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California Energy Commission

REVISED STAFF REPORT

Assembly Bill 2127 Second Electric Vehicle Charging Infrastructure Assessment

Assessing Charging Needs to Support Zero-Emission Vehicles in 2030 and 2035

January 2024 | CEC-600-2024-003

California Energy Commission

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ABSTRACT

The *Assembly Bill (AB) 2127 Second Electric Vehicle Charging Infrastructure Assessment* examines charging needs to support California's zero-emission vehicles in 2030 and 2035. Pursuant to AB 2127, the California Energy Commission is required to publish a biennial report on the charging infrastructure needed for California to meet its zero-emission vehicle targets by 2030. In September 2020, Governor Gavin Newsom issued Executive Order (EO) N-79-20, which expanded zero-emission vehicle adoption targets, including 100 percent zero-emission vehicle sales for light-duty vehicles and 100 percent zero-emission vehicle operations for drayage trucks and off-road vehicles and equipment by 2035 where feasible; and 100% zero-emission medium- and heavy-duty vehicle sales and operations by 2045 where feasible. The California Air Resources Board's Advanced Clean Cars II, Advanced Clean Trucks, and Advanced Clean Fleets regulations have begun to set a pathway to reaching these goals.

The analysis presented in this report projects that California will need 1.01 million chargers (including 39,000 direct-current fast chargers) to support 7.1 million light-duty plug-in electric vehicles in 2030. By 2035, the state will need 2.11 million chargers (including 83,000 direct-current fast chargers) to support 15.2 million light-duty plug-in electric vehicles. To support medium- and heavy-duty plug-in electric vehicles, California will need about 114,500 chargers (109,000 depot chargers and 5,500 en route chargers) for 155,000 vehicles in 2030, and 264,000 chargers (256,000 depot chargers and 8,500 en route chargers) for 377,000 vehicles in 2035.

This expansion of charging will require widespread investment in the grid and effective management of California's electrical grid to reduce potential impacts. Improving charger and vehicle technology along with grid upgrades will make it possible to accommodate charging in ways that will minimize the grid impact.

Installing these chargers will require investments in labor and workforce training and development, as up to 71,500 job-years will be needed for charger installation by 2035. The transition to ZEVs and supporting infrastructure will support jobs of the future.

Keywords: charging, infrastructure, transportation electrification, electric vehicle, network planning

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EXECUTIVE SUMMARY

California's transportation-related emissions contribute roughly half of the state's greenhouse gas emissions, when accounting for emissions from fuel production and vehicle use. Transportation is also a major source of the state's air pollution, contributing nearly 80 percent of smog-forming nitrogen oxides and 95 percent of toxic diesel particulate matter. To achieve the state's long-term air quality and emissions reduction goals, California must rapidly transition toward the widespread use of zero-emission vehicles powered by clean energy. In support of this transition, in September 2020, Governor Gavin Newsom issued Executive Order N-79-20, setting the following targets:

- By 2035, 100 percent zero-emission vehicle sales for new passenger cars and trucks, 100 percent zero-emission vehicle operations for drayage trucks, and 100 percent zero-emission off-road vehicles and equipment, where feasible.
- By 2045, 100 percent zero-emission vehicle operations for medium- and heavy-duty vehicles, where feasible.

Since then, the California Air Resources Board (CARB) has begun establishing pathways to reach the goals of Executive Order N-79-20 by issuing a series of regulations affecting the sale and operation of vehicles in California:

- Advanced Clean Cars II, adopted in 2022, requires an increasing proportion of new passenger vehicle sales to be zero-emission vehicles each year, reaching 100 percent in 2035.
- Advanced Clean Trucks, adopted in 2021, requires an increasing fraction of truck sales to be zero-emission vehicles through 2035, with specific targets for each vehicle class.
- Advanced Clean Fleets, adopted in 2023, requires fleet operators in certain segments to reach 100 percent zero-emission vehicles by 2035 or 2040.
- Innovative Clean Transit, adopted in 2018, requires public transit agencies to transition to zero-emission buses, with 100 percent new zero-emission bus purchases by 2029 and a full transition by 2040.

Assembly Bill 2127 (Ting, Chapter 365, Statutes of 2018) requires the California Energy Commission (CEC) to prepare statewide assessments of the charging infrastructure needed to meet the state's zero-emission vehicle goals through 2030. Executive Order N-79-20 updated the requirement to include higher targets through 2035. Because AB 2127 requires the CEC to assess charging infrastructure needs, this report focuses on plug-in electric vehicles, which include battery-electric vehicles and plug-in hybrid electric vehicles. Hydrogen fuel cell electric vehicles may play an important role in the future of zero-emission transportation, but they are not the focus of this report. The text of AB 2127 is included in Appendix B.

The CEC published the inaugural AB 2127 report in July 2021. This 2023 revised staff report differs from the first report in several important ways. First, this report extends the analysis of charger needs to 2035, when all new passenger vehicle sales and on-road drayage truck operations are required to be zero emission. Second, this report relies upon updated zero-emission vehicle fleet projections from CEC's transportation energy demand forecast in the *2022 Integrated Energy Policy Report Update* (Additional Achievable Transportation

Electrification 3 scenario), which incorporates the expected impact of vehicle regulations implemented by CARB. The modeling also accounts for shifting consumer preference for and availability of longer-range plug-in electric vehicles, as well as increases in charger power levels, resulting in drivers of all vehicle types preferring charging that is either long-duration or high-powered and charging less frequently overall.

For passenger vehicles, this analysis models charger needs beyond single-family homes, specifically public locations and "shared private" locations, which include private lots at workplaces and multifamily housing. While today's average electric passenger vehicle driver charges at home in a single-family dwelling, many Californians do not have convenient access to this option. People who live in multifamily housing or have no access to electricity where they park need convenient charging options. In addition, all electric vehicle drivers will need charging on long trips.

This analysis also evaluates the number chargers of different speeds that will be needed for passenger plug-in electric vehicles, including slower Level 1 and Level 2 charging and faster direct-current fast charging. The slowest charging option is Level 1 (providing about 3–5 miles of range per hour), which is an option for home charging but has less of a role at other locations. Level 2 (providing between 5 and 60 miles of range per hour, depending on the amperage rating) is appropriate for longer dwell times, particularly workplaces and overnight parking. High-powered direct-current fast charging will be increasingly important as long-range battery-electric vehicles make up a larger share of the fleet. Fast charging may also be important for people who do not have convenient charging at home or at their workplace. Direct-current fast charging speeds vary from 50 kilowatts (kW, providing about 145 miles of range per hour) to 350 kW (providing a full charge in about 20 minutes) or more.

In 2030, this report projects that California's 7.1 million plug-in electric passenger vehicles will need 1.01 million chargers, including 39,000 direct-current fast chargers. In 2035, California's 15.2 million plug-in electric passenger vehicles will need 2.11 million chargers, including 83,000 direct-current (DC) fast chargers. Light-duty vehicle charger needs will be impacted by the types of zero-emission vehicle technologies that make up the fleet in the future. Charger needs will also be affected by the mix of slow versus fast chargers that are deployed by the market.

For medium- and heavy-duty electric vehicles, the report evaluates the number of chargers needed at depots and public locations for charging en route. *Depot chargers* are chargers located at trip destinations and locations where vehicles are stored overnight, including depots owned by the vehicle operator and charging locations owned by a third party. Because vehicles spend longer periods at these locations, depot chargers can provide lower-powered charging (20 kW to 150 kW in this analysis). Some vehicles make trips beyond the range of the batteries and rely on en route chargers to replenish range quickly. To support rapid charging, en route chargers must provide higher-powered charging than depots (350 kW to 1,500 kW in this analysis). A wide mix of charging speeds will be necessary to ensure that all medium- and heavy- duty vehicles can meet charging requirements.

In 2030, this analysis finds that California's 155,000 medium- and heavy-duty plug-in electric vehicles will need about 114,500 chargers: 109,000 lower-powered (20–150 kW) depot chargers and 5,500 higher-powered (350–1,500 kW) en route chargers. In 2035, California's

377,000 medium- and heavy-duty plug-in electric vehicles will need 264,500 chargers: 256,000 lower-powered depot chargers and 8,500 higher-powered en route chargers. As with light-duty vehicles, medium- and heavy-duty vehicle charging needs will determine on the types of zero-emission vehicle technologies that make up the fleet in the future. The SB 643 report assesses clean hydrogen fuel production and refueling infrastructure to support medium- and heavy-duty fuel cell electric vehicles and off-road/nonroad applications, in the context of meeting the state's air pollution reduction goals.

California has made progress toward meeting these charger needs. There are about 92,000 public and shared private chargers for light-duty vehicles in California. Between existing chargers and chargers for which funding has been allocated, the state will meet the Executive Order B-48-18 goal of 250,000 chargers, albeit later than 2025. The CEC is closely monitoring the timeline for installation. However, more than 10,000 DC fast chargers are operating in California, and the state has met the fast charging goal set under Executive Order B-48-18 two years early.

Light-Duty Electric Vehicles Will Need 2.1 Million Public and Shared Chargers by 2035

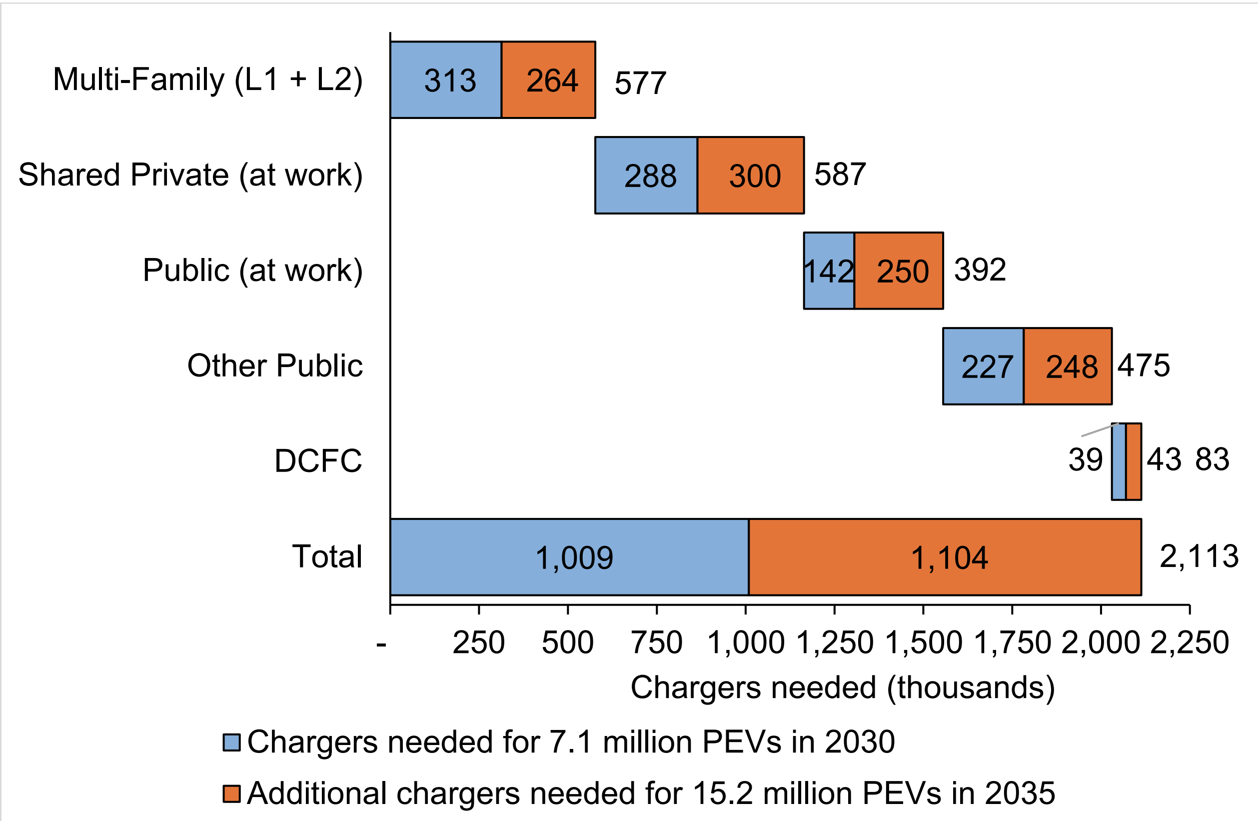
Since the publication of the first AB 2127 Assessment, light-duty zero-emission vehicle adoption has accelerated rapidly in California, with the sales share of zero-emission vehicles more than doubling between 2020 and 2022. Through the second quarter of 2023, cumulative sales in California have reached 1.6 million zero-emission vehicles. Zero-emission vehicles made up 18.8 percent of all light-duty vehicles sold in the state in 2022. In the third quarter of 2023, zero-emission vehicles made up 26.7 percent of new vehicle sales. Battery-electric vehicles make up an increasing proportion of these sales, accounting for 84.6 percent of zero-emission vehicle sales in 2022 compared to 62.9 percent in previous years.

In 2022, plug-in hybrids made up 14.7 percent of zero-emission vehicle sales, and hydrogen fuel cell electric vehicles made up the remaining 0.7 percent of zero-emission vehicle sales. There has also been a trend toward long-range battery electric vehicles; almost all battery-electric vehicles sold in 2022 had more than 200 miles of electric range. Zero-emission vehicle sales have begun to accelerate in larger vehicle segments, indicating that zero-emission vehicles are now able to meet the needs of a wider range of households.

As zero-emission vehicles sales expand under the Advanced Clean Cars II regulation, the CEC projects that California’s light-duty plug-in electric vehicle population will increase to 7.1 million vehicles in 2030 and 15.2 million in 2035. To support these vehicles, the state will need about 2.1 million chargers by 2035 across a range of power levels and location types. Figure 1 provides a breakdown of the types of chargers needed to support light-duty plug-in electric vehicles by 2030 and 2035.

The first AB 2127 assessment relied on the Mobile Source Strategy estimate of 8 million zero-emission vehicles (including 7.5 million plug-in vehicles) in 2030. This AB 2127 assessment uses the transportation energy demand forecast for the *2022 Integrated Energy Policy Report Update* (Additional Achievable Transportation Electrification 3 scenario), which projects 7.1 million zero-emission vehicles (of which more than 99 percent are plug-in vehicles) in 2030. This updated assessment finds a decrease in the number of Level 2 chargers away from home and an increase in the number of direct-current fast chargers compared to the inaugural report. Among Level 2 chargers, more serve long-duration workplace charging events, and fewer serve shorter-duration charging events away from home. These changes largely reflect the shift from plug-in hybrid electric vehicles to long-range battery-electric vehicles in the market and under the Advanced Clean Cars II regulation, as well as refinements to the behavioral model underlying this assessment. While plug-in hybrid electric vehicles must either charge frequently or rely on internal combustion engines for longer travel days, long-range battery-electric vehicles can charge less frequently and use higher-speed charging when they need to charge away from home.

Figure 1: Chargers Needed for Light-Duty Plug-In Electric Vehicles in 2030 and 2035



Models project that California will need more than 1 million public and shared private chargers in 2030 to support 7.1 million plug-in electric vehicles and 2.1 million chargers in 2035 to support 15.2 million plug-in electric vehicles.

Source: CEC staff

Supporting Equitable Charging Access and Aligning Charging With Grid Needs Are Priorities for Light-Duty Vehicle Electrification

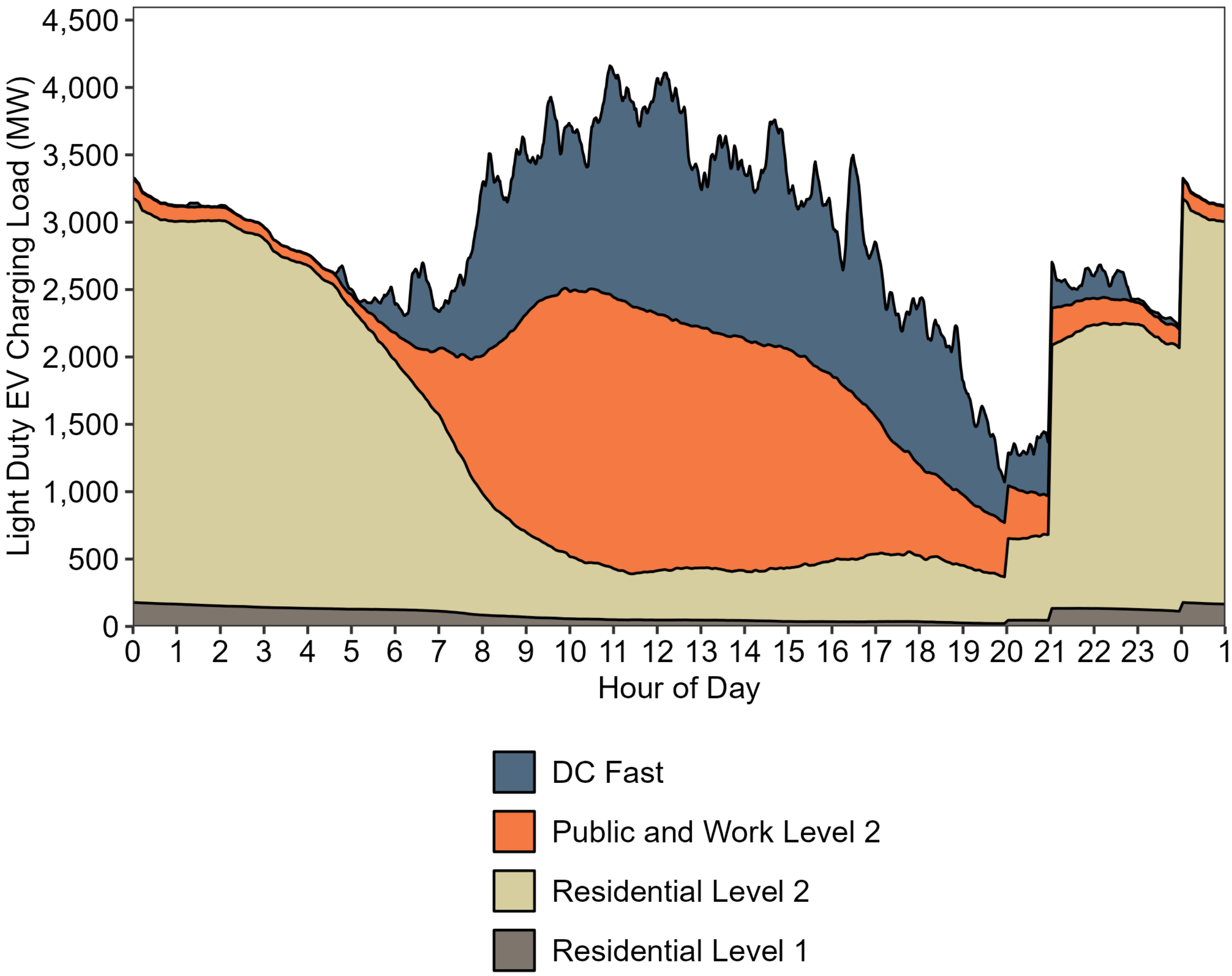
As plug-in electric vehicles make up a larger share of light-duty vehicles on the road, it will be increasingly important to prioritize charging that is grid-friendly and cost-effective for ratepayers and drivers while ensuring that the transition to electric vehicles is equitable. This report explores a range of alternative models for the future of charging infrastructure but pays particular attention to two key questions:

- What are the options for routine charging for households that cannot currently charge at home? The report examines scenarios to explore the potential effects of expanded home charging access, the availability of charging at workplaces, and increasing the presence of DC fast charging.
- How can charging loads be managed to best make use of lower-cost and lower-emission energy and reduce the capacity strain on the grid?

This report uses a "gas station model" alternative future scenario to explore the potential for DC fast charging to meet a larger share of future charging needs than under the baseline. Current EV drivers seem to prefer fast charging and the market has installed these chargers at a higher rate than L2, relative to the targets set by Executive Order B-48-18. California has the goal of 10,000 fast chargers set under Executive Order B-48-18 two years early, but the state is further from reaching the goal of 250,000 total chargers. The "gas station model" alternative future scenario explores the potential for expanded DC fast charger installations. Under this scenario, installing 63,000 additional DC fast chargers by 2030 would decrease the need for L2 chargers at work and public locations by about 402,000 compared to the primary scenario.

Figure 2 shows the projected statewide power demand for light-duty vehicle charging on a typical weekday in 2030. The load reaches about 4,000 MW at the peak between 11 a.m. and 1 p.m. The *2022 Integrated Energy Policy Report Update* planning forecast anticipates vehicle charging to account for less than 10 percent of daily average load and less than 5 percent of load at peak in 2030; this forecast anticipates that vehicle charging will account for less than 20 percent of daily average load and less than 10 percent of load at peak in 2035. Utility-specific time-of-use rates and dynamic rates are expected to move some charging away from peak hours in the late evening and early morning, but additional infrastructure investments may be necessary to shift charging into midday, when solar energy is most plentiful.

Figure 2: Projected Statewide Power for Light-Duty Vehicle Charging for 7.1 Million Zero-Emission Vehicles on a Typical 2030 Weekday



Charging management strategies will be needed to spread electric vehicle charging throughout the day and align loads with generation and grid capacity. Charging away from home occurs mostly during the day, which aligns with renewable generation. Residential charging management technologies should be coordinated with distribution systems to lessen the impact of charging. The steep increase in home charging load at various points in the evening correspond to regional time-of-use rate changes, which many drivers use to time their charging. Dynamic rates and managed charging could help eliminate these timer spikes.

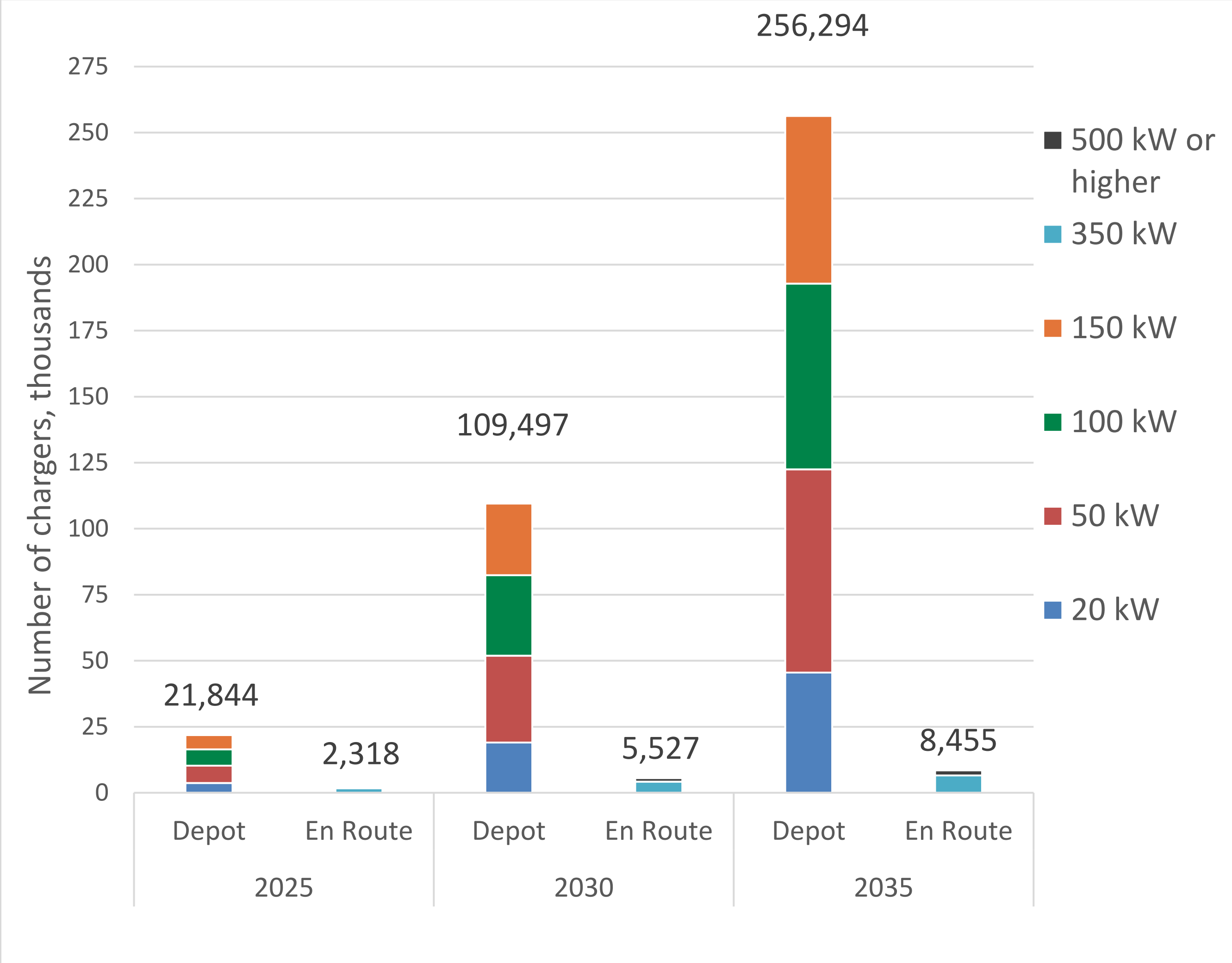
Source: CEC and NREL

This report includes an alternative future scenario based upon a "gas station model" to explore the potential for DC fast charging to meet a larger share of future charging needs than under the baseline. Current EV drivers seem to prefer fast charging when at-home charging is not available or when on road trips. The "gas station model" alternative future scenario explores the potential for expanded DC fast charger installations. Under this scenario, installing 63,000 additional DC fast chargers by 2030 would decrease the need for L2 chargers at work and public locations by about 402,000 compared to the primary scenario.

Medium- and Heavy-Duty Electric Vehicles Will Need 264,500 Chargers by 2035

Advanced Clean Trucks and Advanced Clean Fleets regulations will greatly accelerate the pace of medium- and heavy-duty zero-emission vehicle adoption. As of the end of 2022, there were 2,186 plug-in electric trucks, buses, and delivery vans registered in California and 134 fuel cell buses. The Integrated Energy Policy Report Additional Achievable Transportation Electrification 3 scenario, which is aligned with the Advanced Clean Trucks and Advanced Clean Fleets regulations, is used as the baseline scenario in this report. CEC modeling for the transportation energy demand forecast in the *2022 Integrated Energy Policy Report Update* finds there will be about 155,000 medium- and heavy-duty plug-in electric vehicles in 2030 and 377,000 medium- and heavy-duty plug-in electric vehicles in 2035, with these vehicles spread across a wide range of sectors, as shown in Figure 3. These vehicles will require 109,000 depot chargers and 5,500 en route chargers in 2030, which grows to 256,000 depot chargers and 8,500 en route chargers in 2035. Depot charging needs scale roughly in proportion to the number of plug-in electric vehicles, but en route charger needs grow more slowly because of an increase in power levels and usage.

Figure 3: Projected Charging Infrastructure Needs for On-Road Medium- and Heavy-Duty Electric Vehicles



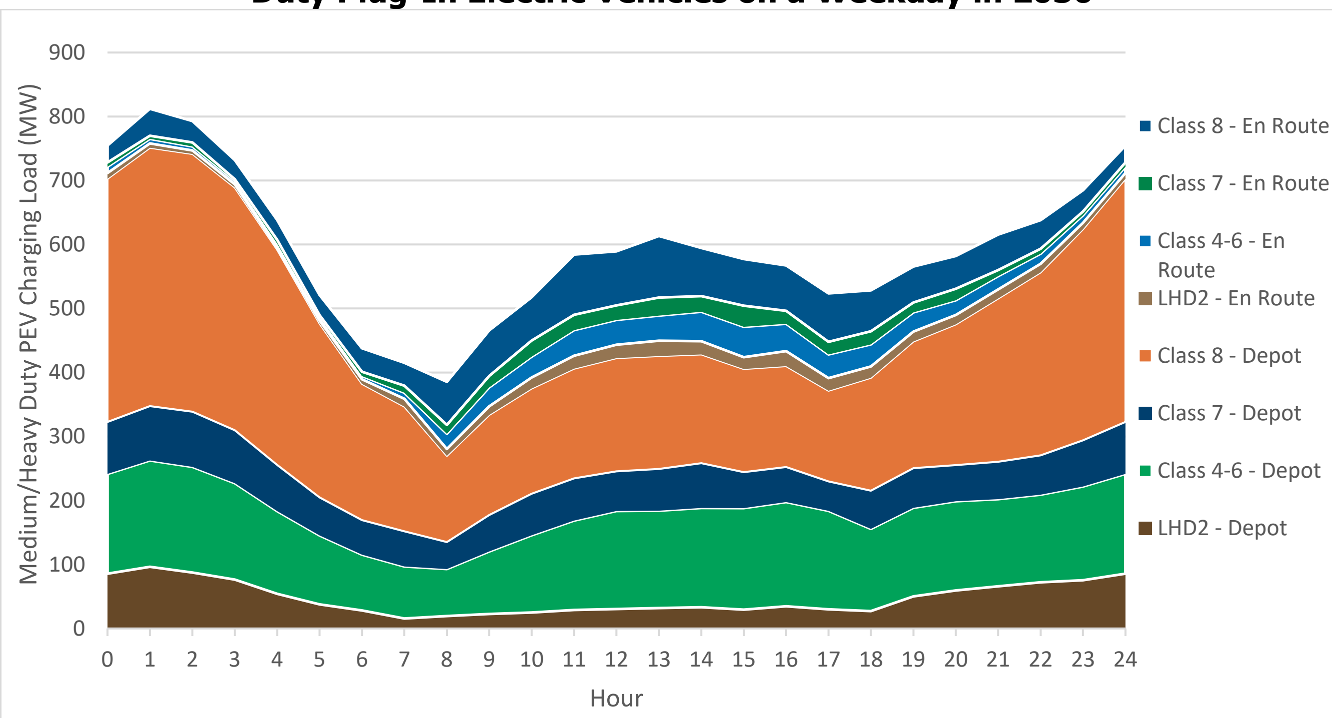
The HEVI-LOAD model for medium- and heavy-duty vehicle charging infrastructure projects that about 109,000 depot chargers, ranging from 20 kW through 150 kW, and 5,500 en route chargers, ranging from 350 kW through 1.5 megawatts (MW), are needed to support about 155,000 medium- and heavy-duty plug-in electric vehicles in 2030. In 2035, the charging need grows to about 256,000 depot chargers and 8,500 en route chargers.

Source: CEC and LBNL

These requirements differ from the previous assessment because of updates that have been made to the medium- and heavy-duty vehicle charging infrastructure modeling framework. In this assessment, charger power levels are broken down into more diverse increments and use vehicle simulation methods to generate energy demand and charging needs at a finer resolution than before. The primary scenario in this assessment includes a larger proportion of smaller and lower-mileage vehicles than in the first AB 2127 assessment, and vehicle efficiency assumptions have been updated. Compared to the first assessment, a smaller number of chargers per vehicle are projected since medium- and heavy-duty vehicle energy demand can be better satisfied by higher charging power levels. In this assessment, depot chargers are broken down into powers ranging from 20 kW to 150 kW, whereas en route chargers range from 350 kW to 1. MW.

Moreover, the report compares charging load profiles for managed and unmanaged charging cases for medium- and heavy-duty vehicles in this assessment to evaluate the effect of shifting peak load to different times throughout the day. Public charging load is difficult to manage because it is opportunistic. Therefore, since depot charging makes up a little more than 82 percent of the total daily medium-and heavy-duty vehicle charging load projected by the models used in this report, altering depot charging behavior and shifting the associated load have the biggest impact on the grid. Figure 4 shows the projected statewide medium- and heavy-duty vehicle charging demand on a typical weekday. By altering parking flexibility, deferring charging events, and using dynamic pricing schemes, the 6 p.m. ramp peaking at 1 p.m. can be shifted to earlier hours in the day when overall energy demand is lower to ease the stress on electrical grid equipment.

Figure 4: Projected Statewide Charging Demand for 155,000 Medium- and Heavy-Duty Plug-In Electric Vehicles on a Weekday in 2030



The highest demand for medium- and heavy-duty vehicle charging will occur overnight starting around 6 p.m. and peaking at 1 a.m. Some of this demand can be shifted to times of the day when demand is lower by using dynamic utility pricing schemes, more flexible parking, and deferral of charging events to avoid periods of high demand. (LHD2 refers to light-heavy-duty trucks with a gross vehicle weight rating between 10,001 and 14,000 pounds)

Source: CEC and LBNL

Preparing the Grid for Transportation Electrification

Increased load from charging medium- and heavy-duty vehicles can present a unique challenge compared to light-duty passenger vehicle charging. However, larger charging stations for passenger vehicles may share some characteristics of medium- and heavy-duty vehicle charging. Specifically, electric utilities, the state, and stakeholders should ensure the grid is ready for incorporating new load through appropriate grid upgrades and load-integration strategies. As the number of chargers throughout the state grows over time, it will require coordinated planning and upgrades to the distribution and transmission systems to adapt to the additional load resulting from vehicle electrification. State agencies have, and will continue to, coordinate efforts to meet state goals.

State agencies are refining existing tools and adding new tools to address this new load proactively. The transportation demand forecast in the *2022 Integrated Energy Policy Report Update* (Additional Achievable Transportation Electrification 3 scenario) considers an increased amount of electric vehicle adoption that is used to inform resource procurement and grid planning in the utilities' integrated resource plans. Coordination on resource assumptions in the CEC's demand forecast also takes place in the Joint Agency Steering Committee, which is a group of interagency staff members working together to address key barriers in the context of long-term procurement and transmission planning processes.

Through the EVSE Deployment and Grid Evaluation (EDGE) tool, the CEC is seeking to help project managers deploy charging infrastructure throughout the state by providing them with access to the most current grid information. This tool is under development and will be designed to help users identify good locations to install chargers that will support rapid electric vehicle growth rates within California soon. The tool could aid stakeholders in identifying areas where there may be excess capacity or where proactive upgrades should be made.

Improving Vehicle-Grid Integration Can Benefit Drivers and the Grid

Widespread vehicle-grid integration, where vehicles and charging systems are responsive to grid conditions, can help ensure California can achieve cost-effective and timely decarbonization of its electric power and transportation systems. Vehicle-grid integration describes technologies and strategies that alter the charging behavior of plug-in electric vehicles in a manner that benefits the grid while ensuring driver needs are met. For example, vehicle-grid integration can help ensure that drivers charge up on the cleanest and cheapest electricity available, and at times that reduce constraint on the electric system. More advanced functionality of vehicle-grid integration includes the ability to enable vehicles to power buildings or the grid when needed.

Despite the immense potential of vehicle-grid integration, the products, services, electricity rates, and policies that exist today are nascent and must continue to develop to support customer-friendly and widespread vehicle-grid integration. The expanded adoption of vehicle-grid integration will require continued coordinated contributions from state agencies, utilities, charging providers, automakers, customers, and others. Specifically, California must continue to develop compensation programs, customer products and services, electrical capacity at potential charging locations, vehicle and grid planning processes, and customer education to support widespread vehicle-grid integration.

Labor and Workforce Training and Development Support for Electric Vehicle Charging Infrastructure Deployment Is Critical

Current and projected investments for charger deployments require that the state thoughtfully consider the range of labor and workforce training and development issues involved in providing this infrastructure to meet the state’s zero-emission vehicle goals and realize other benefits. Electric vehicle charging infrastructure career pathways must be intentionally cultivated with collaboration among the state’s workforce entities, employers, training partners, trades, and workers. In addition, the state should take a high-road economic approach that embeds equity, climate, and jobs priorities for businesses and workers and expand workforce opportunities for underserved communities and populations that can participate in the electric vehicle supply equipment industry.

CHAPTER 1: Background

Policy Context

Despite progress in reducing statewide greenhouse gas (GHG) emissions, California's transportation-related emissions contribute roughly half of the state's GHG emissions when accounting for emissions from fuel production as well as fuel use in vehicles. Transportation is a major source of the state's air pollution, contributing nearly 80 percent of smog-forming nitrogen oxides (NOx) and 95 percent of toxic diesel particulate matter.[1] To achieve the state's long-term air quality and GHG emissions reduction goals, California must rapidly transition toward the widespread use of zero-emission vehicles (ZEVs) powered by clean energy. In support of this transition, in September 2020, Governor Gavin Newsom issued Executive Order N-79-20,[2] which calls for:

- All in-state sales of new passenger cars and trucks to be zero-emission by 2035.
- All drayage trucks operating in the state to be zero-emission by 2035.
- All medium- and heavy-duty vehicles operating in the state to be zero-emission by 2045, where feasible.
- All off-road vehicles and equipment to be zero-emission by 2035, where feasible.

The California Air Resources Board (CARB) has begun establishing pathways to reaching the requirements of Executive Order N-79-20 by issuing a series of regulations affecting the sale and operation of vehicles in California:

- Advanced Clean Cars II (ACCII), adopted in 2022, requires an increasing proportion of new passenger vehicle sales to be ZEVs each year, reaching 100 percent in 2035.[3]
- Advanced Clean Trucks (ACT), adopted in 2021, requires an increasing fraction of truck sales to be ZEVs through 2035, with specific targets for each vehicle class.[4]
- Advanced Clean Fleets (ACF), adopted in 2023, requires fleet operators in certain segments to reach 100 percent ZEVs by 2035 or 2040.[5]

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1 California Energy Commission staff. 2019. *2019 Integrated Energy Policy Report*. California Energy Commission. Publication Number: CEC-100-2019-001-CMF. Available at https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2019-integrated-energy-policy-report.

