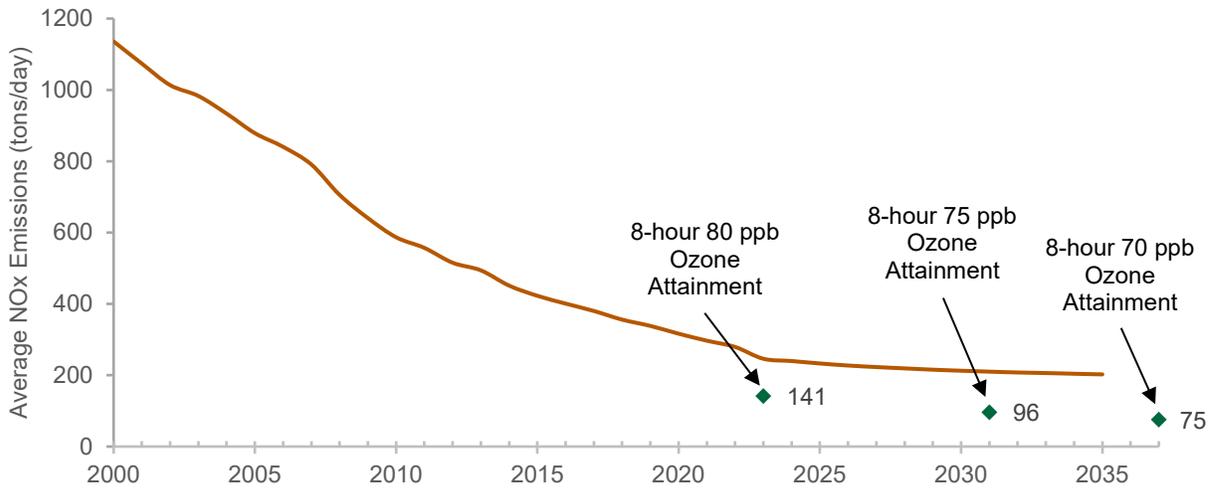
11 [CARB 2017 Climate Change Scoping Plan: The Strategy for Achieving California’s 2030 Greenhouse Gas Target](#). The scoping plan has a goal of 107 MMT from vehicle emissions, or what CARB terms “transportation.” The CEC’s analysis presented in Figures 1 and 2 considers transportation-related emissions 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/2016mobsr.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 NOx 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 yellow line represents actual and anticipated NOx emissions in tons per day, and the green diamonds represent NOx emissions estimated necessary to attain specific federally mandated NOx concentrations.¹⁵ While substantial progress is being made, projected NOx 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 distribution centers in California and across the country. Medium-duty (MD) trucks, such as

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.

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 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 PM2.5 emissions.¹⁶ Viewed from a different metric, trucks accounted for 1 percent of all vehicle trips but 6 percent of 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 causes 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 account for 50 percent of truck VMT as well.¹⁹ California has adopted stringent policies to

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

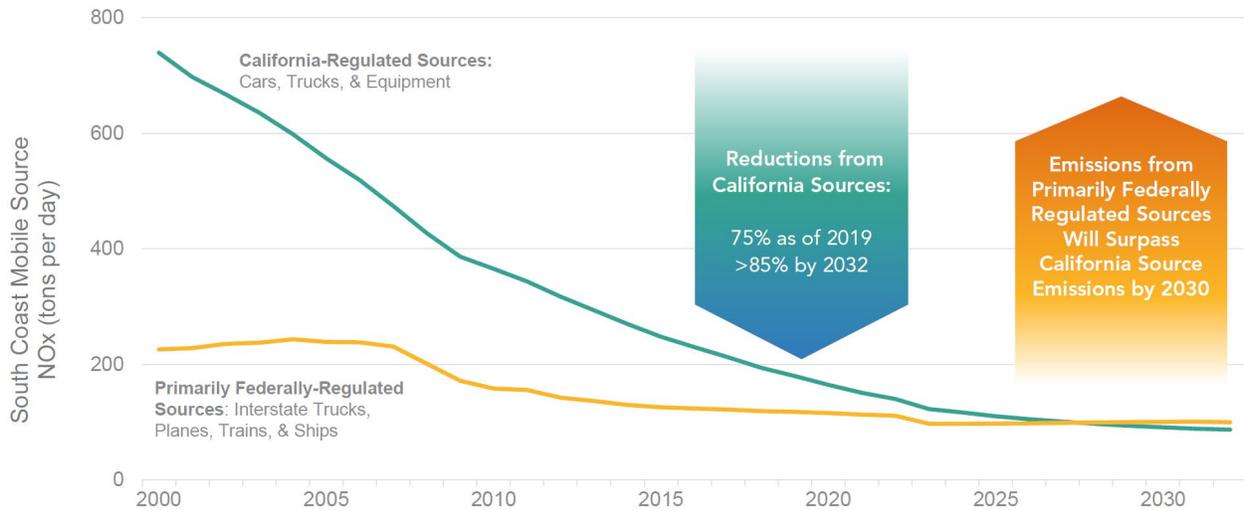
17 California Department of Transportation. 2020.

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

19 CARB. [2016 Mobile Source Strategy](https://ww3.arb.ca.gov/planning/sip/2016sip/2016mobsrsrc.pdf). <https://ww3.arb.ca.gov/planning/sip/2016sip/2016mobsrsrc.pdf>. p. 77.

manage vehicles under its control, but the state cannot meet federal NOx air quality standards without a federal low-NOx vehicle standard.²⁰ See Figure 4.

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



Source: CARB, CEPAM 2016 SIP - Standard Emission Tool (v1.05), <https://www.arb.ca.gov/app/emisinv/fcemssumcat/fcemssumcat2016.php>



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 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

20 CARB. [2020 Mobile Source Strategy](https://www3.arb.ca.gov/planning/sip/2020mss/pres_marwbnr.pdf). March 25, 2020 Public Webinar. https://www3.arb.ca.gov/planning/sip/2020mss/pres_marwbnr.pdf.

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-NOx 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/bhp-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 NOx 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 (ZEBs) by 2023, rising to 100 percent in 2029. Full electrification of the school 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 NOx emissions, which will result in health benefits for individuals and communities in California. The value of these health benefits are due to fewer instances of premature mortality, fewer hospital and emergency room visits, and fewer lost days of school and work.”²⁴

21 CARB. [Initial Statement of Reasons for the Proposed Advanced Clean Trucks Regulation](https://ww3.arb.ca.gov/regact/2019/act2019/isor.pdf). 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](https://ww3.arb.ca.gov/regact/2020/hdomnibuslownox/isor.pdf).” 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](https://ww3.arb.ca.gov/regact/2018/ict2018/isor.pdf?_ga=2.234292958.178464358.1599585982-1771686935.1580939935). 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.

24 CARB. “[Public Hearing to Consider the Proposed Innovative Clean Transit Regulation. Staff Report: Initial Statement of Reasons](https://ww3.arb.ca.gov/regact/2018/ict2018/isor.pdf?_ga=2.234292958.178464358.1599585982-1771686935.1580939935).” August 7, 2018.

Passenger Vehicles

Light-duty (LD) passenger vehicles account for 70 percent of transportation-related GHG emissions, and emissions have been increasing since 2013.²⁵ Rising GHG emissions are primarily due to Californians driving more miles, although the trend in consumer preferences for larger vehicles is also a contributing factor.

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 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.

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>.

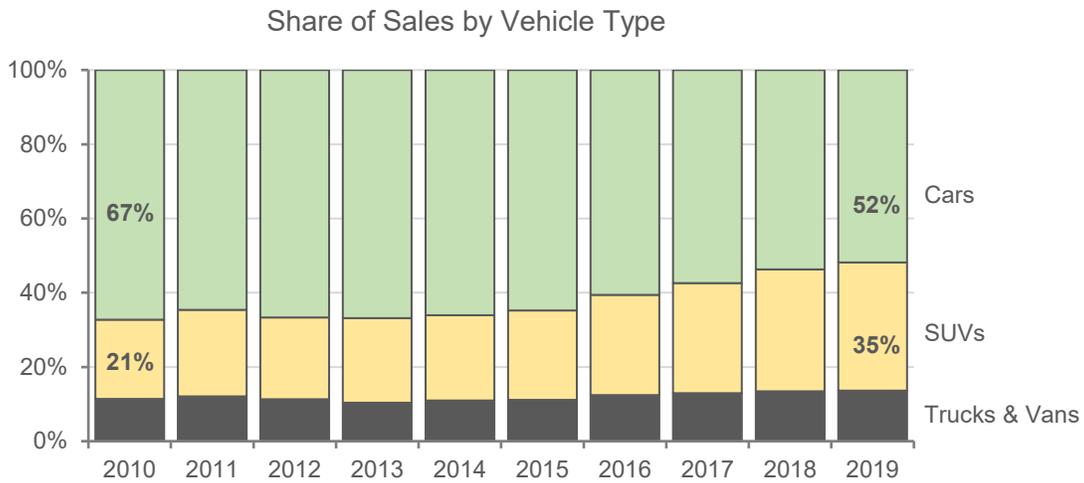
27 Gage, Jesse. “[Light-Duty Vehicle Trends Heavier, Yet More Efficient](#).” Presentation at the June 11, 2020, IEPR workshop on Transportation Trends and Light-Duty ZEV Market Update.
<https://efiling.energy.ca.gov/GetDocument.aspx?tn=233411&DocumentContentId=65925>.

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>.

29 Vehicle curb weight does not capture all of 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

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 CO₂ emissions. However, the emissions increase for battery-electric vehicles (BEVs) is not as sensitive to increases in vehicle weight.³¹ (See Figure 6 below.³²) As

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 their potential implications.

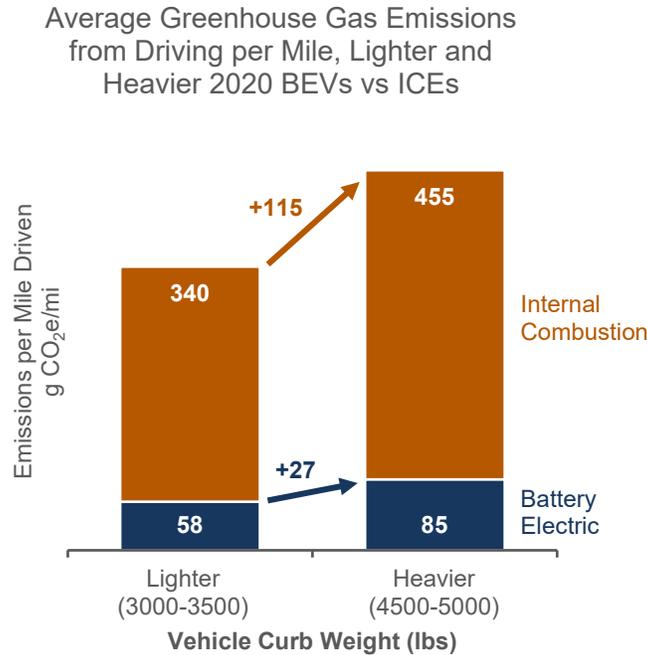
30 In some cases, automakers use engine and other vehicle efficiency gains to offset the larger vehicle weight or more aggressive engines. However, if the same efficiency gains occurred without increasing vehicle weight or increasing aggressive acceleration profiles, the vehicle would have better fuel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

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 is 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

consumers opt for larger vehicles, including SUVs and crossovers, ensuring more BEV options becomes especially important for minimizing emissions.

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



Credit: CEC staff based on California DMV data

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.

Vehicle Miles Traveled are Increasing

Californians are also driving more miles each year, despite state efforts to reduce daily mileage. Solo drivers traveling long distances between suburban housing, job centers, retail centers, grocery stores, and other key destinations typify the high levels of vehicle miles traveled (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 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 NOx and PM2.5 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.

33 California Air Resources Board. [2018 Progress Report](https://ww2.arb.ca.gov/sites/default/files/2018-11/Final2018Report_SB150_112618_02_Report.pdf). 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.

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

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 sustainable community strategies' VMT reduction targets. 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

34 VMT data from Elliot Martin, PhD. 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.

36 Ibid.

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

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 However, these strategies are often undermined as local and regional land-use authorities struggle to colocate jobs, housing, and other 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 indicative of systemic racism, which excludes many minority residents from environmentally safer neighborhoods and districts located away from freight and industrial zones. The Native American exposure quotient for diesel PM is relatively low on the figure, primarily because most tribal lands in

38 Governor’s Office of Planning and Research. “[Transportation Impacts \(SB 743\)](https://opr.ca.gov/ceqa/updates/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](https://efiling.energy.ca.gov/GetDocument.aspx?tn=234188&DocumentContentId=67033). pp. 36–37, 44–48, and 54–56. <https://efiling.energy.ca.gov/GetDocument.aspx?tn=234188&DocumentContentId=67033>.

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). <https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-30>.

California are in rural parts of the state away from major transportation 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

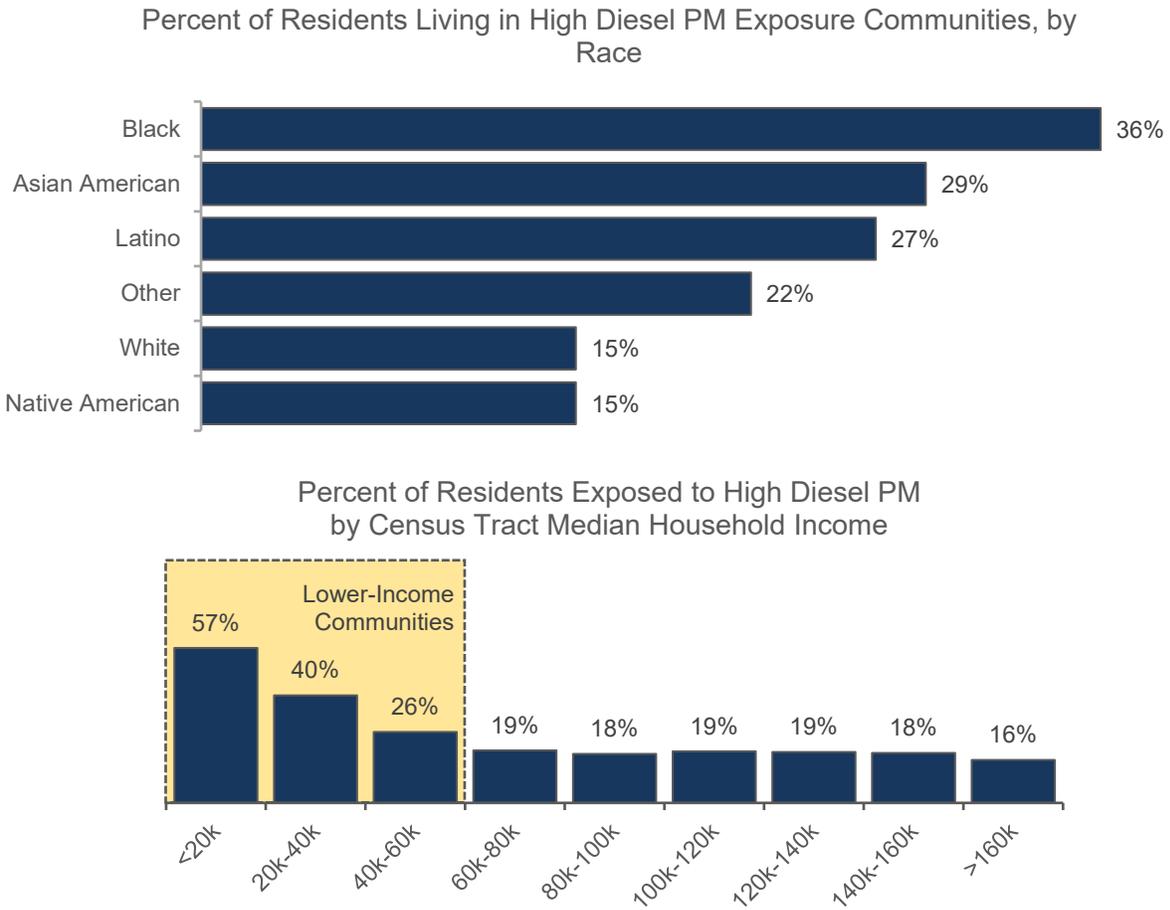
Household income also plays a large role in the likelihood of exposure to high levels of diesel PM. Figure 8 also displays the percentage of residents living in census tracts with high diesel PM exposure, categorized by the median income of the census tracts. Residents in low-income communities are much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

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). 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 Tribal Air Association: Status of Tribal Air Report](https://7vv.611.myftpupload.com/wp-content/uploads/2020/06/2020-NTAA-Status-of-Tribal-Air-Report.pdf). 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). <https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-30>.