2 Governor Gavin Newsom. Executive Order N-79-20. Issued September 23, 2020. https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-text.pdf.

3 California Air Resources Board. "Advanced Clean Cars II Regulations: All New Passenger Vehicle Sold in California to Be Zero Emission by 2035," https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/advanced-clean-cars-ii.

4 California Air Resources Board. "Advanced Clean Trucks Fact Sheet: Accelerating Zero-Emission Truck Markets," https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-trucks-fact-sheet.

5 California Air Resources Board. "Advanced Clean Fleets Regulation Summary: Accelerating Zero-Emission Truck Markets." https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-fleets-regulation-summary.

- Innovative Clean Transit, adopted in 2018, requires public transit agencies to transition to zero-emission buses, with 100 percent new zero-emission bus purchases by 2029 and a full transition by 2040.[6]

Preceding N-79-20, former Governor Edmund G. Brown Jr. issued Executive Order B-48-18,[7] which directed California to install 250,000 electric vehicle chargers, including 10,000 direct-current (DC) fast chargers, to support 1.5 million ZEVs statewide by 2025. B-48-18 further established a target of 5 million ZEVs statewide by 2030. The 5 million ZEVs goal represents the level of vehicle adoption consistent with ensuring that statewide greenhouse gas emissions are reduced to 40 percent below the 1990 level by 2030.[8] In 2018, Assembly Bill (AB) 2127[9] codified this 2030 ZEV target and tasked the California Energy Commission (CEC) with preparing biennial assessments of the charging infrastructure needed to meet these goals. While vehicles fueled by electricity or hydrogen are considered ZEVs, the AB 2127 assessment focuses exclusively on plug-in electric vehicles (PEVs), which include battery-electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). The evaluations in this report represent a high case, where almost all ZEVs are PEVs; this representation is consistent with the current market and trends with the majority of customer adoption being plug-in electric vehicles.

First AB 2127 Assessment Findings

The first AB 2127 assessment,[10] published in July 2021, examined the existing and future charging infrastructure needs throughout California. These needs include the chargers, make-ready[11] electrical equipment, supporting hardware and software, and other programs for on-road and off-road vehicle categories.

The first AB 2127 assessment used vehicle population projections from the *Draft 2020 Mobile Source Strategy* from the CARB, which was the only analysis at the time that addressed the EO N-79-20 goals. This analysis estimated that 8 million light-duty ZEVs and 180,000 medium- and heavy-duty ZEVs would be needed in 2030 to meet the EO N-79-20 goals.

Key findings from the first AB 2127 assessment included the following:

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6 California Air Resources Board. "Innovative Clean Transit (ICT) Regulation Fact Sheet." https://ww2.arb.ca.gov/resources/fact-sheets/innovative-clean-transit-ict-regulation-fact-sheet.

7 Governor Edmund G. Brown, Jr. Executive Order B-48-18. Issued January 26, 2018. https://www.ca.gov/archive/gov39/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/index.html.

8 California Air Resources Board staff. 2021. *Revised Draft 2020 Mobile Source Strategy.* California Air Resources Board. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://ww2.arb.ca.gov/sites/default/files/2021-04/Revised_Draft_2020_Mobile_Source_Strategy.pdf.

9 Assembly Bill 2127 (Ting, Chapter 365, Statutes of 2018). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB2127.

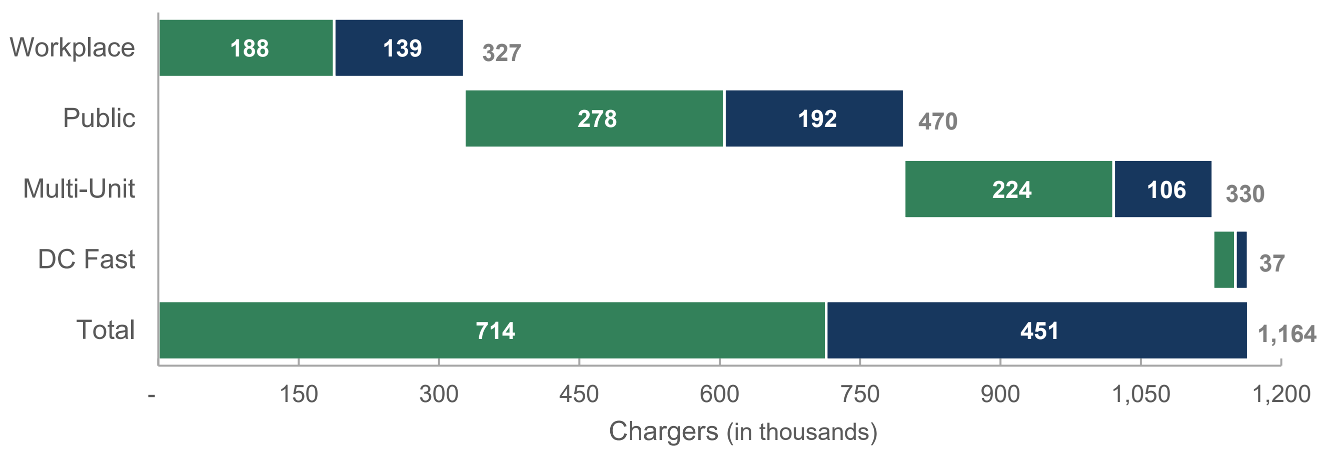
10 Alexander, Matt, Noel Crisostomo, Wendell Krell, Jeffrey Lu, and Raja Ramesh. July 2021. *Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment: Analyzing Charging Needs to Support Zero-Emission Vehicles in 2030 – Commission Report*. California Energy Commission. Publication Number: CEC-600-2021-001-CMR. https://efiling.energy.ca.gov/getdocument.aspx?tn=238853.

11 "Make-ready" refers to the electrical infrastructure required to operate a charger, such as transformers or wiring.

- To support 5 million and 8 million light-duty passenger ZEVs, respectively, in 2030, California needs more than 700,000 and nearly 1.2 million public and shared private chargers.
- California needs about 157,000 chargers to support 180,000 medium- and heavy-duty ZEVs in 2030.
- Light-duty vehicle charging was projected to reach around 5,500 megawatts (MW) at the peak around midnight and 4,600 MW at a daytime peak around 10 a.m. on a typical weekday in 2030.
- Medium- and heavy-duty vehicle charging was projected to reach around 2,000 MW at the peak around 5 p.m. on a typical weekday in 2030, though significant variation exists among vehicle types.

Figure 5 shows the composition of the projected 2030 light-duty charging infrastructure network in the first AB 2127 assessment, while Figure 6 illustrates the projected statewide load profile in 2030 from light-duty charging.

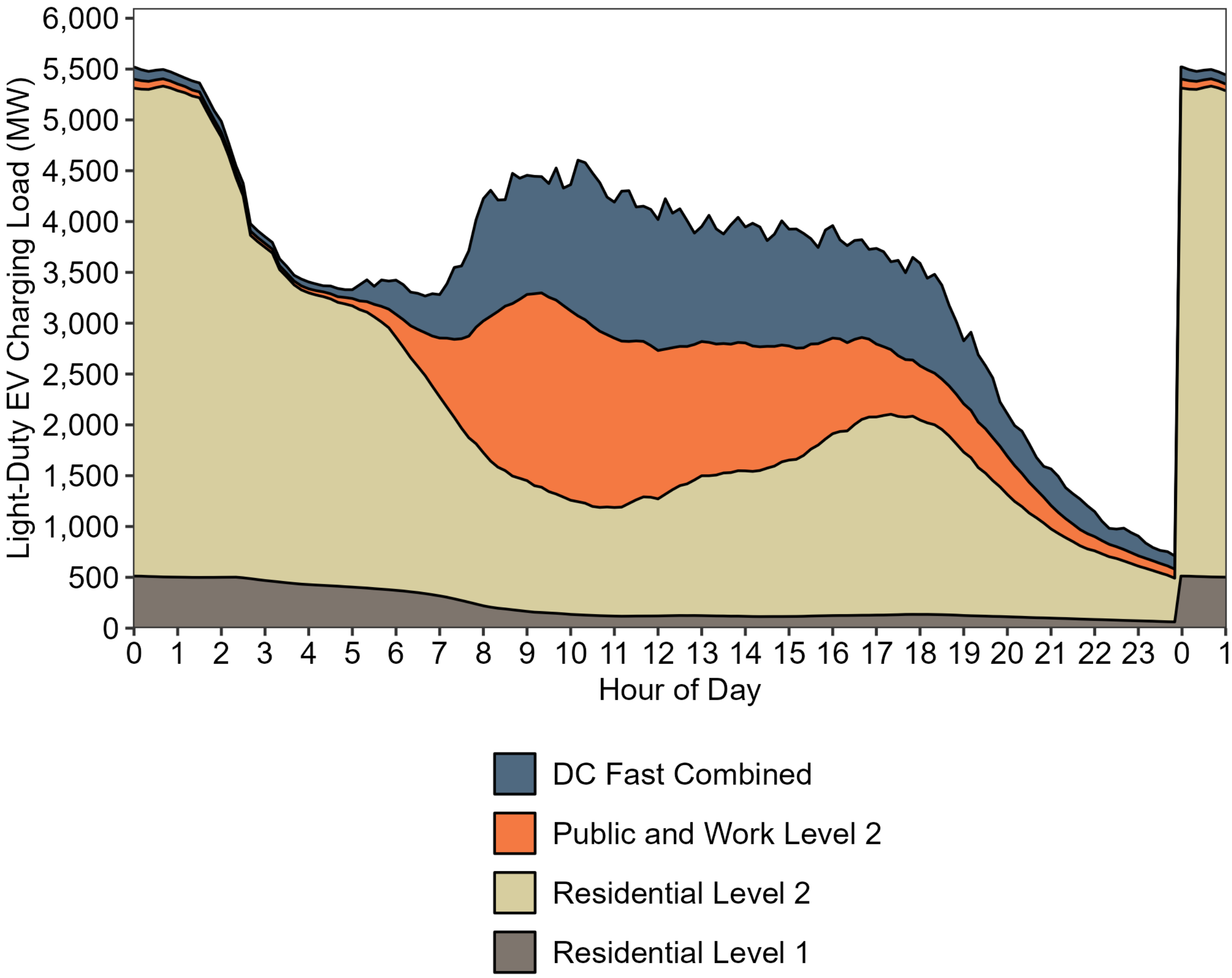
Figure 5: Projected 2030 Charger Counts to Support 5 Million and 8 Million Light-Duty Zero-Emission Vehicles from the First AB 2127 Assessment



The first AB 2127 assessment projected that California would need more than 700,000 shared private and public chargers in 2030 to support 5 million ZEVs as called for in AB 2127 and nearly 1.2 million chargers to support 8 million ZEVs to achieve the goals of the Executive Order N-79-20. Counts for chargers at workplaces, public destinations, and multiunit dwellings generally indicate the number of Level 2 chargers needed. In some cases, Level 1 chargers may be sufficient at select multiunit dwellings. These values do not include chargers at single-family homes.

Source: CEC and National Renewable Energy Laboratory

Figure 6: Projected Statewide Power for Light-Duty Charging for 8 Million ZEVs on a Typical 2030 Weekday From the First AB 2127 Assessment



The first AB 2127 assessment found that light-duty charging would peak around 5.5 GW at midnight and 4.6 GW at 10 a.m. Demand for DC fast charging, as well as public and work Level 2 charging, occurs mostly during the day. Assuming timed midnight residential charging resulted in a large spike in charging load at midnight, illustrated with a twenty-fifth hour on the right.

Source: CEC, National Renewable Energy Laboratory, and UC Davis

Beyond these key findings, the first report identified several actions to support the widespread deployment of charging infrastructure:

- Continue public support for charger deployment, using public funds to leverage private funds, and eventually transition to a self-sustaining private market.
- Continue modeling efforts to project the quantities, locations, and electrical grid loads of chargers needed to meet statewide travel demand.
- Support innovative charging solutions and financing mechanisms.
- Support local efforts to prepare for transportation electrification.
- Ensure equitable distribution of charger deployment throughout the state.

- Align charging with renewable generation and grid needs.
- Prioritize standardized charger connectors and, for networked charging, prioritize hardware capable of standardized communications protocols.

Second AB 2127 Assessment

The second AB 2127 assessment reports on progress toward meeting the state's goals and supporting the actions identified above. This report discusses new quantitative modeling of projected charger demand based on updated adoption scenarios and improved assumptions. It also introduces topics not discussed in the first assessment, such as workforce needs and reliability of charging infrastructure.

Chapter 2 describes current trends in the zero-emission vehicle market and highlights the progress made toward meeting California's transportation electrification targets through rules like Advanced Clean Cars II, Advanced Clean Trucks, and Advanced Clean Fleets.

Chapter 3 describes the state of existing charging infrastructure in California, including a discussion of the CEC's Counting Chargers effort, charger reliability standards, and the SB 1000 investigation of equity concerns in PEV charging.

Chapter 4 presents the modeling results for charging infrastructure needs through 2035. EVI-Pro 3 (p. 40) and WIRED (p. 57) are used to assess the infrastructure needed to support light-duty PEVs. HEVI-LOAD (p. 61) addresses the needs of medium- and heavy-duty PEVs. EDGE (p. 71) explores the potential impacts of PEV charging on the grid across a range of scales.

Chapter 5 discusses the tradeoffs between scenarios presented in Chapter 4 and identifies focus areas for future charging infrastructure investments.

Chapter 6 explores vehicle-grid integration and the potential of technological advances in vehicles and chargers to improve outcomes of vehicle charging on the electrical grid.

Chapter 7 discusses the labor and workforce aspects of the expansion of charging infrastructure, including analysis of total workforce needs and the training and apprenticeship programs necessary to meet these needs.

Chapter 8 summarizes the results of the report and highlights the major policy directions necessary to ensure that the future of PEV charging is efficient, reliable, and equitable.

CHAPTER 2: Zero-Emission Vehicle Trends and Market Evolution

Introduction

Transportation electrification[12] (TE) continues to gain momentum among state governments, utilities, industry, and consumers. Purchases of PEVs are growing rapidly, driven by policy, a wider range of available models, and more chargers installed. California is supporting TE with legislation, policy, regulation, and public funding. Since the first AB 2127 Report in 2021:

- CPUC issued a decision on its Transportation Electrification Framework,[13] which established a five-year funding cycle approach to utility TE funding, adopted a further defined role for utilities in advancing TE, and authorized an additional $600 million (with the opportunity to spend up to $1 billion) for light-, medium-, and heavy-duty charging infrastructure starting in 2025.[14]
- CARB issued the Advanced Clean Cars II[15] and Advanced Clean Fleets[16] regulations, which aligned with Governor Newsom's mandate for 100 percent ZEV sales by 2035 for light-duty vehicles, 100 percent ZEV operations for drayage trucks by 2035, and 100 percent ZEV operations for medium- and heavy-duty vehicles by 2045, where feasible.
- CEC has received more than $1 billion to invest in ZEV infrastructure.[17]
- Vehicle manufacturers have committed to an electric future,[18] and California is now home to 55 manufacturers of ZEVs and ZEV-related equipment, including eight battery manufacturers.[19]

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12 While this report focuses on battery-electric vehicles, fuel cell electric vehicles are another zero-emission technology expected to play a role in transportation electrification, such as for large trucks.

13 CPUC Decision (D.) 22-11-040: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M499/K005/499005805.PDF.

14 California Public Utilities Commission. "Transportation Electrification," https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/transportation-electrification.

15 California Air Resources Board. "Advanced Clean Cars II Regulations: All New Passenger Vehicle Sold in California to Be Zero Emission by 2035," https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/advanced-clean-cars-ii.

16 California Air Resources Board. "Advanced Clean Fleets Regulation Summary: Accelerating Zero-Emission Truck Markets." https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-fleets-regulation-summary.

17 California Energy Commission Staff. 2021. *2021–2023 Investment Plan Update for the Clean Transportation Program,* https://efiling.energy.ca.gov/GetDocument.aspx?tn=240977.

18 See, for example, COP26 DECLARATION ON ACCELERATING THE TRANSITION TO 100% ZERO EMISSION CARS AND VANS, 2021, signed by GM, Ford, and global manufacturers. https://ukcop26.org/cop26-declaration-on-accelerating-the-transition-to-100-zero-emission-cars-and-vans/.

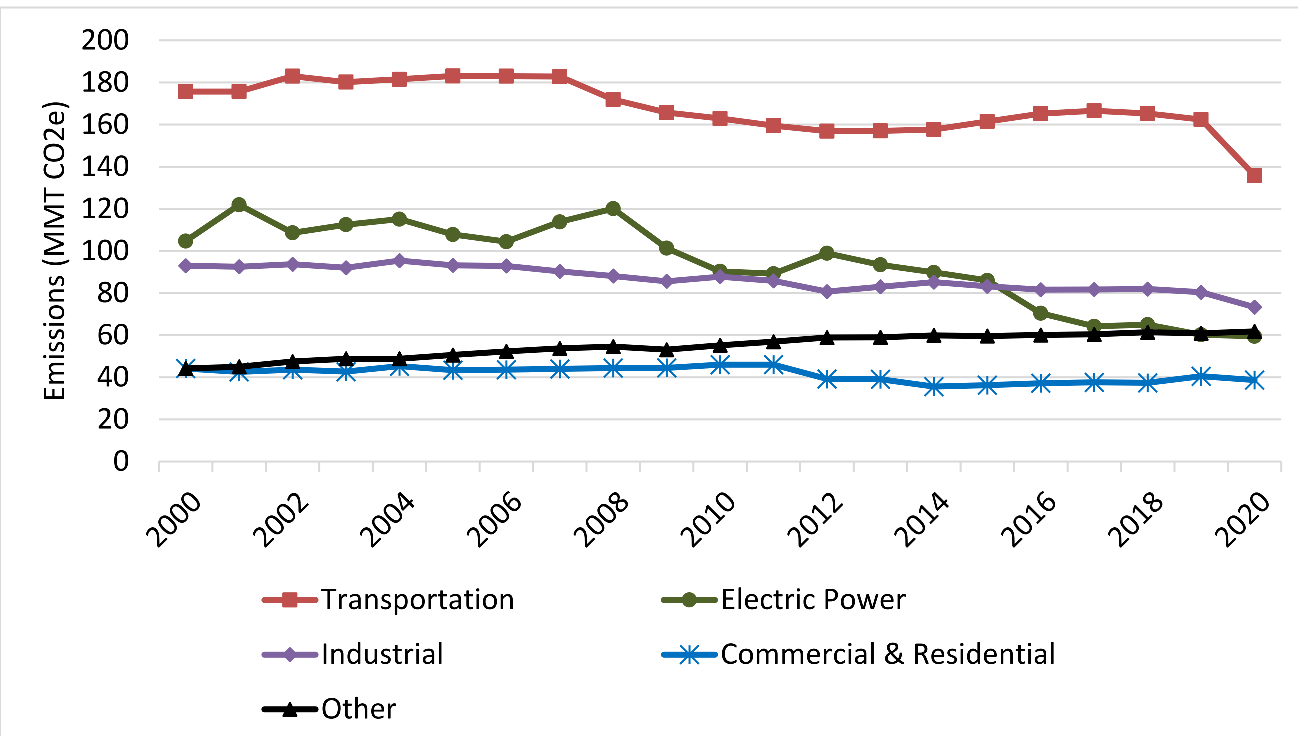
19 Retrieved from the Energy Commission ZEV-Related Manufacturing Dashboard, January 2023 https://experience.arcgis.com/experience/b2f1969d31274eb3a56418336bb23561.

- The charging industry is maturing, with increased attention to interoperability and reliability, and continuing to grow and create good jobs across a range of segments, including innovation, manufacturing, construction and installation, and service and maintenance. Both investor-owned and publicly owned electric utilities are executing pilots to experiment with vehicle-grid integration[20] and planning for growth in electricity demand.

Greenhouse Gases and Other Pollutants

Transportation accounts for about half of California's greenhouse gas emissions, more than from any other sector, and trended upward between the mid- and late 2010s, even as overall emissions declined (Figure 7). However, transportation emissions declined more in the pandemic year of 2020 than did overall emissions, as vehicle miles traveled in California fell 13 percent. In 2021, vehicle miles traveled rebounded to 95 percent of prepandemic levels and remained steady in 2022.[21]

Figure 7: California Greenhouse Gas Emissions, 2000–2020



California GHG emissions have decreased overall since 2020, with a decrease in emissions from the transportation sector accounting for much of this change. (High GWP are gases with high global warming potential, such as methane.)

Source: CARB, "GHG Emissions Inventory 2000–2020," 2022. [Online]. Available: https://ww2.arb.ca.gov/ghg-inventory-data

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20 Investor-owned utility pilots are tracked at https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/transportation-electrification/vehicle-grid-integration-activities.

21 From September 2022 Department of Transportation *Vehicle Miles Traveled Report*, available by request from Caltrans https://dot.ca.gov/programs/traffic-operations/census/mvmt.

If all vehicles were electric today, there would still be emissions from fossil fuels used in the generation of California's electricity. However, state law calls for retail sales of electricity to be carbon-free by the end of 2045,[22] potentially eliminating transportation emissions.

Mobile sources (primarily cars and trucks) account for more than half of emissions contributing to unhealthy ozone and particulate matter pollution,[23] and policy makers are increasingly turning to electrification to address pollution concerns, especially in low-income and disadvantaged communities. For example, the South Coast Air Quality Management District, with CARB and CEC funding, administers the Joint Electric Truck Scaling Initiative, putting 100 electric trucks on the road for two large fleets of primarily drayage trucks. The effort should reduce pollution in the neighborhoods near the Ports of Los Angeles and Long Beach.[24]

Transportation electrification is not the only policy for addressing pollution and other problems due to transportation. It is CARB policy to reduce vehicle miles traveled per capita[25] via walking, biking, carpooling, and public transportation. These policies address the same greenhouse gas and other pollution concerns as TE does while providing additional economic, environmental, and personal benefits.

Light-Duty ZEV Sales and Market Evolution

As the light-duty ZEV market has evolved, several trends have emerged that may push charging needs toward higher-powered charging infrastructure, which CEC staff and researchers have attempted to reflect in the charging infrastructure models that form the core of this report. BEV sales have increased more rapidly than PHEV and FCEV sales, a trend that may continue under the ACCII regulations that cap PHEV sales at 20 percent of ZEV sales beginning in 2026. If this trend continues, charging will continue to supply a large proportion of the energy required by ZEVs. The increased availability of PEV SUVs and pickup trucks, as well as a general market trend toward SUVs, will mean that future PEVs will likely be heavier and therefore require more energy. In addition, vehicle range and battery technology are improving, increasing the number of vehicles capable of higher-powered charging. Larger batteries also encourage increased speed of the onboard charger, creating a potential to increase charging speed and capability of Level 2 chargers. The above vehicle changes signal a general trend of faster charging with fewer stops to charge.

While only about 12 percent of the U.S. population, California accounts for about 40 percent of ZEV ownership nationwide, and 2022 sales data show this ratio persisting. ZEV sales increased rapidly in California in 2021 and 2022, comprising 18.8 percent of all new light-duty vehicle sales in 2022 (Figure 8). While BEV sales continue to grow, PHEV sales leveled off at about

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22 Senate Bill 100 (2018), https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB100.

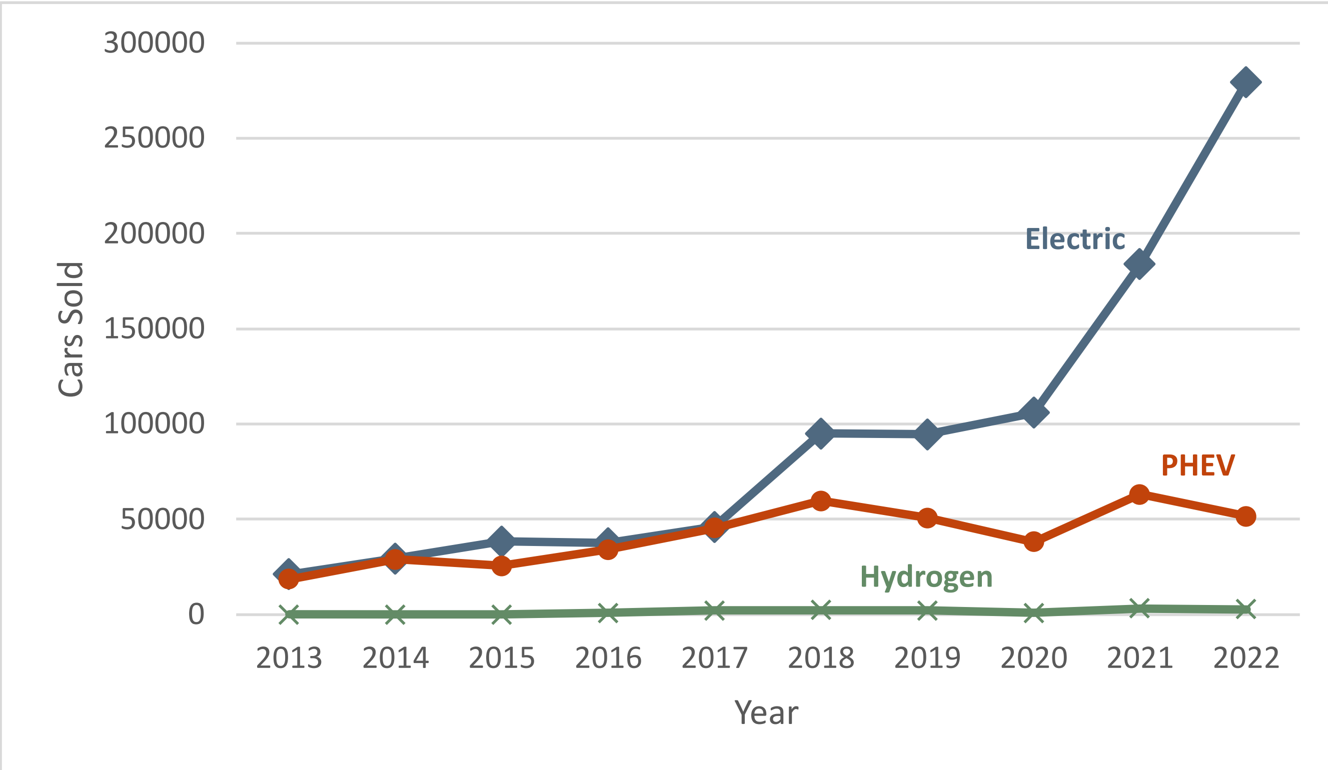
23 California Air Resources Board. "Low Emission Vehicle Program," https://ww2.arb.ca.gov/our-work/programs/low-emission-vehicle-program.

24 California Air Resources Board. "LCTI: Joint Electrification Truck Scaling Initiative (JETSI)," https://ww2.arb.ca.gov/lcti-joint-electric-truck-scaling-initiative-jetsi.

25 California Air Resources Board. "CARB 2017 Scoping Plan-Identified VMT Reductions and Relationship to State Climate Goals," https://ww2.arb.ca.gov/resources/documents/carb-2017-scoping-plan-identified-vmt-reductions-and-relationship-state-climate; the draft *2022 Scoping Plan* calls for a 25 percent reduction in VMT by 2030.

50,000 vehicles per year for the last few years. Hydrogen-powered fuel cell electric vehicles (FCEVs) have not increased in sales like BEVs or PHEVs: FCEV sales averaged about 3,000 per year in 2021 and 2022, and FCEVs comprise less than 1 percent of new ZEV sales.[26] U.S. drivers now have 134 ZEV models to choose from, up from 7 in 2012.[27]

Figure 8: California ZEV Sales by Fuel Type



For each year, the number of all-electric, plug-in hybrid electric and hydrogen-fueled car sales is shown. Sales of battery electric vehicles have increased more rapidly than sales of PHEVs. Hydrogen-powered vehicles do not make up a significant part of light-duty ZEV sales in California.

Source: Derived from California Energy Commission ZEV Dashboard; raw data are available at https://www.energy.ca.gov/files/zev-and-infrastructure-stats-data

Beginning in 2020, SUVs began to claim an increasing share of ZEV sales in California (Figure 9). Manufacturers greatly expanded the number of SUV models available, going from about 20 percent of all models in 2020 to about 50 percent of announced models for 2024. SUVs generally get lower mileage than sedans, so this trend may affect the amount and speed of charging needed (Chapter 5).

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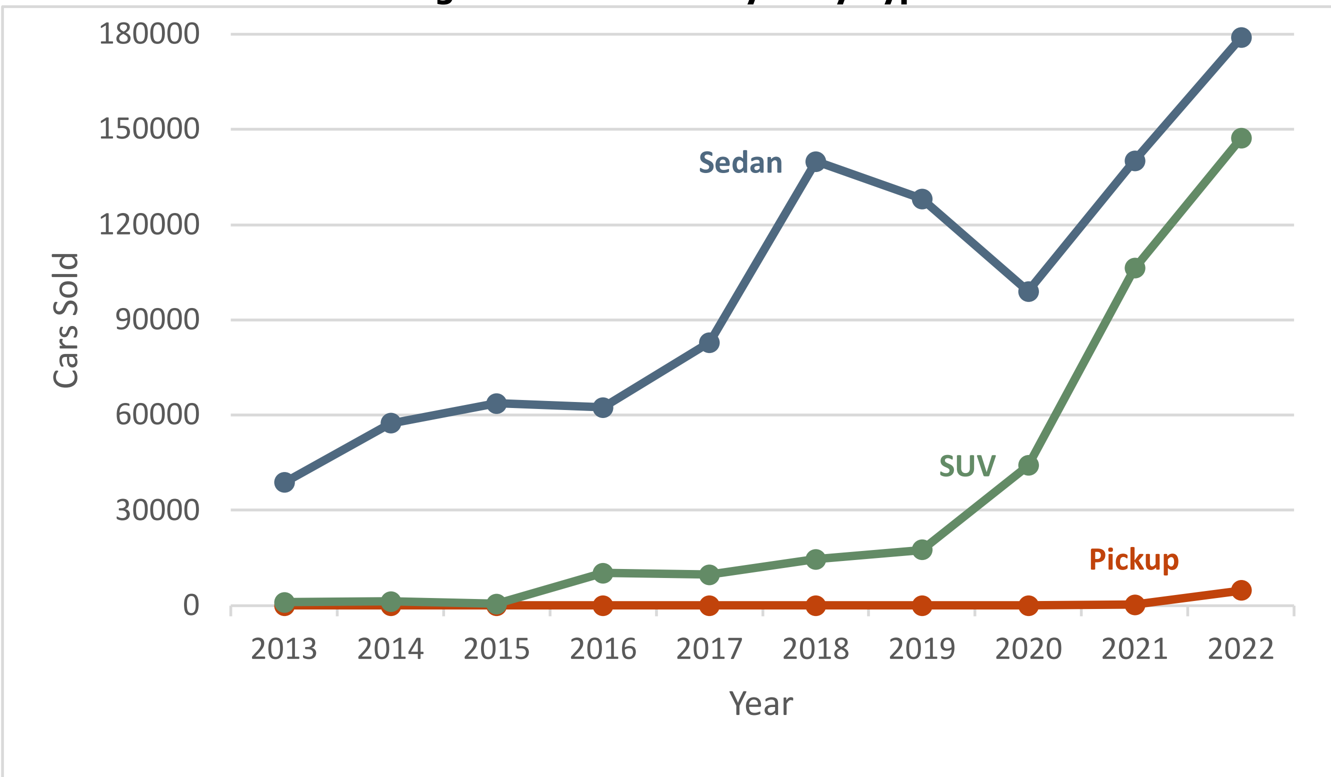
26 California Energy Commission. 2023. "New ZEV Sales in California." Data last updated October 31, 2023. Retrieved November 20, 2023 from https://www.energy.ca.gov/zevstats.

27 "Light-Duty Offerings by Fuel Type," https://afdc.energy.gov/data/10303. Includes plugin hybrids but not other hybrids.

Figure 9: ZEV Sales by Body Type



For each year, the number of ZEV sedan, pickup, and SUV sales is shown. While almost all ZEVs sold before 2019 were sedans, an increasing share of new ZEVs are SUVs, and sales of ZEV pickup trucks have also begun to increase.

Source: Derived from California Energy Commission ZEV Dashboard; raw data are available at https://www.energy.ca.gov/files/zev-and-infrastructure-stats-data.

Battery-electric vehicle ranges have increased substantially in recent years, making the vehicles a better option for long-distance travel and necessitating higher charging speeds. CEC staff has worked with researchers to ensure that the models presented in this report reflect this emphasis on long-range vehicles and high-speed charging. The average range among available 2023 BEV models is about 249 miles, and the maximum is 520 miles.[28] The average has grown steadily since it was 100 miles in 2015.[29] Despite the growing ranges, a 2021 survey of drivers found "range anxiety" is still a barrier to purchasing BEVs, and most drivers overestimated the range required by their driving habits.[30] If battery pack prices continue to decline, prices of EVs are projected reaching parity with comparable gas vehicles by about 2030, and sooner in some vehicle segments.

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28 For cars under $30,000, the longest range is 258 miles; for cars under $60,000 the longest range is 358 miles. Kane, Mark. 2022. "US Electric Car Prices: Cheapest To Most Expensive," Inside EVs. https://insideevs.com/news/565883/electric-car-prices-us-20220207/.

29 EPRI, *Systemic Challenges and Barriers to Consumer EV Adoption*, 2022. https://www.epri.com/research/products/000000003002025413.

30 Herberz, M., Hahnel, U.J.J. & Brosch, T. "Counteracting Electric Vehicle Range Concern With a Scalable Behavioural Intervention." *Nat Energy* 7, 503–510 (2022). https://doi.org/10.1038/s41560-022-01028-3.

Medium- and Heavy-Duty ZEV Sales and Market Evolution

The zero-emission truck market is in the early stages but growing rapidly. At the end of 2022, there were more than 2,300 medium- and heavy-duty ZEVs operating in California, including 1,708 buses, 272 trucks, and 340 delivery vans.[31] California is the largest American market for these vehicles, but adoption is increasing throughout the country. As shown in Figure 10, there are 1,215 medium- and heavy-duty ZEV trucks in service in the United States as of December 2021; more than half (738) were in California.[32] Medium- and heavy-duty ZEVs are more common in Europe, where deployments are in the tens of thousands, and China, which has hundreds of thousands of ZEV trucks and buses.[33] However, in the United States, there were 140,000 orders for new ZEV trucks to be delivered in the coming months and years,[34] and the number of models available to order had grown from 19 in 2019 to 164 in 2021.[35]

While electrified medium-duty truck deployments have been growing since 2010, heavy-duty deployments began in 2019. Nearly all these trucks were BEVs, but deployment of hydrogen fuel cell electric trucks is coming, with 30 funded by the joint CARB/CEC Zero Emission Drayage Truck and Infrastructure Pilot Project.[36] In October 2023, the Alliance for Renewable Clean Hydrogen Energy Systems (ARCHES) was selected for negotiations by the Department of Energy for up to $1.2 billion to implement a California clean hydrogen hub.[37] The system includes clean renewable hydrogen production that will enable decarbonization in port operations, power generation, and heavy-duty transportation, including targets of more than 5,000 class 8 fuel cell trucks and 1,000 fuel cell transit buses. Other projected benefits include nearly $3 billion in avoided health cost per year, more than 200,000 family supporting jobs, and projections for carbon negative hydrogen at the cost of diesel by 2030.[38]

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31 California Energy Commission. 2023. "Medium- and Heavy-Duty Zero-Emission Vehicles in California." Data last updated December 31, 2022. Retrieved November 6, 2023, from https://www.energy.ca.gov/zevstats.

32 CALSTART. January 2022. "Zeroing in on Zero-Emission Trucks," https://calstart.org/wp-content/uploads/2022/02/ZIO-ZETs-Report_Updated-Final-II.pdf.

33 CALSTART. October 2022. "Zero-Emission Truck and Bus Update," https://globaldrivetozero.org/site/wp-content/uploads/2022/10/ZE_TruckBus_update.pdf.