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 data

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

42 California Department of Public Health. [COVID-19 Race and Ethnicity Data](https://www.cdph.ca.gov/Programs/CID/DCDC/Pages/COVID-19/Race-and-Ethnicity-Data.aspx). Daily updated data as of November 16, 2020, accessed on November 18, 2020. [https://www.cdph.ca.gov/Programs/CID/DCDC/Pages/COVID-](https://www.cdph.ca.gov/Programs/CID/DCDC/Pages/COVID-19/Race-and-Ethnicity-Data.aspx)

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 vehicular 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. (See Figure 9.)

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



Photo Credit: Twitter/@MikeSington, April 6, 2020 (<https://www.timesunion.com/news/article/clean-clear-air-Los-Angeles-photos-coronavirus-15204855.php>)

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). <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)." 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, 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 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, impacts 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 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

49 DiFelicianantonio, Chase. "[Chevron to Cut up to 15 Percent of Global Workforce.](https://www.sfchronicle.com/business/article/Chevron-to-cut-up-to-15-of-global-workforce-15299120.php)" *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.](https://www.kqed.org/news/11831607/shutdown-of-marathons-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.

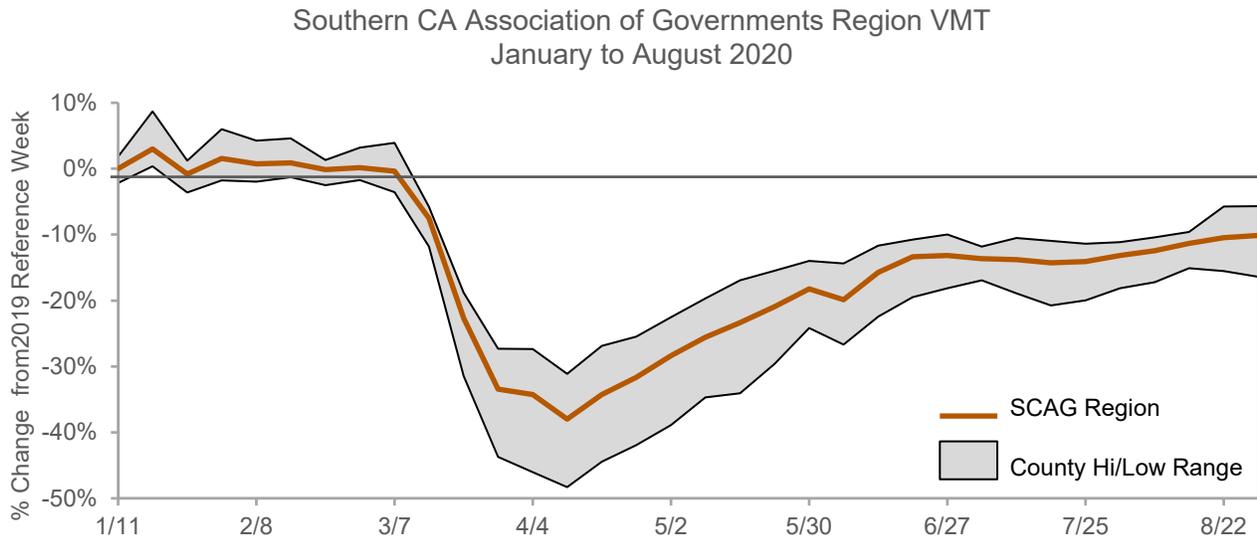
52 Boudette, Neal E. "[Looking to Buy a Used Car in the Pandemic? So is Everyone Else.](https://www.nytimes.com/2020/09/07/business/used-cars-pandemic.html?searchResultPosition=1)" *New York Times*. September 7, 2020. <https://www.nytimes.com/2020/09/07/business/used-cars-pandemic.html?searchResultPosition=1>.

53 IEA press release. "[Electric Car Sales This Year Resist COVID-19's Blow to Global Car Market.](https://www.iea.org/news/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>.

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)



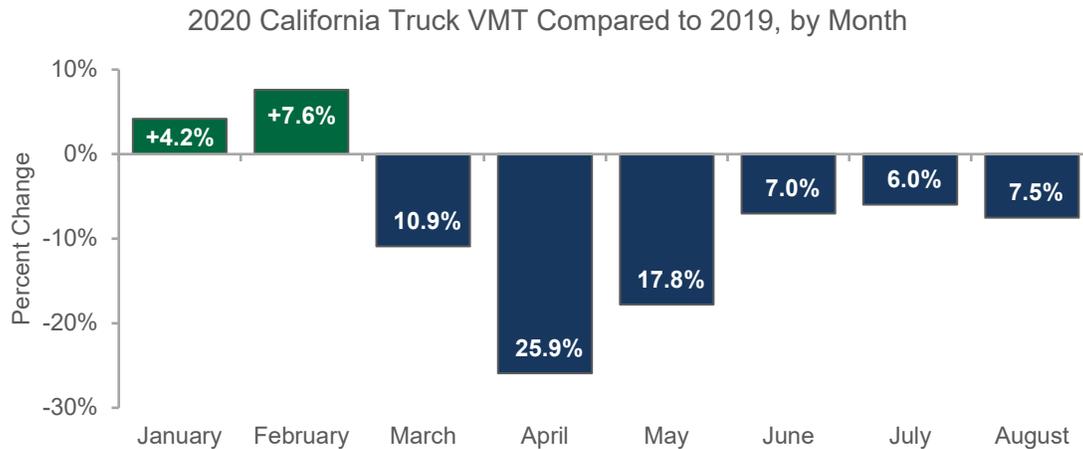
Data Source: Southern California Association of Governments

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 this recent decline, long-term truck VMT could increase to 119 million by 2040. Truck VMT in urban areas is also increasing rapidly, up 17 percent since 2015,

54 California Transit Association. “[Transit Watch: Public Transit in Crisis](https://caltransit.org/news-publications/our-newsroom/transit-watch/).” November 23, 2020. <https://caltransit.org/news-publications/our-newsroom/transit-watch/>.

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 expands.

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). <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). <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.^{62,63}

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.”⁶⁴ 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.⁶⁵

61 Guynn, Jessica. “[How Would You Like to Work From Home ‘Forever’? Twitter is Encouraging Employees to Do So.](https://www.usatoday.com/story/tech/2020/05/12/twitter-work-from-home-forever/3118879001/)” *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.](https://news.ucr.edu/articles/2020/08/04/pandemic-driving-reductions-wont-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>.

63 UC Riverside School of Business. “[COVID-19, Commuting, and Clean Air: A Look at Pandemic-Era Mobility and Transportation Emissions in California.](https://ucreeconomicforecast.org/wp-content/uploads/2020/08/Mobility_Emissions_COVID19_CEFD_White_Paper_August_2020.pdf)” July 2020. https://ucreeconomicforecast.org/wp-content/uploads/2020/08/Mobility_Emissions_COVID19_CEFD_White_Paper_August_2020.pdf.

64 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.

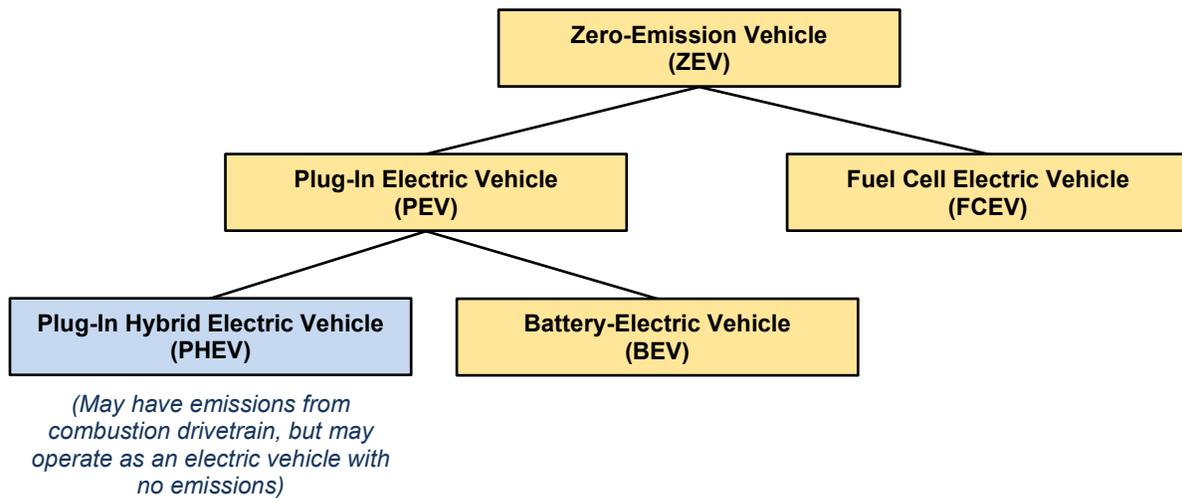
65 Curry, Melanie. “[What Benefits Telecommuting May Bring Are Still Very Much Unknown.](https://cal.streetsblog.org/2020/08/04/what-benefits-telecommuting-may-bring-are-still-very-much-unknown/)” StreetsBlogCal. August 4, 2020. <https://cal.streetsblog.org/2020/08/04/what-benefits-telecommuting-may-bring-are-still-very-much-unknown/>.

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.

ZEV deployment is 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.

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

66 [Executive Order B-55-18](https://www.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf). <https://www.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf>.

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

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.

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

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

Policy Origin	Objectives	Goals and Milestones
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

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). <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). □ <https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program>.

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 in AQIP funding, and the Legislature has deferred action on the 2020-2021 Cap-and-Trade Expenditure Plan. 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.⁷³

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

71 Doughman, Pamela. 2020. [Electric Program Investment Charge 2019 Annual Report](https://ww2.energy.ca.gov/2020publications/CEC-500-2020-009/CEC-500-2020-009-CMF.pdf). 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](https://ww2.arb.ca.gov/sites/default/files/2020-09/fy2021_fp_dis). 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 CARB. 2020. [The Fiscal Year 2020-2021 Funding Plan for Clean Transportation Incentives](https://ww2.arb.ca.gov/sites/default/files/2020-09/fy2021_fp_discussion_document_0.pdf). Staff Discussion Draft. September 19, 2020. https://ww2.arb.ca.gov/sites/default/files/2020-09/fy2021_fp_discussion_document_0.pdf.

funded by cap-and-trade auction proceeds, for which Fiscal Year 2020-2021 funding has not been released.⁷⁴

Recommendations

- **The state should invest in additional research to more thoroughly understand the trends 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 full electrification of light-duty passenger vehicles by 2035, the state needs to ensure that there is a full range of zero-emission vehicle (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 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**

⁷⁴ CARB. 2020. [Proposed Fiscal Year 2020-21 Funding Plan for Clean Transportation Incentives](https://ww2.arb.ca.gov/sites/default/files/2020-11/proposed_fy2020-21_fundingplan.pdf). November 6, 2020. https://ww2.arb.ca.gov/sites/default/files/2020-11/proposed_fy2020-21_fundingplan.pdf.

registered outside California but operate within the state. California has NO_x 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 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.⁷⁵

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.

⁷⁵ 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

Future Mobility: “Blue-Skies” or “Dirty Skies”?

- | | |
|---|---|
| ✓ Cars are all electric | ✓ Increased congestion |
| ✓ Energy mix is clean | ✓ Electricity produced with coal |
| ✓ Increased capacity | ✓ Increased travel demand |
| ✓ Better livability | ✓ More car-dependence of society |
| ✓ Integration with public transit | ✓ Reduced role of transit |
| ✓ Everybody shares intelligent vehicles | ✓ “Ghost” vehicles traveling on streets |

The future will largely be shaped by the policies that are developed today...

Credit: 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.⁷⁶ As one of the 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 is key to

76 Shaheen, Susan, Ph.D. et al. U.C. Berkeley Institute for Transportation Studies. UCCONNECT. “[Future of Mobility White Paper](https://escholarship.org/uc/item/68g2h1qv).” 2018. <https://escholarship.org/uc/item/68g2h1qv>.

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.⁷⁷ In the United States, nearly half of urban millennials have Uber on their smartphones.⁷⁸ These companies are outcompeting traditional taxi services. For example, in San Francisco, ride-hailing trips outnumber taxi trips by a factor of 12 to 1.⁷⁹ 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 finding 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.⁸⁰ 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-hailing displacement of other transportation modes increases total GHG emissions by 69 percent.⁸¹

77 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>.

78 Ibid.

79 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>.

80 Ibid.

81 Ibid.

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.⁸² At present, electrification rates are very low, with estimated use of EVs for ride-hailing at less than 1 percent.⁸³

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 (CO₂) 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 2023.⁸⁴ 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 2030.⁸⁵ 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 2040.⁸⁶

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

82 Ibid.

83 Fleming, Kelly, and Mollie Cohen-D'Agostino. "[Policy Pathways to TNC Electrification in California](https://policyinstitute.ucdavis.edu/wp-content/uploads/TNC-Electrification_May2020-v2.pdf)." 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.

84 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). https://ww2.arb.ca.gov/sites/default/files/2019-12/SB%201014%20-%20Base%20year%20Emissions%20Inventory_December_2019.pdf.

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

86 Khosrowshahi, Dara. "[Driving a Green Economy](https://www.uber.com/newsroom/driving-a-green-recovery/)." Uber Newsroom. September 8, 2020. <https://www.uber.com/newsroom/driving-a-green-recovery/>.

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 become more likely.⁸⁷

Researchers anticipate that AVs could become commercially available between 2025 and 2035.⁸⁸ As of October 2020, the California Department of Motor Vehicles has provided 60 manufacturers autonomous vehicle testing permits (with a driver), with five holding permits for driverless testing.⁸⁹ The CPUC is developing regulations for AV use in California through its Order Instituting Rulemaking on Regulations Relating to Passenger Carriers, Ridesharing, and New Online Enabled Transportation Services.⁹⁰

Researchers from the UC Davis Institute for Transportation Studies have developed a set of policy recommendations for the CPUC that would maximize the environmental and social benefits of AVs.⁹¹ A staff-level interagency working group convened by the Governor’s Office of Planning and Research (OPR) has developed a similar set of policy recommendations.⁹²

87 Governor’s Office of Planning and Research. [Statement on Automated Vehicles](https://opr.ca.gov/planning/transportation/automated-vehicles.html). OPR Website. <https://opr.ca.gov/planning/transportation/automated-vehicles.html>.

88 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](https://escholarship.org/uc/item/9g12v6r0).” 2018. <https://escholarship.org/uc/item/9g12v6r0>.

89 DMV web page. “[Autonomous Vehicle Testing Permit Holders](https://www.dmv.ca.gov/portal/vehicle-industry-services/autonomous-vehicles/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/>.

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

91 UC Davis Policy Institute for Energy, the Environment, and the Economy. “[Comments of UC Davis Policy Institute for Energy, Environment, and The Economy on the Commission’s Regulation of Autonomous Vehicles](https://3rev.ucdavis.edu/sites/g/files/dgvnsk6431/files/files/page/AV%20Regulation%20Q1%201_21_20_0.pdf).” Submitted to the CPUC’s Order Instituting Rulemaking on Regulations Relating to Passenger Carriers, Ridesharing, and New Online-Enabled Transportation Services. CPUC Rulemaking 12-12-011. Submitted January 21, 2020. https://3rev.ucdavis.edu/sites/g/files/dgvnsk6431/files/files/page/AV%20Regulation%20Q1%201_21_20_0.pdf.

92 UC Davis Policy Institute for Energy, the Environment, and the Economy. “[Comments of UC Davis Policy Institute for Energy, Environment, and The Economy on the Commission’s Regulation of Autonomous Vehicles](https://3rev.ucdavis.edu/sites/g/files/dgvnsk6431/files/files/page/AV%20Regulation%20Q1%201_21_20_0.pdf).” Submitted to the California Public Utilities Commission’s Order Instituting Rulemaking on Regulations Relating to Passenger Carriers, Ridesharing, and New Online-Enabled Transportation Services. CPUC Rulemaking 12-12-011.

These policy recommendations include the following:

- Electrify AVs as quickly and comprehensively as possible to maximize emissions benefits.
- Promote pooled use of AVs, especially through TNCs, to reduce congestion, VMT, and emissions.
- Promote the use of car-sharing for AVs to discourage use of privately owned, single occupancy vehicles.
- “Right-size” AVs. This involves matching different types of travel requests to vehicles appropriate for the trip needs. For example, a single passenger trip would use a smaller AV than a multipassenger trip.
- Program AVs in urban areas to operate at reduced speeds to improve urban livability and pedestrian safety.

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 October 2020, Californians have purchased 764,000 ZEVs (as shown in Figure 14),⁹³ while ZEV sales in the rest of the United States were about 840,000.⁹⁴ Sales of ZEVs in California have steadily increased since 2010 and comprised 8 percent of the new light-duty vehicle market in 2018. See Chapters 3 and 5 for a discussion of battery-electric and fuel cell electric vehicle sales trends.

Submitted January 21, 2020.

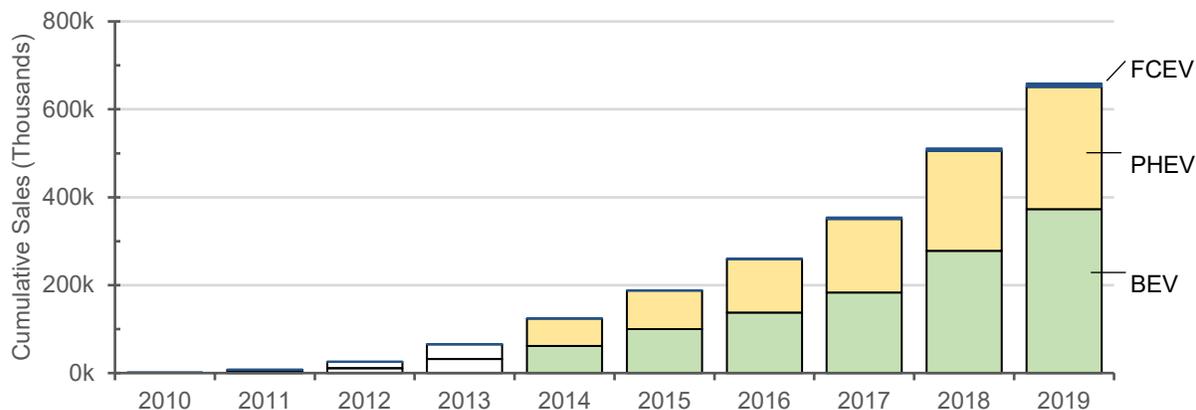
https://3rev.ucdavis.edu/sites/g/files/dgvnsk6431/files/files/page/AV%20Regulation%20Q1%201_21_20_0.pdf.

California Multi-Agency Workgroup on AVs. “[Automated Vehicle Principles for Healthy and Sustainable Communities](https://www.opr.ca.gov/docs/20181115-California_Automated_Vehicle_Principles_for_Healthy_and_Sustainable_Communities.pdf).” OPR Website. 2018. https://www.opr.ca.gov/docs/20181115-California_Automated_Vehicle_Principles_for_Healthy_and_Sustainable_Communities.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 U.S. ZEV sales data is based upon [data](#) from the U.S. Department of Energy. Accessed December 1, 2020. <https://www.energy.gov/eere/vehicles/articles/fotw-1153-september-28-2020-cumulative-plug-vehicle-sales-united-states-reach>.

Figure 14: Cumulative Sales of New ZEVs in California



Source: CEC ZEV Dashboard

California companies are also global leaders for the three Revolutions. California is the largest producer of ZEVs in the country, and home to more than 34 ZEV-related manufacturers that have a combined market capitalization of nearly \$500 billion. Based on a recent Los Angeles County Economic Development Corporation report, more than 60 electric vehicle (EV) and charging infrastructure companies are based in California. The report analyzes the “EV ecosystem” and finds that California had 276,000 EV related jobs in 2018. These sectors include utilities, construction, manufacturing, management, retail, and professional services.⁹⁵ Based on a less expansive set of job categories, industry data indicate over 700,000 automotive jobs in California.⁹⁶ With transportation equipment (including vehicles) as the second-largest export for the entire state, ZEVs are an increasing share of the state’s economy.⁹⁷

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 Markle, Lauren. [LAEDC Report: California and SoCal EV Industry is Growing, Giving Region Global Competitive Advantage](https://laedc.org/2020/03/01/laedc-ev-industry-report/). Los Angeles County Economic Development Corporation web page. March 1, 2020. <https://laedc.org/2020/03/01/laedc-ev-industry-report/>.

96 Alliance of Automobile Manufacturers. [“Autos Drive California Forward.”](https://autoalliance.org/in-your-state/CA/) AutoAlliance web page. December 8, 2020. <https://autoalliance.org/in-your-state/CA/>.

97 International Trade Association web page. [“National Trade and State Export Data.”](http://tse.export.gov/tse/tsehome.aspx) Accessed November 16, 2020. <http://tse.export.gov/tse/tsehome.aspx>.

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). <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](https://www.detroitnews.com/story/business/autos/general-motors/2020/06/16/gms-cruise-making-progress-self-drive-technology/3197539001/)." *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](https://www.bizjournals.com/sanjose/news/2020/07/09/amazon-zoox-purchase-terms-employee-stock-options.html)." *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](https://www.zdnet.com/article/amazon-to-pay-over-1-billion-to-secure-self-driving-startup-zoox-report/)." *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 in the near term 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](https://laborcenter.berkeley.edu/wp-content/uploads/2020/09/Putting-California-on-the-High-Road.pdf). 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). 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](https://laborcenter.berkeley.edu/wp-content/uploads/2020/09/Putting-California-on-the-High-Road.pdf). 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 may be at risk — the *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, such as the unionized BYD and Proterra bus manufacturing plants in Southern California. Other manufacturers have been reported for violations of wage, health and safety, and worker protection rules, notably at Tesla's nonunionized Fremont manufacturing plant. 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 incentivize "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 also 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 strategies¹⁰⁵ 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.

105 Zabin, Carol. 2020. [Putting California on the High Road: A Jobs and Climate Action Plan for 2030](https://laborcenter.berkeley.edu/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/>.

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

Lastly, the AB 398 report recommends strategies and plan 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

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). <https://www.energy.ca.gov/event/workshop/2020-08/session-1-clean-transportation-equity-jobs-and-economic-recovery>.

108 Ibid.

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 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](https://www.energy.ca.gov/programs-and-topics/programs/clean-transportation-program/clean-transportation-program-investment-5) 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 electric vehicles (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](https://www.kigtinc.com/single-post/2020/01/22/Electric-Vehicle-Network-Technician-EVNT-Training-Fellowship-Program) 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](https://leginfo.ca.gov/faces/billTextClient.xhtml?bill_id=201920200AB841) (Ting, Chapter 372, Statutes of 2020).
https://leginfo.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 as much as one-third 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](https://www.energy.ca.gov/news/2020-05/geothermal-lithium-recovery-projects-get-boost-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](https://www.energy.ca.gov/proceedings/business-meetings) for Business Meetings. <https://www.energy.ca.gov/proceedings/business-meetings>.

115 [Assembly Bill 1657](https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200AB1657) (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

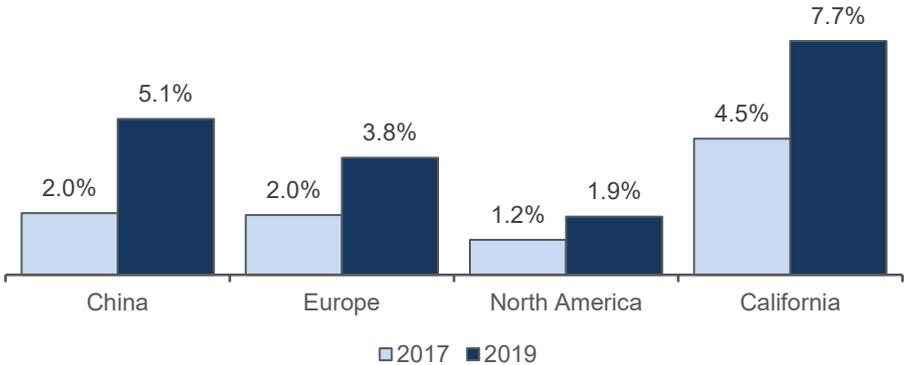
Plug-in Electric Vehicles (PEVs): Innovation, Decreasing Costs, and Market Growth

Light-Duty PEV Sector on the Rise

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

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 zero-emission vehicle (ZEV) markets. Globally, cumulative ZEV sales more than doubled from 3 million to nearly 7 million between 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.¹¹⁶

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



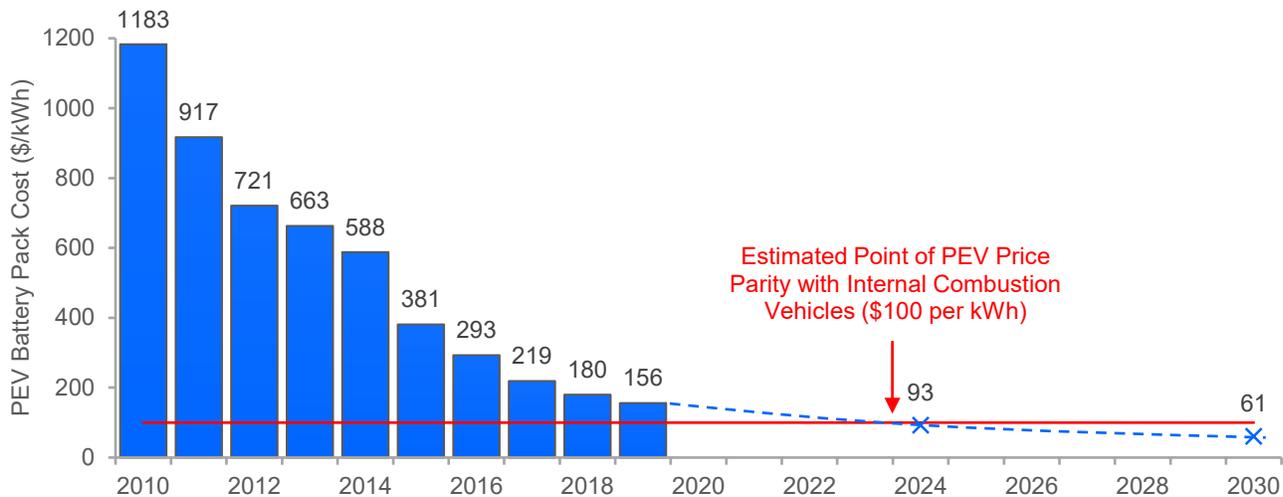
Sources: Bloomberg New Energy Finance (BNEF), California New Car Dealers Association, California Energy

116 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](https://ofv.no/bilsalget/bilsalget-i-2019) are available at <https://ofv.no/bilsalget/bilsalget-i-2019>. [2017 sales](https://ofv.no/bilsalget/bilsalget-i-2017) are available at <https://ofv.no/bilsalget/bilsalget-i-2017>.

Battery prices are a leading indicator of 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).¹¹⁷

Figure 16: BNEF PEV Battery Cost Declines

Bloomberg New Energy Finance PEV Battery Pack Prices, Historical and Projected



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 internal combustion engine (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

117 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>.

Reports concludes that fuel and maintenance savings of electric vehicles can save Californians \$889 to \$1,471 per year in fuel and \$240 to \$540 per year in maintenance.¹¹⁸

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 2024.¹¹⁹ 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 EV 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.¹²⁰ Guidehouse Insights consultants¹²¹ project a similar 19.5 million PEVs for all of North America.¹²² 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 some continued ZEV policy support from several directions, including programs such as 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

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

119 Albanese, Nicholas. BloombergNEF. "[Electric Vehicle Outlook 2020](https://efiling.energy.ca.gov/getdocument.aspx?tn=233410)." 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>.