34 *Zeroing in on Zero-Emission Trucks, op. cit.*

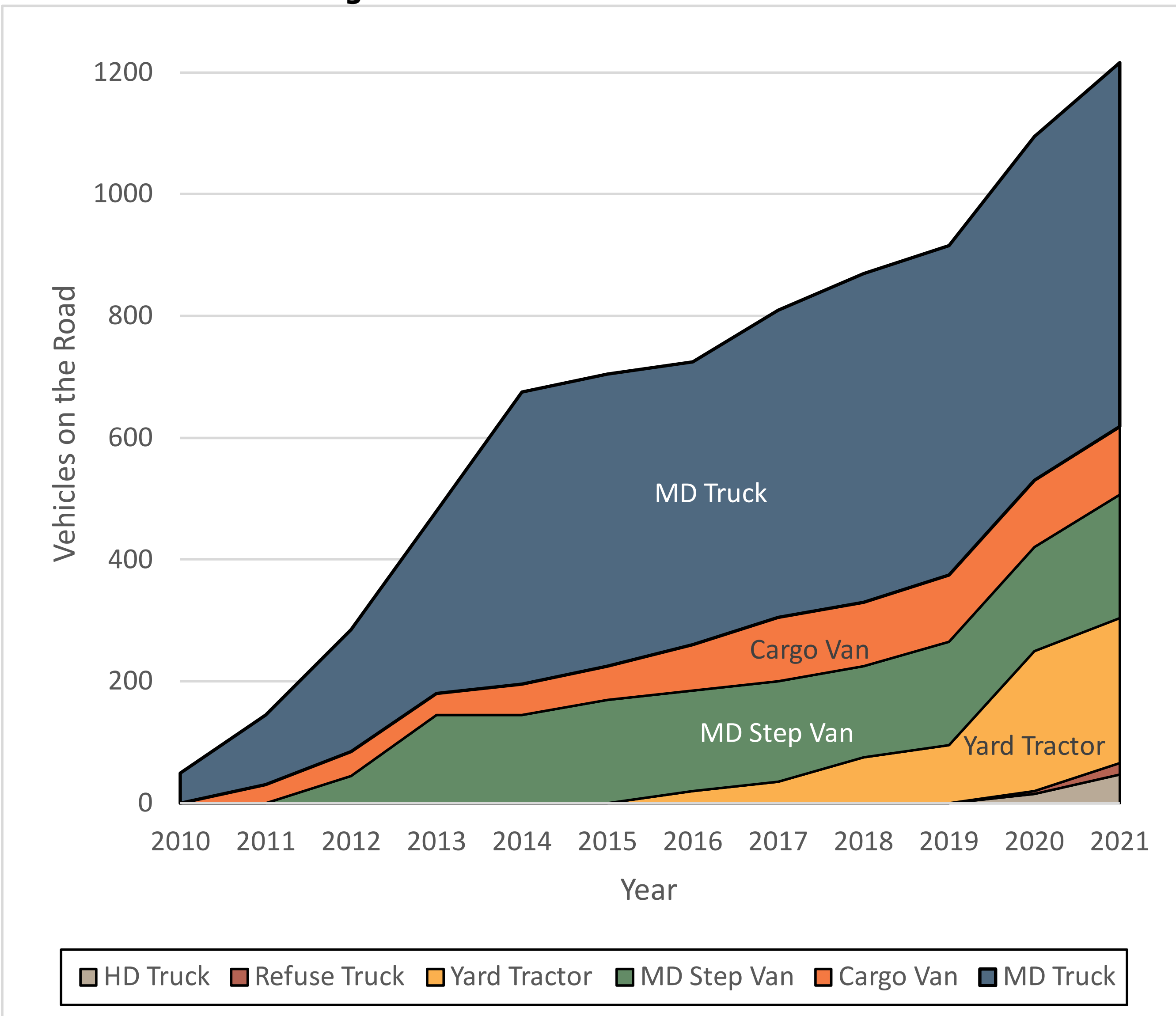
35 *Zeroing in on Zero-Emission Trucks, op. cit.*

36 *Zeroing in on Zero-Emission Trucks, op. cit.*

37 Arches H2. October 2023. "California Awarded Up to $1.2 Billion to Advance Hydrogen Roadmap and Meet Climate and Clean Energy Goals." https://archesh2.org/arches-named-regional-h2hub/

38 California Governor's Office of Business and Economic Development. September 2023. "CA's Clean Hydrogen Market Development." https://efiling.energy.ca.gov/GetDocument.aspx?tn=252171&DocumentContentId=87170.

Figure 10: Zero-Emission Truck Trends



Deployment of zero-emission trucks in the United States by category, by year.

Source: CALSTART, *Zeroing in on Zero-Emission Trucks,* 2022

In 2021, battery packs were three to six times more expensive per kilowatt-hour for trucks than for cars. Truck battery prices will face some of the same supply-chain pressures as car batteries, but CALSTART and BloombergNEF both predict cost parity between BEV and diesel trucks will be achieved by 2030.[39][40] Trucks are larger and typically operate more hours per day than cars, and companies may have stronger incentives not to modify their duty cycles to make time for charging, so trucks are expected to use high-powered charging more than cars.

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39 *Zeroing in on Zero-Emission Trucks, op. cit.*

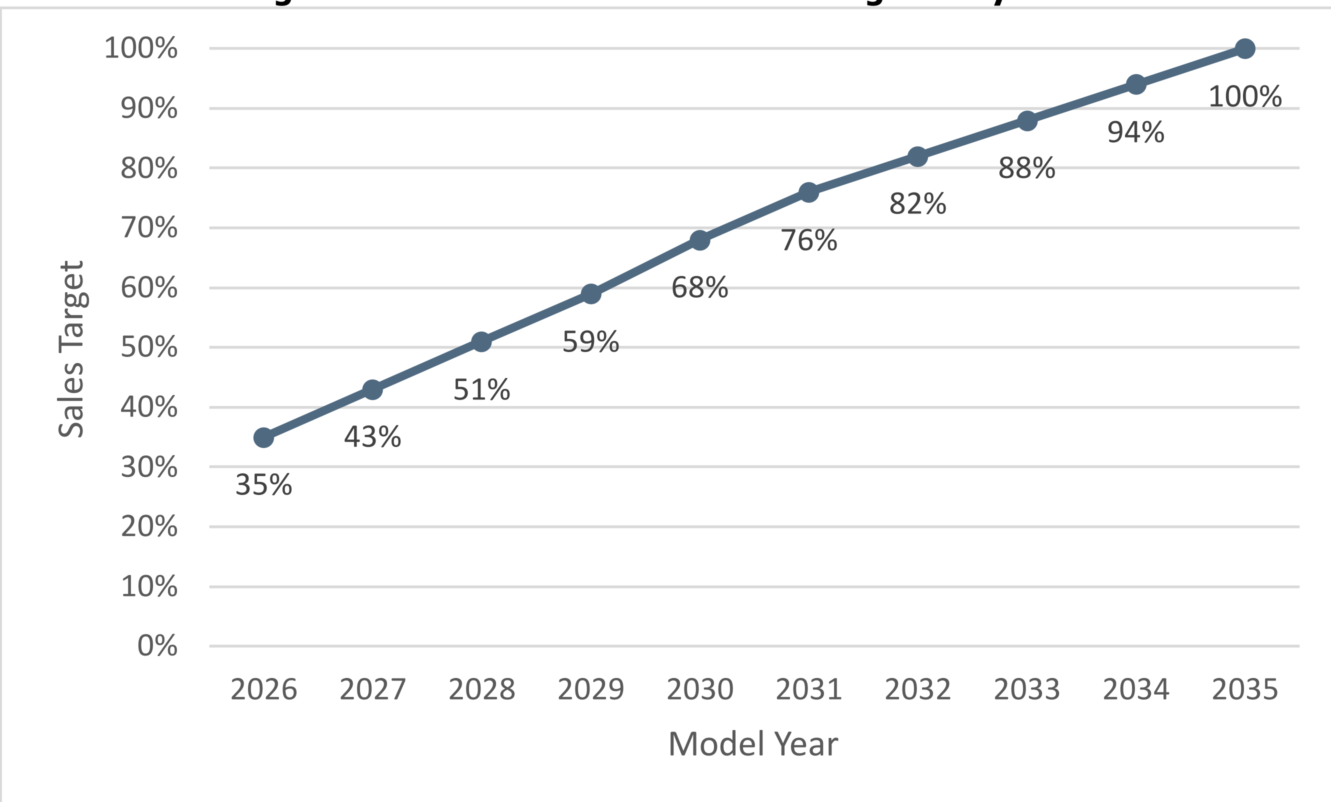
40 Nicola, Stefan, Rafaela Lindeberg, and William Wilkes. April 2023. "The Race to Clean Up Trucking Emissions Is Just Getting Started." Bloomberg. https://www.bloomberg.com/news/articles/2023-04-13/the-race-to-clean-up-trucking-emissions-is-just-getting-started.

State EV Adoption Goals

Advanced Clean Cars II

In 2022, CARB adopted the Advanced Clean Cars II (ACC II) regulation, which requires 100 percent of new passenger vehicles delivered for sale in California to meet a zero-emission standard by 2035, following the path shown in Figure 11. PHEVs may count for up to 20 percent of a manufacturer's ZEV total, provided the all-electric range of the vehicle is at least 50 miles. Combined with internal combustion emission rules in the same regulation, improved air quality is projected to result in $13 billion in benefits over the life of the regulation.[41]

Figure 11: ACC II Sales Schedule for Light-Duty ZEVs



The Advanced Clean Cars II regulation requires that 100 percent of all new light-duty vehicles sold in 2035 must be ZEVs.
Source: CARB. https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/advanced-clean-cars-ii

Advanced Clean Trucks and Advanced Clean Fleets

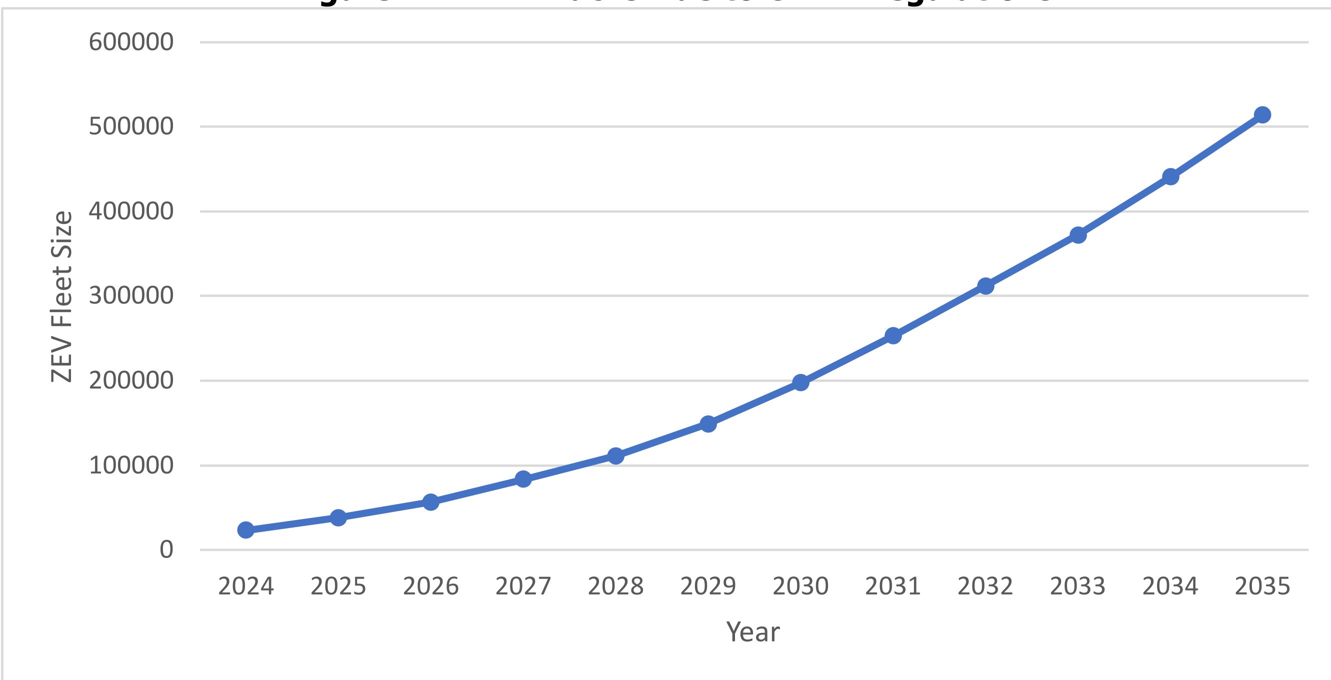
CARB also mandated zero-emission medium-duty and heavy-duty trucks, through rules applying to manufacturers and truck owners. The Advanced Clean Trucks (ACT) regulation,[42] adopted in 2021, requires an increasing fraction of truck sales to be ZEV by 2035, with

41 California Air Resources Board. "Advanced Clean Cars II Regulations: All New Passenger Vehicle Sold in California to Be Zero Emission by 2035," https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/advanced-clean-cars-ii.

42 California Air Resources Board. "Advanced Clean Trucks Fact Sheet: Accelerating Zero-Emission Truck Markets," https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-trucks-fact-sheet.

different sales timelines set for different vehicle classes. The Advanced Clean Fleets (ACF) regulation,[43] adopted in 2023, requires 100 percent of medium- and heavy-duty vehicle operations in certain sectors to be ZEVs by 2035 or 2040 and requires certain fleet owners to achieve targets for the percentage of ZEVs in their fleets on the road, not just new purchases. Advanced Clean Fleets requires faster fleet electrification for certain uses, with drayage fleets being 100 percent ZEV by 2035. Figure 12 shows how the combination of ACT and ACF will affect vehicles on the road according to CARB modeling.[44] For reference, there are 1.8 million medium-duty and heavy-duty vehicles on the road in California.

Figure 12: ZEV Trucks Due to CARB Regulations



Number of ZEV trucks on the road each year as a result of CARB's ACT and ACF regulations.

Source: CARB, "Proposed Advanced Clean Fleets Regulation," Appendix F, Figure 5. https://ww2.arb.ca.gov/rulemaking/2022/acf2022

43 California Air Resources Board. "Advanced Clean Fleets Regulation Summary: Accelerating Zero-Emission Truck Markets." https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-fleets-regulation-summary.

44 This analysis of the combined effect of ACT and ACF on the number of vehicles on the road in California includes Class 2B vehicles (vehicles with gross vehicle weight ratings between 8,501 and 10,000 pounds). Because these are light-duty vehicles, they are excluded from the MDHD scenario used in this report. The CARB modeling result shown in Figure 11 includes about 45,000 more vehicles in 2030 and about 144,000 more vehicles in 2035 than the CEC MDHD scenario shown in Figure 25.

CHAPTER 3:
Existing Charging Infrastructure

California has made good progress in positioning itself as a leader in ZEV adoption. There are more than 1.1 million PEVs[45] on the road that are supported by a range of public, shared, and private chargers throughout the state. However, a strong focus on ZEV infrastructure deployment is required to ensure progress does not stall. This chapter discusses the state of charging in California today and identifies key steps necessary to ensure that the continued expansion of charging is equitable and reliable:

- The CEC's Counting Chargers project, which provides information for the Zero Emission Vehicle and Infrastructure Statistics EV Chargers dashboard,[46] is key to understanding the current state of charging and identifying areas of need. In addition to tabulating publicly accessible chargers, this project has identified shared private chargers, which many drivers rely on for charging while at work or at apartments. CEC staff and NREL researchers used charger counts from this project to calibrate the EVI-Pro 3 model for light-duty charging. CEC staff is developing proposed regulations to gain better data on shared private chargers and medium- and heavy-duty depot chargers.
- Charger reliability is a key concern as more drivers switch to PEVs. The CEC, in collaboration with the CPUC, has begun implementing Assembly Bill 2061 (Ting, Chapter 345, Statutes of 2022) to develop reliability recordkeeping and reporting requirements. Further, the CEC includes reliability performance requirements in CEC funding agreements. These standards will be used to direct CEC funding toward charging projects that are reliable and bring value to the public. The CEC will initiate field testing, slated to begin in early 2024.
- The SB 1000 project assesses whether chargers are disproportionately deployed by income level, population density, or geographical area. The reports issued under this project have highlighted charging inequities in disadvantaged and rural areas.[47] Ensuring that the charger needs identified in the AB 2127 assessment are distributed equitably is key to ensuring California will be able to meet its transportation electrification goals.

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45 California Energy Commission. 2023. "Light-Duty Vehicle Population in California." Data last updated April 28, 2023. Retrieved September 29, 2023, from https://www.energy.ca.gov/zevstats.

46 California Energy Commission. "Electric Vehicle Chargers in California," https://www.energy.ca.gov/zevstats.

47 *Disadvantaged communities* are census tracts that score within the top twenty-fifth percentile of the Office of Environmental Health Hazards Assessment's California Communities Environmental Health Screening Tool (CalEnviroScreen) 3.0 scores, as well as areas of high pollution and low population, such as ports. Rural areas classified using data from the U.S. Census Bureau 2010 Urban and Rural Classifications. At the time of this analysis, disadvantaged community designations under CalEnviroScreen 4.0 and urban and rural classifications from the 2020 census had not yet been finalized.

Charger Types and Definitions

Chargers, sometimes referred to as *electric vehicle supply equipment* (EVSE), are manufactured appliances that safely deliver electricity to charge a PEV. When discussing chargers, the CEC uses precise nomenclature to avoid confusion between common terms such as "charger" and "charging station." These definitions are summarized in Table 1.

Table 1: Definitions of Common Charging Terms

Electric Vehicle Supply Equipment (EVSE)	A device with one or more charging ports and connectors for charging EVs.
Charger	The system within an EVSE that charges one EV. A charging port may have several connectors but can provide power to charge only one EV through one connector at a time. Also referred to as a charging port.
Connector	A physical socket with a specified pin configuration. A charger may have one or multiple connectors.
Charging Station	A charging station is a physical address where one or more chargers are available for use. This is the same usage as for "gas station." A charging station can be public, shared private, or private.
Public	A public charging station has parking space(s) designated by a property owner or lessee to be available to and accessible by the public for any period.
Shared Private	A shared private charging station has parking space(s) designated by a property owner or lessee to be available to and accessible by employees, tenants, visitors, and/or residents. Parking spaces are not dedicated to individual drivers or vehicles.
Private	A private charging station has parking space(s) that are privately owned and operated, often dedicated for a specific driver or vehicle (for example, a charger installed in the garage of a single-family home).

Source: CEC

As summarized in Table 2, three categories are used to describe light-duty PEV chargers: Level 1, Level 2, and DC fast charging. Level 1 and Level 2 chargers deliver alternating current (AC) electricity to the vehicle and typically use the SAE J1772 standard connector. Recent industry announcements indicate that future Level 1 and Level 2 chargers may also use the J3400 or North American Charging Standard (NACS) connector.[48] While all PEVs today can use the SAE J1772 connector,[49] not all have a separate charging port compatible with direct current (DC) fast charging. DC fast chargers deliver DC electricity to the vehicle. Three types of connectors are used for DC fast charging in the North American market: CHAdeMO, Combined Charging System (CCS), and NACS. However, CHAdeMO is largely being phased out.

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48 NACS supports both AC and DC charging, and therefore may be used with Level 1, Level 2, or DC chargers. Many automakers recently announced that vehicle models released as early as 2024 would be equipped with a NACS inlet. Several EVSPs have also announced that they will incorporate NACS connectors into their chargers.

49 Tesla vehicles require an adapter supplied at purchase to use the J1772 connector.

Table 2: Types of Chargers

Charger Type	Typical Input Voltage	Charge Power	Typical Charge Times[50]
Level 1 charger	120 volts AC	Up to 1.4 kilowatts	About 4 miles range added per hour at 1.4 kilowatts
Level 2 charger	208/240 volts AC	Up to 19.2 kilowatts	About 32 miles range added per hour at 9.6 kilowatts
DC charger	Varies[51]	Up to 350 kilowatts with the CCS connector[52] Up to several megawatts with the Megawatt Charging System connector	About 139 miles range added in 10 minutes at 250 kilowatts

Source: CEC staff

Historically, most chargers installed in California have been Level 2 chargers, which are appropriate for locations with longer dwell times, such as at homes, schools, movie theaters, some retail, and so on. For drivers who make mostly short trips or who cannot easily access a 208/240 volt circuit at home, Level 1 charging may suffice despite longer charge times. Because of the lower power, Level 1 charging offers less flexibility in the charging schedule and presents limited opportunities for load shift and minimizing electricity cost.[53] Further, Level 1 charging is less electrically efficient than Level 2 charging,[54] and data indicate that drivers who discontinued EV ownership and switched back to a gas vehicle were much more likely to have been limited to Level 1 charging at home.[55] For these reasons, CEC will continue

50 Calculations assume 3.95 miles per kWh for average vehicle efficiency, typical for passenger cars per EPA fuel economy figures.

51 Most DC chargers for passenger cars require a three-phase, 480-volt AC input. Some chargers may also accommodate DC input, particularly those supporting charge powers exceeding several hundred kilowatts and integrated with on-site storage or generation.

52 The J3400/NACS connector does not specify a maximum power. J3400 supports both 500 V and 1000 V configurations but does not specify a maximum current.

53 Harnessing load flexibility to shift electricity consumption will be critical to realizing California's decarbonization goals and helping drivers save on charging costs. These topics are described in greater detail in Chapter 4.

54 A study found that Level 2 charging is around 90 percent efficient, while Level 1 charging is less than 84 percent efficient. The lower electrical efficiency of Level 1 chargers means that less electricity consumed from the grid is delivered into the vehicle battery. Sears, Justine, David Roberts, Karen Glitman. 2014. "A comparison of electric vehicle Level 1 and Level 2 charging efficiency." IEEE. https://ieeexplore.ieee.org/document/7046253.

55 A UC Davis analysis found that Level 1 home charging was more strongly correlated with discontinuation of EV ownership than Level 2 home charging. Hardman, Scott and Gil Tal. 2021. "Why Are Some California Consumers Abandoning Electric Vehicle Ownership?" National Center for Sustainable Transportation. https://escholarship.org/uc/item/5s738624.

emphasizing Level 2 charging in its own investments while acknowledging that Level 1 charging is sufficient for some drivers.

DC fast charging can deliver higher charging powers (and therefore shorter charge times) by bypassing the onboard charger of the vehicle and delivering DC electricity directly to the battery. DC charging is widely used in charging situations with short dwell times such as at highway-adjacent stations serving road trippers, grocery stores, or urban stations serving residents without at-home charging. As battery technology improves and more cars are able to accept higher-powered charging at 150 kW and above, DC chargers will be able to support a quicker "in-and-out" experience similar to what gas stations offer today. For medium- and heavy-duty vehicles, the charging power up to several megawatts will sometimes be necessary to charge batteries used in tractors, buses, and other large vehicles in a reasonable amount of time. However, some medium- and heavy-duty vehicles can charge overnight using a high-powered Level 2 charger.

Counting Chargers

Light-Duty Electric Vehicle Charger Counts

California has set specific goals to increase the supply of zero-emission vehicles and plug-in electric vehicle chargers, including 250,000 electric vehicle chargers (of which 10,000 are direct current fast chargers) by 2025. Tracking and counting the number of electric vehicle chargers, specifically shared private chargers, in California has been challenging, as available data and methods to obtain counts do not provide a comprehensive count of all shared private chargers in California.

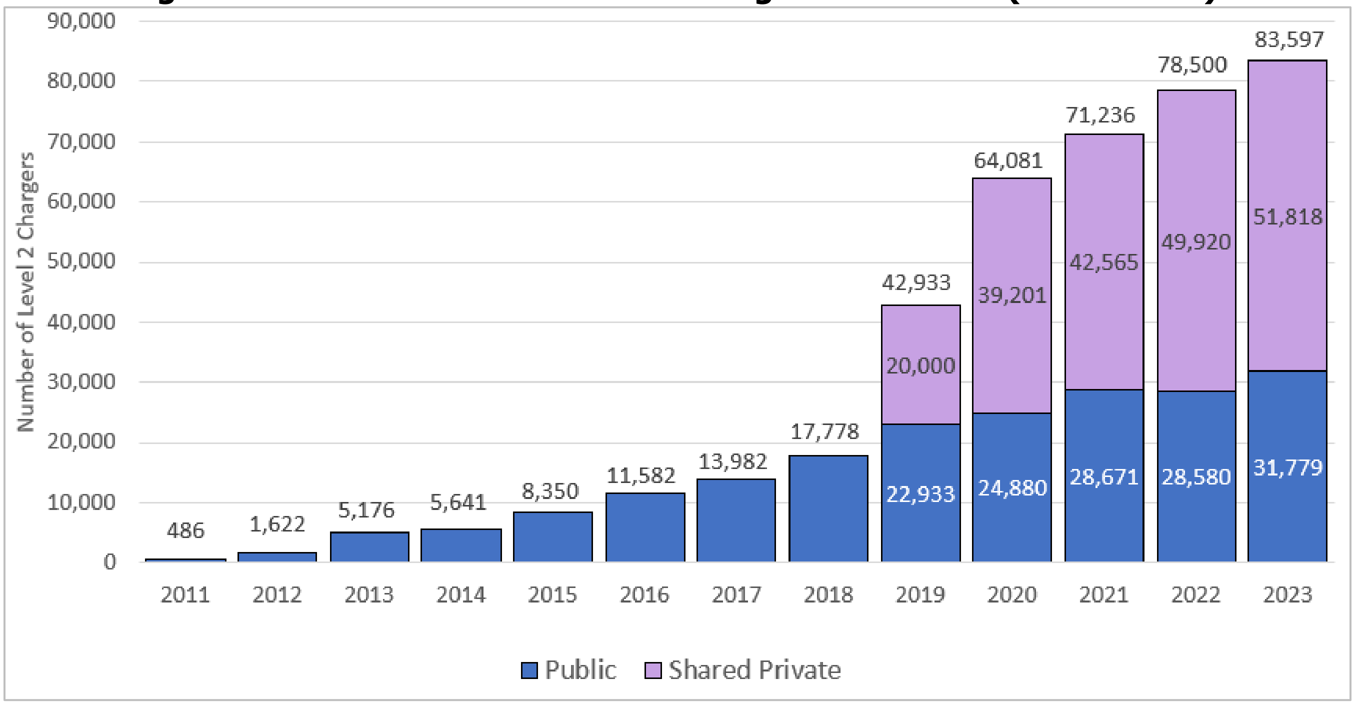
CEC staff obtained public charger counts from the Alternative Fuels Data Center (AFDC) Station Locator managed by the National Renewable Energy Laboratory (NREL). State law requires station operators or developers to report data on publicly available chargers to NREL. The AFDC Station Locator has been transitioning the counting system to count locations, ports, and connectors since 2019. The AFDC Station Locator now counts the number of ports available to charge a vehicle rather than the number of connectors, as previously counted. Therefore, a charger with two connectors that can only charge one vehicle at a time is considered one for counting chargers. Previously, AFDC would have considered this two.

CEC staff obtained shared private charger counts using voluntary surveys. The surveys were sent to electric vehicle service providers (EVSP) and non-EVSPs (public agencies and electric utilities). The surveys collected counts of shared private chargers (typically found in workplaces, multifamily housing, fleets, and other nonpublic venues) in the state. These counts did not categorize chargers by market segment (workplace, public, fleet, and so forth) or include dedicated private chargers such as those installed for personal use at single-family homes.

CEC staff aggregated, or collected, charger counts from the surveys with public charger counts from the AFDC to estimate the existing stock of chargers in the state. The results were published onto the CEC's Zero-Emission Vehicle and Infrastructure Statistics Dashboard.[56] Because the survey was voluntary, the number of shared private chargers does not represent all the shared private chargers in California.

As shown in Figures 13 and 14, as of September 2023, California has nearly 94,000 public and shared private chargers.

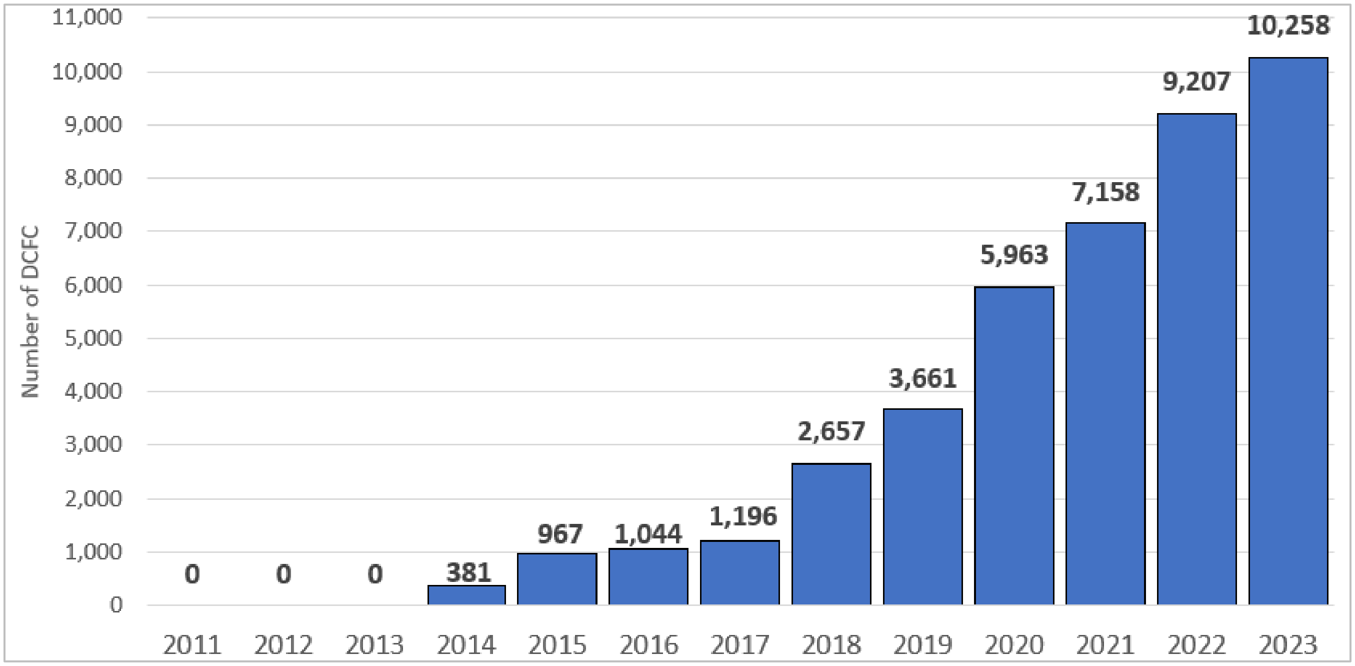
Figure 13: Level 2 Electric Vehicle Chargers Over Time (2011–2023)



Source: AFDC data and CEC staff analysis

56 California Energy Commission. "Electric Vehicle Chargers in California." Data last updated September 15, 2023. Retrieved September 15, 2023, from https://www.energy.ca.gov/zevstats.

Figure 14: DC Fast Chargers Over Time (2011–2023)



Note: Data for 2013 are available only at the station level and do not provide breakout of Level 2 and DCFC. Although 2013 shows 0 DCFC, some DCFC may be accounted for in Figure 12 above.

Source: AFDC data and CEC staff analysis

CEC staff is examining tools, including regulatory action, to ensure better data collection. These tools will allow a more accurate accounting of the number of shared private chargers throughout the state.

Medium- and Heavy-Duty Vehicle Charging Counts

CEC staff is exploring ways to track charging for medium- and heavy-duty (MDHD) vehicles. CEC staff expects rapid electrification of the state's MDHD vehicles partly because of expanded offerings from manufacturers and new regulations to drive the adoption of zero-emission MDHD vehicles. Tracking charging for these vehicles differ from the light-duty sector partly because of the large variation in vehicle and equipment types and duty cycles. The lack of a unified charging connector standard for MDHD and equipment adds to the complexity of tracking. CEC staff will use tools to collect this information to ensure California can track progress toward state goals.

Reliability of Chargers

The reliability of electric vehicle charging infrastructure (chargers) is a growing concern.[57] CEC staff began investigating the issue in late 2021 and held workshops, met with relevant stakeholders and experts, and conducted technical research on this topic. Staff found that there is evidence of shortcomings in EVSE reliability. The CEC has developed reliability-related

57 The CEC takes a wholistic, consumer-focused view of EV charger reliability. A *reliable charger* is a charger that charges your electric vehicle on the first try.

performance, recordkeeping, and reporting requirements that are included in CEC funding agreements. Staff will work closely with stakeholders to iterate and improve upon these requirements to ensure that chargers funded through these agreements are maintained, reliable, and valuable to the public.

AB 2061 addresses charger reliability. This legislation has two key elements. The first is a requirement for the CEC, in coordination with the California Public Utilities Commission (CPUC), to develop uptime recordkeeping and reporting standards for all chargers that received an incentive from a state agency or through a charge on ratepayers. The second requirement is that the CEC assess the uptime of chargers biennially. More recently, the passage of Assembly Bill 126 (Reyes, Chapter 345, Statutes of 2023) requires the CEC to set uptime and operations and maintenance requirements for publicly funded and ratepayer-funded chargers.

For California's investments in EV charging infrastructure to be successful, drivers must be able to charge their electric vehicles reliably. A variety of factors influence whether a consumer will be able to successfully charge their vehicle. Primary among them are the operative state of the charger and related components, the ability for the electric vehicle to successfully communicate with the make and model of the charger, and the success of peripheral payment systems in authorizing payment. Furthermore, the modeling results in this report assume functioning chargers, and results from the models are used to direct investments and policy decisions. Unreliable chargers would increase the number of chargers needed, affect the efficiency of charger investments, and increase uncertainty around investments and policy decisions regarding charging infrastructure.

This section discusses the steps the CEC has taken to ensure the reliability of chargers that it funds, ways the CEC will work to harmonize existing reliability requirements with those required by AB 2061, and the tools the CEC is developing to assess the uptime of chargers in California.

Reliability Standards

CEC staff has developed and implemented reliability standards for chargers funded by the CEC. These standards include performance requirements, recordkeeping and reporting requirements, and maintenance requirements. The standards already developed by staff will be required for CEC solicitations that are released before the AB 2061 rulemaking being finalized. They will also guide initial staff proposals for the uptime recordkeeping and reporting requirements, operations and maintenance requirements, and minimum reliability performance requirements required by AB 2061 and AB 126.

AB 2061 requires the uptime recordkeeping and reporting requirements to be made in coordination with the CPUC. The recordkeeping and reporting requirements, operations and maintenance requirements, and minimum reliability requirements of AB 2061 and AB 126 apply to all funded chargers installed after January 1, 2024. CEC staff issued a draft Staff Report including proposed regulations under AB 2061 on August 24, 2023. Staff is reviewing stakeholder comment and expects to open a formal rulemaking in the first quarter of 2024.

Assessment of Charger Uptime

Beginning January 1, 2025, AB 2061 requires the CEC to conduct a biennial assessment of the uptime of charging station infrastructure. Unlike the other requirements required by AB 2061, this assessment is not limited to publicly funded or ratepayer-funded chargers. The CEC intends to conduct an overall assessment of reliability in the state as outlined in AB 2061. The CEC is considering a range of options to expedite this assessment, including:

1. A field monitoring program to annually test a significant number of chargers in California across disadvantaged, nondisadvantaged,[58] rural, and urban communities.
2. Voluntary data requests to charger network providers and charger operators.
3. A mechanism for consumers to report downed chargers directly to the CEC.
4. Conducting a rulemaking to require all chargers in California to provide uptime and reliability related data to the CEC.

The data from the tools discussed here will allow CEC staff to assess the overall health of the charging network in California. This assessment will give a clearer picture of what parts of the industry are problematic and need addressing, where investments need to be directed, and whether models need additional parameters to account for unreliable chargers. Equally important, the assessment will provide a more transparent view of the success of public investments in electric vehicle charging infrastructure.

Senate Bill 1000

Senate Bill 1000 (Lara, Chapter 368, Statutes of 2018) requires the CEC, as part of developing the Clean Transportation Program Investment Plan, to assess whether chargers are disproportionately deployed by income level, population density, or geographical area. If the CEC finds that chargers have been disproportionately deployed, the CEC shall use Clean Transportation Program funds and other mechanisms to deploy chargers more proportionately, unless the CEC finds that the disproportionate deployment was reasonable and furthered state energy and environmental policies as articulated by the CEC.

Staff published the first SB 1000 assessment, *California Electric Vehicle Infrastructure Deployment Assessment: Senate Bill 1000 Report*,[59] on December 30, 2020. The report assessed the geographic distribution and density of public Level 2 and direct-current fast chargers by income level and population density. The report concluded that low-income communities,[60] on average, have fewer public chargers per capita than middle- or high-income

58 Disadvantaged communities defined by CalEnviroScreen 4.0

59 Hoang, Tiffany. 2020. *California Electric Vehicle Infrastructure Deployment Assessment: Senate Bill 1000 Report*. California Energy Commission. Publication Number: CEC-600-2020-009. https://www.energy.ca.gov/publications/2020/california-electric-vehicle-infrastructure-deployment-assessment-senate-bill.

60 *Low-income communities* are census tracts with median household incomes at or below 80 percent of the statewide median income or with median household incomes at or below the threshold designated as low income by the Department of Housing and Community Development's list of state income limits adopted under Health and Safety Code Section 50093.

communities.[61] Public chargers are unevenly distributed across state air districts and counties but correlated with county populations and rates of adoption for plug-in electric vehicles.

CEC staff published the second assessment, *Senate Bill 1000 California Electric Vehicle Infrastructure Deployment Assessment Drive Times to Direct-Current Fast Chargers,*[62] on July 14, 2022. The report assessed drive times from census tract residential population centers to the nearest public fast charging station to identify communities with sparse public fast charging coverage, defined as a drive time of 10 minutes or more. Drive-time analysis allows the identification of charging network gaps that discourage travel within California communities and travel to and from those communities. According to the second report, rural communities have less public fast charging coverage than urban communities[63] (Figure 15). About 88 percent of urban communities are within 10 minutes of a public DC fast charger; in contrast, about 40 percent of rural communities are within 10 minutes of one.