120 Ibid.

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

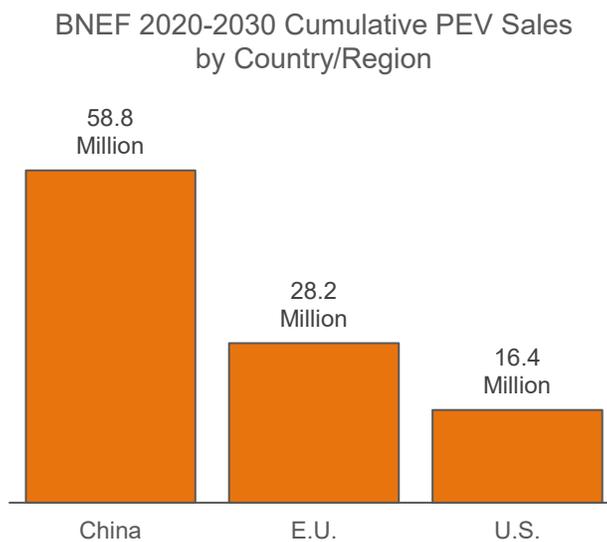
122 Chawan, Ajay. Guidehouse Insights. "[IEPR Workshop Transportation Trends and ZEV Market Update](https://efiling.energy.ca.gov/GetDocument.aspx?tn=233401&DocumentContentId=65917)". Presentation at the June 11, 2020, IEPR workshop on Light-Duty ZEV Update and Trends in Larger Vehicles. <https://efiling.energy.ca.gov/GetDocument.aspx?tn=233401&DocumentContentId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

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 have substantially more total sales from 2020 to 2030 compared to the United States.¹²³

Figure 17 compares BNEF's estimate of cumulative sales for China, the European Union (EU), and the United States. In contrast to BNEF's analysis, a recent International Energy Agency (IEA) assessment suggests that current U.S. policies are not enough to achieve this level of cumulative sales.¹²⁴ IEA's assessment does not consider California's new 2035 100 percent light-duty ZEV sales goal. 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



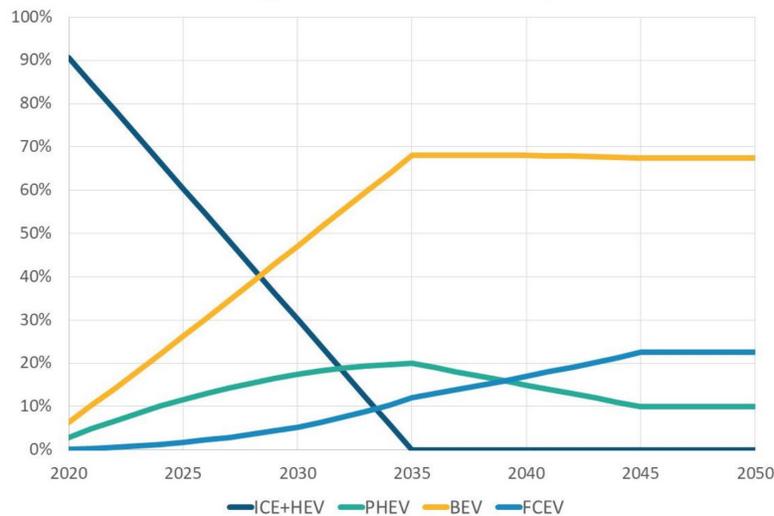
Data Source: BNEF

123 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>.

124 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 2045.¹²⁵ To contribute to this goal, the 100 percent LD ZEV goal established by Executive Order N-79-20 will play a key role.¹²⁶ 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 Mobile Source Strategy’s sales scenario 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 sufficient to have a complete LD ZEV stock by 2045.¹²⁷

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



Credit: CARB

125 [Executive Order B-55-18](https://www.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf). <https://www.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf>.

126 [Executive Order N-79-20](https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-text.pdf). <https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-text.pdf>.

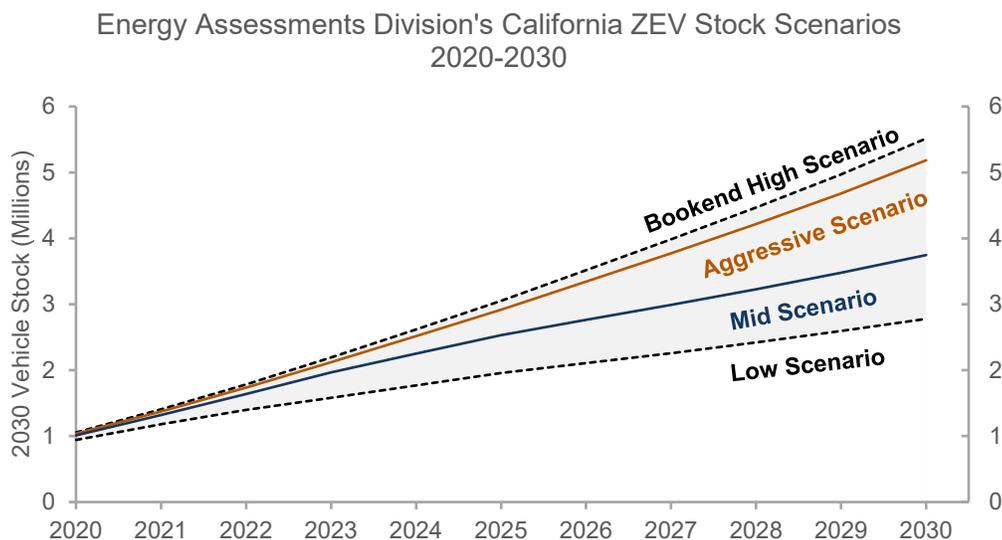
127 CARB. [2020 Mobile Source Strategy Draft](https://www2.arb.ca.gov/sites/default/files/2020-11/Draft_2020_Mobile_Source_Strategy.pdf). November 24, 2020. https://www2.arb.ca.gov/sites/default/files/2020-11/Draft_2020_Mobile_Source_Strategy.pdf. pp. 57-60.

PHEVs, which can burn gasoline, pose a challenge to the 2045 carbon neutrality goal because of their 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 cause consumer preferences to gravitate 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. 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 force outcomes based on the ZEV regulation or the new Executive Order N-79-20. For this reason, it contrasts with CARB's scenario, which is based on market penetration levels 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. 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 II.

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.¹²⁸ The company affirmed that it had sufficient capital to maintain technology rollout, highlighting its new Ford Mach-E crossover SUV to be 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 cost.¹²⁹ 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.¹³⁰ This finding may suggest that, while there is some acknowledgement of an electric future, it will not come in the next few years without active state policies and incentives. 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

128 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). <https://efiling.energy.ca.gov/GetDocument.aspx?tn=234186&DocumentContentId=67034>.

129 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).” <https://www.media.volvocars.com/us/en-us/media/pressreleases/248305/poll-finds-americans-feel-electric-vehicles-are-the-future-of-driving>.

130 Consumer Reports press release. “[New Survey Shows Strong Support for Electric Vehicles Across Economic Spectrum](https://advocacy.consumerreports.org/press_release/evsurvey2019/).” July 18, 2019. https://advocacy.consumerreports.org/press_release/evsurvey2019/.

percent supported an expansion of federal EV tax incentives, and 65 percent support government support of additional PEV charging infrastructure.¹³¹

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 much lower rates of electric vehicle adoption.¹³² 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 directly in the study.¹³³ 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

131 Yale Program on Climate Change Communication press release. “[New Poll: Voters Support Stimulus for Clean Energy, Not Fossil Fuels](https://climatecommunication.yale.edu/news-events/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/>.

132 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](https://www.elementascience.org/article/10.1525/elementa.419/).” *Elementa Science Anthology*. <https://www.elementascience.org/article/10.1525/elementa.419/>.

133 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://www2.arb.ca.gov/our-work/programs/accessible-clean-transportation-options-sb-350). <https://www2.arb.ca.gov/our-work/programs/accessible-clean-transportation-options-sb-350>.

COVID-19 crisis.¹³⁴ 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.¹³⁵

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 multiple 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.¹³⁶ 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 "Green Raiteros" program¹³⁷ 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

134 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). <https://efiling.energy.ca.gov/GetDocument.aspx?tn=234187&DocumentContentId=67035>.

135 Ibid.

136 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) (<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) (<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) (<https://efiling.energy.ca.gov/GetDocument.aspx?tn=235112&DocumentContentId=67987>).

137 EVgo press release. "[Green Raiteros Connects Rural Californians to Vital Services](https://www.evgo.com/about/news/green-raiteros-connects-rural-californians-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>.

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.¹³⁸ 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.¹³⁹ As costs continue to decline across the passenger vehicle ZEV market, maintaining strong new 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).¹⁴⁰ 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 the reliability of the battery of the used vehicle, the availability of EV

138 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). <https://efiling.energy.ca.gov/GetDocument.aspx?tn=234187&DocumentContentId=67035>.

139 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). <https://efiling.energy.ca.gov/GetDocument.aspx?tn=234187&DocumentContentId=67035>.

140 Paszkiewicz, Laura. Bureau of Labor Statistics. 2003. "[The Cost and Demographics of Vehicle Acquisition](https://www.bls.gov/cex/csxanthol03.pdf)." Consumer Expenditure Survey Anthology. <https://www.bls.gov/cex/csxanthol03.pdf>.

mechanics in the area, and the appropriate charging infrastructure available in the community.¹⁴¹ 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.¹⁴²

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 electric vehicles (FCEVs) is in Chapter 5. This IEPR Update will not discuss electrification of rail, which is another important aspect of transportation.¹⁴³

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

141 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>.

142 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.

143 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.

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.¹⁴⁴

The Greenlining Institute emphasized the extent to which communities should "help drive the project's direction."¹⁴⁵ 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. Disadvantaged community advocates want to make the highway a zero-emissions freight corridor and are seeking additional collaboration with community stakeholders to ensure a broad range of input into the visioning and planning process.

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 2025.¹⁴⁶ Walmart announced a global goal of complete freight operations electrification by 2040.¹⁴⁷ 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

144 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>.

145 Ibid, p. 5.

146 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/>.

147 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>.

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 their 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.¹⁴⁸ 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.

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.¹⁴⁹ 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

148 Johnson, Caley, Erin Nobler, Leslie Eudy, and Matthew Jeffers. 2020. [Financial Analysis of Battery Electric Transit Buses](https://www.nrel.gov/docs/fy20osti/74832.pdf). 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.

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

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.¹⁵⁰ 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.¹⁵¹ 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.¹⁵² These routes take advantage of the limited range of vehicles and charging at a central location. Rivian's comments regarding its recent contract 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.

150 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>.

151 Various workshop presenters. May 20, 2020, IEPR workshop on Medium- and Heavy-Duty ZEVs [transcript](#).
<https://efiling.energy.ca.gov/getdocument.aspx?tn=233611>.

152 Voets, Alex. May 20, 2020, IEPR workshop on Medium- and Heavy-Duty ZEVs [transcript](#).
<https://efiling.energy.ca.gov/getdocument.aspx?tn=233611>.

The non-profit organization Ceres has established a Corporate EV Alliance of 16 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.¹⁵³ 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.

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.¹⁵⁴ 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 for 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

153 Ceres. 2020. [The Road to Fleet Electrification](https://www.ceres.org/resources/reports/road-fleet-electrification). <https://www.ceres.org/resources/reports/road-fleet-electrification>.

154 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). <https://ww3.arb.ca.gov/regact/2019/act2019/appg.pdf>.

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.¹⁵⁵ 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.¹⁵⁶

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.¹⁵⁷ 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

155 ICF. 2019. [ICF Truck Report](https://caletc.com/wp-content/uploads/2019/12/ICF-Truck-Report_Final_December-2019.pdf). https://caletc.com/wp-content/uploads/2019/12/ICF-Truck-Report_Final_December-2019.pdf.

156 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)." https://theicct.org/sites/default/files/publications/ICCT_EV_HDVs_Infrastructure_20190809.pdf.

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

(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
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 ¹⁵⁸	\$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 bureaucratic details and processes involved with maximizing programmatic opportunities.¹⁵⁹

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

158 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.

159 May 20, 2020, IEPR workshop on Medium- and Heavy-Duty ZEVs [transcript](https://efiling.energy.ca.gov/getdocument.aspx?tn=233611). <https://efiling.energy.ca.gov/getdocument.aspx?tn=233611>.

regulation, it is important to help build the momentum for a smooth ramp up to the sales requirements in 2024.

Making Money Per Mile

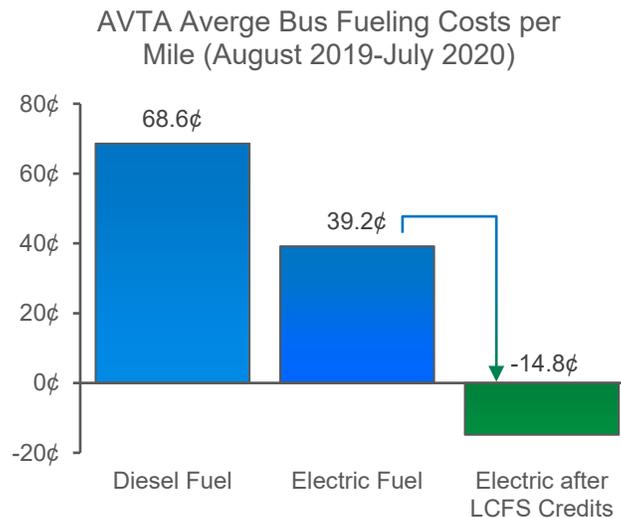
California’s LCFS provides revenue for low carbon-fuels, especially electricity. With an increasingly renewable electricity grid and the option to book and claim zero-emission electricity sources, revenue from these credits may more than offset the cost of the electricity. A key example of this is the 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 fiscal incentives for zero-emission vehicles (off-road, medium- and heavy-duty, and passenger) and infrastructure that are phased down 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 the scale-up of new vehicle electrification and the accelerated turnover of fossil fuel vehicles to electric vehicles. These should be adjusted over time to match trends in new and used vehicle markets 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 zero-emission vehicles (ZEVs) as well.
- **The state should explore the creation of financing programs that support fleet operators with the acquisition of medium- and heavy-duty ZEVs and the installation of related fueling infrastructure.** While direct fiscal incentives may be needed to help many types of medium- and heavy-duty vehicles transition toward ZEVs, the state should diversify its financial support to better meet the needs of its fleet operators. The low total cost of ownership and short payback periods for ZEVs in certain applications (such as transit buses) suggests an opportunity to leverage lifetime cost savings in order 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).¹⁶⁰ California has half of all passenger PEVs in the United States but only one-quarter of publicly available chargers.¹⁶¹ But investments by utility ratepayers and private industry are accelerating, fueled in part by the state’s commitment to electrifying transportation (Figure 23).¹⁶² Carmakers are partnering with charging providers to

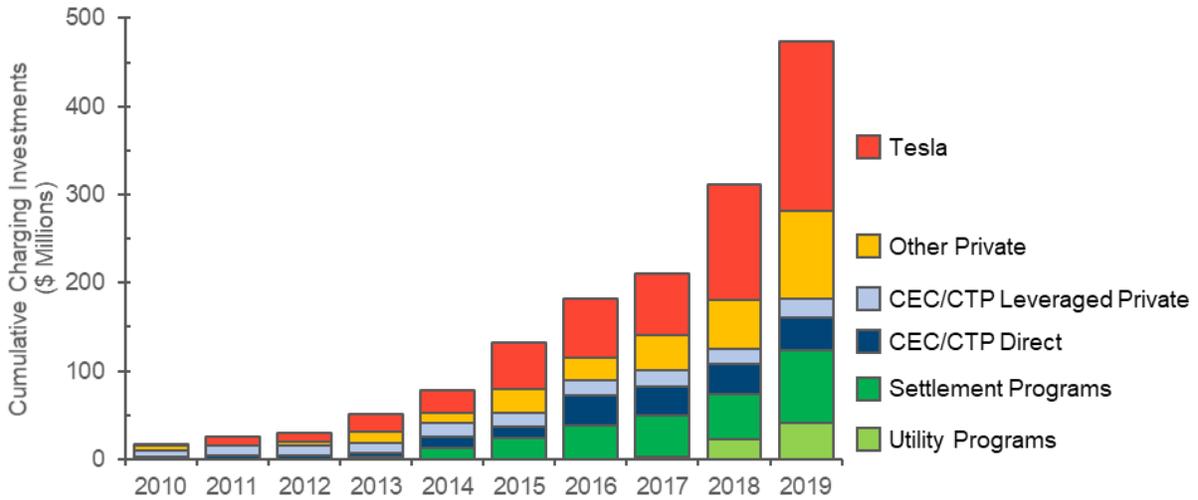
160 Level 1 charging provides about 4 miles of range per hour of charging. Level 2 typically provides about 35 miles per hour of charging but can range from 12 to 70 miles, depending on the vehicle and charger. DC fast charging also varies by vehicle and charger, with most chargers able to restore a 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.

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

162 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).”
<https://efiling.energy.ca.gov/GetDocument.aspx?tn=234906&DocumentContentId=67768>.

make it easier for their customers to access convenient charging. For example, General Motors is partnering with EVgo to expand charging access.¹⁶³ Further, VW’s newly announced electric ID.4¹⁶⁴ SUV, Lucid’s Air sedan,¹⁶⁵ and the Ford Mach E¹⁶⁶ come with packages of free charging on the Electrify America Network for up to three years. Government also has a role to play in the near term to leverage private investment to fill gaps and ensure access and benefits for low-income and disadvantaged communities.

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

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

164 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."](https://media.electrifyamerica.com/en-us/releases/112) September 21, 2020. <https://media.electrifyamerica.com/en-us/releases/112>.

165 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) <https://media.electrifyamerica.com/en-us/releases/7>.

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

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, 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 to use funding mechanisms available to address the disproportionality. 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 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). There are about 57,000 L2 chargers in public or private-shared spaces and about 5,000 DCFCs. The CEC's latest survey of chargers shows that the state is roughly 67,000 chargers short of the 2025 goal, as depicted in Figure 24.¹⁶⁷ (This predicted gap does not account for any investments in charging infrastructure that may be made without support from CEC, utility, or settlement funds.)

167 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). <https://www.energy.ca.gov/programs-and-topics/programs/clean-transportation-program/clean-transportation-program-investment>.

Figure 24: Making Progress Toward 2025 Charger Needs

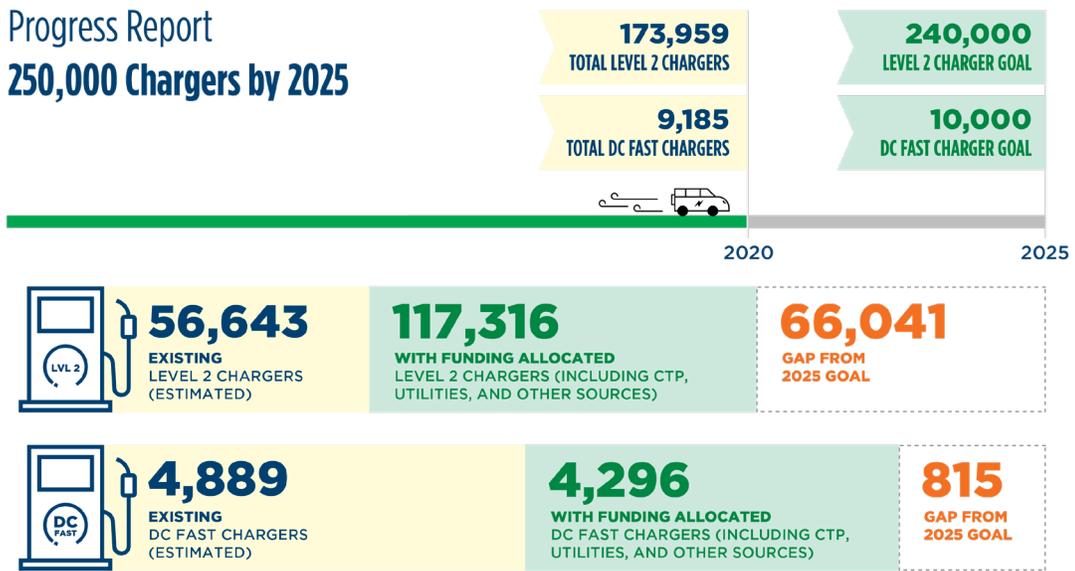


Image source: CEC

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).

Charging Infrastructure Model	Description
HEVI-LOAD ¹⁶⁸	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

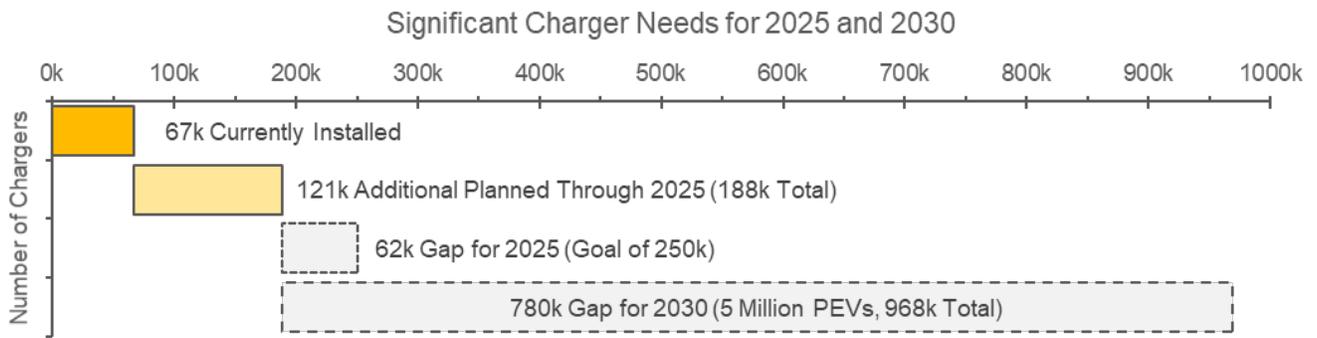
Source: CEC staff

One key takeaway from the overall modeling conversation is that charging infrastructure needs will continue to grow past 2025, and very 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 one million public or private-shared chargers (Figure 25), almost four times the 2025 goal.¹⁶⁹ 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 have ramped up further than the established goal of 5 million ZEVs on the road, making the charging need even larger. Under a near 8 million ZEV 2030 scenario, charger needs could exceed 1.5 million.

168 The HEVI-LOAD was formerly known as “HEVI-Pro.”

169 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](https://efiling.energy.ca.gov/getdocument.aspx?tn=234215). August 2020. <https://efiling.energy.ca.gov/getdocument.aspx?tn=234215>.

Figure 25: Charger Needs for 5 Million Light-Duty PEVs, Including Chargers for Road Trips



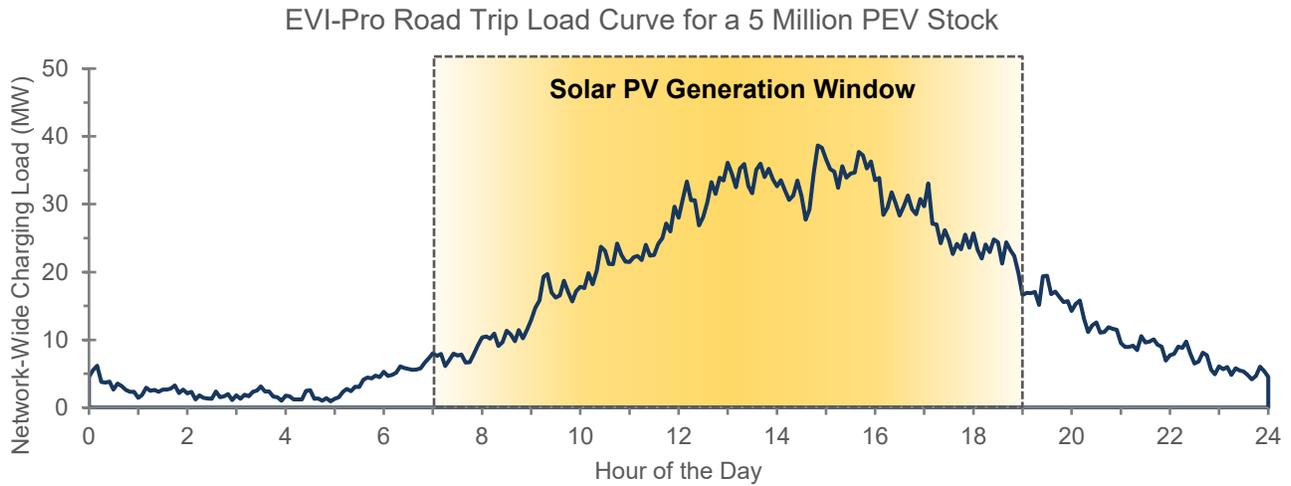
Credit: CEC

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 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 26 on EVI-Pro RoadTrip’s average daily results.)¹⁷⁰

170 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)" [https://efiling.energy.ca.gov/GetDocument.aspx?tn=234213&DocumentContentId=67049.](https://efiling.energy.ca.gov/GetDocument.aspx?tn=234213&DocumentContentId=67049)

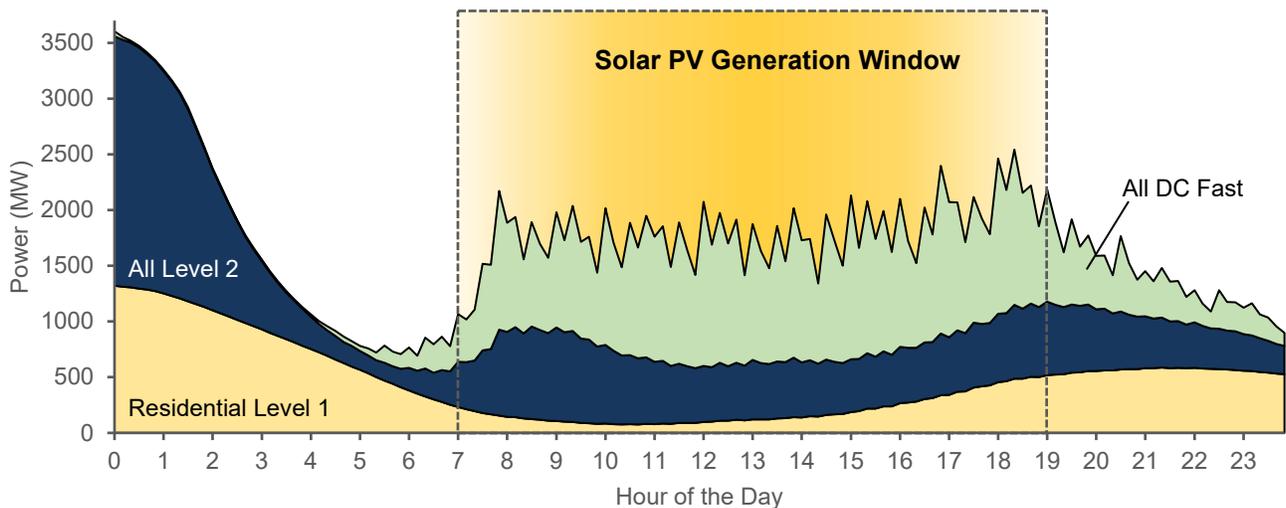
Figure 26: EVI-Pro Road Trip Charging Load Modeling Shows Partial Alignment with Solar Generation on a Typical Day in 2030



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 27 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 particular note is the near instantaneous demand spike of nearly 2500 megawatts at 12:00 a.m.

Figure 27: Load Profile for a Typical Weekday for EVI-Pro 2 With 5 Million PEVs

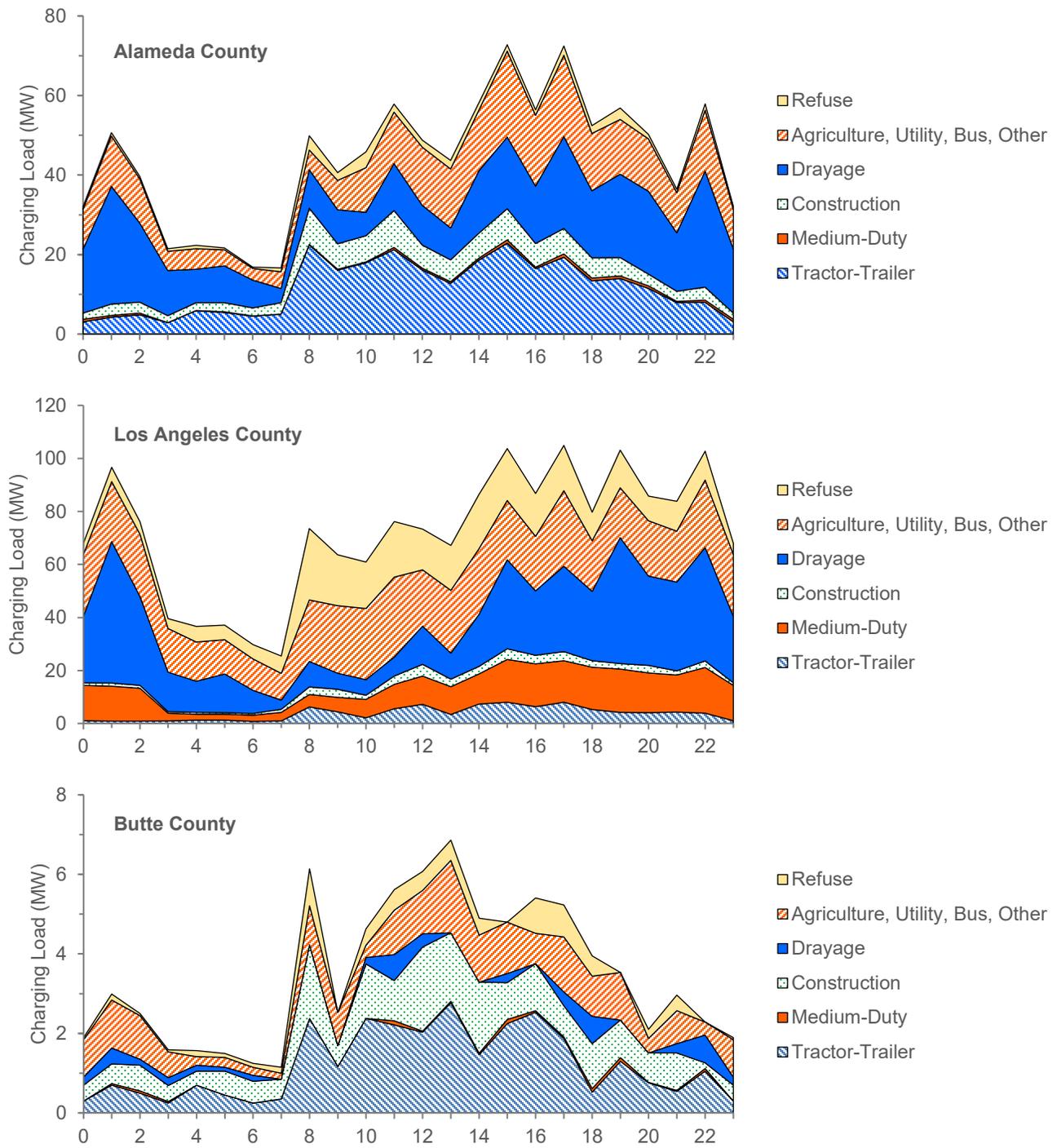


Data Source: National Renewable Energy Laboratory

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.)¹⁷¹ Preliminary results from HEVI-LOAD indicate that the bulk of MD/HD vehicle charging generally occurs during the day.