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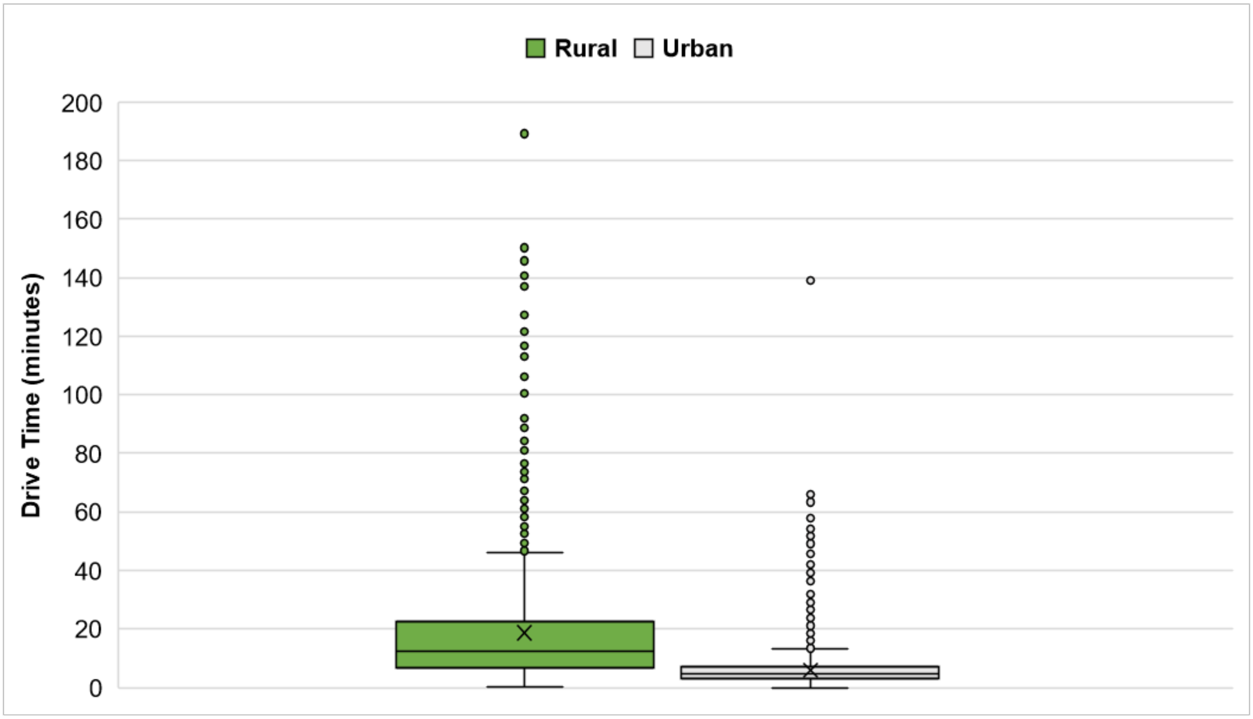
61 *Middle-income communities* are census tracts with median household incomes between 80 to 120 percent of the statewide median income, or with median household incomes between the threshold designated as low- and moderate-income by the Department of Housing and Community Development's list of state income limits adopted under Health and Safety Code Section 50093.

High-income communities are census tracts with median household incomes at or above 120 percent of the statewide median income or with median household incomes at or above the threshold designated as moderate-income by the Department of Housing and Community Development's list of state income limits adopted under Health and Safety Code Section 50093.

62 Hoang, Tiffany. 2022. *Senate Bill 1000 California Electric Vehicle Infrastructure Deployment Assessment. California Energy Commission.* Publication Number: CEC-600-2022-059. https://www.energy.ca.gov/publications/2022/2022-senate-bill-1000-california-electric-vehicle-infrastructure-deployment.

63 Rural communities are census tracts where at least 50 percent of the census tract land area is designated rural by the U.S. Census Bureau. Urban communities are all other census tracts.

Figure 15: Drive Time to the Nearest Public DC Fast Charging Station by Urban and Rural Communities



Public direct-current fast-charging station coverage is sparser in rural communities than urban communities. Drive times for rural communities range from less than five minutes to more than three hours. Drive times for urban communities range from less than five minutes to more than two hours. [64]

Source: CEC staff

About 11 percent of all low-income communities are rural. Low-income rural communities have the least access to public fast charging — 69 percent are 10 minutes or more from a public DC fast charger, which is more than any other group (Table 3).

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64 Source: California Energy Commission analysis using data from the U.S. Census Bureau 2010 Urban and Rural Classifications, U.S. Department of Energy's Alternative Fuels Data Center as of February 2, 2021, and California Air Resources Board California Hydrogen Infrastructure Tool roadway data. Underlying data are available on the SB 1000 webpage at https://www.energy.ca.gov/programs-and-topics/programs/clean-transportation-program/electric-vehicle-infrastructure.

Table 3: Drive-Time Ranges by Income Level and Urban or Rural Area

Income and Community Type	0 to 5 mins	6 to 9 mins	10 plus mins	N/A	Total
Low-Income Rural	16%	14%	69%	1%	100%
Low-Income Urban	61%	28%	11%	0%	100%
Middle-Income Rural	19%	22%	58%	1%	100%
Middle-Income Urban	62%	24%	14%	0%	100%
High-Income Rural	25%	29%	45%	1%	100%
High-Income Urban	54%	32%	14%	0%	100%

Drive times from rural community population centers are long, especially for low-income rural communities. More than half of all low-income rural communities and more than half of all middle-income rural communities have drive times of 10 minutes or more to a public direct current fast charging station.[65]

Source: CEC staff

About 92 percent of disadvantaged communities[66] in California are urban and tend to be close to major highways where public direct-current fast charging stations are more likely to be found. Despite greater average fast charging station coverage in disadvantaged urban communities than nondisadvantaged urban communities, gaps still exist where about 11 percent of disadvantaged urban communities have drive times of 10 minutes or more. Figure 16 shows that several disadvantaged communities in the Los Angeles area have long drives to public fast charging.

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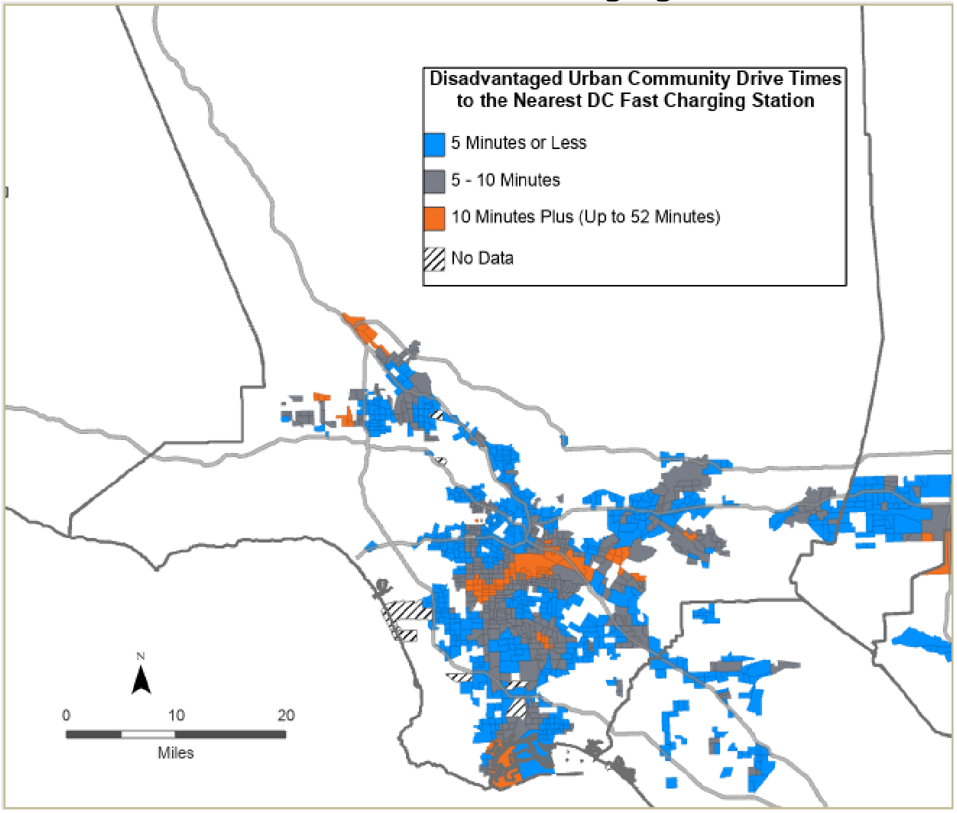
65 Source: California Energy Commission analysis using data from the U.S. Census Bureau 2014-2018 American Community Survey Median Household Income and Average Household Size 5-Year Estimates, California Department of Housing and Community Development 2020 State Income Limits, U.S. Census Bureau 2010 Urban and Rural Classifications, U.S. Department of Energy Alternative Fuels Data Center as of February 2, 2021, and California Air Resources Board California Hydrogen Infrastructure Tool roadway data.

66 *Disadvantaged communities* are census tracts that score within the top twenty-fifth percentile of the Office of Environmental Health Hazards Assessment's California Communities Environmental Health Screening Tool (CalEnviroScreen) 3.0 scores, as well as areas of high pollution and low population, such as ports. (At the time of this analysis, disadvantaged community designations under CalEnviroScreen 4.0 had not been finalized.)

Figure 16: Map of Los Angeles Area Disadvantaged Community Drive Times to the Nearest Public DC Fast Charging Station



About 11 percent of disadvantaged urban communities have drive times 10 minutes or more to a public DC fast charging station. Of these, most are between 10 and 30 minutes; 7 percent are between 30 and 46 minutes.[67]

Source: CEC staff

Lack of access to charging infrastructure is a significant barrier to EV adoption and use. Despite investments within low-income and disadvantaged communities, charging coverage gaps persist. Solutions to improve charging access will vary and depend on the intersecting characteristics of a community. CEC staff will continue to refine and update the analysis to identify charging network gaps in underserved communities and build charging infrastructure that serves all Californians. The next assessment will build upon the CEC's *Home Charging Access in California* report,[68] published January 7, 2022, and include analysis of alternatives to home charging by income level, population density, and geographical area.

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67 Source: California Energy Commission analysis using data from the U.S. Census Bureau 2010 Urban and Rural Classifications, California Environmental Protection Agency disadvantaged community designations using the California Office of Environmental Health Hazard Assessment's CalEnviroScreen 3.0 mapping tool, U.S. Department of Energy Alternative Fuels Data Center as of February 2, 2021, and California Air Resources Board California Hydrogen Infrastructure Tool roadway data. At the time of this analysis, urban and rural classifications from the 2020 census had not yet been finalized.

68 Alexander, Matt. January 2022. *Home Charging Access in California*. California Energy Commission. Publication Number: CEC-600-2022-021. Available at https://www.energy.ca.gov/publications/2022/home-charging-access-california.

CHAPTER 4: Modeling California Charging Needs

This chapter explores the number of chargers that will be needed to meet California's ZEV goals through 2035. The modeling results presented here project that California will need 1.01 million public and shared private chargers, including 39,000 DCFC chargers, to support 7.1 million light-duty plug-in electric vehicles in 2030, and 2.11 million chargers, including 83,000 DCFC chargers, to support 15.2 million light-duty plug-in electric vehicles in 2035. To support medium- and heavy-duty plug-in electric vehicles, California will need 109,000 depot chargers and 5,500 en route chargers for 155,000 vehicles in 2030, and 256,000 depot chargers and 8,500 en route chargers for 377,000 vehicles in 2035. The rest of this chapter describes the models and assumptions used to produce these results and identifies the types and locations of chargers that will be key to allowing the state to meet its ZEV goals.

Modeling Overview

This analysis seeks to identify the number and types of PEV chargers that will be needed for the state to meet ZEV adoption targets from now through 2035. These results are intended to help direct statewide and local strategy to the most beneficial charging solutions. In doing this, it is important to improve equity and decrease costs, identify charging strategies that support grid health, and ensure that the expansion of charging infrastructure is well-planned and well-integrated with the grid. While a statewide analysis is important, it does not provide a single solution that will be optimal at every location and for every use case. Considering local land use, grid capacity, and at- and near-home charging is necessary to design a system that is usable, affordable, and equitable.

Over the last year, state agencies have formalized many of the state's ambitious ZEV adoption, climate, and air quality goals. The modeling results presented in this chapter are built around scenarios that comply with the Advanced Clean Cars (ACC) I and II, Advanced Clean Fleets (ACF), Advanced Clean Trucks (ACT), and Innovative Clean Transit (ICT) regulations. For each of the main light-duty and medium- and heavy-duty infrastructure analyses, CEC staff presents a scenario based on CARB's projections for the impact of its regulations and the Additional Achievable Transportation Electrification 3 (AATE3) scenario developed by the CEC's Energy Assessments Division for the Integrated Energy Policy Report.

To quantify California's charging needs at the statewide and local levels, the CEC has partnered with the National Renewable Energy Laboratory, Lawrence Berkeley National Laboratory, and the University of California, Davis, to develop quantitative analysis tools covering various vehicle classes, use cases, and local conditions. The models presented in this section build and improve on the models used for the first AB 2127 assessment. Table 4 summarizes the models included in this report.

Table 4: Summary of CEC Charging Infrastructure Quantitative Analyses

Model	Description
Electric Vehicle Infrastructure Projection Tool (EVI-Pro 3)	Projects Level 1, Level 2, and DC fast charging infrastructure needs to enable electrified intraregional (under 100 miles) travel for vehicles with a gross vehicle weight rating (GVWR) of 10,000 pounds or less.
Electric Vehicle Infrastructure for Road Trips (EVI-RoadTrip)	Projects DC fast charging infrastructure needs to enable electrified long-distance/interregional (at least 100 miles) travel for vehicles with a gross vehicle weight rating (GVWR) of 10,000 pounds or less.
Widespread Infrastructure for Ride-Hailing PEV Deployment (WIRED)	Projects additional charging infrastructure needs to enable electrification of ride-hailing services via transportation network companies.
Medium- and Heavy-Duty Electric Vehicle Infrastructure Load, Operation, and Deployment (HEVI-LOAD)	Projects charging infrastructure needs to enable electrification of on-road medium- and heavy-duty vehicles with a GVWR of 10,001 pounds and above.
EVSE Deployment and Grid Evaluation (EDGE) Model	Geospatially analyzes to track local grid capacity, travel demand, and vehicle load.

Source: CEC staff

EVI-Pro 3

The Electric Vehicle Infrastructure Projection tool (EVI-Pro 3) projects the number, locations, and types of chargers required to meet the needs of California's light-duty PEV drivers for intraregional trips (under 100 miles). EVI-Pro 3 uses travel survey data, vehicle characteristics, and charging costs to estimate the charging demand from travel by light-duty PEVs and design a supply of shared Level 1, Level 2, and DC fast chargers capable of meeting the charging needs without requiring significant changes to people's daily schedules.

The original EVI-Pro 1 model, developed in 2016 through a collaboration between the CEC and the National Renewable Energy Laboratory (NREL), set the standard for charging infrastructure assessments in California[69] and across the United States.[70] The EVI-Pro 2 model built on this foundation, incorporating evolving technology and market conditions, and was

69 Bedir, Abdulkadir, Noel Crisostomo, Jennifer Allen, Eric Wood, and Clément Rames. 2018. California Plug-In Electric Vehicle Infrastructure Projections: 2017-2025. California Energy Commission. Publication Number: CEC-600-2018-001. https://efiling.energy.ca.gov/getdocument.aspx?tn=222986.

70 Electric Vehicle Infrastructure Projection Tool (EVI-Pro) Lite. U.S. Department of Energy Alternative Fuels Data Center, November 30, 2020. https://afdc.energy.gov/evi-pro-lite.

used to estimate the charging infrastructure needed to support nearly 8 million ZEVs by 2030 as part of the first AB 2127 assessment published in 2021.[71]

Changes to the EVI-Pro 3 Model

EVI-Pro 3 has been upgraded to provide a more realistic depiction of charging behavior, deliver results at a higher level of geographic detail, and address changes in PEV ownership and technology from now to 2035.

- **Heterogeneous depiction of charging behavior:** Simulated drivers have a range of preferences for how to charge their vehicles rather than behaving homogeneously. Model simulates a wider range of activity types.
- **Level of detail:** The model produces separate charger counts for public and shared private chargers at commute destinations of various types, based on the proportion of California's population working in different economic sectors, according to the California Employment Development Department.[72] The model estimates infrastructure needs at the level of traffic analysis zones (TAZs),[73] which are used for transportation planning in the California Statewide Travel Demand Model. Because EVI-Pro 3 produces infrastructure estimates at the TAZ level, the outputs can be harmonized with those of the RoadTrip model, which is used to estimate the amount of infrastructure needed to support long-distance travel.
- **Changes in PEV ownership and technology:** The model simulates a wider range of vehicle body styles and electric ranges. The model incorporates higher-powered AC and DC charging types and produces DC fast charger needs broken down by power level (50, 150, 250, and 350 kW).

The decision to split charging at commute destinations into public and shared private charging and differentiate by workplace type is particularly worth highlighting. In addition to providing a more complete depiction of charging needs, this change allowed CEC staff and NREL to compare the results of the model with the findings of the CEC's Counting Chargers effort.

In the first AB 2127 Assessment, EVI-Pro 2 provided charger needs estimates separately for four types of Level 2 charging: home (single-family), home (multifamily), work, and public. Work charging was defined by the activity done while charging, not the location type. Because many potential locations of public charging (shopping centers, downtowns, entertainment

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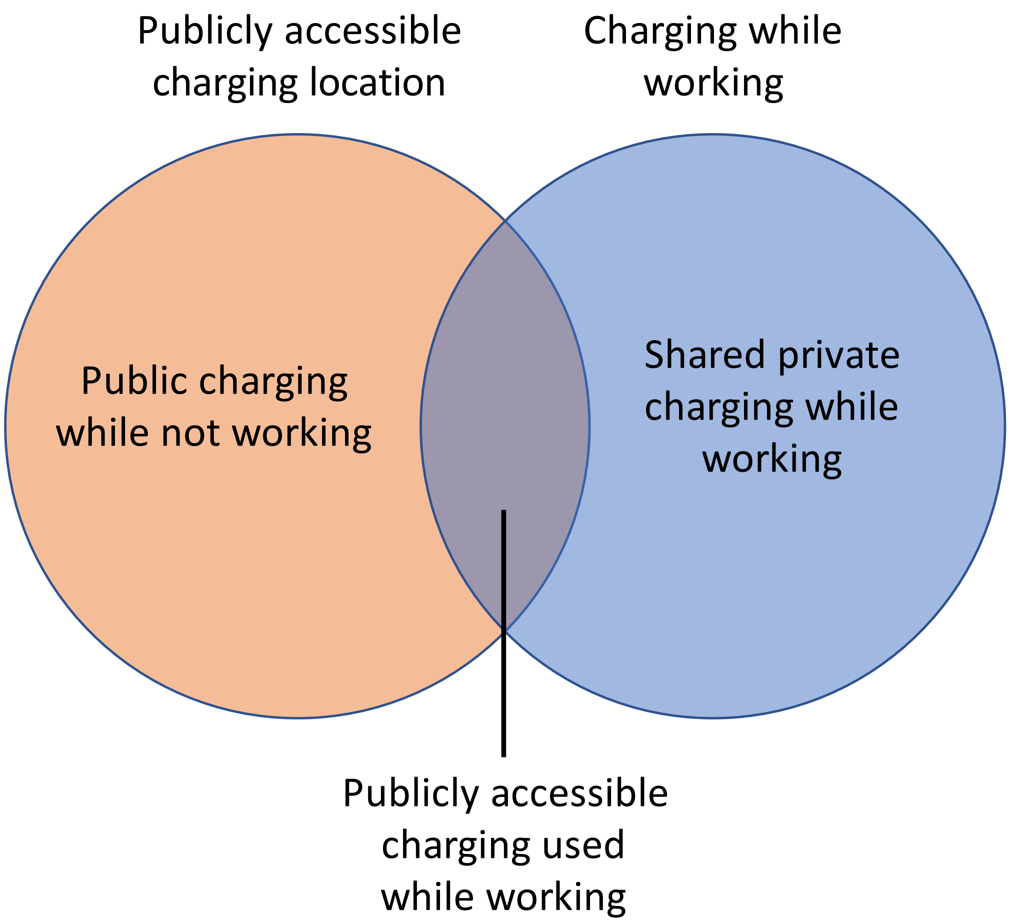
71 Alexander, Matt, Noel Crisostomo, Wendell Krell, Jeffrey Lu, and Raja Ramesh. July 2021. *Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment: Analyzing Charging Needs to Support Zero-Emission Vehicles in 2030 – Commission Report*. California Energy Commission. Publication Number: CEC-600-2021-001-CMR. https://efiling.energy.ca.gov/getdocument.aspx?tn=238853.

72 California Employment Development Department. 2023. "Industry Employment & Labor Force March 2022 Benchmark." https://labormarketinfo.edd.ca.gov/data/employment-projections.html.

73 *Traffic analysis zones* (TAZs) are geographic units used in transportation planning, including in the transportation models that are used as data sources for the charging models presented in this report. Transportation models use TAZs as origin and destination locations rather than modeling trips between all possible pairs of locations. Different transportation models use different sizes of TAZs depending on the desired complexity of the model, but in general, TAZs are smaller in densely developed areas and larger in sparsely developed areas.

destinations, and so forth) are also work locations, EVI-Pro 3 has been updated to provide results both by location/activity type and access type. The reasoning behind this change is that while some charging locations serve only specific activities and users, other charging locations can serve a wide range of potential users. Figure 17 shows the intersection of publicly accessible charging with charging while working. The left circle depicts all publicly accessible charging; the right circle depicts charging while working. The intersection represents when people use public chargers while working. Publicly accessible charging locations that people can use to charge their vehicles while they are at work include parking garages in downtowns, retail establishments whose employees use chargers while working, and other publicly accessible locations.

Figure 17: Venn Diagram of the Relationship Between Publicly Accessible Charging and Charging While at Work



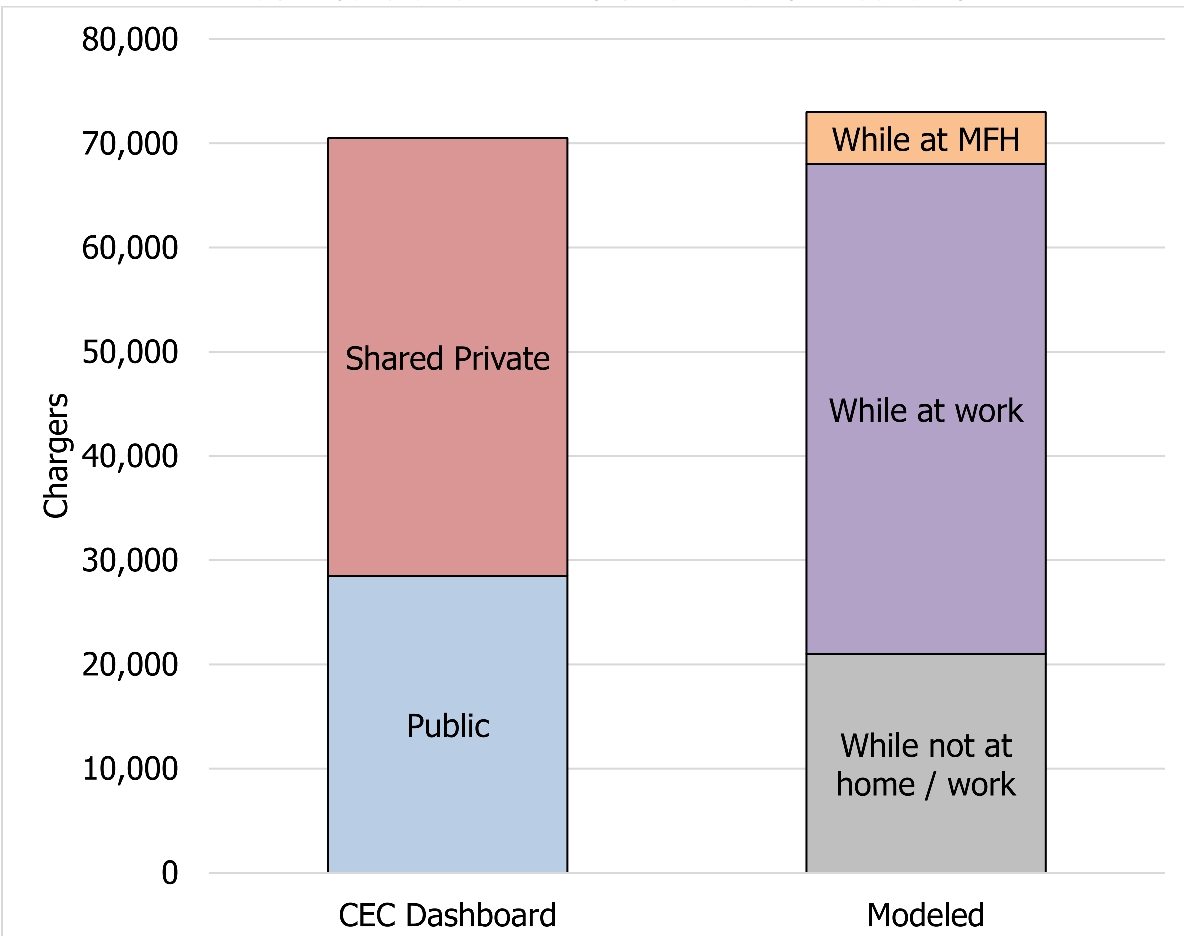
While some people work at locations where shared private charging makes sense, many people work at businesses and location types where publicly accessible chargers shared with customers or workers at nearby businesses could meet their needs.

Source: CEC

While early market workplace charging may have catered to commuters working in office jobs with private parking lots, characterizing workplace charging in proportion to the occupations of all Californians will make this category of publicly accessible workplace charging grow and better reflect the needs for wider vehicle adoption.

This change also has the benefit of better harmonizing with the CEC's Counting Chargers effort, which classifies chargers as either public access or shared-private access. To develop this aspect of the model, CEC staff and NREL developed a validation scenario to compare the estimate of charging needs of the EVI-Pro 3 for 2021 with the number of chargers identified by counting chargers, the results of which are shown in Figure 18. This analysis sought to understand the link between the charger access categories included in Counting Chargers and the behavioral categories used by EVI-Pro 3 and check that the model was producing reasonable results. Charging at multifamily housing ("While at MFH" in the figure) likely relies on shared private chargers accessible only to the residents of a building. Charging while at retail, entertainment, or other locations relies primarily on public chargers. Charging while at work can use either kind of charger, depending on work location. This analysis suggests that charging while at work corresponds mostly to shared private charging locations, but this finding may change as PEV ownership expands.

Figure 18: Shared Charging Comparison Between CEC Counting Chargers Dashboard and EVI-Pro 3 Calibration Scenario



The EVI-Pro 3 back casting exercise attempted to link existing shared charging infrastructure to modeled activity locations. This exercise showed that while most charging "while at work" likely uses shared private chargers, other charging uses public chargers.

Source: National Renewable Energy Lab

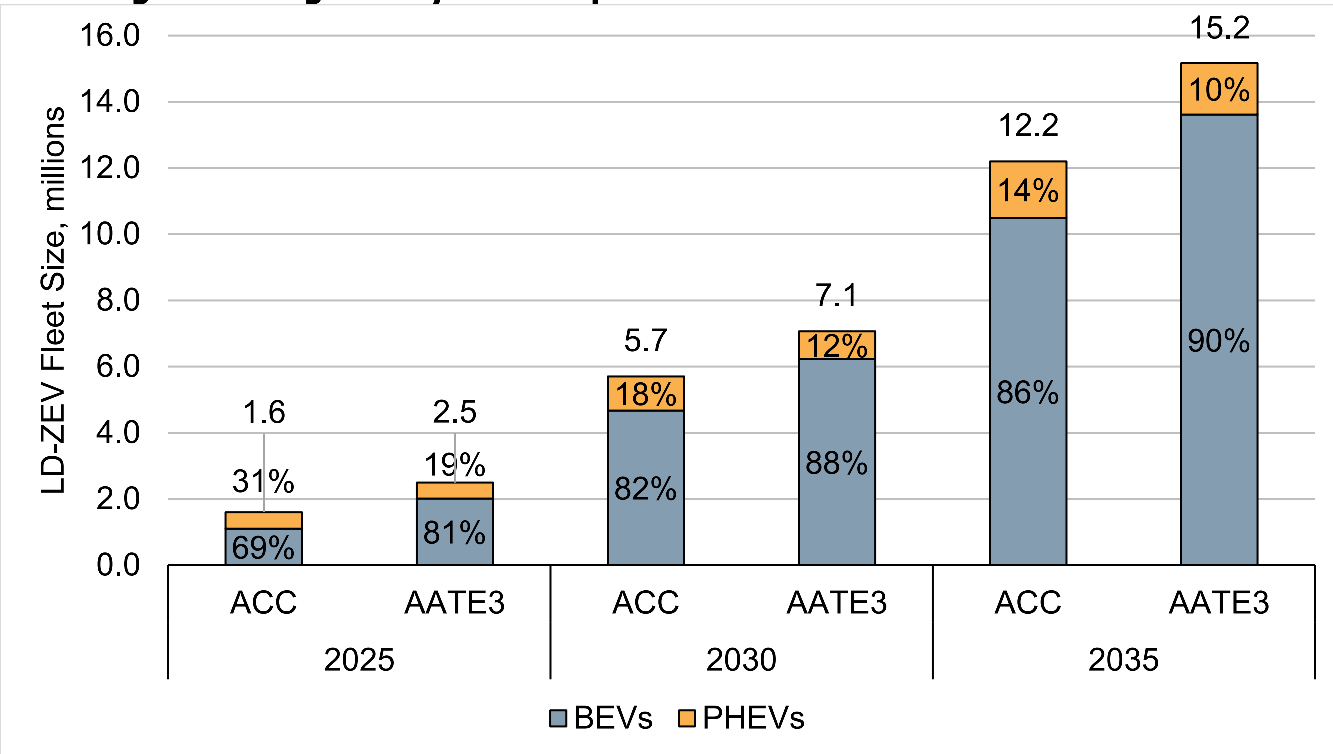
Light-Duty PEV Adoption Scenarios

California has made significant progress toward electrifying light-duty transportation since the publication of the first AB 2127 Assessment in 2021. As of the end of 2022, there are more than a million light-duty ZEVs on the roads in California. Through the second quarter of 2023, cumulative sales in California have reached 1.6 million zero-emission vehicles. Zero-emission vehicles made up 18.8 percent of all light-duty vehicles sold in the state in 2022 and rose to 26.7 percent of light-duty vehicle sales in the third quarter of 2023. In addition, the Advanced Clean Cars II regulation puts California on a path to reaching 100 percent light-duty ZEV sales by 2035.

Because of this progress, CEC staff and NREL were able to develop a narrower range of EV adoption scenarios for EVI-Pro 3 than in the first assessment. The first assessment included three main scenarios for light-duty ZEV adoption: the CEC's IEPR low forecast, the CEC's IEPR high forecast, and CARB's Mobile Source Strategy. CARB's Mobile Source Strategy was included to project the necessary vehicle population to meet state air quality and climate policy goals, including 100 percent zero-emission new passenger car sales by 2035 per Executive Order N-79-20. The IEPR low forecast included 1.9 million ZEVs, the IEPR high forecast included 5.0 million ZEVs, and the Mobile Source Strategy included 8 million vehicles. PEVs made up 95 to 96 percent of the light-duty ZEV population in each scenario. In this assessment, CEC staff presents two scenarios for light-duty vehicles: CARB's projections of the minimum PEV fleet size resulting from the Advanced Clean Cars II regulations and the CEC's Energy Assessments Division Additional Achievable Transportation Electrification 3 (AATE3) scenario developed for the 2022 Integrated Energy Policy Report (IEPR). The scenario derived from CARB has a PEV population of 5.7 million in 2030, and the AATE3 scenario has a PEV population of 7.1 million in 2030.

The AATE3 scenario is treated as the primary scenario in this report because this scenario allows staff to account for the potential needs of a larger fleet if PEV adoption continues to accelerate, whereas the ACC scenario represents the minimum possible impact of the ACC II regulation. The AATE3 scenario complies with the ACC II regulation but is based on a larger total light-duty vehicle (LDV) population and assumes higher annual LDV sales and an overall greater trend toward BEVs. Figure 19 shows the light-duty CARB scenario as ACC II and the CEC scenario as AATE3 for BEVs and PHEVs (including both plug-in vehicles that have an internal combustion engine and a small number of plug-in vehicles that also use hydrogen fuel cell technology).

Figure 19: Light-Duty PEV Adoption Scenarios Used in This Assessment



This assessment uses two scenarios for the number of light-duty PEVs in California in 2025, 2030, and 2035. The lower ACC scenario corresponds to CARB's projections of the minimum PEV fleet size resulting from the Advanced Clean Cars regulations. The higher AATE3 scenario corresponds to the CEC's Energy Assessments Division's AATE3 scenario, which complies with the Advanced Clean Cars regulations but assumes a larger total fleet size and a higher proportion of BEVs in all years.

Source: CEC staff

In addition to updating the ZEV fleet size, the CEC staff and NREL have made several changes to other key modeling assumptions for EVI-Pro 3 to bring the model up to date:

- Hydrogen fuel cell electric vehicles (FCEVs) are expected to play a smaller role in the electrification of light-duty vehicles compared to medium- and heavy-duty vehicles. The adoption scenario used in this assessment assumes that FCEVs will make up between 1 percent and 1.4 percent of the light-duty ZEV fleet from 2023 to 2035. If FCEV adoption increases, the number of PEV chargers needed would decrease.
- A small number of plug-in FCEVs are included in the AATE3 scenario starting in 2024. By 2035, plug-in FCEVs will make up roughly one-quarter of FCEVs and 0.27 percent of all ZEVs. Plug-in hydrogen fuel cell electric vehicles will be assumed to behave the same as PHEVs with internal combustion engines in EVI-Pro 3.
- BEVs will make up a larger share of light-duty ZEVs than was predicted when the first AB 2127 report was published. This change is due both to ACCII capping PHEV sales at a lower value than was assumed in scenarios for the first AB 2127 report and a shift in the market away from PHEVs and short-range BEVs toward long-range BEVs.

- Access to charging at home will decrease as the PEV fleet increases in size. CEC staff derives this assumption from a CEC study based on a charging access survey conducted by NREL.[74]
- EVI-Pro 3 uses updated vehicle ranges and energy efficiency ratings.

As in the first assessment, this assessment includes "alternative future" scenarios to address the uncertainties inherent in projecting infrastructure needs a decade in the future. Each of these scenarios modifies the inputs and assumptions of the 2030 AATE3 scenario to generate a new set of network infrastructure and load profile results.

Compared to the adoption scenarios used in the first AB 2127 assessment, this scenario includes slightly fewer total ZEVs but a larger share of BEVs, particularly long-range BEVs that can accept higher charging speeds. Table 5 outlines critical modeling differences between EVI-Pro 1, EVI-Pro 2, and EVI-Pro 3. Appendix B provides more details on parameters and inputs used in EVI-Pro 3 for the baseline scenarios and alternative future scenarios.

Table 5: Comparison of Primary Input Parameters for EVI-Pro 1-3

Input	EVI-Pro 1	EVI-Pro 2	EVI-Pro 3
ZEV Population	1.5 million in 2025	8 million in 2030	7.1 million in 2030 and 15.3 million in 2035
PEV (BEVs + PHEVs) Population	1.25 million in 2025	7.5 million in 2030	7.1 million in 2030 and 15.2 million in 2035
Within ZEVs, PEV / Hydrogen Fuel Cell Electric Vehicle Split	87%/13% in 2025	95%/5% in 2030	99%/1% in 2030 and 2035
Within PEVs, PHEV / BEV Split	45%/55% in 2025	33%/67% in 2025 30%/70% in 2030	19%/81% in 2025 12%/88% in 2030 10%/90% in 2035
PEVs w/ Home Charging	92% in 2025	67% in 2030	78% in 2025 66% in 2030 60% in 2035
Time-of-Use Rate Responsiveness	Not included	67% in 2030	50% in 2025 100% in 2030 and 2035

Source: CEC and National Renewable Energy Laboratory

74 Alexander, Matt. January 2022. *Home Charging Access in California*. California Energy Commission. Publication Number: CEC-600-2022-021. Available at https://www.energy.ca.gov/publications/2022/home-charging-access-california.

Charging Infrastructure Needs

EVI-Pro 3 projects that to support routine intraregional travel by 7.1 million BEVs and PHEVs in 2030, California will need to install 313,000 shared private Level 1 and Level 2 chargers at multifamily housing sites, 656,000 public and shared private Level 2 chargers at commute destinations and other activity locations, and 32,800 DCFC chargers.[75]

To support 15.2 million light-duty BEVs and PHEVs in 2035, California will need to install 577,000 shared private Level 1 and Level 2 chargers at multifamily housing sites, 1.45 million public and shared private Level 2 chargers at commute destinations and other activity locations, and 72,800 public DCFC chargers[76] across a range of location types.