171 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)." <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 further below.

Standardization and Interoperability

Standardization of charging connectors is another aspect to effective charging infrastructure buildout. 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, and Tesla's proprietary 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 charging connectors, even from within a specific vehicle OEM, is a common frustration among vehicle operators.¹⁷² 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.¹⁷³ Regardless of when MD and HD vehicle manufacturers converge on connector design, continued fragmentation in the market confuses consumers and means that chargers used today may be obsolete several years later. 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 that explores the various costs associated

172 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>.

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

with charging infrastructure.¹⁷⁴ 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,”¹⁷⁵ 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. 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.¹⁷⁶ However, there is a consistent perception that charging will be difficult and expensive. A common factor in many disadvantaged communities is the high number of people who live in MUDs.¹⁷⁷ 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 density than high-income tracts.¹⁷⁸ While this difference is somewhat modest, the need for

174 Rocky Mountain Institute. “[Reducing Charging Infrastructure Costs](https://rmi.org/the-hidden-costs-of-ev-charging-infrastructure/).” January 16, 2020. <https://rmi.org/the-hidden-costs-of-ev-charging-infrastructure/>.

175 “Future proofing” is the process of trying to predict future events and developing methods to minimize the stress of future events.

176 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). <https://efiling.energy.ca.gov/GetDocument.aspx?tn=234187&DocumentContentId=67035>.

177 Ibid.

Various presenter comments. August 4, 2020, IEPR workshop on Engaging Communities for Charging Infrastructure Needs [transcript](https://efiling.energy.ca.gov/GetDocument.aspx?tn=235912&DocumentContentId=68870). <https://efiling.energy.ca.gov/GetDocument.aspx?tn=235912&DocumentContentId=68870>.

178 Hoang, Tiffany. “[SB 1000 Electric Vehicle Charging Infrastructure Deployment Assessment](https://efiling.energy.ca.gov/getdocument.aspx?tn=234182).” Presentation at the August 4, 2020, IEPR workshop on Plug-In Electric Vehicle Charging Infrastructure. <https://efiling.energy.ca.gov/getdocument.aspx?tn=234182>.

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 of public charging, the equivalent gasoline price may sometimes approximate the same as current gasoline costs, or even more. Some creative public charging business models may be able to keep the cost to charge very low by putting charging within a value-add 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.¹⁷⁹ 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.¹⁸⁰

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.¹⁸¹ For example, car-sharing programs in

179 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). <https://efiling.energy.ca.gov/GetDocument.aspx?tn=234187&DocumentContentId=67035>.

180 CEC Chair David Hochschild comments. 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), p. 56. <https://efiling.energy.ca.gov/GetDocument.aspx?tn=234187&DocumentContentId=67035>.

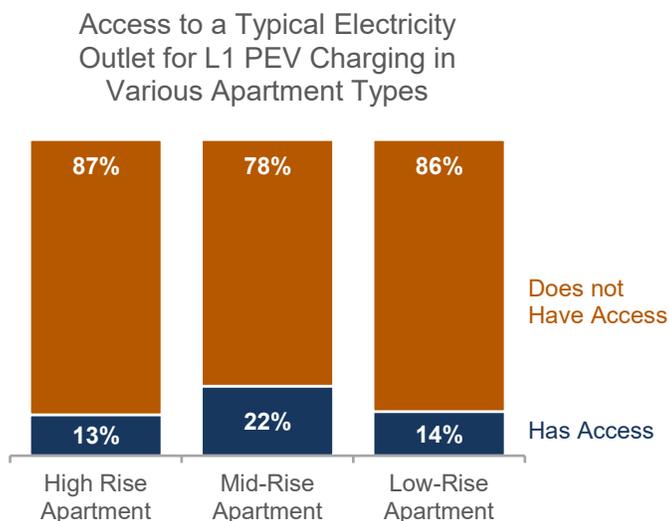
181 See transcripts for the May 20, 2020, IEPR workshop on Medium- and Heavy-Duty ZEVs transcript (<https://efiling.energy.ca.gov/getdocument.aspx?tn=233611>), the June 11, 2020, IEPR workshop on Transportation Trends and Light-Duty ZEV Market Update [transcript](https://efiling.energy.ca.gov/GetDocument.aspx?tn=234187&DocumentContentId=67035) (<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](https://efiling.energy.ca.gov/GetDocument.aspx?tn=235912&DocumentContentId=68870) transcript (<https://efiling.energy.ca.gov/GetDocument.aspx?tn=235912&DocumentContentId=68870>).

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). Recent CEC/NREL analysis estimates that only about one in seven MUD units in California has access to L1 charging.¹⁸² (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.

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



Credit: CEC

¹⁸² 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.

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-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.

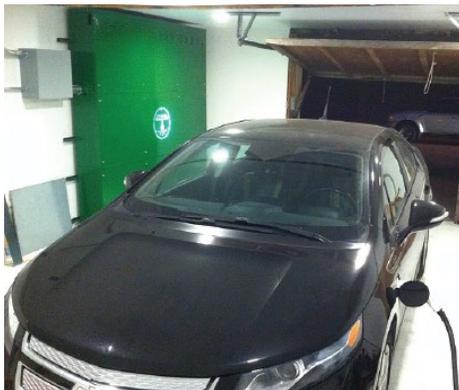


Image Credit: PowerTree Services

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 DER 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 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 a 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.¹⁸³ 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.¹⁸⁴ 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 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):** This program created by the CEC's Clean Transportation Program offers incentives for publicly available charging projects, implemented by the Center for Sustainable Energy. Existing projects have been funded at \$75.5 million, including \$4.5 million in matching partner funding. For 2020, an additional \$84.1 million is planned, including more than \$30 million from matching partner funding.¹⁸⁵
- **CARB/Volkswagen Settlement:** Volkswagen's subsidiary Electrify America plans to spend \$800 million from 2017 to 2026 on ZEV infrastructure, education, and access. For

183 West Coast Clean Transit. 2020. [West Coast Clean Transit Corridor Initiative](https://www.westcoastcleantransit.com/).
<https://www.westcoastcleantransit.com/>. p. 40.

184 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>.

185 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>.

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.¹⁸⁶

- **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.¹⁸⁷
- **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.¹⁸⁸

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 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 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,

186 Electrify America. 2018. [California ZEV Investment Plan: Cycle 2](https://www.electrifyamerica.com/assets/pdf/Cycle%202%20California%20ZEV%20Investment%20Plan.3e6ce81a.pdf).
<https://www.electrifyamerica.com/assets/pdf/Cycle%202%20California%20ZEV%20Investment%20Plan.3e6ce81a.pdf>.

187 Sisto, Carrie. "[CPUC Transportation Electrification and Vehicle-Grid Integration Programs](https://efiling.energy.ca.gov/GetDocument.aspx?tn=233625&DocumentContentId=66203)." 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>.

188 CPUC. 2020. [CPUC/NRG Settlement Agreement](https://www.cpuc.ca.gov/General.aspx?id=5936). <https://www.cpuc.ca.gov/General.aspx?id=5936>.

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.¹⁸⁹ The ruling gave IOUs an opportunity for case-specific CPUC approval of IOU charging infrastructure programs. The case-by-case approach shall be 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.¹⁹⁰ 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.

With increasing private investor interest in charging infrastructure technology,¹⁹¹ it is critical to recognize the potential for VGI solutions enabled by these project developers. VGI solutions can confer benefits for renewables penetration and vehicle owners. For example, additional IOU programs as currently structured may become a less effective use of ratepayer funds and may introduce an uneven playing field, potentially in tension with the investment and cost recovery mechanism identified in Assembly Bill 841 (Ting, Chapter 372, Statutes of 2020). By mid-2021, the CPUC is directed to approve a utility tariff or rule that authorizes IOUs to design

189 CPUC. 2014. [Decision 14-12-079](#).

<https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M143/K682/143682372.PDF>.

190 See <https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442463904> or www.cpuc.ca.gov/zev.

191 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>.

and dispatch electric distribution infrastructure¹⁹² for separately metered charging on the utility side of the customer's meter. The costs are tracked in a memorandum account and would be recovered in the utilities' subsequent general rate case.¹⁹³ Encouraging the development of utility-side electric distribution costs for separately metered charging may remove incentives for project developers and utilities to reduce capital expenditures and manage load. These incentives may be removed because the costs of the EV load are "added not integrated" with the system and would be subject to EV-only rates that cannot be balanced with other non-EV load.¹⁹⁴ This authorization has the potential to disadvantage charging solutions that impact the grid less. It is important for regulators to foresee this well ahead of time and plan for a smooth dovetailing of a private charging market with current funding programs to maximize VGI. While utilities have a role in helping shape this market in response to their own load management capabilities, innovative approaches to using existing funding channels may present a unique opportunity. Optimizing private, public, and ratepayer investment that leverages costs and maximizes infrastructure built per dollar invested may require new approaches that open markets to ensure competitive access for developers, broad availability, and low costs for consumers.

Create Market Opportunities for Accelerating Charging Infrastructure and VGI

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 typically serve only charging infrastructure electricity demands by increasing the power capacity of the grid. Some charging options are independent of the grid, and others specifically target low grid impacts¹⁹⁵ with behind-the-

192 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."

193 Public Utilities Code 740.19

194 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>.

195 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>.

meter storage.¹⁹⁶ 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 resiliency (Chapter 7) is large. However, IOU funding programs focused predominantly on utility distribution infrastructure expansion do not value the benefits of these alternatives. A focus on meeting energy demands created by transportation electrification, rather than necessarily increasing the power capacity of the grid, may help the charging infrastructure market value all options more adequately.¹⁹⁷

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 commercial and industrial sites.¹⁹⁸ Several risk factors in charging infrastructure investment are potentially lowered under this model, including the elimination of ratepayer impacts for demand charges or grid infrastructure, a shortened project development cycle, investor confidence in capital expenditure from understanding the project risk before construction, and simpler permitting to reduce overhead. Cambridge Capital concludes that with CEC and developers bringing equity financing to a project development company that is sold after construction begins to an infrastructure asset owner that is funded via long-term debt, state or ratepayer funding under this model could be leveraged up to 40 times with the right regulatory framework.

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 potential for 5 million PEVs on the road by 2030 requires planning for 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

196 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>.

197 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>.

198 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>.

charging funding programs. Continuing with existing charging funding programs alone will not be enough to build out the charging infrastructure needed to achieve state goals and could lead to missed opportunities for accelerated charging infrastructure installation and the VGI benefits.

Some existing regulations already target charging infrastructure deployment and use without directly funding chargers themselves. For example, CARB's Low Carbon Fuel Standard 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,¹⁹⁹ as well as incremental fuel credits to encourage smart charging.²⁰⁰

New approaches to maximize behind-the-meter capacity (such as coordinating distributed generation and energy efficiency deployments simultaneously with charging) could be a more efficient use of public and ratepayer funds. New regulatory and funding mechanisms may be needed to spur private investment, ensure buildout to meet demand, and ensure low costs for all Californians, especially those in disadvantaged communities or low-income communities.

Maximizing Charger Benefits at the Lowest Cost Will Spur Private Investment

In collaboration with CPUC staff, the CEC made its first steps on developing and presenting a new approach to funding charging infrastructure cost effectively. In workshops on both June 24 and August 4, 2020, CEC staff presented a potential funding pathway to leverage additional funds currently used for charging infrastructure.²⁰¹ The approach is analogous to the Federal Public Utility Regulatory Policies Act (PURPA), which required public utilities to buy power from independent operators that could produce power at a lower cost than what the utility would have paid. The difference between what the utility would have paid and what they paid to the independent producer is known as "avoided cost of producing power." Analogously, the

199 [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.

200 [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.

201 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>.

“avoided cost of charging” is 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. The approach received many supportive comments from the public. Comments emphasized the potential for it to enhance charging infrastructure, but also encouraged additional development with input from stakeholders.

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 is not predicated upon 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 approaches such as CALeVIP. In this new option, the public funding (which could pool capital from driver and pollution fees or electric ratepayers) is optimized for the lowest-cost solution. 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 their cost. This approach has the potential to leverage public, ratepayer, and other existing funding sources in a way that can 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.²⁰² 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. Multiple approaches to manage increasing renewables on the grid are in order. For PEVs, encouraging charging during peak renewable generation, particularly for vehicles which 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. This can be done with Vehicle-Grid Integration (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.²⁰³ 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 if needed and 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 Terms²⁰⁴):

- *VIG* (or managed, controlled, or “smart” charging) involves controlled ramping-up or ramping-down of chargers of individual or multiple PEVs.

202 Staff analysis of data from Energy Information Administration’s [Electricity Data Browser](https://www.eia.gov/electricity/data/browser/).
<https://www.eia.gov/electricity/data/browser/>.

203 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>.

204 VGI Working Group [Glossary of Terms](#).
<https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442455744>.

- V2G involves controlled (dis)charging of energy from individual or multiple PEVs to facility circuits connected to the electric power system.
- V2X involves controlled discharging of energy from individual or multiple 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 previously 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.²⁰⁵

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.²⁰⁶ Charging “happy hours” that have very low cost or even free

205 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>.

206 Ibid.

charging for users 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.²⁰⁷

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.²⁰⁸ Additional grid services, integration with solar photovoltaic (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 the 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 cycling²⁰⁹ within defined ranges.²¹⁰ One recent study found that a smart VGI model could enhance battery life compared to drivers that

207 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). <https://www.osti.gov/biblio/1557041>.

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

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

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

charge to 100 percent every night, with a smart VGI algorithm reducing battery capacity fade by 9.1 percent.²¹¹

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).²¹² 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.²¹³

Targets for VGI are Essential to Signal for Scale Up

Equipment to manage VGI for home use is cost-competitive with nonnetworked charging equipment,²¹⁴ so the major hurdles are consumer acceptance, implementing appropriate capabilities, and an effective regulatory framework to maximize 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.