Compared to the first AB 2127 assessment Mobile Source Strategy scenario, which included 7.5 million light-duty PEVs in 2030, the AATE3 scenario for 7.1 million PEVs in 2030 has slightly lower total Level 1 and Level 2 charger counts and slightly higher DCFC charger counts. This change reflects changes in the adoption scenario and model assumptions:

- EVI-Pro 3 projects that California will need about 4 percent fewer chargers at multifamily housing sites (313,000 chargers compared to 327,000). This number generally matches the change between the AATE3 scenario, which contains 7.1 million PEVs, and the Mobile Source Strategy scenario, which contains 7.5 million PEVs.
- EVI-Pro 3 projects a need for about 18 percent fewer total Level 2 chargers at work and public sites (656,000 compared to 797,000). This change can be attributed to the decline in totals PEVs and the shift away from PHEVs, which used large amounts of Level 2 away from home in the first assessment, to long-range BEVs, which need to charge less often away from home and often use DCFC when they do.
- EVI-Pro 3 projects a need for 7 percent more DC fast chargers (32,800 compared to 30,600). This modification mirrors the change in Level 2 charging away from home — more BEVs means more demand for high-speed charging and less demand for low-speed charging away from home.

Table 6 shows the total numbers of Level 1, Level 2, and DC fast chargers needed in 2025, 2030, and 2035 under the AATE3 scenario. EVI-Pro 3 produces a range of values for each scenario to provide a sense of the uncertainty about future travel behavior and charging needs. The text, tables, and figures in the body of the report are based on the average value for each scenario. Appendix D contains high and low values for statewide charger counts, annual results for the AATE3 scenario from 2025 to 2035, and county-by-county results for the baseline scenario and ACC II scenarios.

75 This number is the count of DCFC chargers needed to support routine/intraregional travel by BEVs in 2030. DCFC counts for long-distance/interregional travel and transportation network company vehicles are provided in the sections on EVI-RoadTrip and WIRED, respectively, and the section titled "Combined DC Fast Charging Needs for Light-Duty Vehicles" provides combined results for all three models.

76 As with the DCFC count for 2030, this number is for routine/intraregional travel only. Other DCFC needs are covered in later sections.

Table 6: Total Number of Chargers for Intraregional Travel by Privately Owned Light-Duty Vehicles in 2025, 2030, and 2035 Under AATE3 Scenario

Category and Location	Plug Type	2025	2030	2035
Single-Family Housing	Level 1	703,993	1,373,064	2,328,896
Single-Family Housing	Level 2	1,078,200	2,728,362	5,717,384
Multi-family Housing	Level 1	21,738	121,975	196,388
Multi-family Housing	Level 2	26,284	191,346	380,628
Shared Private (While at Work)	Level 2	116,227	287,713	587,384
Public (While at Work)	Level 2	40,837	141,710	391,590
Public (Nonwork Activities)	Level 2	36,899	226,761	474,732
Total Public and Shared Private	Level 1 and Level 2	241,984	969,505	2,030,721
Total for Routine Intraregional Travel	DCFC	12,343	32,831	72,768

Source: National Renewable Energy Lab

Table 7 breaks down the number of Level 2 chargers at nonhome locations for work and nonwork activities. Work chargers are allocated to three location types based on the proportion of California’s population working in different economic sectors. Chargers associated with nonwork activities are allocated to “Retail” and “Other” locations. As PEV adoption expands, an increasing share of workplace charging events will take place at locations like retail and entertainment establishments where public charging may be able to serve workers and customers.

Table 7: Number of Public and Shared Private Level 2 Chargers Serving Work and Nonwork Charging Events Away From Home Under the AATE3 Scenario

Access	Location	2025	2030	2035
Shared Private	Office	102,091	206,123	293,692
Shared Private	Retail	6,283	34,354	129,225
Shared Private	Other	7,853	47,237	164,468
Public	Office	31,413	85,885	195,795
Public	Retail	23,161	139,146	323,516
Public	Other	23,161	143,440	347,011

Source: National Renewable Energy Lab

Table 8 shows the number of DCFC chargers needed by power level. Because DCFC charging events usually take place during trips rather than at the destination, EVI-Pro 3 assumes drivers prefer speed and assign vehicles to the highest-powered charger that their vehicles can accept. Improving vehicle technology means that more vehicles will be able to accept higher-powered charging, and the declining number of lower-powered (150 kW or less) DC fast chargers after 2025 reflects an increased share of vehicles able to accept higher charging speeds, rather than an absolute decreased demand for lower-powered DCFC. Demand for lower-powered chargers may persist if they offer less costly charging than higher-powered DC fast chargers and if some drivers do not require the extra charging speed.

EVI-Pro 3 estimates the number of DCFC chargers to support routine intraregional travel by BEVs. However, the total number of DCFC chargers needed in California also includes the results of the EVI-RoadTrip and WIRED models, which estimated DCFC needs for long-distance travel and transportation network company vehicles, respectively. DCFC needs from EVI-RoadTrip, WIRED, and the combination of all three models are covered later in this chapter.

Table 8: Number of DC Fast Chargers of Different Power Levels Needed to Support Routine Intraregional Travel Under the AATE3 Scenario

DCFC Power Level	2025	2030	2035
150 kW or less	2,482	4,268	4,910
250 kW	5,429	10,731	21,462
350 kW	4,433	17,833	46,396

Source: National Renewable Energy Lab

Grid-Friendly Charging

As PEV ownership expands, vehicle charging will comprise an increasing share of California's energy demand. Coordinated investments in the grid and charging infrastructure will support charging and community needs locally and statewide. EVI-Pro 3 produces load curves covering all charging of privately owned light-duty PEVs based on the assumption that drivers will generally choose the lowest-cost, most convenient charging option that works with their schedule. Under this assumption, charging at home is the first choice when available, followed by Level 2 charging at work, Level 2 charging at other locations, and then DCFC. Some drivers are assumed to prefer DCFC over other nonhome charging locations. Appendix C identifies the full mix of charging behaviors for drivers in this model.

Most PEV charging is done at home, so optimizing home charging is particularly important for the grid. Because home charging has the most flexible schedule, some can be adjusted to integrate with the grid and make the best use of clean energy. The primary scenario produced by EVI-Pro 3 assumes that most people will seek to charge their vehicles at less expensive times of day, taking advantage of whatever time-of-use (TOU) rates apply in their region.

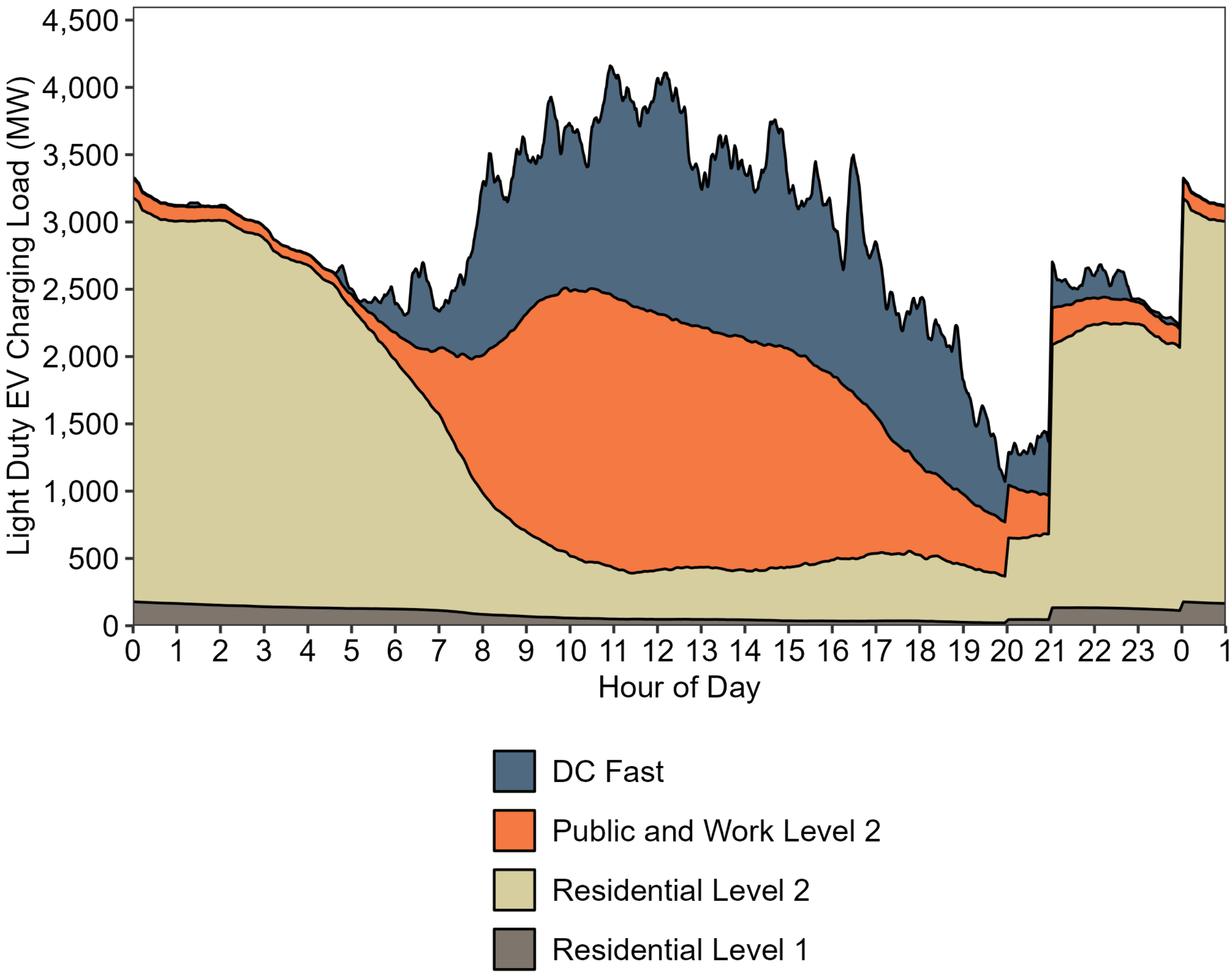
Figure 20 shows the load curve for light-duty charging on a typical weekday in 2030. In this scenario, charging is split into three groups:

- Some drivers start charging after the peak period ends for their region.
- Some drivers wait until the lowest-cost period starts in their region.
- Some drivers delay charging until later in the night, leaving just enough time to ensure that their vehicle will be sufficiently charged by the time they leave home.

Because all drivers in the first two behavior groups plan to start charging at the same time in each region, their behavior causes "timer spikes,"[77] where many vehicles in an area start charging simultaneously, causing a sudden increase in energy demand. Under this scenario, the timer spikes are smaller than the single spike at midnight presented in the first AB 2127 assessment, and the overall peak of charging is in midday.

77 The CPUC's proposed decision concerning implementation of SB 676 identifies EV participation in demand response as a near-term policy action with broad support and notes that "EV charging load's demand responsiveness could be a source of local or system capacity … through either a tariff-based mechanism or by allowing EVs to bid into resource adequacy markets." CPUC. November 2020. *Proposed Decision Concerning Implementation of Senate Bill 676 and Vehicle-To-Grid Integration Strategies*, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M350/K963/350963223.PDF.

Figure 20: EVI-Pro 3 Load Curve From PEV Charging in 2030 Under Primary Scenario



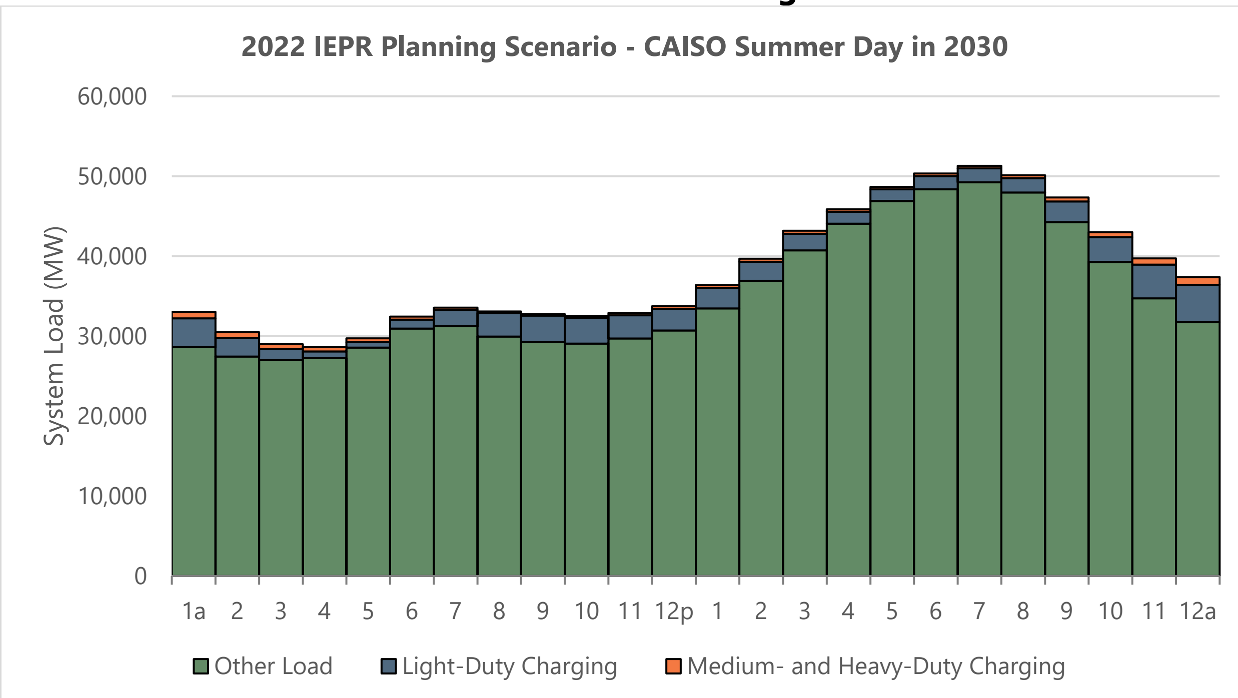
Under the baseline scenario, TOU rates have the effect of spreading home charging throughout the evening and night. The overall peak charging load occurs in midday, when many cars are charging at commute destinations and DC fast charging is near the peak.

Source: CEC and NREL

To explore the effects of different home charging patterns on energy use, CEC staff and NREL developed alternative future scenarios specifically targeted at home charging. As light-duty PEV ownership increases, managing charging loads to adapt to changes in the fleet of PEVs will be increasingly important for grid planning and investments. Appendix E contains load curves for all alternative future scenarios.

A systemwide load analysis as part of the 2022 IEPR Planning Scenario, which incorporates the AATE 3 scenario used in this report, anticipates vehicle charging to account for less than 10 percent of daily average load and less than 5 percent of load peak in 2030. This systemwide load analysis anticipates that vehicle charging will account for less than 20 percent of daily average load and less than 10 percent of load at peak in 2035. Figure 21 shows the total systemwide load from all sources on a summer day in 2030 under the IEPR planning scenario. While electric vehicle charging is expected to represent a relatively small part of total systemwide load, this analysis does not address location-specific and circuit-specific impacts, which may be significant. These impacts are assessed in the section on the EDGE tool.

Figure 21: Systemwide Load From All Sources, Including Vehicle Charging, in 2030 Under the IEPR Planning Scenario



Source: CEC

Areas of Focus

As PEVs make up a larger share of light-duty vehicles on the road, it will be increasingly important to focus charging investments in the areas that are most grid-friendly and cost-effective while ensuring that the transition to PEVs is equitable and convenient for drivers. To support this analysis, CEC staff and NREL developed "alternative futures" scenarios for EVI-Pro 3 built around specific changes to PEV charging priorities or policy, as was done in the first AB 2127 assessment. This section describes two of those scenarios and summarizes the remaining scenarios. Appendix E contains a list of assumptions and complete results from all alternative futures scenarios developed for this report.

Alternatives to Conventional Home Charging

As highlighted in the CEC's *Zero-Emission Vehicle Infrastructure Plan*, maximizing access to home charging is a priority for the state.[78] Charging at home can be the cheapest and most convenient option for fueling a PEV, but it may not be an option for all households. A CEC analysis based on a survey conducted by NREL found that even under the most optimistic scenario, no more than 70 percent of vehicles would have access to charging at home. Furthermore, home charging access is particularly challenging for households in multifamily

78 Lopez, Thanh and Madison Jarvis. 2022. *Zero-Emission Vehicle Infrastructure Plan (ZIP)*. California Energy Commission. Publication Number: CEC-600-2022-054-REV. https://www.energy.ca.gov/sites/default/files/2022-12/600-2022-054-REV.pdf.

housing or with many vehicles that require charging.[79] For the state to meet its emissions goals and ensure that the transition to PEVs is equitable, there must be a way for households currently without access to home charging to charge their vehicles conveniently.

The primary scenario assumes that most people will use public and shared private Level 2 chargers at work and public destinations as their primary means of charging away from home. Under this scenario, DCFC is used either if they do not spend enough time at any destination with charging to refuel their vehicle or if they need fast charging along a travel corridor to reach a distant destination. This section explores two possible alternatives: higher home access and a DCFC-focused approach sometimes referred to as the "gas station model."

Higher Home Access

One way to ensure that charging is not a barrier to PEV adoption is to expand the range of charging options available near homes. Options to achieving this expansion include supporting more charging in parking lots of multifamily housing structures (Chapter 5, Level 2 at Home and Other Destinations), curbside charging, and neighborhood charging. A limited amount of charging in multifamily housing is considered part of the primary scenario for this report but could be an option for more households if additional investments are made. Curbside charging requires installing charging infrastructure along streets to serve vehicles that do not have a private parking location. Neighborhood charging means installing numerous chargers at locations where home charging access is lower, possibly at publicly owned facilities like schools, parks, and libraries. Expanding near-home charging would require a varied mix of options in different parts of California, depending on the specific land use, parking, and electrical grid conditions present in a location.

To explore the effect of expanded near-home charging access on the state's overall charging infrastructure needs, CEC and NREL developed an alternative future scenario assuming a higher level of residential charging access (77 percent as opposed to 67 percent for the baseline scenario). This scenario indicates that for 2030, if more residents of single-family homes were able to install charging and 130,000 more Level 1 and Level 2 chargers were installed near multifamily housing, the need for Level 2 chargers at other locations would decrease by 40,000, and the need for DCFC chargers would decrease by 4,200.

Ubiquitous DCFC/"Gas Station Model"

Improvements to battery technology and the availability of higher-powered chargers may make expanded DCFC a realistic routine charging option for many people. This approach is sometimes referred to as the "gas station model" because relying on a distributed network of fast chargers might closely resemble the current pattern of refueling for internal combustion engine vehicles. The "gas station model" is not the primary scenario for this report, but staff highlights it as an alternative future scenario because many existing drivers have shown a preference for fast charging, especially on long travel days and if they do not have charging at home. California reached the goal of 10,000 fast chargers set under Executive Order B-48-18

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79 Alexander, Matt. January 2022. *Home Charging Access in California.* California Energy Commission. Publication Number: CEC-600-2022-021. https://www.energy.ca.gov/publications/2022/home-charging-access-california.

two years early, while the goal of 250,000 chargers total by 2025 is still in progress and expected to be achieved later than 2025.

To explore the effect of expanded DCFC investment on overall infrastructure needs, EVI-Pro generated an alternative future scenario assuming people without access to charging at home use DCFC as their primary means of charging. In addition, in this scenario the increased availability of fast charging is assumed to lead some home charging demand to shift to DCFC. The gas station model alternative future scenario included in this report is a hypothetical scenario in which large amounts of charging are switched to DCFC. Under this scenario, nearly two-thirds of all charging by light-duty vehicles is done at DCFC chargers, compared to less than a quarter in the base case. Under this scenario for 2030, installing 63,000 additional DCFC chargers throughout the state will decrease the need for public and shared private Level 2 chargers by 402,000 compared to the primary scenario. The gas station model is discussed in more detail in Chapter 5.

Other Alternative Futures Scenarios

In addition to the expanded at- and near-home home charging and ubiquitous DCFC scenarios, CEC and NREL developed additional alternative future scenarios to explore areas of uncertainty in the AATE3 baseline scenario for 2030. These scenarios explore the effect of decreased charging access at commute destinations, free public Level 2 provided as an amenity, and various overnight charging patterns implemented through time-of-use (TOU) rates for home charging.

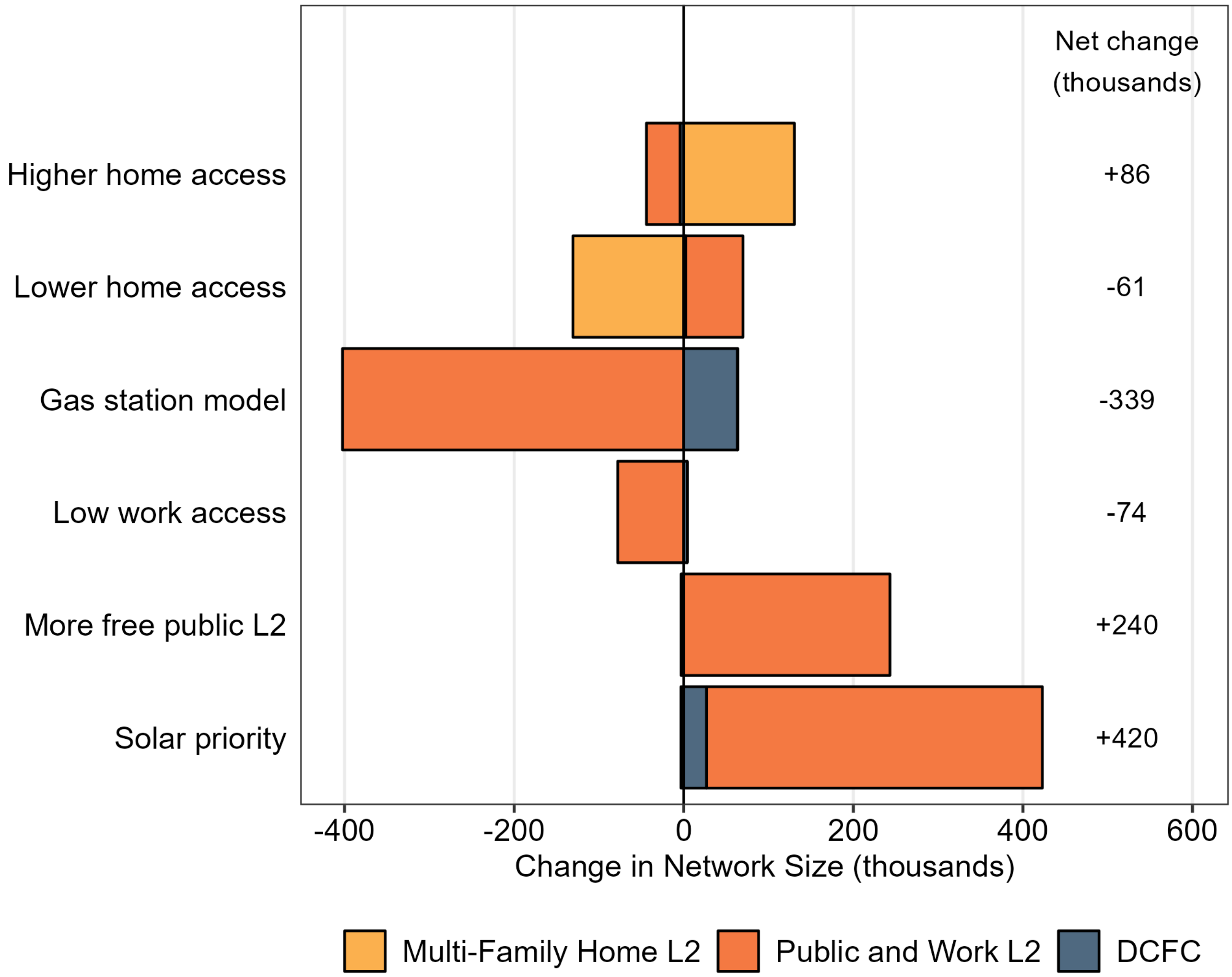
The following alternative future scenarios were developed for this report (the name of each scenario is in **bold** text):

- **Higher home access** and **lower home access** scenarios. These scenarios adjust home charging access by 10 percentage points from the baseline. The **higher home access** scenario assumes 76 percent of vehicles will be able to charge at home. The **lower home access** scenario assumes 56 percent of vehicles will be able to charge at home.
- **Gas station model** scenario. This scenario adjusts the charging priority of drivers without access to charging at home. Under the baseline, drivers use DC fast charging only if it is the only option that works in their schedule. Under this scenario, DC fast charging is the first choice of all drivers who are not able to charge at home, and some home charging demand shifts to DC fast charging.
- **Low-work-access** scenario. This scenario adjusts the commute fraction down from the baseline. Under the baseline, 50 percent of vehicles will be able to charge at a commute destination. Under the **low-work-access** scenario, only 40 percent of vehicles will be able to charge at a commute destination.
- **More free public Level 2** scenario. This scenario adjusts the availability of free public Level 2 provided by shopping and entertainment activity locations as an amenity. Under the baseline, 20 percent of drivers have access to free public Level 2. Under the **more free public Level 2** scenario, 40 percent of drivers have this option.

- **Solar priority** scenario. This scenario shifts charging behavior to maximize charging between 10 a.m. and 3 p.m., resulting in increased need for chargers at locations where people are present during this time.
- Several **home grid scenarios**. These scenarios adjust the proportion of drivers in the four TOU categories discussed in the section on grid-friendly charging. Because these scenarios apply only to charging while at home, they have minimal effect on the total number of chargers needed.

Aside from the home grid scenarios, all the alternative future scenarios included in this report generate significantly different estimates of the number of chargers needed to support light-duty vehicles in California. Figure 22 shows the change in number of chargers required under each scenario. Charger counts and load curves for all alternative future scenarios are included in Appendix E.

Figure 22: Difference in 2030 Charger Counts Between Alternative Future Scenarios and Baseline Scenario



The mix of charger types and locations powering California PEVs in 2030 may vary substantially depending on what sorts of charging are prioritized. Under the high and low home access scenarios, there is a tradeoff between Level 1/Level 2 chargers at homes and Level 2/DCFC chargers at activity locations. In the gas station model, DCFC is the primary means of charging away from home. Under the solar priority scenario, away-from-home charging options are expanded to shift charging to the daytime.

Source: CEC and NREL

EVI-RoadTrip

The Electric Vehicle Infrastructure for Road Trips (EVI-RoadTrip) model projects the number and locations of DC fast chargers needed to enable electrified road trips within and across California’s borders. In contrast to EVI-Pro 3, which considers the charging needed to support routine travel by all PEVs, EVI-RoadTrip focuses only on long-distance interregional (100+ mile) trips by BEVs. EVI-RoadTrip analyzes DC fast chargers to support BEVs only. The EVI-RoadTrip model is largely unchanged from the first AB 2127 assessment but has been updated to use the AATE3 scenario.

Table 9 shows the number of DC fast chargers needed to support interregional travel by BEVs under the AATE3 scenario. The EVI-RoadTrip model predicts that California will need 5,461 DC fast chargers to support 6.25 million BEVs in 2030 and 7,685 DC fast chargers to support 13.68 million BEVs in 2035. These estimates represent a slight increase over similar results from the first AB 2127 assessment, largely because BEVs are now predicted to make up a much larger share of the LDV fleet than they were under previous scenarios.

Table 9: DC Fast Charging Infrastructure Needed to Support Interregional Travel by Light-Duty BEVs Under AATE3 Scenario

Charger Power	2025 (2.03 million BEVs)	2030 (6.25 million BEVs)	2035 (13.68 million BEVs)
150 kW	1,562	177	31
250kW	1,790	1,475	880
350kW	7	3,809	1,626
450kW	-	-	5,147
Total	3,359	5,461	7,685

Source: CEC and NREL

WIRED

The Widespread Infrastructure for Ride-Hailing EV Deployment (WIRED) model, developed by UC Davis, assesses the need for additional charging infrastructure to support PEVs operated by transportation network companies (TNCs) statewide beyond what is needed to support other light-duty vehicles. The model provides estimates for the entire state with additional focus in three major California regions that are projected to account for roughly 80 percent of the PEV TNC travel in California:[80] San Diego County, the Greater Los Angeles region, and the San Francisco Bay Area. WIRED uses empirical data from Lyft and Uber trips and aims to minimize charger equipment cost, network installation size, driver use cost, travel time, and charging time. The model outputs the number of chargers needed statewide as well as at the aggregated census tract level for the three regions mentioned above. Compared to the WIRED analysis included in the first AB 2127 assessment, this analysis has been expanded to cover the entire state, extended to cover EVs driving for TNCs through 2035, and rescaled based on the substantial decline in ride hailing post-COVID.

Ensuring that sufficient charging is available for these vehicles is necessary to ensure that TNCs can comply with the Clean Miles Standard, enacted by SB 1014, which requires TNCs to electrify 50 percent of vehicle miles traveled by 2027 and 90 percent starting in 2030.[81]

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80 CARB staff. November 19, 2020. Clean Miles Standard Workshop. "Proposed Regulation Targets." https://ww2.arb.ca.gov/sites/default/files/2020-11/CMS%20Workshop%206_public%20%28002%29.pdf.

81 CARB staff. 2020. "Clean Miles Standard Regulation: Passengers and Communities to Benefit From Lower Emissions With Actions by Transportation Network Companies," https://ww2.arb.ca.gov/resources/fact-sheets/clean-miles-standard-regulation-passengers-and-communities-benefit-lower.

Electrifying TNC vehicles is particularly important because these vehicles are generally driven significantly more and generate substantially more GHG emissions than privately owned vehicles.[82]

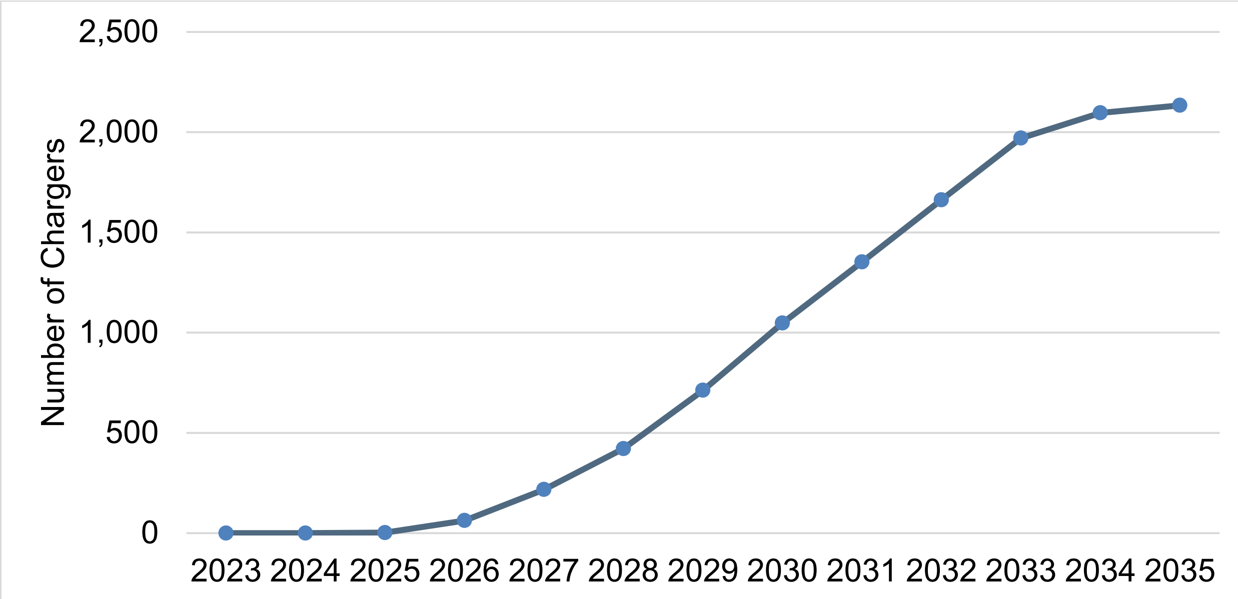
Modeling Results

WIRED projects a steady increase in the number of DC fast chargers required statewide as the Clean Miles Standard vehicle mile electrification requirement increases. The model assumes that 40 percent of TNC drivers will have access to charging at home and will start each day with a full battery, using DCFC only when needed. Other drivers will rely entirely on DCFC for their charging. Chargers installed to support TNC drivers could either be publicly accessible or made available only for TNC drivers, but the charger estimates for WIRED represent an additional number of chargers needed to support TNC vehicles beyond what is estimated in EVI-Pro and EVI-RoadTrip.

Figure 23 shows the number of chargers needed statewide, while Figure shows the regional needs for charging infrastructure. By 2030, more than 1,000 DC fast chargers will be needed across the state to serve TNCs, and by 2035, more than 2,100 DC fast chargers will be needed. As Figure 24 shows, the need for these chargers will be highest in the Greater Los Angeles and San Francisco Bay Area regions, each of which will require roughly 800 chargers to support TNC vehicles by 2035. Even after expanding the analysis to cover the entire state, estimates for TNC charging infrastructure needs in 2030 are 50 percent lower than those shown in the first AB 2127 assessment because the model has been updated to account for the general decline in TNC usage since the start of the COVID pandemic. Appendix F provides annual results from WIRED, as well as maps of charging needs in each region.

82 Jenn, Alan. 2019. *National Center for Sustainable Transportation*. "Emissions Benefits of Electric Vehicles in Uber and Lyft Services." UC Davis Institute of Transportation Studies, https://escholarship.org/uc/item/15s1h1kn.

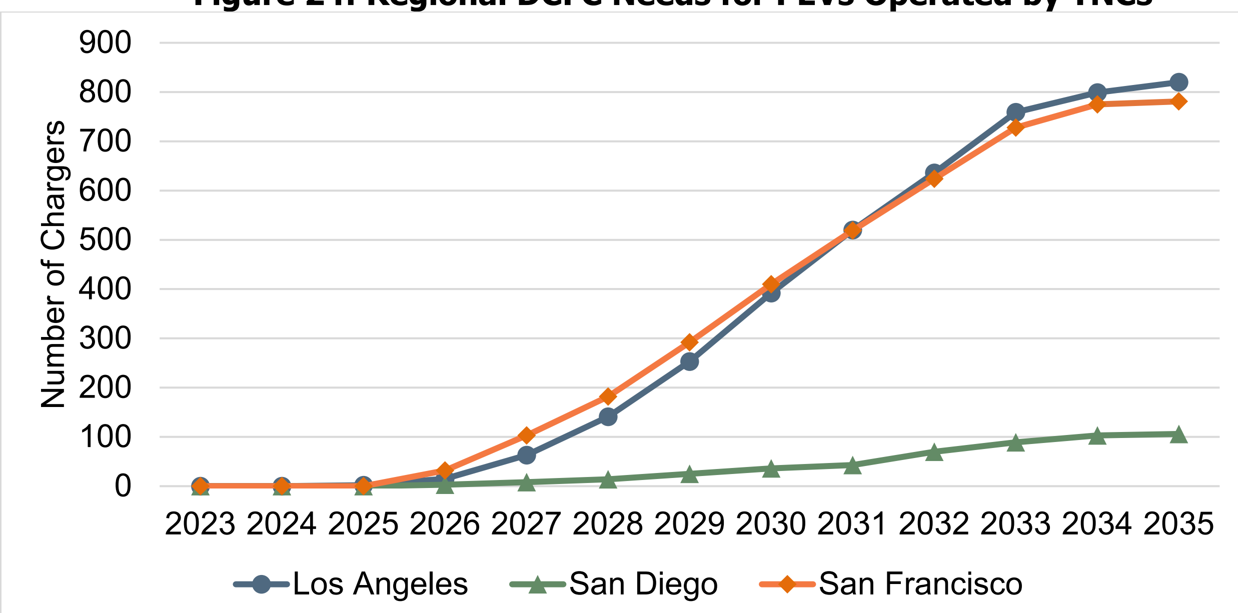
Figure 23: Number of DCFC Chargers Needed to Support TNC Electrification Under the Clean Miles Standard



Aggregated DC fast charging needs modeled by WIRED

Source: UC Davis

Figure 24: Regional DCFC Needs for PEVs Operated by TNCs



Regional DC fast charging needs modeled by WIRED in the Greater Los Angeles region, San Diego County, and the San Francisco Bay Area

Source: UC Davis

The results highlight the reliance of PEVs used for TNC service on DC fast chargers.[83] TNC charging needs are highest in areas where these services make the most trips, like airports and downtown areas. The need for high-speed charging at these locations is particularly important because drivers are not paid for time spent charging.

Combined DC Fast Charging Needs for Light-Duty Vehicles

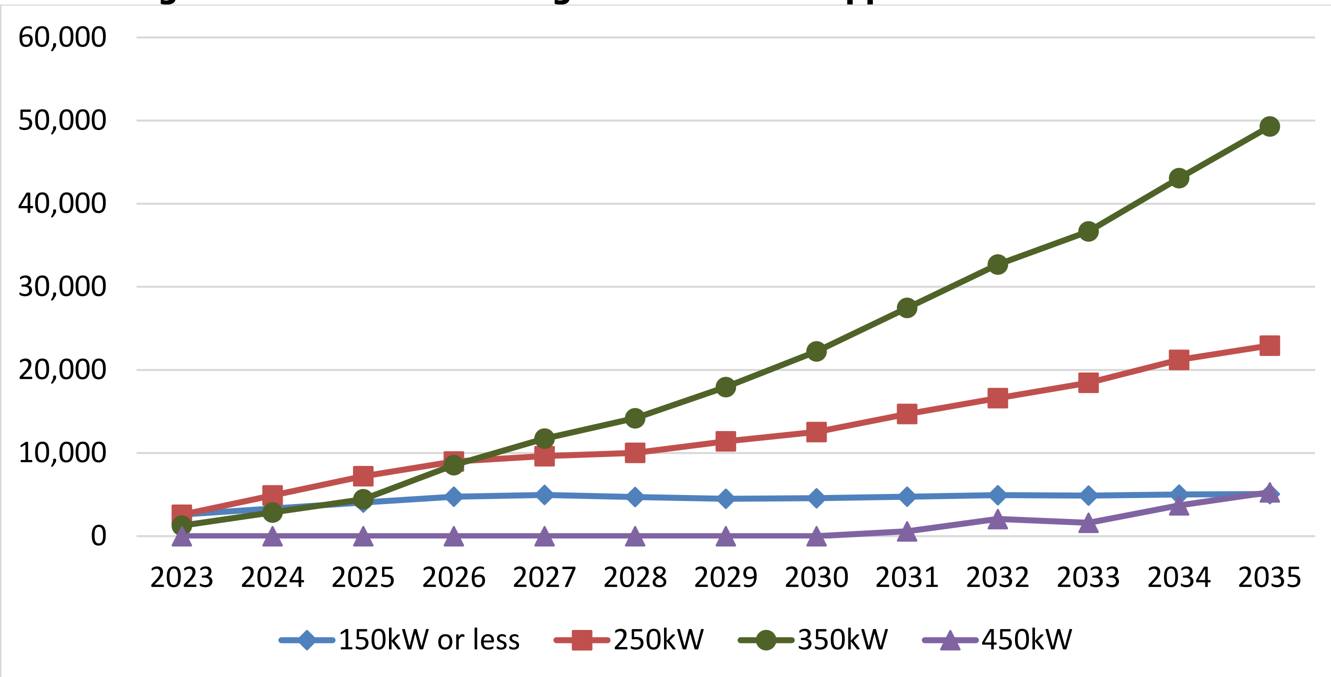
The three models for light-duty EV charging infrastructure presented in this chapter provide estimates for how many DC fast chargers are needed to serve three use cases:

- EVI-Pro 3 includes DC fast chargers used by BEV drivers during their daily routine travel, typically because they do not have access to charging at home and do not make any stops long enough to receive enough charging with Level 2.
- EVI-RoadTrip includes DC fast chargers used by BEV drivers on long-distance trips. On these trips, high-speed charging is necessary to ensure that drivers can reach their destination in a reasonable amount of time.
- WIRED includes DC fast chargers used by TNC drivers of BEVs.

These models provide separate estimates for the number of chargers needed in California; the pool of DC fast chargers needed for light-duty EVs in California is the total number of chargers across all three models, although a DC fast charger may serve several purposes to some degree. Figure 25 shows the number light-duty EV DC fast chargers of each power level needed from 2025 to 2035 under the AATE3 scenario. As noted in the EVI-Pro section, the transition away from lower-powered (150 kW or less) DC fast chargers after 2025 is driven by improving vehicle technology. Demand for lower-powered chargers may persist if they offer less costly charging than higher-powered DC fast chargers and if some drivers do not require the extra charging speed.

83 Jenn, Alan. 2021. *Charging Forward: Deploying Electric Vehicle Infrastructure for Uber and Lyft in California.* Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-20-63, https://escholarship.org/uc/item/6vk0h1mj.

Figure 25 Total DCFC Chargers Needed to Support LDVs 2023–2035



Total DC fast charging needs by power level combined between EVI-Pro 3, EVI-RoadTrip, and WIRED, assuming TNC BEVs have similar charging capabilities as privately owned BEVs.

Source: NREL and UC Davis

HEVI-LOAD

The Medium- and Heavy-Duty Electric Vehicle Infrastructure Load, Operations, and Deployment (HEVI-LOAD) model is designed to determine regional fueling infrastructure needs through 2030 for depot and en route charging and refueling for on-road and off-road medium- and heavy-duty (MDHD) battery electric and hydrogen fuel cell electric vehicles. The model determines the number, locations, and types of charging infrastructure and hydrogen refueling station deployments to support California's zero-emission vehicle adoption targets. HEVI-LOAD studies charger power levels ranging from 20 kW to 1.5 MW. HEVI-LOAD began development in 2020 under a collaboration between Lawrence Berkeley National Laboratory and the CEC and consisted of two modeling phases with separate approaches: top-down and bottom-up.

Infrastructure needed to support zero-emission MDHD vehicles is also the focus of other studies produced by the CEC and other state agencies. The SB 643 Assessment is a statewide analysis of clean hydrogen fuel production and refueling infrastructure to support medium- and heavy-duty fuel cell electric vehicles and off-road/nonroad applications. The CEC published the staff draft of the first SB 643 report in September 2023,[84] and future editions will be published every three years. The Senate Bill 671 Clean Freight Corridor Efficiency Assessment

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84 Villareal, Kristi. 2023. 2023 *Staff Report on Senate Bill 643: Clean Hydrogen Fuel Production and Refueling Infrastructure to Support Medium-and Heavy-Duty Fuel Cell Electric Vehicles and Off-Road Applications*. California Energy Commission. Publication Number: CEC-600-2023-053. https://www.energy.ca.gov/publications/2023/senate-bill-643-clean-hydrogen-fuel-production-and-refueling-infrastructure

identifies the top six freight corridors in California and three potential scenarios of zero-emission freight infrastructure needs. In addition, the SB 671 Assessment identifies barriers and recommended solutions related to the transition to zero-emission freight that fall within the main categories of time, economic feasibility, and a complex stakeholder ecosystem.[85]

The second AB 2127 Assessment includes two major changes to the HEVI-Load model:

- The HEVI-Load model now determines charging needs of individual vehicles using a bottom-up approach based on simulated travel patterns. The first version of the HEVI-Load model in the first AB 2127 Assessment used a top-down approach that estimated overall charging needs based on fleet-level statistics.
- Charging locations are classified into lower-speed "depot" charging, meaning any charging at an origin or a destination, and higher-speed en route charging.[86] Both of which can be used at any time of day, with a range of charger power levels included in each category. In the first report, charging was divided into depot charging, which was available only at night, and public charging, which was available only in the day.

Bottom-Up Modeling Approach

The top-down approach of HEVI-LOAD, shown in the first AB 2127 assessment, used three steps: vehicle projection, trip disaggregation, and infrastructure assessment. Researchers derived electric vehicle adoption forecasts from a combination of a truck choice model within the CEC's *Transportation Energy Demand Forecast* (TEDF) and CARB's *Mobile Source Strategy*. Energy consumption profiles sourced from CARB's Emission Factor (EMFAC) model were disaggregated into individual trips using survey information and vehicle payload calculations. From this step, the top-down approach used a probabilistic process to determine whether a vehicle would need to recharge during a trip. The first assessment used this method to generate charger numbers and vehicle load profiles statewide and on a per-county basis.

For the second AB 2127 assessment, the HEVI-LOAD model employs a bottom-up, agent-based modeling framework. The model simulates individual vehicle trips and calculates aggregated energy demand, specific to each vehicle application category, for multiple regions. HEVI-LOAD determines the number and power level of chargers needed to meet this energy demand. HEVI-LOAD determines the amount of charging MDHD vehicles need by simulating the trips these vehicles make, using origin-destination pair data from the Caltrans California Statewide Travel Demand Model (CSTDM). The vehicles move along the transportation network and take the shortest possible path to reach the respective destinations. In this model, charging events occur either at en route chargers, if the battery of a vehicle does not have enough energy to last the entire trip, or at depot chargers between trips.

85 The draft assessment and, once it is adopted, the final assessment, is located on the California Transportation Commission Senate Bill 671 website. https://catc.ca.gov/programs/sb671.

86 The name of this charger type has also been changed from the staff draft of this AB 2127 Assessment to improve clarity. In the staff draft, en route charging was referred to as "public" charging. This name was changed to clarify that depot charging can occur at a range of locations, including privately owned depots, shared/third-party depots, and other MDHD vehicle destinations, such as warehouses. In addition, en route charging locations may not necessarily be accessible by the public.

HEVI-LOAD uses location data sourced from the California Statewide Truck Parking Study (CSTPS) conducted by Caltrans. The model then aggregates characteristics from the simulated vehicles up to the traffic analysis zone (TAZ) level. Since the CSTDM trips do not have detailed start, end, and duration information, HEVI-LOAD probabilistically assigns them a start time and end time to increase the temporal resolution of driving behavior by using real-world GPS location data provided by UC Riverside and West Virginia University. Appendix G provides details on the distribution of start and end times, overall trip duration, and the interval between two consecutive trips used to calibrate the CSTDM data. As the model simulates trips, it determines the energy need of each vehicle based on the specific road segments it travels along and assumed energy needs of that vehicle (class-level energy needs in kWh / mile are listed in Appendix G). The model calculates the charging needs of vehicles that make stops at each parking location based on state of charge and time of day. Finally, the model determines the number of chargers at each power level suitable to support these vehicles.

Revised Charger Classifications

Depot chargers provide lower-speed charging at existing destinations and have power levels between 20 kW and 150 kW. En route chargers provide higher-speed charging to allow vehicles to complete longer routes and have power levels between 350 kW and 1.5 MW. Both depot and en route chargers can provide charging at any time of day or night. The charger classification used in this assessment differs from the one used in the first AB 2127 assessment, which included 50 kW depot chargers used exclusively for overnight charging and 350 kW public chargers used exclusively for daytime charging. Because all daytime charging was assigned to 350 kW public chargers, there were more public chargers and more energy delivered through public chargers in the first assessment than there are for en route chargers in this assessment.

HEVI-LOAD determines the amount of charging MDHD vehicles need by simulating the trips made by vehicles of each type and use case, using origin-destination pair data from the Caltrans California Statewide Travel Demand Model (CSTDM). The vehicles move along the transportation network and take the shortest possible path to reach the respective destinations. In this model, charging events occur either at public chargers en route, if the battery of a vehicle does not have enough energy to last the entire trip, or at depot chargers between trips. “Depots” in this model include chargers located at trip destinations like warehouses, depots operated by vehicle owners or a third party, and locations operated by charging-as-a-service providers.

In the primary scenario, all vehicles are assumed to have access to depot charging, but this report includes an alternative future scenario that assumes that some vehicles will use high-speed charging as a replacement for depot charging. Vehicles do not necessarily charge whenever they are parked, but most vehicles charge at a depot at least once every 1–3 days. Depot charging events can occur if the vehicle is parked overnight or if the battery state of charge is below 50 percent. Most EV drivers use depot chargers for most of their charging.

HEVI-LOAD uses location data sourced from the California Statewide Truck Parking Study (CSTPS) conducted by Caltrans. The model then aggregates characteristics from the simulated vehicles up to the traffic analysis zone (TAZ) level. Since the CSTDM trips do not have detailed start, end, and duration information, HEVI-LOAD probabilistically assigns them a start time and

end time to increase the temporal resolution of driving behavior by using real-world GPS location data provided by UC Riverside and West Virginia University. Appendix G provides details on the distribution of start and end times, overall trip duration, and the interval between two consecutive trips used to calibrate the CSTDM data. As the model simulates trips, it determines the energy need of each vehicle based on the specific road segments it travels along and assumed energy needs of that vehicle. (Class-level energy needs in kWh/mile are listed in Appendix G.) The model calculates the charging needs of vehicles that make stops at each parking location based on state of charge and time of day. Finally, the model determines the number of chargers at each power level suitable to support these vehicles.

The updated HEVI-LOAD model uses a range of charger power levels based on vehicle-specific charging capacity and the amount of time available for charging. For depot charging, some smaller and lower-mileage vehicles are assumed to use 20 kW chargers, which could include high-powered (for example, 19.2 kW) Level 2 chargers. Larger vehicles generally use 50 kW or more powerful chargers to ensure that charging will be completed before the vehicle departs for its next trip. For enroute charging, 350 kW chargers are most common, but some vehicles will use higher-powered chargers to minimize time spent charging. The speed of en route charging is an area of uncertainty for MDHD electrification. This assessment assumes that 350 kW chargers will be the default for en route chargers because 350 kW charging systems have already begun to be deployed in large numbers. If the Megawatt Charging System (MCS) or other charging systems that permit higher charging speeds are adopted rapidly, the resulting charging system would likely include more high-powered chargers but fewer total en route chargers.

Medium- and Heavy-Duty PEV Adoption Scenarios

In the first AB 2127 assessment, HEVI-LOAD incorporated four adoption scenarios for MDHD vehicles in 2030: Medium Charging Demand and High Charging Demand scenarios from the TEDF, a preliminary analysis conducted by CEC and LBNL, and CARB's Mobile Source Strategy. The MDHD ZEV populations in these scenarios were 75,000, 81,000, 130,000, and 180,000, respectively.

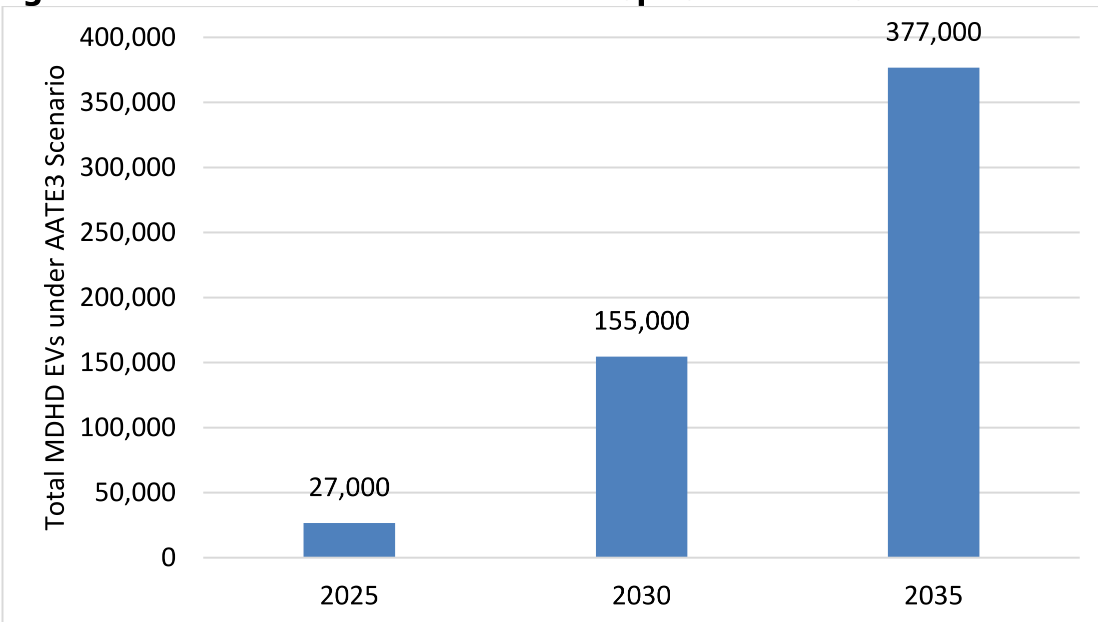
In this assessment, CEC staff uses the CEC's Additional Achievable Transportation Electrification 3 (AATE3) scenario developed for the IEPR as the primary scenario for medium- and heavy-duty ZEV adoption. The AATE3 scenario assumes compliance with the Advanced Clean Trucks (ACT)[87] and Advanced Clean Fleets (ACF)[88] regulations. This scenario has a population of nearly 155,000 MDHD PEVs in 2030 and 377,000 MDHD PEVs in 2035, as shown in Figure 25. The AATE3 scenario applies the maximum ZEV share from CARB's ACF scenario as the ZEV sales share for new vehicles in each class included in the CEC's Truck Choice and Freight Model. This results in a slightly higher projection of medium- and heavy-duty ZEVs than CARB anticipates will be the minimum effect of the ACT, ACF, and ICT regulations. CARB's analysis of the combined effect of ACT and ACF includes Class 2B vehicles (vehicles

87 California Air Resources Board. "Advanced Clean Trucks Fact Sheet: Accelerating Zero-Emission Truck Markets," https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-trucks-fact-sheet.

88 California Air Resources Board. "Advanced Clean Fleets Regulation Summary: Accelerating Zero-Emission Truck Markets." https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-fleets-regulation-summary.

with gross vehicle weight ratings between 8,501 and 10,000 pounds). Because these are light-duty vehicles, they are excluded from the MDHD scenario used in this report. As a result, the AATE3 scenario shown in Figure 26 includes about 45,000 fewer vehicles in 2030 and about 144,000 fewer vehicles in 2035 than the CARB estimate shown in Figure 12.

Figure 26 MDHD Vehicle MDHD PEV Adoption Scenarios in HEVI-LOAD



HEVI-LOAD uses the CEC's Energy Assessment Division's AATE3 scenario as the primary scenario for MDHD EV adoption in 2025, 2030, and 2035. This scenario applies a maximum ZEV PEV percentage share between CARB's ACT+ACF fleet projections and the CEC's Truck Choice and Freight Model.

Source: CEC

Compared to the Mobile Source Strategy (MSS) scenario, used in the first assessment, the AATE3 scenario includes several differences in MDHD fleet size, fleet composition, and efficiency:

- AATE3 has 14.4 percent fewer zero-emission MDHD vehicles in 2030 compared to the MSS (155,000 compared to 180,000).
- AATE3 has a larger proportion of small and low-mileage classes among the zero-emission MDHD fleet in 2030, resulting in a 27.6 percent decrease in average per-vehicle daily energy use compared to the MSS. This change is partly due to differences in the total number of vehicles (of all fuel types) in each class and partly due to changes in expected ZEV sales shares because of the Advanced Clean Fleets regulation. The 2030 MDHD fleets in MSS and AATE3 are compared in Table 10. This table is generalized to allow comparison between MSS and AATE3, but there is substantial variability in average daily miles traveled within each category, particularly for Class 8. Vehicle counts and daily mileage for each of the 40 vehicle types included in the HEVI-Load model can be found in Appendix G.
- AATE3 assumes that MDHD vehicles use on average 37.8 percent less energy per mile than was used in the first AB 2127 assessment. The major cause of this change is that

in the first AB 2127 assessment, vehicles were assumed to always have a full load, whereas this assessment assumes that vehicles sometimes are not carrying a full load.

These factors all contribute to lower expected MDHD energy needs in this assessment than in the first assessment. All told, these changes result in a roughly 60 percent decrease in total energy for MDHD vehicles, and a 55 percent decrease in per-vehicle energy use.

Table 10: Number of MDHD ZEVs and Average Daily Mileage in MSS and AATE3 Scenarios for 2030, by Weight Class

Gross Vehicle Weight Rating Class	Total ZEVs (MSS)	Average Daily Miles (MSS)	Total ZEVS (AATE3)	Average Daily Miles (AATE3)	ZEVs as a proportion of all vehicles in this class (AATE3)
Class 3	8,970	57.3	26,932	51.8	12.5%
Classes 4, 5, 6, and 7	72,421	51.6	76,200	53.3	24.8%
Class 8	99,245	96.5	51,441	88.1	16.2%
Total MDHD	**180,636**	**76.5**	**154,572**	**64.6**	**18.4%**

Source: CEC staff

The first AB 2127 assessment included infrastructure needs analysis for on-road MDHD BEVs. CEC staff is incorporating additional use case analyses within HEVI-LOAD. In future versions of this assessment, the modeling framework will be updated to include an infrastructure analysis for off-road ZEVs using CARB's OFFROAD2021 model for vehicle inventory, emissions, and duty cycles. Modeling will also be improved for transit buses and expanded to address infrastructure needed for electrification at ports and airports.

While not included in the AB 2127 report, hydrogen fuel cell electric vehicles will also be included in future modeling developments in HEVI-LOAD. The model will assess the hydrogen refueling infrastructure needs of on-road fuel cell MDHD vehicles in future assessments.

MDHD Infrastructure Needs

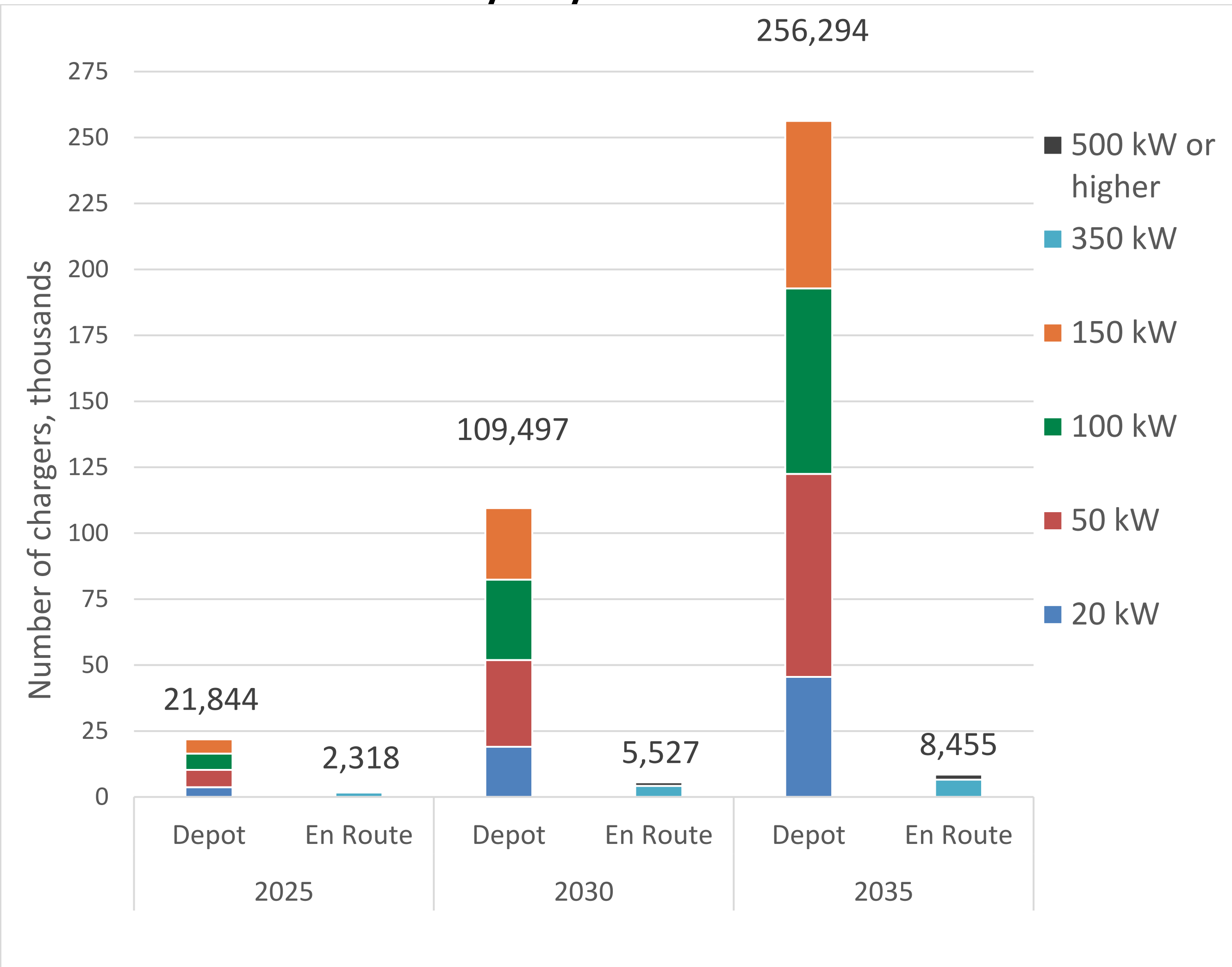
HEVI-LOAD estimates that to support 155,000 MDHD PEVs in 2030, California will need about 109,000 lower-speed depot chargers and 5,500 higher-speed en route chargers. In 2035, HEVI-LOAD projects a need for roughly 256,000 depot chargers and 8,500 en route chargers. In each modeled year, charger power levels range from 20 kW to 150 kW for depot chargers and 350 kW to 1.5 MW for en-route chargers. In 2030, about 82 percent of total MDHD charging load is estimated to be served by depot charging and 18 percent is served from en route charging. In 2035, about 84 percent of total MDHD charging load is estimated to be from depot charging and 16 percent is from en route charging. The CEC will continue to monitor the market and make modeling adjustments over time as the MDHD industry evolves as it could gravitate toward en route chargers in greater numbers.

Figure 27 shows the growth in charging infrastructure need and corresponding power levels through time. In the first AB 2127 assessment, chargers were modeled as being either 50 kW or 350 kW, of which 141,000 and 16,000 were projected, respectively, to support 180,000 MDHD vehicles in 2030. This report estimates fewer chargers will be needed compared to the first AB 2127 Assessment for a range of reasons. The primary scenario includes fewer MDHD ZEVs. A larger proportion of MDHD ZEVs in this scenario are smaller and lower-mileage vehicles. Vehicles are assumed to be more efficient. Some energy demand is satisfied by fewer, higher-powered chargers.

More depot chargers are needed than en route chargers because depot charging allows vehicles to make the best use of vehicle idle time, avoid waiting for charging during the trip, and avoid having to pay for high-powered en route charging. The model assumes that most vehicles will rely on depot chargers for the bulk of their charging and will need to charge at a depot every 1–3 days, depending on driving patterns and vehicle range. Depot chargers can serve vehicles both in the daytime and at night, but each depot charger will serve at most one vehicle between the hours of 6 p.m. and 7 a.m. each night.

Charger utilization, the proportion of time each day that a charger is in use, is a key uncertainty in charging infrastructure modeling, particularly for en route chargers. This assessment assumes that en route chargers for MDHD vehicles will average around 4.5 percent utilization per day in 2030. In 2035, en route chargers for MDHD vehicles are assumed to have about 6.5 percent utilization. In both cases, chargers providing charging speeds of 1,000 kW or higher have somewhat lower utilization than lower-powered chargers. If actual utilization is higher than this, a smaller number of chargers would be able to serve the same charging demand. Actual utilization may also be affected by peak demand and drivers' tolerance of queues, as well as station economics. As more MDHD stations are installed, monitoring utilization over time will provide more insight into this issue and help determine the appropriate mix of depot charging versus en route retail stations. Regardless, en route charging will play an essential role for long-haul vehicles and smaller fleets that do not readily have access to depot charging.

Figure 27: Projected Charging Infrastructure Needs for On-Road Medium- and Heavy-Duty Electric Vehicles



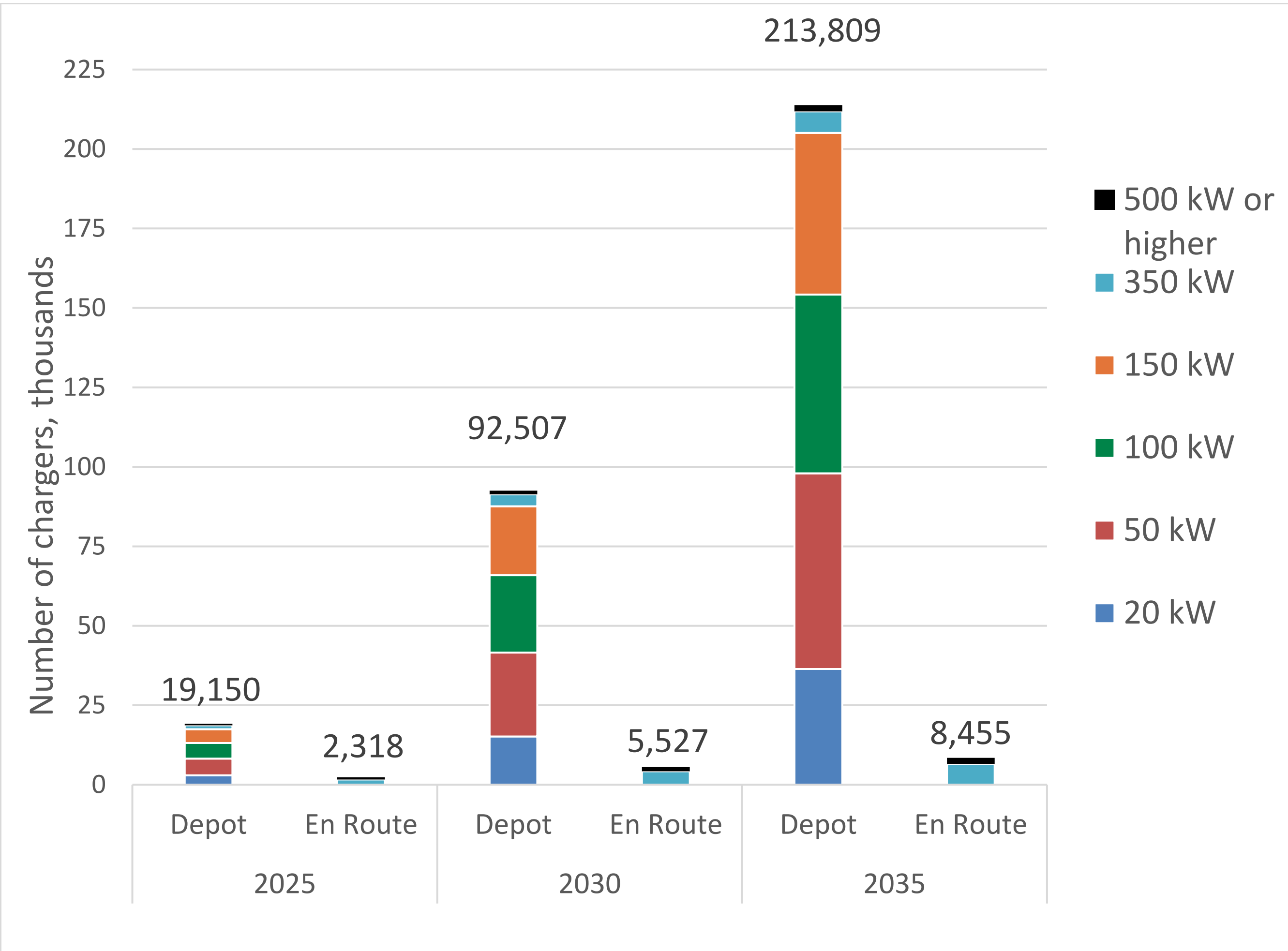
HEVI-LOAD projects that about 109,000 depot chargers, ranging from 20 kW through 150 kW, and 5,500 en route chargers, ranging from 350 kW through 1.5 MW, are needed to support about 155,000 MDHD vehicles in 2030. In 2035, the charging need grows to about 256,000 depot chargers and 8,500 en route chargers.

Source: CEC and LBNL

High-Speed Depot Alternative Future

The primary scenario for HEVI-Load assumes that depot charging is an option for all vehicles, but this may not be the case. Low-speed depot charging may not be an option for a range of MDHD vehicles including vehicles that do not have time to charge slowly, such as drayage trucks used for multiple shifts. Vehicles that may not have access to depot charging include owner-operator vehicles without dedicated depots, leased vehicles that do not return to depots overnight, and fleets with insufficient grid capacity to install charging at their depot. For the revised report, CEC staff developed an alternative future scenario to explore the potential for high-speed charging at or near existing destinations to replace lower-speed depot chargers. These high-speed depot chargers may be installed by fleet operators, third-party depot operators, or charging-as-a-service providers. Under this scenario, 20 percent of vehicles rely on high-speed depot replacement chargers, resulting in total 2030 charger needs of 87,598 low-speed depot chargers, 4,910 high-speed depot and depot replacement chargers, and 5,527 en route chargers. Figure 28 shows the charger needs in 2025, 2030, and 2035 under this alternative future scenario. A full breakdown of charger needs under the high-speed depot alternative future scenario can be found in Appendix H.

Figure 28: Projected Charging Infrastructure Needs for On-Road Medium- and Heavy-Duty Electric Vehicles Under the High-Speed Depot Alternative Future Scenario



Under the high-speed depot alternative future scenario, 20 percent of depot charging is shifted from slower chargers (20 kW to 150 kW) to faster chargers (350 kW to 1500 kW).

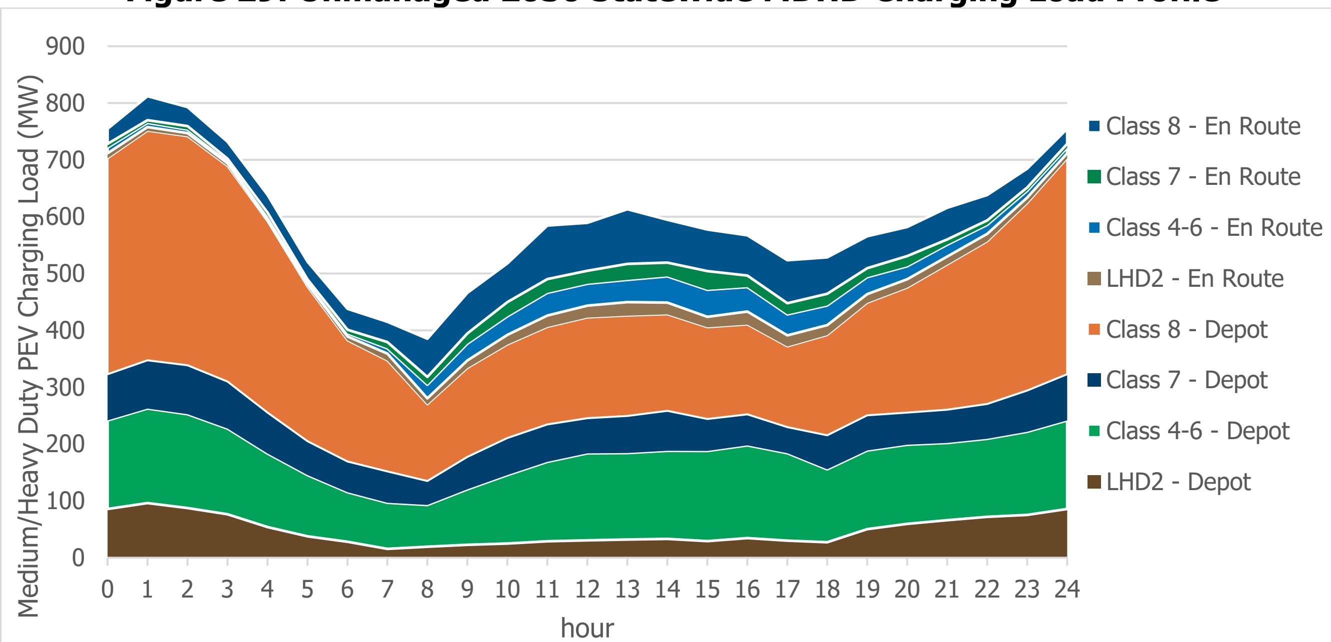
Source: CEC and LBNL

MDHD Charging Load

HEVI-LOAD analyzes charging load profiles for all vehicles simulated in the model for managed and unmanaged charging cases. In the unmanaged case, vehicles are assumed to charge immediately whenever a charging request is generated. However, in the managed charging case, the model incorporates several factors that affect the charging behavior of the simulated vehicles and the impact vehicle charging has on California's electric grid. Vehicles in the managed case have more flexibility in the amount of time they can wait to charge, and the energy pricing schemes are more dynamic when compared to unmanaged charging.

Figure 29 and Figure 30 show the load profiles for both scenarios broken down into four vehicle categories: LHD (vehicles with a GVWR of 10,001–14,000 lbs.), Classes 4–6, Class 7, and Class 8, which are direct mappings from the CSTDM categories of light truck, medium truck, and heavy truck. Both figures reflect the AATE3 vehicle adoption scenario for 2030. Charging in the unmanaged scenario starts ramping up around 6 p.m. and peaks at about 800 MW around 1 a.m. In the managed scenario, the charging peak is instead shifted to the hours between 10 a.m. and 5 p.m., with another small peak of about 725 MW around 3 a.m. The model assumes that vehicles which return to base around high-demand periods will defer charging until after 11 p.m., and vehicles returning before 3 p.m. will start charging immediately until about 5 p.m. If the battery is still not fully charged, the vehicle waits until early the next morning to finish charging.