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

212 July 15, 2020, IEPR workshop on ZEV Resilience and Three Revolutions in Transportation [transcript](https://efiling.energy.ca.gov/getdocument.aspx?tn=234949), <https://efiling.energy.ca.gov/getdocument.aspx?tn=234949>.

213 "[Nuvve and Blue Bird Announce Availability of Nationwide Vehicle-to-Grid \(V2G\) School Bus Offer.](https://www.prnewswire.com/news-releases/nuvve-and-blue-bird-announce-availability-of-nationwide-vehicle-to-grid-v2g-school-bus-offer-301131309.html)" 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.](https://www.prnewswire.com/news-releases/nuvve-corporation-and-lion-electric-announce-vehicle-to-grid-v2g-collaboration-301177245.html)" November 19, 2020. <https://www.prnewswire.com/news-releases/nuvve-corporation-and-lion-electric-announce-vehicle-to-grid-v2g-collaboration-301177245.html>.

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

The CEC has established a roadmap with several recommendations on accelerating VGI.²¹⁵ There are several targets for VGI implementation moving forward:

1. Incentives for 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 any site's charging technology 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 sessions, including time- and location-specific charging data from across the state, are needed to conduct 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**

215 California VGI Roadmap Update [web page](https://www.energy.ca.gov/programs-and-topics/programs/california-vehicle-grid-integration-roadmap-update). <https://www.energy.ca.gov/programs-and-topics/programs/california-vehicle-grid-integration-roadmap-update>.

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 analogous 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 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 100 deployed hydrogen fuel stations. As of November 2020, 44 stations are in operation, with another 18 in development and allocated funding for roughly 110 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.

Fuel Cell Electric Vehicles (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 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.²¹⁶ 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.²¹⁷ 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 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 LD Mirai FCEV.²¹⁸ Other than the fuel stacks, a fuel cell electric truck mostly needs additional

216 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). <https://efiling.energy.ca.gov/getdocument.aspx?tn=234946>.

217 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>.

218 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>.

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 both light-duty and MD/HD vehicles, higher vehicle cost, lack of model availability, and higher cost of hydrogen (particularly green hydrogen). California is a global leader on overcoming these barriers.

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 provides rebates for LD FCEV purchases or leases, and 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 OEMs estimates 48,000 LD FCEVs will be sold in California by 2025. In comparison, 50,000 LD FCEVs are expected in Asia by 2025 and fewer in Europe. By contrast, Asia dwarfs North America and Europe for expected adoption of fuel cell buses, MD trucks, and other non-LD applications such as portside equipment, freight applications, commuter rail, trains, and trams. By 2025, China has a target of 50,000 commercial vehicles, and the rest of Asia has a target of 5,000; in contrast, North America is expected to have between 100 and 1,000 MD and HD FCEVs.

Table 4: Estimated Light-Duty and Other FCEV Deployment by 2025

Continents	Light-Duty FCEVs	Buses, Medium- and Heavy-Duty Trucks, Port-side Equipment, Freight, Commuter Rail, Trains, and Trams
North America ²¹⁹	Up to 48,000	<ul style="list-style-type: none"> • Buses: between 40 and 370 • Medium-duty trucks: between 40 and 400 • Heavy-duty trucks: between 10 and 50 • Port-side equipment: 10 pilot • Rail freight (locomotives): one locomotive • Commuter rail: one commuter rail system
Asia	Up to 50,000 ²²⁰	<ul style="list-style-type: none"> • Buses: between 1,000 and 3,000²²¹ • Trucks: between 1,000 and 2,000²²² • Tram: 1²²³

219 CEC staff analysis and CARB OEM survey. May 1, 2020.

220 Email from Dominika Kalinowska with GIZ on April 19, 2020.

[International Partnership on Fuel Cells and Hydrogen in the Economy](https://www.iphe.net/republic-of-korea). <https://www.iphe.net/republic-of-korea>.

Korea Herald [web page](http://www.koreaherald.com/view.php?ud=2020001250000032). <http://www.koreaherald.com/view.php?ud=2020001250000032>.

Deign, Jason. "[China to Eliminate Subsidies for Fuel Cell Cars](https://www.greentechmedia.com/articles/read/china-to-estimate-subsidies-for-fuel-cell-cars)." Greentech Media. October 15, 2019. <https://www.greentechmedia.com/articles/read/china-to-estimate-subsidies-for-fuel-cell-cars>.

221 California Fuel Cell Partnership. By the Numbers [web page](https://cafcp.org/by_the_numbers). https://cafcp.org/by_the_numbers.

222 Ibid.

International Partnership for Hydrogen and Fuel Cells in the Economy [web page](https://www.iphe.net). <https://www.iphe.net>.

223 Salvacion, Manny. "[China Presents the World's First Hydrogen-Fueled Tram](http://en.yibada.com/articles/21142/20150321/china-worlds-first-hydrogen-fueled-tram.htm#)." Yibada web page. March 21, 2015. <http://en.yibada.com/articles/21142/20150321/china-worlds-first-hydrogen-fueled-tram.htm#>.

Continents	Light-Duty FCEVs	Buses, Medium- and Heavy-Duty Trucks, Port-side Equipment, Freight, Commuter Rail, Trains, and Trams
Europe	Between 1,000 and 3,000 ²²⁴	<ul style="list-style-type: none"> • Buses: between 50 and 100²²⁵ • Trucks: Between 100 and 200²²⁶ • Train and Trams: 2²²⁷

Source: CEC

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.

224 Email from Dominika Kalinowska with GIZ on April 19, 2020.

International Partnership for Hydrogen and Fuel Cells in the Economy [web page](https://www.iphe.net). <https://www.iphe.net>.

225 Carr, Jackson. "[Germany Fuel Cell Industry Developments](http://www.fchea.org/in-transition/2019/3/18/germany-fuel-cell-industry-developments)." Fuel Cell and Hydrogen Energy Association web page. March 25, 2019. <http://www.fchea.org/in-transition/2019/3/18/germany-fuel-cell-industry-developments>.

226 CEC staff analysis of projects in California. May 1, 2020.

227 Carr, Jackson. "[Germany Fuel Cell Industry Developments](http://www.fchea.org/in-transition/2019/3/18/germany-fuel-cell-industry-developments)." Fuel Cell and Hydrogen Energy Association web page. March 25, 2019. <http://www.fchea.org/in-transition/2019/3/18/germany-fuel-cell-industry-developments>.

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.²²⁸ 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 CO₂ 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 is because hydrogen gas is completely separated from the carbon in the feedstock, maximizing CO₂ capture at the point of production.²²⁹

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.

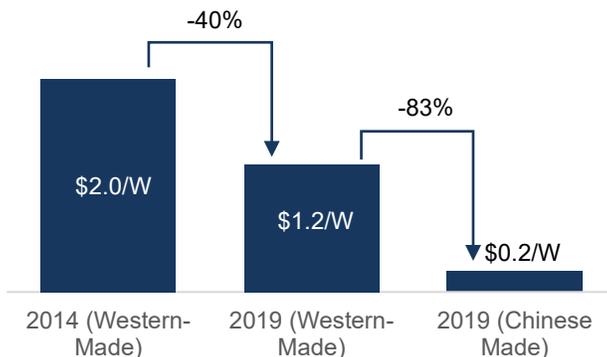
On July 2, 2020, the CEC hosted an IEPR workshop on hydrogen and FCEV market status. The workshop began with a presentation from BNEF highlighting large cost reductions for the supply of renewable hydrogen. For example, alkaline electrolyzer costs in western countries have declined 40 percent in the last five years. Current electrolyzers available in China have

228 As articulated in Germany's [National Hydrogen Strategy](#), p. 2.
https://www.bmbf.de/files/bmwi_Nationale%20Wasserstoffstrategie_Eng_s01.pdf.

229 Baker, Sarah E., Joshua 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: 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.

been as low as 83 percent lower than current western alkaline electrolyzers. (See Figure 30.²³⁰)

Figure 30: 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.

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

230 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>.

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 October 2020, 62 stations are either in operation or development, and the proposed awards under GFO-19-602 are expected to add 111 stations, for a total of 173 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 2020.²³¹ With some station developers indicating the possibility of building stations without grant funding, California may be able to close the gap of 27 stations to reach the 200 stations goal by 2025 (Table 5).

Table 5: Progress Toward 200 Hydrogen Stations by 2025

Category	Hydrogen Refueling Stations
Number of Existing Open Retail	44
Number for Which Funding has Been Allocated	128
Total	173
2025 Goal (Executive Order B-48-18)	200
Gap From Goal	27

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 it did not diminish the light-duty customer experience. This approach was taken to potentially

231 Vacin, Gia. “[Approaches to Assessing ZEV Funding Program Benefits](https://efiling.energy.ca.gov/getdocument.aspx?tn=234906).” Presentation at the September 25, 2020, IEPR workshop on Approaches to Assessing Funding Program Benefits. <https://efiling.energy.ca.gov/getdocument.aspx?tn=234906>.

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 6 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 6: 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
Norway	6
Austria	5
Netherlands	5
Italy	4
Brazil	2
Czech Republic ²³²	2
India	2

Source: CEC and IPHE

232 FuelCellsWorks. “[ORLEN Invests in the First Hydrogen Stations in the Czech Republic.](https://fuelcellsworks.com/news/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/>.

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.²³³

Additional support for FCEVs comes in the form of vehicle purchase rebates. The Clean Vehicle Rebate Project offers \$4,500 rebates for FCEVs up to \$7,000, depending on income, almost twice that offered for PEVs. While these rebates are beneficial to the market and can increase volumes and decrease production costs, panelists at the July 2 IEPR workshop emphasized the long-term view of ensuring sufficient refueling capacity, as hydrogen infrastructure is a key barrier to market growth.

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 where a station makes sense for a growing network of passenger cars.²³⁴ By 2030, China aims to have 1,000 stations, Japan aims for 900, and South Korea aims for 500.

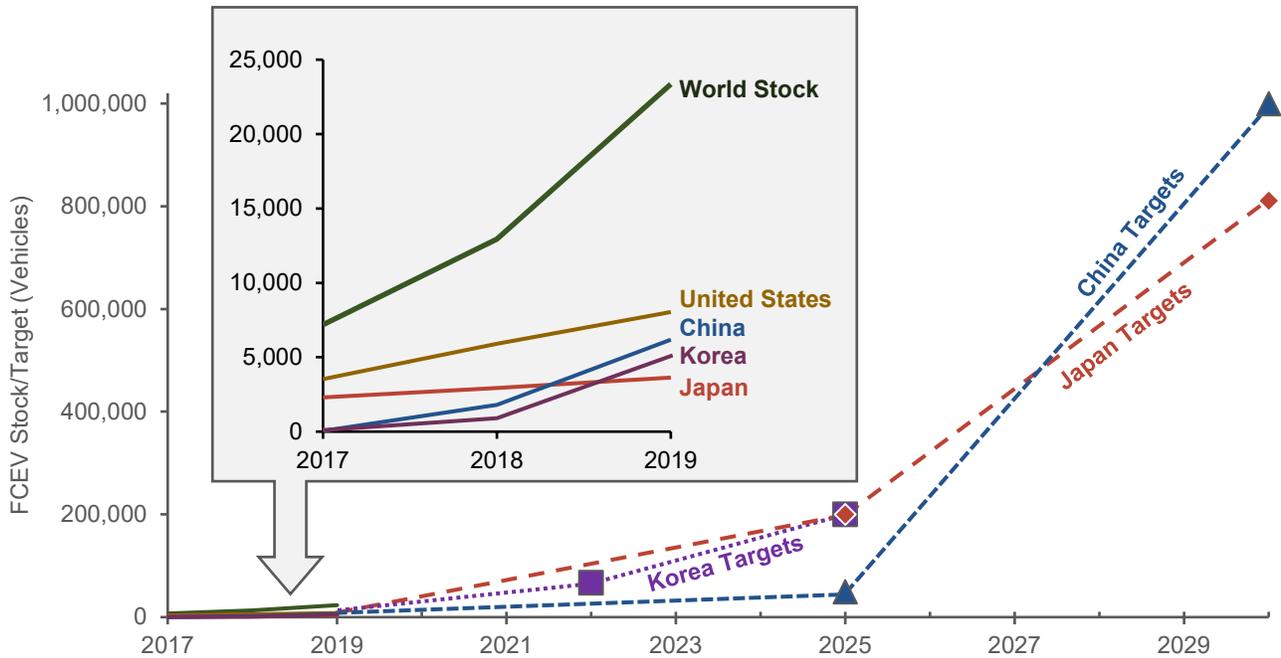
The International Energy Agency (IEA) presented specific FCEV targets in the July 2, 2020, IEPR workshop, shown in Figure 31 below. Some of the most aggressive targets are from Japan, South Korea, and China. Japan aims to achieve 200,000 FCEVs by 2025 and 800,000 by 2030. The vehicles are expected to be mostly light duty because of the investments Toyota and Honda 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

233 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>.

234 H2 Mobility [web page](https://h2.live/en/h2mobility). <https://h2.live/en/h2mobility>.

FCEVs and 2,000 fuel cell electric buses by 2022 and 200,000 by 2025.²³⁵ Hyundai is another major OEM investing in fuel cell technology. Finally, China aims to have 1 million FCEVs by 2030, focused more on medium- and heavy-duty applications.

Figure 31: International Targets 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.²³⁶

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,

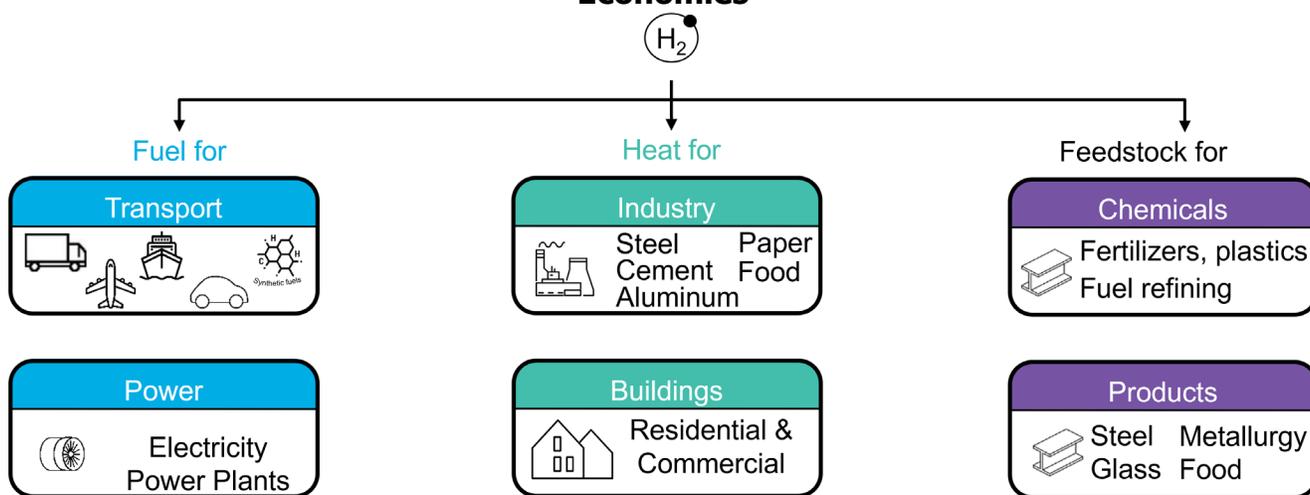
235 South Korea Ministry of Economy and Finance press release. "[Government Releases an English Booklet on the Korean New Deal.](http://english.moef.go.kr/pc/selectTbPressCenterDtl.do?boardCd=N0001&seq=4948)" July 28, 2020. <http://english.moef.go.kr/pc/selectTbPressCenterDtl.do?boardCd=N0001&seq=4948>.