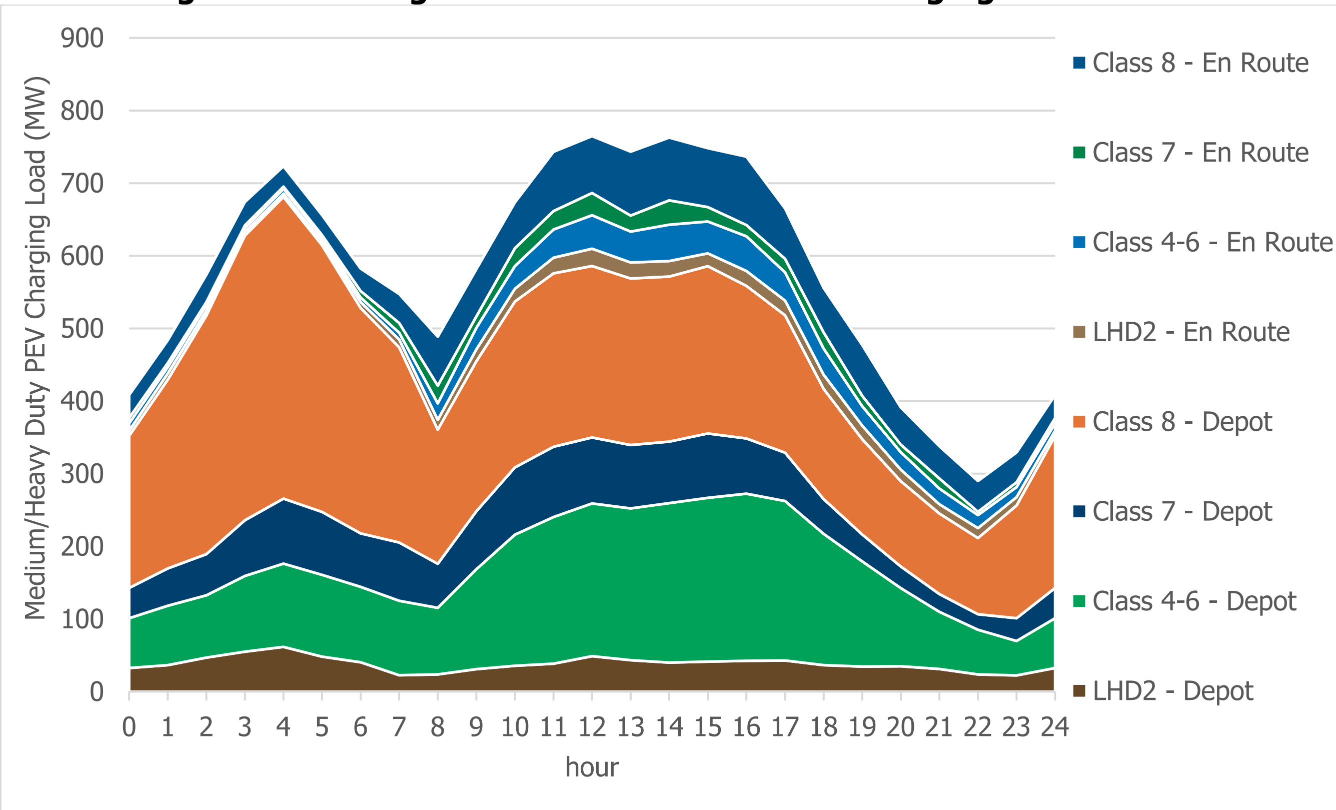
Figure 29: Unmanaged 2030 Statewide MDHD Charging Load Profile



Unmanaged charging results in a large aggregate demand peak of about 800 MW at 1 a.m. during typical weekday conditions. Class 8 trucks contribute the largest portion of the demand because of the overall battery size, energy consumption, and tendency to use depot charging.

Source: CEC and LBNL

Figure 30: Managed 2030 Statewide MDHD Charging Load Profile



In the managed charging scenario, peak load is shifted from between 8 p.m. and 1 a.m. to between 10 a.m. and 5 p.m., with a similar overall magnitude. In this case, vehicles tend to avoid high electricity demand periods while maintaining normal duty cycle operations.

Source: CEC and LBNL

Increased load from charging MDHD vehicles will require grid planning. As the number of chargers throughout the state grows, utilities will have to make upgrades to the physical components of the distribution system such as transformers, primary and secondary circuits, and substations. As a result, HEVI-LOAD, via integration with functionality from the CEC's EVSE Deployment and Grid Evaluation (EDGE) tool analysis, conducted a site-specific capacity mapping study to estimate the impact that the energy demanded by the simulated vehicles of the model could have on specific locations throughout the state. This study is discussed in the following section on the EDGE tool analysis.

EVSE Deployment and Grid Evaluation (EDGE)

The ability to address local grid constraints related to EV charging is a focus area and is vital to enabling widespread transportation electrification in all sectors. This is especially true in the MDHD context since these vehicles rely on high-powered chargers at depots and when recharging on route. Properly distributing the large number of chargers detailed in earlier sections in this report will require identifying locations that can sufficiently and economically host them, balanced with the needs of MDHD fleets.

Depending on the overall power level, circuit-level capacity constraints, and other factors, EV charging will impact areas of the electrical grid transmission and distribution systems in different ways.[89] In cases where a small number of relatively low-powered chargers is deployed, such as a small group of Level 2 chargers, there may not be a need to upgrade grid equipment beyond the transformer level. However, deploying many high-powered fast chargers at a site may trigger an upgrade for several components up to the primary distribution circuit and possibly even the substation.

In the first AB 2127 assessment, analysis of California's electric grid system appeared to indicate that many of the primary distribution circuits that serve customers in Pacific Gas and Electric, Southern California Edison, and San Diego Gas and Electric territories have limited capacity to serve new load. However, the analysis relied on the utilities' Load Integration Capacity Analysis (ICA) maps that reflect only past load profile data rather than current or future load and lack the granularity that project developers need.

To help identify localized grid capacity concerns, the CEC developed the EDGE visualization tool, which is designed to help users identify candidate locations to deploy electric vehicle charging infrastructure and plan associated behind-the-meter equipment investments. EDGE is designed to highlight areas where new EV charging load is expected to grow through time and exceed grid capacity limitations. This information could be used to identify "low-hanging fruit" opportunities where charging infrastructure could potentially be deployed without overloading existing local electric grid equipment. Utility planners could also use this information to identify similar opportunities in the form of least-regrets grid upgrade projects. Highlighting regions where modeled load exceeds the grid hosting capacity could guide proactive utility planning conversations and potentially help address regional grid constraints before project developers submit infrastructure project applications. Identifying areas of needed grid upgrades in advance has the potential to help reduce long lead times for distribution system upgrades, especially if initially targeting those areas with the highest likelihood of needing grid upgrades based on current circuit capacity and projected EV load.

EDGE inputs and processes regional grid condition data and information from CEC's charging infrastructure projection models. EVI-Pro provides data for light-duty infrastructure, and HEVI-LOAD provides data for medium- and heavy-duty infrastructure. Both data are in the form of generated charging load profiles in 2025. For the electric grid system, EDGE sources information from the IOU Grid Needs Assessment (GNA) data portals instead of the ICA maps, which were used in the first assessment. The GNA data provide information regarding the amount of "headroom" that primary circuits and substations have that can accommodate new load before requiring attention through 2025. The GNA data do not provide any information on the secondary distribution system. This is a data gap that the CEC hopes to resolve if sufficient data can be obtained from the utilities.

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89 The distribution system covers the last stage of energy transmission, from substations down to end users. Substations change the voltage of transmission grid level electricity into a lower voltage range so that it can be safely delivered to buildings along distribution lines. Distribution lines that operate between substations and transformers are part of the primary distribution system. Transformers then further step this voltage down and, depending on local energy needs, service drop lines that deliver electricity directly to end users in homes and businesses. Distribution lines operating between transformers and endpoints make up secondary distribution system.

On a TAZ basis, EDGE compares the load that EVs are expected to produce over time against the capability of existing circuits to take on new load. The result is the "capacity indicator metric" for each TAZ throughout California. When a region shows a negative capacity indicator metric value, it means that the modeled EV charging load there exceeds the local grid capacity and may require grid equipment upgrades or other solutions to support expected load growth. This calculation depends on the power levels of the chargers modeled in EVI-Pro and HEVI-LOAD, and any changes made to those assumptions will directly affect the capacity indicator metric values produced by EDGE.

The vision for EDGE is to provide users with the capability to identify good candidate locations to install charging infrastructure, as well as hotspots where the grid may not suitably accommodate large EV charging load without upgrades via a publicly accessible tool hosted online. The CEC will work with the CPUC, California Independent System Operator (California ISO), and other utility planners and regulators by sharing information on regional capacity indicator metric values to provide insight on where clustered EV charging load is projected to grow over time and could potentially constrain electric system infrastructure. This relationship could provide insight for the utilities to improve grid planning.

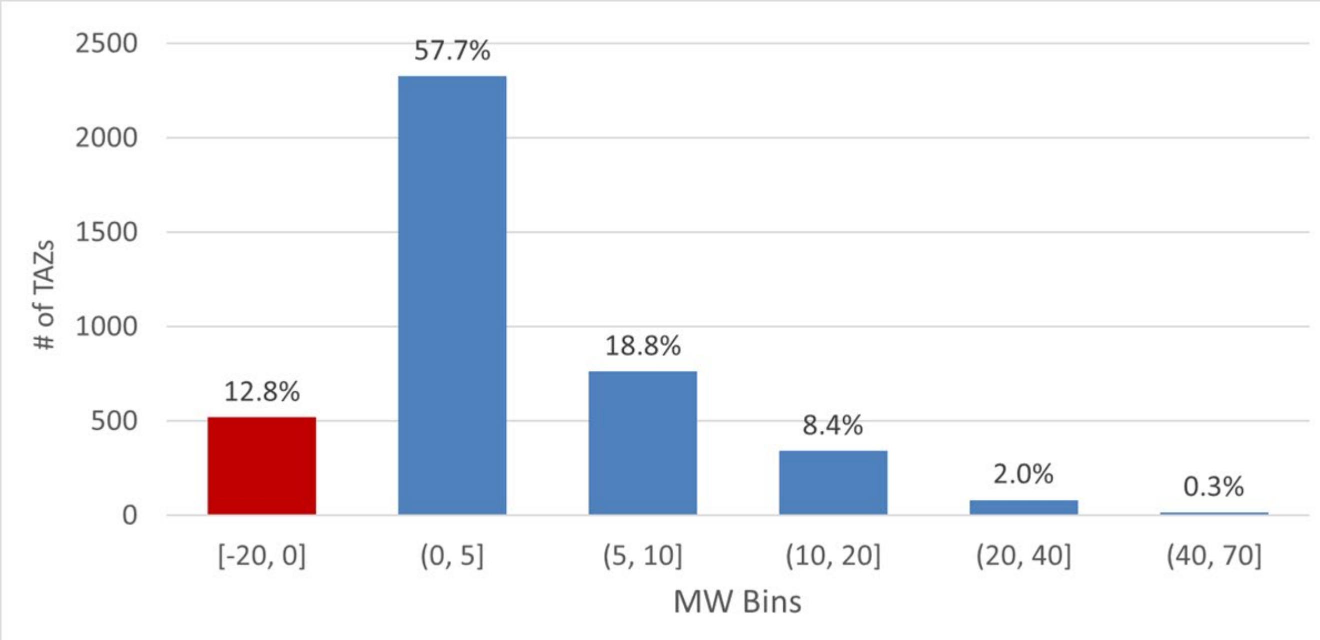
Modeling Results

For this analysis, EDGE combines the TAZ load profiles from EVI-Pro and HEVI-LOAD and compares the resultant combined peak load for LD vehicles and MDHD vehicles in 2025 to the regional circuit capacity from the IOUs' GNA data in 2025. EDGE highlights areas that may need grid equipment upgrades to accommodate for any capacity deficits. The following results have not been peer reviewed by utilities and there could be additional factors impacting current and future grid capacity that are not captured in the current analysis. The CEC is refining the EDGE tool including an upcoming workshop and public release of the tool.

When looking at the capacity of individual circuits in 2025 throughout all IOU territories, nearly 60 percent have up to 1 MW of additional capacity to host new load, with another 4 percent having 0 MW or less. Analysis of the individual circuits is further discussed in Appendix I.

When assessing capacity indicator metric values at the TAZ level, about 26 percent of the 5,454 TAZs in California do not have any grid capacity data associated with them. This lack of grid capacity data is because either the data are redacted in the IOU portals or the TAZs fall outside IOU service territories. Of the remaining TAZs with data, about 13 percent, or 516 TAZs, have a negative capacity indicator metric value, indicating that the overall modeled EV charging peak load may exceed the aggregated circuit capacity in those areas. Another nearly 58 percent of TAZs with grid data have 5 MW or less available before capacity is exceeded. These data can be seen in Figure 31.

Figure 31: Distribution of Capacity Indicator Metric Values in California TAZs in 2025

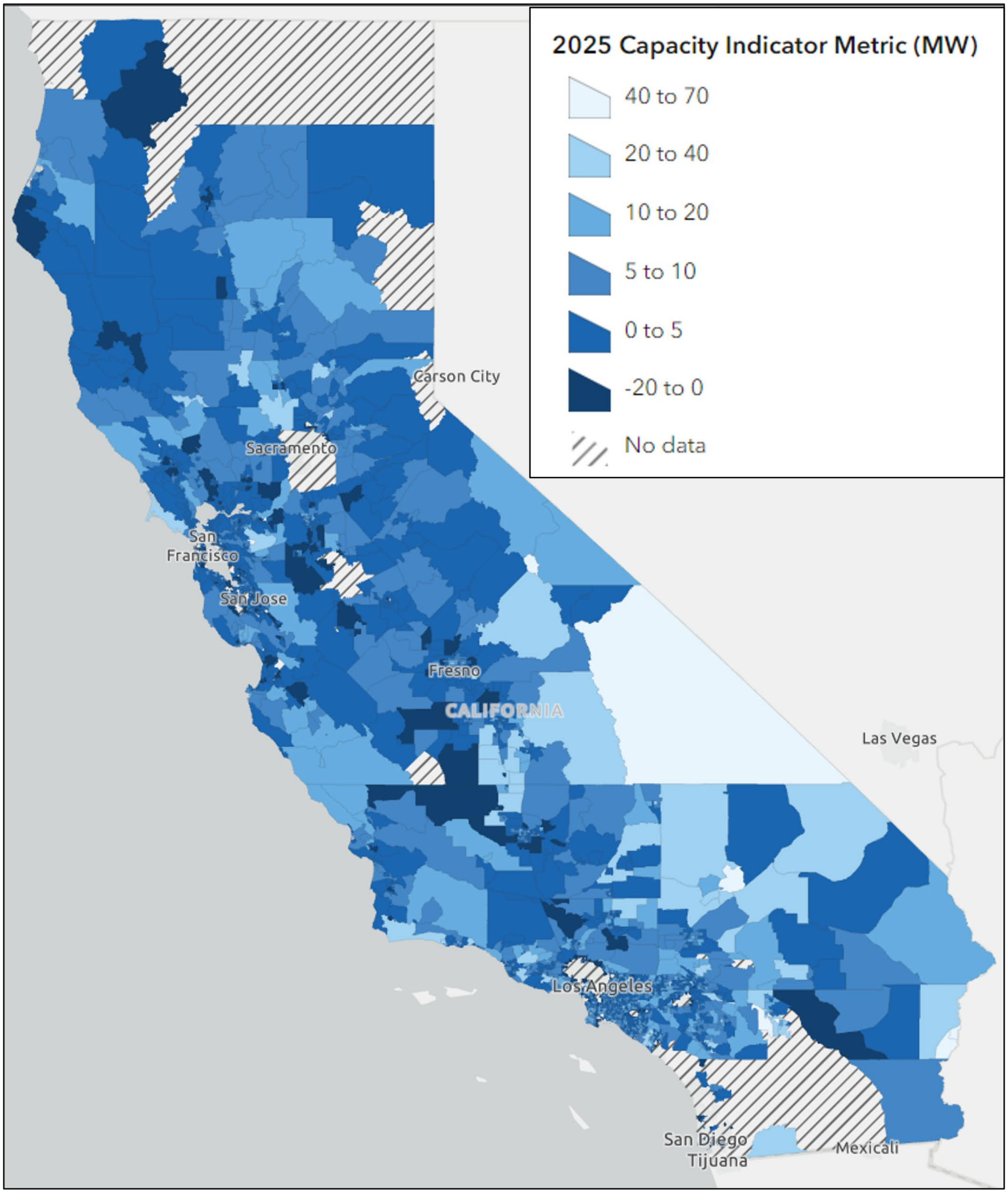


Of the 4,029 TAZs in California with IOU grid data associated with them, nearly 13 percent potentially have EV charging peak loads that exceed the available circuit capacity in 2025. Another nearly 58 percent have 5 MW or less of additional capacity beyond projected EV charging demand before needing attention. These are areas in which planners may want to focus their attention in the near term.

Source: CEC staff

TAZs with a potential negative capacity indicator metric value are scattered throughout the state with 370 in PG&E's service territory, 126 in SCE's service territory, and 24 in SDG&E's service territory, but some areas have a high concentration of them. A map of the overall statewide view in EDGE can be seen in Figure 32, and zoomed-in views of the negative capacity indicator metric value regions can be found in Appendix I at the end of this report. Many of these TAZs with negative capacity indicator metric values are clustered around the Interstate 5 (I-5) corridor, especially in the San Joaquin Valley. Moreover, some locations near the San Pedro Bay ports as well as many regions in the counties making up the San Francisco Bay Area — such as in San Francisco, San Mateo, Santa Clara, and Alameda Counties — also have clustered TAZs where the available capacity is exceeded by expected EV load growth in 2025. The large capacity deficit values in these regions are due to the combination of a high amount of projected EV load growth and lower-than-average grid capacity. There are some TAZs throughout the state that have higher EV load growth or less grid capacity than these, but the overlap of these two factors in the regions listed above identifies them as areas in which to prioritize and focus grid planning to address grid constraints early.

Figure 32: Statewide EDGE Map of Capacity Indicator Metric Values in TAZs



A map from the CEC's EDGE Visualization Tool showing TAZs in California and the associated capacity indicator metric values using 2025 GNA circuit capacity forecasts and 2025 EV infrastructure load projections. Regions with negative capacity indicator metric values potentially have larger EV charging load than available circuit capacity and are colored dark blue on the map. Areas with hashed lines have no utility grid data associated with them in EDGE.

Source: CEC staff

Barriers and Future Refinements

In the first assessment, the EDGE tool used grid data from the IOUs' ICA maps. However, after several discussions with the IOUs, CEC staff updated EDGE to use GNA data instead. There are several differences between these datasets that affect the functionality of EDGE. The ICA data provided a more geospatially granular look at the circuit nodes in each utility territory, whereas the GNA data show only information for the large overall primary circuits and substations. This distinction can lead to a different interpretation of grid readiness such that more capacity is apparent in GNA data, but the spatial resolution is decreased. Some flexibility in site location within a circuit is therefore implied in these results. In addition, the ICA data provide only a static snapshot of information at the time the values were updated and do not provide any time-dependent variability, whereas the GNA data provide annual forecasts for the five years after the dataset is updated.

EDGE is best situated to provide utility planners with information that affects system-level planning, such as primary circuit or substation upgrades. However, more geospatially granular information could be implemented in future iterations of the tool to give users the ability to assess particular sites where they may be interested in deploying charging infrastructure. However, this will require more data from the electric utilities. Furthermore, EDGE combines the capacity of different circuits within a TAZ, but the limits on the power available on any one site is best evaluated at a circuit level, as shown in Appendix I. There may be significant grid limitations for large sites even if TAZ-level results show capacity.

CEC staff held a closed beta testing period in May 2023 in which a small set of users tested early functionality and provided feedback and suggestions for improvement. In October 2023, the CEC released the initial public version of the tool and held a public workshop to gather feedback and announce the release of the tool. EDGE will be constantly monitored and updated when additional data and more information that are relevant to the analysis become available. The GNA datasets are updated annually to include additional forecast years and future load calculations with expected growth and deficiencies, so that information will be reflected in EDGE as well.

Moreover, CEC staff is exploring a project proposal with a national laboratory to develop a toolset for small to medium utilities to conduct their own analyses to produce results similar to the IOU GNA data. This toolset will allow the creation of an environment in which utilities — primarily publicly owned utilities — would, if the information does not already exist, create data reflecting the physical characteristics of the electric grid system in their service territories. These data would then be housed and managed by the utility and could be queried for integration within the EDGE tool. The project would give utilities the ability to perform power flow analyses on circuit components in their system using circuit-specific EV adoption forecasts and geospatially granular charging load growth projections as the foundation to identify and prioritize impact mitigation solutions. This work would help supplement the large data gaps existing in EDGE and create a more comprehensive understanding of the infrastructure hosting capabilities in specific regions throughout the state.

CHAPTER 5: Meeting California's Charging Needs

Near-Term Charging Infrastructure Needs for Light-Duty Vehicles

California's charging infrastructure needs will grow rapidly once ACC II takes effect in 2026, but PEV ownership has already begun to increase, increasing the importance of the state's commitment to support the market as it matures. Charging infrastructure needs for 2030 and 2035 are large but are more subject to uncertainty than near-term needs. In contrast, charging infrastructure needs for 2025 are more predictable as they more directly reflect today's trends. The base case model in this report estimates that California will need 257,689 public and shared-private chargers, including 15,705 DCFC chargers to support 2.5 million light-duty PEVs by 2025. California has 93,855 public and shared private chargers, including 10,258 DCFC chargers,[90] indicating a shortfall of 163,834 chargers, including 5,447 DCFC chargers that will need to be installed over the next few years to support the vehicles that will be on the road soon. However, different mixes of DCFC and Level 2, such as the gas station model, may proliferate. California requires a steady growth of charging infrastructure to support the state ZEV targets in 2025 and beyond.

To determine progress toward achieving the state's goal of 250,000 public and shared private chargers by 2025, CEC staff estimates the number of projected charger installations for which funding has been allocated through state/federal programs, ratepayer-funded programs, and settlement agreements. The state has met the 10,000 DCFC goal two years ahead of schedule. Table 11 shows the progress toward meeting California's goal of 250,000 chargers in 2025 and toward the estimated charging needs for 2030 from the models presented in this report.

Table 11: Progress Toward 250,000 Chargers

Category	Chargers
Existing Chargers (Estimated)*	93,855
Number of Chargers for Which Funding Has Been Allocated (includes anticipated funding from Clean Transportation Program)**	167,000
Total	260,855
2025 Goal (Executive Order B-48-18)	*250,000*
Gap From 2025 Goal	0
AB 2127 Report 2030 Estimate of Charging Needs	1,008,844
Gap From 2030 Estimates	747,989

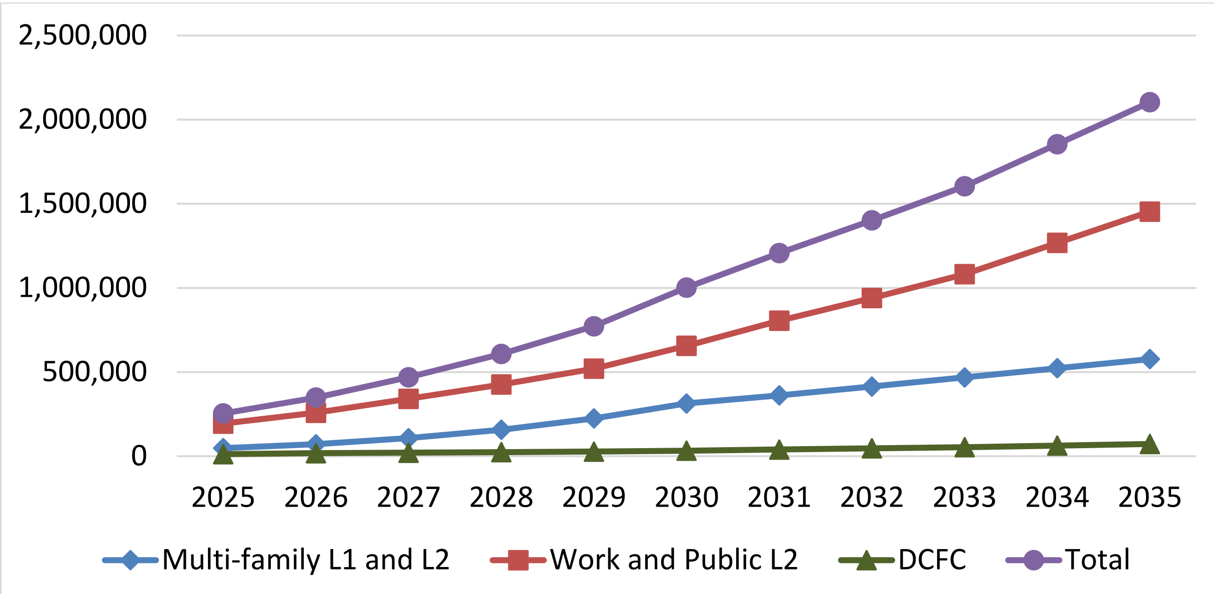
* Existing charging ports estimated based on available data from U.S. Department of Energy's Alternative Fuels Data Center and surveys to electric vehicle network service providers, utilities, and public agencies in California. Not included in this table are an estimated 560 statewide public or shared-private Level 1 chargers.

90 California Energy Commission. 2023. "Electric Vehicle Chargers in California." Data last updated September 15, 2023. September 29, 2023, from https://www.energy.ca.gov/zevstats.

** Estimate of ports from other state programs derived from public presentations and statements by utilities, CPUC, CARB, other entities, and CEC. Includes funding from the State Budget Act of 2021 and State Budget Act of 2022 intended to close the gaps for Level 2 and DC fast chargers; the estimated number of chargers could change as solicitations are released.

Charger needs will increase steadily as more Californians adopt light-duty PEVs. Figure 33 shows annual charger needs from 2025 to 2035 under the primary AATE3 scenario. While California is on track to meet charger needs in 2025, the state will need nearly four times as many chargers in 2030 and more than eight times as many in 2035.

Figure 33: Total Annual Charger Needs for Light-Duty PEVs Under the AATE3 Scenario



The number of chargers serving light-duty PEVs in California will increase steadily through 2035, when California PEVs will need 2.11 million public and shared private chargers, including more than 80,000 DC fast chargers.

Source: CEC, NREL, and UC Davis

As discussed in Chapter 2, sales of light-duty PEVs (particularly BEVs) increased rapidly since 2021, and PEVs made up nearly 25 percent of LDV sales in California in the first half of 2023. If sales continue to increase at this rate, California will reach the AATE3 scenario 2025 fleet size assumption of 2.5 million PEVs by 2025. If sales increase more rapidly in the second half of 2023 and 2024, California may reach 2.5 million PEVs sooner than expected. Annual charger estimates for 2026 (available in Appendix D) could be used to assess charger needs if California reaches a higher PEV fleet size in 2025.

Supporting Routine Charging

An equitable transition to PEVs will require fairly priced and convenient ways for all drivers to meet their routine charging needs. Home charging access is a priority, but residents of multifamily housing, renters, and lower-income households may not have access to conventional home charging. The modeling results in this report include a range of potential alternatives to conventional home charging, including expanding home charging access through programs like curbside charging, investment in charging at multifamily housing, and expanded DCFC charging. The expansion of DCFC charging is particularly relevant given that DCFC installations are ahead of state targets. In the primary scenario, DCFC operates as one of many away-from-home charging options alongside workplace and public Level 2. In the "gas station model" alternative future scenario, DCFC replaces most nonhome charging and accounts for more than half of all charging.

The expanded at- and near-home charging approach aligns most closely with providing grid-friendly and convenient access. The potential benefits of this approach are that expanding access to charging near home would provide many more households with a charging option that is as convenient as those who have home charging in single-family homes. Long dwell times at home also mean that this option could rely on less expensive charging equipment than a DCFC-heavy scenario while having the flexibility to adjust charging times to minimize cost and support the grid. The potential drawbacks of this approach are that home charging may be more difficult to shift to the daytime than other charging system designs, and that it may require installing more chargers overall than other approaches.

Level 2 at Home and Other Destinations

The primary scenario of this report assumes that most drivers will prefer Level 2 charging at home and work for their routine charging needs because it is convenient and requires minimal behavioral change. In this scenario, Level 2 charging at home, work, and other destinations will account for about 77 percent of all LDV charging load, with DCFC making up the remaining 23 percent. Because Level 2 charging is slower than DCFC, more Level 2 chargers are needed per vehicle, but overall Level 2 charging may be less expensive than DCFC to install and use.

Charging flexibility and timing are key considerations for ensuring that transportation electrification supports the grid. Home Level 2 charging is inherently the most flexible option, but it generally concentrates charging at night. Because Level 2 charging times are shorter than the amount of time most people spend at home overnight or the energy needed for average daily driving, home charging events could be shifted substantially within this window without inconveniencing drivers. TOU rates or charging management systems or both could be methods of optimizing charging loads for grid health and clean energy.

After home charging, Level 2 charging while at work is the second-most-used routine charging option among PEV drivers. Work charging may be less flexible than either home Level 2 or DCFC. However, most people work during the day, when solar energy is most plentiful, meaning workplace charging can play a role in maximizing renewable energy use. As PEV adoption increases, retail, dining, and entertainment work locations may become highly important charging locations for workers while serving many customers who may also want to charge. Staff used EVI-Pro 3 to take an initial look at this issue by separating work Level 2 charging by location and access based on the proportion of Californians working in various economic sectors.

California Green Building Standards Code

Building codes are one mechanism to increasing charging access at homes. The California Green Building Standards Code – Part 11, Title 24, California Code of Regulations (CALGreen) sets minimum standards for newly constructed residential and nonresidential buildings and, in some cases, existing parking facilities serving multifamily buildings. These building standards help to increase EV charging access and may mitigate costs for future retrofits.

The 2022 CALGreen Code, which was effective on January 1, 2023, requires the installation of raceways and electrical panel capacity that can accommodate a 208/240V 40-amperes branch circuit for newly constructed one- and two-family dwellings and town-houses with attached parking garages.

When parking is provided, newly constructed multifamily dwellings, hotels, and motels with less than 20 dwelling units must generally have a total of 10 percent of parking spaces provided be EV capable[91] and 25 percent be EV ready[92]. Those with 20 or more dwelling units must additionally have Level 2 EV chargers installed for 5 percent of parking spaces provided. When new parking serving multifamily buildings is added, or when electrical systems of existing residential parking facilities are added or altered and a building permit is required, 10 percent of total parking added or altered must be EV capable.

During the 2021 Triennial Code Adoption Cycle, the California Department of Housing and Community Development (HCD), in consultation with the California Air Resources Board (CARB), estimated that the 2022 CALGreen code will add approximately 75,000 low-power Level 2 EV receptacles and Level 2 EV chargers in newly constructed multifamily buildings and approximately 18,000 additional EV capable spaces between 2023 and 2025.[93] [94] For newly constructed hotels and motels constructed between 2023 and 2025, it is estimated that the 2022 CALGreen code will add approximately 2,000 EV capable spaces and 15,000 to 19,000 low-power Level 2 EV receptacles and Level 2 EV chargers.

DCFC and the Gas Station Model

In contrast, the gas station model assumes that drivers prefer DCFC over all other away-from-home charging options, and some home charging shifts to DCFC. Under this scenario, DCFC accounts for about 65 percent of all LDV charging. This scenario would allow more vehicles to be served by a significantly smaller number of chargers and might make it easier to shift charging loads to daytime hours, when more solar energy is available. As DCFC charging speeds increase, more drivers might opt to fit DCFC charging events as brief stops during their regular travel patterns rather than relying on lower-speed charging at longer dwell-time destinations.

Cost, to install and to charge, and equity are key concerns for DCFC. The gas station scenario would entail building a smaller number of chargers than the primary scenario, but it may be

91 An EV capable space is a vehicle space with electrical panel space and load capacity to support a branch circuit and necessary raceways, both underground and/or surface mounted, to support EV charging.

92 An EV ready space is a vehicle space which is provided with a branch circuit; any necessary raceways, both underground and/or surface mounted; to accommodate EV charging, terminating in a receptacle or a charger.

93 The additional 18,000 Level 2 capable spaces assume that one (1) percent of existing building will undergo parking facility retrofits that require the installation of Level 2 capable infrastructure.

94 State of California Building Standards Commission. March 2021. [45-Day Initial Statement of Reasons for Proposed Building Standards of the California Department of Housing and Community Development Regarding the 2022 California Green Building Standards Code](). Available at https://www.dgs.ca.gov/BSC/Rulemaking/2021-Triennial-Code-Adoption-Cycle/2021-Public-comments.

less expensive to build out a robust network of Level 2 chargers. In addition, the cost of charging for drivers at DCFC is likely to be higher than at home Level 2 chargers, possibly resulting in a less equitable charging ecosystem, especially for drivers without access to charging at home. Future editions of the AB 2127 Assessment may consider installation cost and cost to drivers of various infrastructure scenarios.

The gas station model provides potential benefits for grid management but also comes with drawbacks. Because DCFC charging events can be relatively brief, some drivers may be willing to prioritize charging at periods of lower demand to minimize charging cost, particularly if site-specific pricing or very low-cost charging is available during off-peak times and when solar penetration is high. On the other hand, gas-station-style DCFC has the potential to concentrate charging during regular travel times, adding electrical load at times when heating and cooling loads are higher and solar generation is low, such as early morning in winter and late afternoon in summer and fall. Pairing on-site energy storage with DCFC has the potential to reduce impacts by allowing load shifting. Further, strong time-of-use rates could help influence charging behavior to times of high solar generation.

At the workshop on the staff draft of this report,[95] CEC staff highlighted the gas station model alternative future scenario and asked for stakeholder comment on the roles of Level 2 and DCFC in the future of transportation electrification. Many workshop and written comments addressed modeling assumptions and funding prioritization between Level 2 and DCFC. Comments in favor of expanded DCFC investment highlighted the revealed preference for DCFC among current drivers, the potential role of high-power DCFC as an enabler for market growth, and the potential for DCFC to fill the gap before more charging can be installed in multifamily homes. Comments in favor of Level 2 charging identified long-duration L2 as the most convenient charging option for drivers and the cheapest option to install and use. Most comments that focused on grid and clean energy aspects indicated that Level 2 charging was more compatible with charging management, load flexibility, and solar energy. One comment suggested that time-of-use pricing, site-specific pricing, and providing free charging during off-peak times could make it possible to manage and shape DCFC loads and work well with the grid. Additional strategy discussions will take place during the development of the next edition of the Zero-Emission Vehicle Infrastructure Plan.

95 The CEC conducted a workshop September 7, 2023, to present the draft Staff Report of the second AB 2127 Assessment and discuss differences from the first AB 2127 Assessment. The slides and recording from this workshop are available here: https://www.energy.ca.gov/event/workshop/2023-09/assembly-bill-ab-2127-assessment-workshop-staff-draft-report.

CHAPTER 6:
Vehicle-Grid Integration

Vehicle-grid integration (VGI) can play a powerful role preparing the electric system to accommodate new charging load reliably and cost-effectively. VGI describes technologies and strategies that alter the time, charging level, or location of charging in a manner that benefits the grid while ensuring driver needs are met. By taking advantage of the flexibility of the charging schedule of a vehicle[96] or by intelligently integrating with local electric loads and generation, VGI can shift and adjust the charging load on the grid. VGI technologies and strategies can help maximize customer savings, minimize carbon emissions, and support reliable and economic power grid operation. VGI appears in various forms, including:

- **Smart charging,** also called managed charging or V1G, which adjusts charging time or power level in response to utility rates, demand-response events, local site controllers, or other signals.
- **Bidirectional charging,** which enables a PEV to export energy from the onboard battery to buildings (vehicle-to-building [V2B]), homes (vehicle-to-home [V2H]), or the grid (vehicle-to-grid [V2G]). When equipped with the appropriate power electronics and electrical switching,[97] bidirectional charging can provide power to a site during a grid outage.
- **Automated load management (ALM) systems,** which manage charging load with the objective of reducing or eliminating the need for electrical capacity upgrades on the utility or customer side of the meter, or both.[98]
- **Distributed energy resource (DER) supported charging systems**, which integrate one or more chargers with DERs[99] to reduce or time-shift electric load on the grid without compromising the charging experience. Examples include chargers featuring both a grid connection and an integrated battery and several chargers supported by on-site solar generation and storage.

96 PEVs are often plugged in for several hours but typically only need to charge for a small portion of that time, resulting in a scheduling flexibility for when the charge occurs.

97 Bidirectional charging for backup power in particular may require other hardware such as transfer switches (to disconnect the site from the distribution system) and additional panels to isolate critical loads. Furthermore, power electronics used for backup power must be capable of independently generating voltages to support local loads. The number of additional “boxes” needed to enable bidirectional charging will depend on the features requested by the customer and the electrical architecture used by the automaker and charger manufacturer.

98 This definition is used by CPUC. Importantly, ALM may enable a project to safely oversubscribe a breaker, panel, or other applicable point of electrical connection.

99 DERs are decentralized generation or storage devices connected to the distribution grid. DERs include rooftop solar photovoltaics, on-site batteries and other energy storage systems, and electric vehicles. As noted later in this chapter, the CPUC’s High DER Rulemaking (R.21-06-017) is exploring options to ensure the grid can support the growing number of DERs on the grid.

With broader consumer acceptance and thoughtfully designed products and programs, VGI could provide significant benefits to the electrical grid and customers, including drivers, ride-hail services, fleet managers, and so on. For example, smart charging can help drivers charge with cheaper and cleaner electricity by automatically shifting charging to times when electricity prices and emissions are lowest. Customers with bidirectional charging may enjoy greater energy resilience by using their vehicle as a zero-emission power source during times of high electricity prices, during a grid outage, or while visiting areas that are off-grid. VGI can even provide benefits during the charger deployment process itself. For example, ALM can help a site owner install chargers within the constraints of the existing electrical capacity at a site, potentially yielding a less expensive and quicker deployment by reducing or eliminating the need for upgrades to the site electrical system. VGI strategies such as ALM or DER integration may in some cases enable the installation of charging at sites where adding chargers would otherwise be infeasible.

In addition to customer benefits, VGI also strengthens grid operations and reliability. Using strategies such as electric rates that reflect electric system conditions, electric system operators can reward customers for charging during periods of abundant renewable generation with lower prices and, correspondingly, create an incentive for customers to avoid charging during periods of peak electricity demand with relatively higher prices.

With bidirectional charging, PEVs could export power to homes, facilities, or the grid to reduce electricity demand during peak hours or provide emergency electricity resources during a Flex Alert. Such benefits are not theoretical: SDG&E, Cajon Valley Union School District, and equipment manufacturer Nuvve launched a V2G project last year that enabled electric school buses to earn compensation for sending power back to the grid during peak grid conditions.[100] Building on Cajon Valley's success, several other school districts across California are already activating similar capabilities.