236 Teter, Jacob. "[Hydrogen and Fuel Cells Considerations for the California Energy Commission.](https://efiling.energy.ca.gov/getdocument.aspx?tn=233701)" 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>.

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 pipeline 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 pipeline gas plants and single-turbine peaking plants for power generation. It can also 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.²³⁷

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

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.²³⁸ Salt caverns, depleted gas fields, and rock caverns are being investigated as large-scale storage mediums for renewable hydrogen.²³⁹

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.²⁴⁰

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 goal for the project is to 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.²⁴¹

238 Ibid.

239 Ibid.

240 Razeghi, Ghazal, Jennifer Lee, 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.

241 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](https://www.portoflosangeles.org/references/news_091418_carb_toyota).” 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 PV. 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 kg 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 its usefulness 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 program 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 hydrogen’s use 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

California Faces Potential Energy Resiliency Challenges

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 due to PSPS events.²⁴² In September 2020, hundreds of thousands more lost power in another PSPS event, albeit for less time than in 2019.²⁴³ Further, in August 2020 the state grid operator initiated rolling outages to manage high electricity demand during an extreme heatwave 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.

As the state takes action including increase procurement of generation and storage assets to increase energy reliability, Californians are looking to their own solutions as discussed in Volume II of the *2020 Integrated Energy Policy Report Update (2020 IEPR Update)*.²⁴⁴ One solution consumers are increasingly turning to is fossil-powered back-up generation, typically fueled with diesel or propane. Such back-up power produces air pollution and GHGs 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

242 For a listing of October 2019 PSPS events, see CPUC's October 2019 PSPS Events [web page](https://www.cpuc.ca.gov/Oct2019PSPS/).
<https://www.cpuc.ca.gov/Oct2019PSPS/>.

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

244 Microgrids are generally understood to be a small system of electric users that have a local source of energy supply, which, while connected to electric grid, is capable of functioning independently when needed.

events.²⁴⁵ 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 2020.²⁴⁶ A rapid spike in search engine terms for “backup generator” in California occurred 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” has similar spike timing in search engine interest and averages three times more search activity than “backup generator.” (See Figure 33.²⁴⁷)

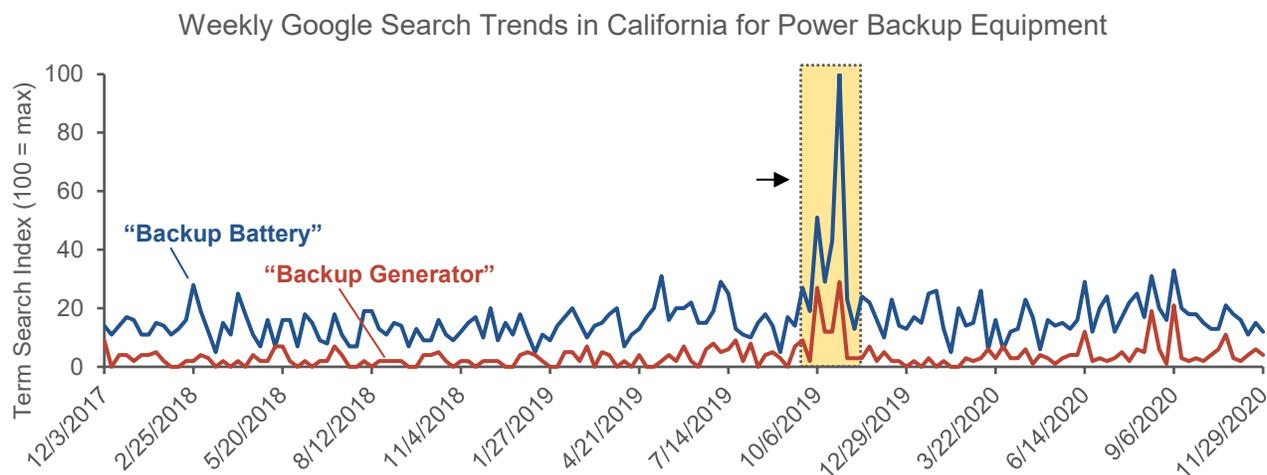
As discussed below, ZEVs can function as a backup generator and provide energy resiliency during a planned or unplanned power shutoff. It is important to bear in mind, however, that ZEVs, backup generators, and microgrids are not a substitute for the investments needed in California’s energy grid to more broadly address energy reliability in California. (For more information about microgrids, see *2020 IEPR Update, Volume II: The Role of Microgrids in California’s Clean and Resilient Energy Future.*)

245 Shao, Elena. “[Demand for Generators Lights Up as PG&E Power Shutoffs Loom.](https://www.sfchronicle.com/business/article/Demand-for-generators-lights-up-as-PG-E-power-14054242.php)” *San Francisco Chronicle*. June 27, 2019. <https://www.sfchronicle.com/business/article/Demand-for-generators-lights-up-as-PG-E-power-14054242.php>.

246 Bromels, John. “[Why Shares of Generac Holdings Jumped More Than 20 Percent in August.](https://www.fool.com/investing/2020/09/09/why-shares-of-generac-holdings-jumped-more-than-20/)” *The Motley Fool*. September 9, 2020. <https://www.fool.com/investing/2020/09/09/why-shares-of-generac-holdings-jumped-more-than-20/>.

247 Data for terms “backup battery” and “backup generator” from Google Trends [web page](https://trends.google.com/trends/?geo=US). <https://trends.google.com/trends/?geo=US>.

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



Data Source: Google Trends

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.²⁴⁸ electric vehicle supply equipment) and 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 its 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 a ZEV, 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

248 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).
<https://www.energy.ca.gov/event/workshop/2020-07/session-1-energy-resilience-and-zevs-workshop-zero-emission-vehicle>.

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.

weekday work hours.²⁴⁹ 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) pilots that include the opportunity for islanding (providing power for a facility when the grid is down), and all buses in the CEC's School Bus Replacement Program have V2G capability. The Twin Rivers School District's pilot VGI program is evaluating prospects for using buses as mobile power sources for emergency centers or to maintain building functions during power losses.²⁵⁰

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 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.²⁵¹ ZEVs that sustain house energy functions for longer than a few days must eventually be refueled, so the enhanced resiliency for homes during power shutoffs requires a

249 National Academy of Sciences 2015. [Overcoming Barriers to Deployment of Plug-in Electric Vehicles](https://www.nap.edu/catalog/21725/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>.

250 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>.

251 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/>.

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 charging companies have chargers that offer unique resiliency advantages. During the July 15, 2020, IEPR workshop on ZEV resilience, two companies — Envision Solar and Freewire — explained the options that they offer to provide energy to battery-electric vehicles (BEVs) without the grid.²⁵²

Envision Solar 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 as 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.

252 July 15, 2020, IEPR workshop on ZEV Resilience and Three Revolutions in Transportation [transcript](https://efiling.energy.ca.gov/getdocument.aspx?tn=234949).
<https://efiling.energy.ca.gov/getdocument.aspx?tn=234949>.

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



Credit: Envision Solar

The company Freewire offers a different resiliency solution. The company offers two battery-based chargers that are designed to draw lower amounts of power from the grid and store them for faster charging. The company's Boost charger can operate at DCFC levels of up to 120 kW while 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. Envision and Freewire are capable of supplying backup power to buildings when properly wired. Similar to Freewire's approach, 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,²⁵³ similar resiliency options are available with this design.²⁵⁴

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

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

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

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 recharge refrigerators and freezers.²⁵⁵

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 options as part of "core planning" for transit agencies, especially as fleet electrification grows.²⁵⁶

Transit agencies are looking to other options for ensuring resiliency. As transit fleets move to 100 percent electric buses (FCEV or BEV), additional options should be broadly considered, including microgrid solutions and onsite storage. AC Transit is also exploring the possibility of using FCEV buses to charge BEV buses, along with a broad array of other resiliency ideas.²⁵⁷ 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 consistent message around energy resiliency for ZEVs is additional battery storage capable of providing power, often connected to solar PV. While battery prices are continuing to decline, used batteries will allow for 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.²⁵⁸ CEC analysis from 2017 estimated that by 2030, up to 13,000 megawatt hours of storage capacity could be made

255 Ganion, Jana. "[Energy Resilience and ZEVs](https://efiling.energy.ca.gov/getdocument.aspx?tn=233849)." 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>.

256 Callaway, Joe. "[Zero-Emission Bus Program](https://efiling.energy.ca.gov/getdocument.aspx?tn=233850)." 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>.

257 Ibid.

258 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/). <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/>.

available through second-life battery use of expected vehicle retirements.²⁵⁹ Several companies intend to take advantage of this potential market, such as ReJoule Energy, RePurpose Energy, and Smartville.²⁶⁰ CEC's EPIC program has provided funding for these California startups to demonstrate different aspects of developing a streamlined second-life battery pathway for the state.²⁶¹ 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 emergency situations for all drivers, especially those in disadvantaged and low-income communities.

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

260 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 system to independently control and monitor the health of batteries using different chemistries.

261 Pyper, Julia. 2020. ["Second Life: Carmakers and Storage Startups Get Serious About Reusing Batteries."](https://www.greentechmedia.com/articles/read/car-makers-and-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>.

- **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.

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 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.

Renewable diesel offers the potential of modest criteria pollutant reductions (including 30 percent of PM and 10 percent of NO_x) compared to conventional diesel.²⁶² Biodiesel has the potential to increase NO_x, but these impacts can be addressed under the Alternative Diesel Fuel regulation.²⁶³ Depending on the feedstocks and processes used to produce these liquid fuels, GHG emissions can vary significantly. The biodiesel and renewable diesel fuel credited

262 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.

263 Ibid.

under the Low Carbon Fuel Standard typically average between two-thirds and three-quarters less GHG emissions relative to conventional diesel.²⁶⁴

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.²⁶⁵ More than 80 percent of this total is imported from other states and countries, spurred by the value of 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 CEC's Clean Transportation Program.²⁶⁶ It recently initiated a tenfold plant expansion to increase production.²⁶⁷ Phillips 66 has announced plans to close its petroleum refinery in Santa Maria and convert its Rodeo petroleum refinery to produce renewable diesel.²⁶⁸ In addition, Marathon Petroleum idled its Martinez petroleum refinery and is evaluating a shift to produce renewable diesel within one to two years.²⁶⁹ Global Clean Energy signed an agreement to produce renewable diesel at a converted petroleum refinery in Bakersfield to deliver fuel to

264 CARB. [Low Carbon Fuel Standard Annual and Quarterly Reporting Tool](https://ww3.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm).
<https://ww3.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm>.

265 Ibid.

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

267 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>.

268 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.)

269 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>.

ExxonMobil.²⁷⁰ 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 1960.²⁷¹ The state has no regulatory ability with GHG emissions from aviation but has recently allowed SAF to be qualified 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.²⁷²

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,²⁷³ with final test results are expected in Spring 2021.²⁷⁴

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 SAF. For instance, the LCFS considers indirect emissions only from crop-based biofuels, not

270 ExxonMobil press release. "[Exxon Mobil and Global Clean Holdings Sign Agreement for Renewable Diesel](https://corporate.exxonmobil.com/News/Newsroom/News-releases/2020/0811_ExxonMobil-and-Global-Clean-Energy-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.

271 U.S. Energy Information Administration. [State Energy Consumption estimates, 1960–2018](https://www.eia.gov/state/seds/sep_use/notes/use_print.pdf). 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.

272 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). <https://efiling.energy.ca.gov/getdocument.aspx?tn=234943>.

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

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

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.²⁷⁵

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.²⁷⁶

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.²⁷⁷ 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 an underutilization of California biodiesel production capacity.

Renewable Gas and Low NOx 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 as a result of state and local government incentives, vehicle

275 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). <https://efiling.energy.ca.gov/getdocument.aspx?tn=234943>.

276 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>.

277 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>.

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 2019.²⁷⁸ 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 (GNA) 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, 2024.²⁷⁹ 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 (CO₂e) per megajoule in 2024.²⁸⁰ Imports of out-of-state biomethane are also expected to grow, stimulated by the value of LCFS credits.

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.²⁸¹

278 CARB. [Low Carbon Fuel Standard Annual and Quarterly Reporting Tool](https://ww3.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm).
<https://ww3.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm>.

279 Gladstein, Cliff. "[An Assessment: California's In-State RNG Supply for Transportation, 2020-2024](https://efiling.energy.ca.gov/getdocument.aspx?tn=234038)." 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>.

280 Ibid.

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

Vehicles that use renewable gas are an increasing share of HD vehicles in the state.²⁸² Cummins, Inc. has begun manufacturing 30,000 advanced pipeline gas engines annually (6.7-, 8.9-, and 12-liter sizes) that have been certified by the United States Environmental Protection Agency (U.S. EPA) and the California Air Resources Board (CARB) as achieving an 80 percent reduction in tailpipe emissions compared to the existing 2010 diesel engine ambient air quality standard.²⁸³ The Cummins engines are the only combustion engines that can meet the U.S. EPA anticipated 2023 standard for low nitrogen oxide (NOx) tailpipe emission levels. Several truck chassis and cab manufacturers have embedded these engines in new product sales. The cumulative growth of pipeline gas trucks in California 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.²⁸⁴ 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

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.

282 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>.

283 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>.

284 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.

credit value sharing between fuel producers and vehicle owners could help cover the cost difference.

As California moves towards 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 simultaneously 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.²⁸⁵ 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 individual dairies to form a “cluster” in which biogas from digesters sited at multiple 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 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 towards consolidation into fewer, larger dairy and feedlot facilities. Although interrelated, these are separate. Industry trends towards 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 agencies²⁸⁶ 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

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

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

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.²⁸⁷

Environmental advocates remain concerned about flush manure management systems at dairy operations, as they are a larger source of manure methane than their dry-managed counterparts or pasture-based operations.²⁸⁸ The bulk of California’s dairies operate as centralized gravity flow of wet manure waste diverted into anaerobic lagoons. A small percent of California dairies are pasture dairies located mostly on California’s Bay Area and north coast, where manure is allowed to dry in the field. *Enteric fermentation*, or the breaking down of 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.²⁸⁹ 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.²⁹⁰

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

288 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). <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.

289 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). <https://ww2.arb.ca.gov/ghg-slcp-inventory>.

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

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.²⁹¹ 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 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.²⁹²

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

291 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>.

292 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.

CPUC through various ongoing proceedings.²⁹³ 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.
- **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.

²⁹³ 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.

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.

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.