For VGI generally, the win-win aspects are not limited to improving customer benefits and addressing grid conditions. Widespread VGI (and load flexibility[101] generally) will help achieve California's climate and decarbonization goals. In the first edition of this report, the CEC wrote: "To fully realize the economic, air quality, and climate benefits of electrification, California must pursue greater vehicle-grid integration, the coordination of charging with grid needs, to ensure that charging is better aligned with clean, renewable electricity without sacrificing driver convenience." The need for load flexibility, which includes VGI, has been repeatedly

100 Sempra. 2022. "SDG&E and Cajon Valley Union School District Flip the Switch on Region's First Vehicle-to-Grid Project Featuring Local Electric School Buses Capable of Sending Power to the Grid," https://www.sempra.com/sdge-and-cajon-valley-union-school-district-flip-switch-regions-first-vehicle-grid-project.

101 *Load flexibility* refers to the ability of electric customers to shift the electricity consumption of devices, appliances, or other loads in response to electricity prices or other signals. VGI can be viewed as load flexibility applied to vehicle charging.

confirmed in subsequent reports from the CEC,[102] CPUC,[103] and others.[104] Accordingly, the remainder of this chapter describes a collaborative vision and framework for achieving widespread VGI in California.

A Framework for Widespread VGI

To support full electrification of transportation, VGI products, programs, and strategies should be widely available, be customer friendly, and serve as a reliable tool to aid grid operations.[105] Given the immense potential and need for VGI, products and policies must continue to evolve to support a seamless, customer-friendly, and scalable VGI ecosystem. CEC has identified five broad areas in need of advancement to attain widespread VGI:

1. **Compensation structures.** To enable and reward widespread load flexibility, California must continue to improve rate design structures and other compensation programs to reflect true grid conditions. This improvement includes further developing dynamic tariffs that better reflect the benefits VGI can provide to the grid, as well as other nonrate compensation programs.
2. **Customer products and services.** Today, the array of incompatible connectors and communication protocols has resulted in customer and market confusion. Even when connectors and communications are aligned, many charging products and services do not support VGI features such as automated smart charging or bidirectional charging. Improved interoperability along with innovation in charging products and services from private industry, will help ensure that customers have easy access to VGI capabilities.
3. **Site readiness for charging.** Because certain VGI benefits are predicated on drivers being able to plug in, California must ensure that sites where cars park are electrically prepared ready for the installation of chargers. Moreover, some forms of VGI may themselves enable site readiness for charger installation (for example, the use of load

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102 The joint agency SB 100 report found that "prioritizing … load-flexibility measures remains critical as the state moves toward a 100 percent clean electricity future." California Energy Commission. 2021. *SB 100 Joint Agency Report: Charging a path to a 100% Clean Energy Future,* https://efiling.energy.ca.gov/EFiling/GetFile.aspx?tn=237167&DocumentContentId=70349

103 CPUC states that "going forward it is essential for California to leverage … demand flexibility management as a critical resource in integrated resource planning (IRP) to meet the State's aggressive GHG emissions reduction targets." Madduri, Achintya, Masoud Foudeh, Paul Phillips. 2022. "Advanced Strategies for Demand Flexibility Management and Customer DER Compensation," California Public Utilities Commission, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/demand-response/demand-response-workshops/advanced-der---demand-flexibility-management/ed-white-paper---advanced-strategies-for-demand-flexibility-management.pdf.

104 An NREL report found that demand flexibility could significantly reduce costs associated with deep decarbonization. O'Shaughnessy, Eric, Monisha Shah. 2021. "The Demand-Side Opportunity: The Roles of Distributed Solar and Building Energy Systems in a Decarbonized Grid," National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy21osti/80527.pdf.

105 Importantly, the appropriate form of VGI will vary depending on the customer and use case. For example, it may not be feasible to schedule or otherwise delay charging at a public fast charger in response to grid signals. However, the charging station developer may find it beneficial to pursue other forms of VGI such as integration with DERs or load management that intelligently distributes power across chargers based on realtime demand.

management strategies and integration with DERs), and industry should leverage such strategies to ensure timely and cost-effective charger deployment.

4. **EV and grid planning processes.** VGI products and services are in an early commercialization stage and have seen limited deployment to date, and limited data exist. As such, CEC and other agencies have captured only load shifting from time-of-use rates in their demand forecasting and not fully considered other potential effects. Continued monitoring of the benefits and performance of VGI can guide forecasting and planning and eventually help planners consider VGI options from the outset. This monitoring could mean more accurate assessments of the need and scale of charging infrastructure and grid upgrades.
5. **Customer ease, confidence, and enrollment.** Customers may not understand the potential bill savings, carbon emission reductions, and other benefits enabled by load flexibility and VGI. Even those who do may hesitate to enroll in unfamiliar VGI rates or programs. Customer-friendly utility enrollment processes, increased product choices, and education campaigns may improve customer confidence and willingness to participate in VGI.

The success of VGI relies on coordination across automakers, charging providers, utilities, automation service providers, regulators, and others; no single entity is entirely responsible for resolving any of the challenges described above. CEC actions can play a role in all five areas, and the remainder of this chapter describes current and planned CEC actions addressing each of these challenges, as well as those from other VGI stakeholders.

VGI Advancement 1: Compensation Structures

A broad portfolio of compensation structures to reward customers for adjusting their charging behavior in response to grid conditions is foundational to VGI. Many electricity rates do not always reflect real-time grid conditions and, therefore, do not consistently reward customers for consuming electricity in grid-friendly ways.[106] In other words, most customers today are not provided with the information or incentives needed to encourage grid-friendly charging consistently, and stakeholders frequently cite the lack of these compensation structures as a primary reason why VGI has struggled to scale.[107]

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106 For example, as noted earlier, most time-of-use rates offer the lowest prices in the middle of the night even on days when grid operators are forced to curtail surplus solar generation during the day. Time-of-use rates are helpful for shifting consumption away from existing peaks but do not sufficiently encourage load shift in response to actual grid conditions. A CPUC paper found that "57% of the highest-priced intervals for wholesale energy prices fell outside the TOU on-peak period." Madduri, Achintya, Masoud Foudeh, Paul Phillips. 2022. "Advanced Strategies for Demand Flexibility Management and Customer DER Compensation," California Public Utilities Commission, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/demand-response/demand-response-workshops/advanced-der---demand-flexibility-management/ed-white-paper---advanced-strategies-for-demand-flexibility-management.pdf.

107 For example, in a broad assessment of barriers to VGI, the final report of the California Joint Agencies VGI Working Group stated "Retail EV charging rates should reflect cost of generation, delivery, GHG, and other relevant value streams; all EV charging rates should be time-variant, starting with simple TOU rates and then enabling optional alternatives such as dynamic rates." Staff notes that various actions at the CEC and CPUC are supporting the development and availability of more grid-friendly rates. California Public Utilities Commission.

To support VGI and decarbonization more broadly, CEC, CPUC, utilities, and community choice aggregators (CCAs)[108] are investigating rates and other programs that better reflect grid conditions. Time-varying rates (including time-of-use rates and hourly or even subhourly dynamic rates), for example, typically encourage consumption during periods of grid abundance with lower prices and encourage load reductions or even export during periods of grid strain with higher prices. In 2022, CPUC staff outlined a rate design framework that could enable widespread load flexibility by providing customers with a unified electricity price capturing several electric system factors in real time, including wholesale energy cost, generation capacity, and distribution capacity.[109] This technology-agnostic rate design approach is distinct from the current and past approaches to rates, which have often emphasized EV-specific or other technology-specific rate structures.

Similarly, in October 2022, the CEC approved revisions to its Load Management Standards, which would require California's largest utilities to develop and propose dynamic rates that reflect actual grid conditions for all customer types. The updated Load Management Standards will spur the development and availability of innovative dynamic rates, and some utilities and CCAs across the state are already launching such rates to select customers, including PG&E,[110] SDG&E, SCE,[111] Valley Clean Energy,[112] and others.

Importantly, the revised Load Management Standards also direct utilities to upload their current and future electricity rates onto CEC's Market Informed Demand Automation Server, or MIDAS. MIDAS is an internet-accessible database housing current electricity rates, carbon emissions data, and Flex Alert status in machine-readable formats.[113] In practice, MIDAS enables internet-connected devices such as smart EV chargers or thermostats to look up the customer's electricity rate automatically and optimize electricity consumption around price. This automation afforded by MIDAS reduces or eliminates the need for customers to program their charger manually and makes it more practical and convenient for customers to enroll in rates that may update at hourly or even subhourly intervals.

While improved electricity rates may help support widespread VGI, other signaling structures such as virtual power plant programs and demand response could play significant roles as well. In 2021, the CPUC directed utilities to launch the Emergency Load Reduction Program

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2020. *Final Report of the California Joint Agencies Vehicle-Grid Integration Working Group,* https://gridworks.org/wp-content/uploads/2020/07/VGI-Working-Group-Final-Report-6.30.20.pdf.

108 Community choice aggregators procure energy for electricity users in a community or region. CCAs do not operate electric distribution infrastructure, and electricity procured by CCAs is delivered via existing distribution infrastructure typically operated by a utility.

109 CPUC termed this approach California Flexible Unified Signal for Energy, or CalFUSE.

110 For example, PG&E's upcoming Day Ahead Hourly Real Time Pricing EV rate.

111 SCE is partnering with TeMix to pilot a dynamic transactive energy rate.

112 Valley Clean Energy is partnering with TeMix and Polaris Energy Services to pilot a dynamic transactive energy rate for agricultural irrigation.

113 "Machine readable" means that data are stored in a standardized format across utilities. This standardized format ensures grid signals can be easily accessed and processed by devices, computers, software, and so on.

(ELRP), which rewards customer load reductions during grid emergency events at $2/kWh.[114] The CEC launched the complementary Demand Side Grid Support Program in 2022, which provides similar levels of incentives for load reductions by customers served by utilities not under CPUC jurisdiction. Other nonrate approaches, such as smart charging programs, may enable load flexibility, particularly for customers that are uninterested in enrolling in newer rates or grid emergency programs.

Customer value and compensation are not limited to bill savings or payments from utilities, and some customers may be more likely to respond to nonmonetary signals. For example, some customers may prefer to optimize charging around the availability of low-carbon or carbon-free electricity (instead of price signals), and others may rely on local signals from a site controller and eschew external signals entirely.[115] Alternatively, companies such as ev.energy and OhmConnect disburse point-based currencies for grid-friendly consumption, and customers can use these points to redeem merchandise, prizes, and other rewards. Similar gamification strategies may yield greater customer interest or more sustained participation than bill savings alone.

The various compensation structures described above provide customers — who ultimately make decisions about their charging behavior — with value and incentives for pursuing VGI and responding to grid conditions. Thoughtfully designed and widely available compensation structures will be the basis for why a typical customer will take an interest in VGI. California will benefit from a broad portfolio of VGI compensation and value structures to serve diverse customers effectively with diverse needs and priorities.

VGI Advancement 2: Customer Products and Services

As grid- and customer-friendly compensation options become increasingly available, Californians will need access to a range of affordable, interoperable VGI products and services[116] to help them easily and confidently generate value from VGI. Most customers view their vehicles primarily as transportation tools, and broad VGI participation will require simple-to-use products and services that deliver clear benefits to the customer. While some power users may enjoy personally optimizing their charging around grid conditions, electricity prices, and expected departure time, most customers will rely on products and services from third parties to manage their relationship with the grid while maintaining an automated and straightforward charging experience. To support industry in developing these products and services, CEC has focused efforts on advancing VGI capabilities and interoperability.

114 The ELRP received widespread media attention following the September 2022 heat waves. Aggregators such as OhmConnect and PowerFlex leveraged ELRP to compensate customers for emergency load reductions.

115 For example, a site with rooftop solar may schedule charging around the availability of surplus solar generation and current demand from other site loads as indicated by a site energy management system.

116 "VGI products and services" is used to broadly capture anything that helps customers manage vehicle charging while considering grid conditions. These may include chargers, charge management software, automation services which connect to a charger or a vehicle, and so on. Such products are typically offered by "third party" companies — that is, entities that enable a more seamless relationship between the customer (the first party) and the utility or electric system (the second party).

VGI Capabilities

Charging products can come in many forms, including chargers, charge management software, automation service providers[117] that connect to a charger or a vehicle, charging controllers, and so on. While charging products already exist on the market today, many make it cumbersome for the customer to participate in VGI, and some offer no VGI capabilities at all. For instance, many home chargers are "nonnetworked" and incapable of connecting to the internet to retrieve electricity prices or other grid signals.[118] Product gaps are even greater with bidirectional charging; standards supporting bidirectional charging were only recently finalized (others are being finalized), few bidirectional charger models exist today, and those that do are offered only through select purveyors.[119]

To help remedy existing gaps, CEC is directing funds to support the development of products with customer-friendly[120] and intelligent VGI capabilities. The Response Easy Charging Products With Dynamic Signals (REDWDS) funding solicitation is intended to provide companies with resources to integrate products with real-time grid signals, improve algorithms to optimize charging around grid conditions and customer preferences, and develop strategies to ensure sustained customer participation, understanding, and value.[121] Importantly, the appropriate level of charging optimization in response to grid signals will vary by customer and use case. For example, to preserve a reliable customer experience, high-power public chargers may have limited or no opportunities to shift charging in response to price signals.

In addition to supporting product development, CEC will also direct funding toward helping markets create economies of scale. For example, as part of the REDWDS solicitation, awardees must also outline plans to deploy their developed product to a minimum number of customers across California and help customers enroll in dynamic rates. Similarly, CEC's draft Clean Energy Reliability Investment Plan calls for rapidly scaling flexible load resources and notes,

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117 Automation service providers and aggregators help customers manage, monitor, and control electricity usage on their devices such as EV chargers, smart light switches, smart thermostats, and so on. Automation service providers and aggregators typically manage many devices across many customers.

118 Similarly, most vehicles do not offer a way to look up electricity rates (even those with a telematics connection), forcing drivers to manually program a charging schedule — a user experience that is too involved for many customers and results in unrealized smart charging opportunities.

119 While CEC investments generally focus on charging and supporting infrastructure, implementation of VGI capabilities in vehicles is also necessary. Helpfully, a growing number of automakers have announced bidirectional capability in available or upcoming vehicle models, including Ford, GM, Hyundai, Lucid, Nissan, and others.

120 "Customer friendly" is broadly defined and means any product that delivers perceived value for the customer in an understandable and frictionless way. Given that different customers have different needs and preferences, customer-friendly products can appear in different forms. For example, some customers may prefer a charging product that simply helps them maximize savings on their electricity bill through intelligent scheduling. Others respond better to a charging product that offers an attractively priced "subscription" for their charging needs in exchange for flexibility in their charging schedule, or a product that rewards grid-friendly charging with points, tiers, and other gamification. CEC funds, including through REDWDS, can help industry explore a variety of customer-friendly approaches and business models.

121 REDWDS funding could support a broad range of product innovation that not only help ensure more products come equipped with VGI capabilities, but that these products provide benefits to customers by going beyond simply ensuring their vehicle is charged. The CEC announced proposed awards for REDWDS in September 2023.

"Funding could be used to support rapid scale up of VGI and V2B, particularly in collaboration with electric vehicle infrastructure buildout funded through separate programs."[122]

Interoperability

A fundamental pillar of CEC's approach to charging infrastructure deployment is a focus on interoperability. Interoperability, which enables different products to seamlessly work together without special effort by the user, yields critical customer experience benefits that will help ensure that charging is consistently accessible, simple, and grid-informed.

Industry alignment on charging connectors and inlets provides a basis for charging interoperability. Most automakers and charging companies use the J1772/CCS connector on products today, though many companies recently announced that future products would begin using the J3400 connector. Importantly, automakers that have announced a switch to J3400 have also indicated that new vehicle models will continue using the J1772/CCS connector through at least 2025, suggesting that both J1772/CCS and J3400 will co-exist for several years. A one-connector future would likely benefit customers and the broader market, and the CEC continues to monitor availability of J3400 products, industry implementation of communication protocols, and other factors as it continuously assesses the most appropriate connector requirements for CEC projects.[123]

Less obvious and equally important is interoperability of charging communication, which helps ensure that vehicles, chargers, and other actors supporting a particular charging session can exchange the necessary information to optimize charging around the grid and the driver. The CEC places particular emphasis on two key communication protocols to support interoperability in charger deployment activities: Open Charge Point Protocol (OCPP) and International Organization for Standardization (ISO) 15118.

OCPP is commonly used for communication between the charger and network software, and ISO 15118 is used for communication between the charger and the vehicle. Because a vehicle and charger are present in every charging session, standardizing communication at this "front" end with these protocols guarantees a consistent way to translate information from a wide variety of sources in the "back" end.[124] For example, as shown in Figure 34, OCPP and ISO 15118 ensure that the vehicle and charger can be informed of grid conditions. This information can come in the form of a price (using data provided by a utility or through MIDAS), a signal from the utility encouraging a load reduction (using a protocol such as IEEE 2030.5 or OpenADR), or a local load management signal (sent from an on-site controller). Going the

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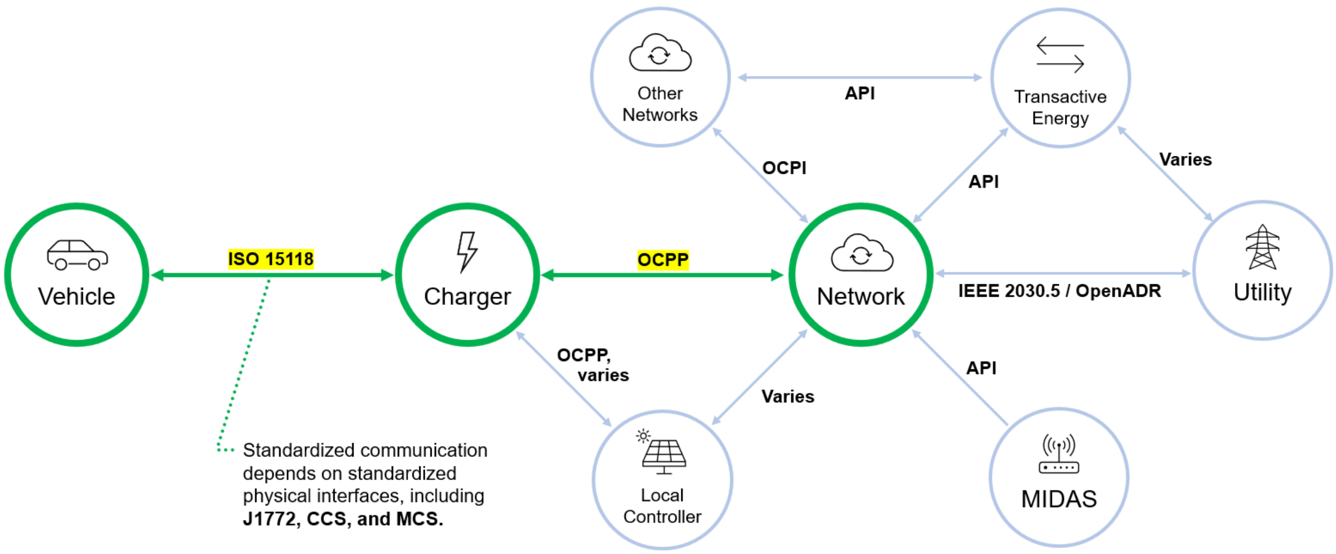
122 In September 2022, the passage of SB 846 tasked CEC with developing a Clean Energy Reliability Investment Plan. SB 846 authorizes up to $1 billion for the implementation of the Clean Energy Reliability Investment Plan.

123 In recognition of the continued use of J1772/CCS by most automakers through 2025, the CEC announced that it would not modify existing connector requirements in the immediate term (as of September 2023). CEC staff will continue monitoring the market and exploring actions to support a one-connector future.

124 While OCPP and ISO 15118 are not the only communication protocols available, they are the most widely adopted among industry globally and thus the most appropriate baseline for interoperable and standardized communication. Other protocols exist for some portions of the communication link, such as Controller Area Network communication, IEEE 2030.5, proprietary telematics links, proprietary charger communication, custom application programming interfaces, and so forth. However, these do not provide the feature set, scalability, and global market adoption afforded by OCPP and ISO 15118.

other direction, standardized front-end protocols enable a vehicle to communicate needs, such as the total energy needed during a charge session, to a home charger, a charging network that manages many chargers, or a transactive energy platform. In short, interoperable charger communication provides a consistent and scalable platform for VGI innovation by unlocking the flexibility to accommodate diverse compensation frameworks, business models, and product types.[125]

Figure 34: Key Interfaces and Communication Protocols to Enable Flexible VGI



Given that the vehicle and charger are present in every charging event, standardizing communication at this front end around globally aligned protocols (ISO 15118 and OCPP, highlighted) will support economies of scale and market certainty. In concert, ISO 15118 and OCPP provide a consistent and flexible platform to accommodate diverse VGI business models and backend signaling schemes.

Source: CEC staff

Implementation of ISO 15118 — the protocol for digital communication between a charger and a vehicle — is especially important for bidirectional charging. The latest version, ISO 15118-20, includes provisions for standardized and cybersecure bidirectional charging controls.[126] These provisions pave the way for a future where any electric vehicle that supports bidirectional charging could supply power to a home, a neighbor's home, a local library, or community

125 Both OCPP and ISO 15118 present interoperability benefits beyond VGI. The charger-network interoperability afforded by OCPP enables a site host to manage a variety of different OCPP-compliant charger brands and models under any OCPP-compliant management software product, expanding choice and preventing vendor lock in. Likewise, a driver with an OCPP-compliant home charger can switch between different management software products based on cost, features, or other factors – much like how an unlocked cell phone can switch among different networks. ISO 15118 enables "plug and charge," which enables a driver to start and pay for a charging session simply by plugging in. These customer benefits are additional non-VGI reasons why CEC maintains a strong emphasis on charger communication interoperability.

126 International Organization for Standardization. 2022. "ISO 15118-20:2022 Road Vehicles – Vehicle to Grid Communication Interface – Part 20: 2nd generation Network Layer and Application Layer Requirements," https://www.iso.org/standard/77845.html.

center, or a microgrid. Following publication in mid-2022, stakeholders have indicated plans to begin implementing ISO 15118-20 to enable bidirectional charging.[127] Helpfully, both J1772/CCS and J3400 appear to support the same underlying communication protocols using powerline communication, including ISO 15118.

While the ISO 15118-20 standard provides a basis for interoperable bidirectional charging, certain technical and implementation gaps remain. Bidirectional chargers that export to or operate in parallel with the grid must undergo a utility process called *interconnection* before powering on.[128] DC bidirectional charging[129] using ISO 15118 for charger-vehicle communication complies with existing California utility interconnection requirements and is being implemented and offered by various companies. AC bidirectional charging may yield total cost advantages over the DC approach. While ISO 15118 also supports AC bidirectional charging, the current standard does not include provisions for communicating certain grid parameters required by many California utilities for interconnection.[130] To avoid the need for different communication standards in different parts of the world, industry workgroups are discussing the gaps that must be addressed in ISO 15118 and OCPP to support communication of grid parameters, such as those required in California.[131] Other groups are working on methods to enable AC bidirectional charging using standards besides ISO 15118, though it remains unclear whether automakers and charging providers have appetite for implementing additional communication standards.[132]

To support the adoption and use of interoperable communication protocols, CEC will require that all chargers funded through its block grant rebate projects — CALeVIP, Communities In Charge, and EnergIIZE — be, at minimum, hardware-ready for ISO 15118 communication and certified for OCPP.[133] These technical requirements represent a floor and mirror those used by

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127 For example, BMW, In-Charge, Shell, Switch.

128 "Interconnection" specifically refers to the utility process for connecting a generating source (such as a vehicle, a battery, or solar photovoltaics) onto the utility distribution system, and requirements for interconnection with California utilities are often described in a document called "Rule 21." Interconnection is distinct from "energization," which is used when discussing nongenerating loads such as a one-way charger. Bidirectional chargers that never interact with the grid are not subject to utility interconnection.

129 Bidirectional charging is typically divided into two types, AC and DC.

130 Notably, Rule 21 requires that generating sources be capable of receiving information describing how the source should respond to electric system abnormalities. Examples include volt-watt and frequency-watt response curves.

131 A subgroup within the ISO is discussing an amendment to ISO 15118-20 to support additional DER and smart inverter functions, such as those outlined in IEEE 1547. Rule 21 requirements are based on IEEE 1547. Separately, the Open Charge Alliance is developing similar updates to OCPP, which will be released as OCPP 2.1.

132 SAE and UL are defining an approach for AC bidirectional charging that relies on SAE J3072 and UL 1741 Supplement C. This architecture would use IEEE 2030.5 for communication between grid operators, the charger, and the vehicle. To date, the CEC is not aware of any commercially available PEVs that have implemented IEEE 2030.5 for charging communication.

133 For block grant-funded chargers, certification for OCPP 2.0.1 or later will be required beginning January 2025. DC chargers must be ISO 15118 ready, and AC chargers must be ISO 15118 ready by July 2024. CEC developed a definition for "ISO 15118-ready" through an expansive effort in 2021–2022, which included dozens of stakeholder conversations, a public workshop, and many docketed comments. Staff tallied more than 30 ISO 15118-ready AC charger models as of late 2022.

the CPUC for ratepayer-funded charging investments, providing alignment and consistency across state agencies.[134] Incorporating ISO 15118-ready requirements in CEC block grants and other solicitations ensures that publicly funded chargers can receive software updates to activate various VGI use cases, even if that software is not available when the equipment is initially installed.[135]

While the standards discussed above are applicable to the charger, various methods for VGI not involving the charger also exist. Some stakeholders raise the possibility for vehicles to retrieve electricity rates and other grid signals using telematics,[136] thus enabling managed charging even without a smart charger. Telematics-based managed charging may be an appropriate and lightweight solution for customers whose vehicles support the feature, particularly for home charging where the customer location and rate are consistent and known. The telematics approach may be less useful for enabling VGI away from home, as telematics systems currently lack the ability to coordinate with local site controllers (for example, automated load management systems) and likely do not have access to relevant grid signals at every location visited by the vehicle. Further, there are ongoing efforts at utilities and the CPUC to determine whether telematics-based submetering is appropriate. (Submetering is distinct from managed charging control.)[137] Telematics-based managed charging can complement smart chargers as part of a multifaceted strategy to maximize opportunities for VGI in California.

VGI Advancement 3: Site Readiness for Charging

While the prior two advancements will enable vehicle charging to generate ongoing driver and grid benefits, both are predicated on the ability for drivers to plug in for a charge. To ensure VGI benefits are widely available, industry, utilities, and policy makers must ensure that sites where cars park are electrically prepared to support installation of chargers — including at workplaces, schools, retail areas, residences, and so on. Importantly, some forms of VGI may themselves be enablers of site readiness for charger deployment, such the use of load management controllers and integration with local DERs. To maximize VGI benefits, California

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134 In its August 2022 submetering decision, CPUC required all ratepayer-funded EVSE to be ISO 15118-ready and OCPP-compliant and certified beginning July 2023. The CPUC reaffirmed these requirements in November 2022 as part of its decision on transportation electrification funding.

135 To further aid industry implementation of these standards, CEC funded DEKRA to open the Vehicle Grid Innovation Lab (ViGIL), which provides a la carte conformance testing and certification services for chargers. The CEC also funded Innos to host the Vehicle Interoperability Testing Symposium (VOLTS) in Long Beach, California, in May 2023.

136 Vehicle telematics systems enable vehicles to communicate information with the automaker's back office. Telematics is often used to transmit basic vehicle commands (such as unlocking doors via an app) and may require a monthly subscription fee. Vehicle telematics implementations are not standardized and are often unique to each automaker, presenting challenges for interoperability and scale.

137 Importantly, this section describes telematics-based charging control. CEC and other state agencies only recently began to evaluate the possibility and usefulness of telematics-based metering for billing. On metering, the CPUC, through D.22-08-024, determined it is "… premature to move forward with telematics at this time." CPUC and the IOUs will host a public workshop in 2023 to explore telematics related issues, with modifications or amendments to the PEV Submetering Protocol to include telematics a possible consideration if parties can justify the need for the CPUC to continue pursuing the issue.

should ensure sites across the state are equipped for the installation of chargers using various approaches, including building codes for new construction, upgrades for existing buildings, as well as certain VGI strategies that themselves support site readiness.

New construction in California is subject to the California Green Building Standards Code, or CALGreen, which already requires a minimum level of electrical capacity to support EV charging based on the building type and number of parking spaces on site.[138] Importantly, CALGreen includes provisions permitting the use of ALM to reduce the total electrical capacity needed for code compliance.

Unlike new construction, many existing sites in California are not well-equipped to host vehicle charging due to limited electrical capacity. The same standards required by code for new buildings may be financially or physically infeasible at existing buildings. Legacy electrical panels used at older buildings typically have lower current ratings and few breaker slots, and often cannot easily accommodate an EV charger or other additional loads. In some cases, it may be appropriate to replace the existing panel with an upgraded one, particularly if the site is also planning to electrify other loads or install new DERs. Panel upgrades can be expensive and cost several thousand dollars for a residential site, and some utilities offer programs to offset the cost of the retrofit.[139] With bidirectional charging, additional electrical equipment may be required at the site such as inverters, subpanels, and transfer switches (which disconnect a site from the distribution system before activating backup power).

Given the cost of panel upgrades, some companies are exploring alternative pathways that rely on sharing circuits among different appliances or tapping into the utility meter socket to add an additional circuit (or several additional circuits) without modifying the existing panel.[140] These solutions may present lower-cost options to homeowners, renters, or other building managers who want to defer or potentially avoid a full panel upgrade.

Beyond simply ensuring sufficient wires and other physical electrical infrastructure, "nonwire" VGI solutions (sometimes called "load management") can help maximize the use of existing electrical infrastructure and may themselves enable the installation of chargers at sites that would otherwise be unable to accommodate added electric demand without upgrades. ALM, for example, can intelligently coordinate the available power of a site between charging and other local electrical loads such as lighting, space conditioning, and cooking loads.[141] Industry

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138 For example, the 2022 CALGreen revision (effective January 2023) requires a newly constructed site with 30 parking spots to include at least 8 parking spots with electrical capacity to support charging, and at least 2 of these spots to also include full installation of a Level 2 charger. For sites with more than 200 parking spots, at least 20 percent of the parking spots must be equipped with electrical capacity to support charging, and at least 25 percent of these must be further equipped with a Level 2 charger.

139 For example, SCE will provide up to $3,600, and SMUD will provide up to $2,500 in rebates for residential panel upgrades.

140 For example, NeoCharge offers an adapter that manages power from a single NEMA outlet among several 240 V loads (such as dryers and EV chargers). ConnectDER is working with Siemens to develop a device that can add a circuit for charging through the meter socket.

141 This ability to coordinate and distribute power can enable a site owner to make the most of existing electrical capacity without going over the limit and triggering an electrical upgrade. Similarly, ALM can enable a site host to

stakeholders are developing standardized safety certifications for such systems,[142] and these standards could help scale the availability of controllers that enable easier charger installation at sites that would otherwise require potentially pricey retrofits, such as at older homes or multiunit dwellings. In some cases, ALM may defer the need for customer- or utility-side upgrades, yielding lower cost per connector and shorter deployment times. Numerous California companies are already deploying ALM at sites across the state.

Like ALM, pairing vehicle charging with battery storage, local generation, and other DERs can also maximize the use of existing electrical infrastructure and create a buffer to soften the charging load seen by the grid. On-site stationary storage or generation (such as a solar canopy) can supplement electricity delivered by the grid, help reduce peak usage electricity fees,[143] and minimize or eliminate the need for electrical upgrades.[144] Likewise, battery swapping and chargers with built-in batteries[145] achieve similar grid benefits by leveraging batteries as a buffer against surges in customer charging demand. Such solutions may be cost-effective when considering costs beyond the charging hardware itself, such as expenses and wait times for site and utility upgrades. To simplify the integration of DERs with charging, many charging providers have begun offering "charging as a service" packages, which include site design and deployment in addition to charger installation and operation. By maximizing the amount of charging that can be supported on the existing electric grid, both ALM and DER-integrated charging will be crucial to support timely and cost-effective installation of chargers and mitigate the effects of nationwide grid component supply shortages.[146]

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share a single circuit or panel among multiple chargers, netting more total connectors and serving more drivers than would have been possible without ALM. For instance, a 50 amp circuit could normally accommodate a 9.6 kilowatt charger at 40 amps. With ALMS, multiple chargers could be connected to the 50 amp circuit, with each charger adjusting the power delivered to a plugged-in vehicle up or down as needed to stay below the circuit limit.

142 For example, the pending UL 3141 standard could cover ALM as well as power control systems. UL 3141 could provide a standard certification for products that make it easier and safe to add electric load (such as chargers) at sites with constrained electrical capacity.

143 "Demand charges" are billed by the utility based on the peak power usage at a site. Batteries and other generation can help a site "flatten the curve" to reduce peak power usage and therefore demand charges.

144 For example, Electrify America recently expanded the use of on-site storage and solar to support additional DC fast chargers. Electrify America notes that some sites already exceed 1 MW of electrical load during times of higher customer demand.

145 For example, Freewire's Boost DC fast charger uses a 27 kW grid connection and a 160 kWh built-in battery to provide 150 kW of charge power to a vehicle. Such products offer customers a prepackaged solution that avoids the need for additional site integration design and construction.

146 The ability of ALM and DER integration to reduce or eliminate utility upgrades is especially important, given concerns about utility energization timelines (see "16. Service Energization Timing Expectation" in E-5167) and nationwide grid component supply shortages. The federal government reports that lead times for transformers — equipment needed for electrical capacity upgrades — have increased to more than two years for larger transformers. In response to these challenges, the CPUC established a 125-day target for average energization time, and the federal government is exploring the use of the Defense Production Act to expand domestic grid component manufacturing capacity. Additional state and federal assistance may be appropriate to help utilities prepare for accelerated electrification.

As charging technologies move toward megawatt-level power to support electrification of tractors and other large vehicles, on-site storage and generation may be necessary in some cases to supplement existing and available utility power. For example, WattEV's planned electric truck stop in Bakersfield will initially feature 5 MW of solar generation and 4.5 MWh of storage capacity in addition to a 4 MW grid connection.[147]

VGI Advancement 4: EV and Grid Planning Processes

The CEC and CPUC have supported the maturation of the VGI ecosystem through various proceedings,[148] rates,[149] and technology investments.[150] In addition to these efforts, there are opportunities to better incorporate VGI into EV and grid planning at both state agencies. Limited data exist on the performance and reliability of various VGI strategies, and several types of VGI — such as customer response to dynamic rates or bidirectional charging — are not fully considered within EV and grid planning processes. As VGI scales, data collected from earlier deployments can inform how grid forecasting and planning processes should be updated to consider the effect of VGI strategies.

Specifically, the CEC and CPUC are embarking on an effort to better align various internal modeling efforts and ensure that results from CEC models are appropriately transmitted to the CPUC to inform utility planning efforts. There are two key VGI-related modeling efforts at CEC:

- Grid modeling: The Energy Assessments Division maintains models to forecast future electricity demand, including for electric transportation. These models also include load curves, and results are reported in the *Integrated Energy Policy Report (IEPR).* Forecasts published in the *IEPR* are used by CPUC and utilities for grid planning.
- EV modeling: The Fuels and Transportation Division maintains models such as EVI-Pro 3 and HEVI-LOAD to support its AB 2127 analysis. These models are designed to project needed charging infrastructure counts and associated load curves, and results are reported in the AB 2127 assessment (this publication).

To ensure consistency, the Fuels and Transportation Division and the Energy Assessments Division are collaborating to ensure harmonization between the two modeling tracks. Further, both modeling tracks are exploring new VGI scenarios that will begin to quantify the effects of VGI that can be incorporated into planning processes at the CEC and CPUC. The CPUC independently conducts VGI-related modeling for its grid planning activities as well.[151]

147 WattEV plans up to 40 MW of solar generation on site to support several MW-level truck chargers.

148 For example, the CPUC recently approved a transportation electrification program as part of the R-18-12-006 proceeding.

149 For example, PG&E's upcoming Day Ahead Hourly Real Time Pricing EV rate. Importantly, time-of-use rates are already widely offered and used by electric customers across California. CPUC ordered investor-owned utilities begin offering time-of-use rates by default in 2019.

150 For example, GFO-21-303 funded deployments of V2B for backup power through the Electric Program Investment Charge.

151 For example, CPUC hosted a workshop in September 2022 to discuss inputs and assumptions for VGI to be used in integrated resource planning. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-

The CEC's IEPR forecasts are particularly important in planning grid upgrades because they are used by the CPUC for Integrated Resource Planning and the Distribution Planning Processes.[152] The Integrated Resource Planning process relies on IEPR forecasts to identify portfolios of electricity resources to reliably and cost-effectively meet the load forecasted by the CEC while meeting the state's decarbonization goals. In addition, the CPUC transmits the resource portfolios developed within the IRP process to the California ISO for its annual transmission planning process (TPP). The ISO uses these portfolios as part of its TPP analysis to identify system-level transmission solutions and upgrades.[153]

The CPUC's Distribution Planning Process uses IEPR forecasts to help identify areas of the distribution system needing upgrades to serve future electrical demand. Potential upgrades are detailed as part of the Distribution Planning Process Grid Needs Assessment and Distribution Deferral Opportunity Report. Notably, the CPUC's High DER Rulemaking (R.21-06-017) is investigating updates to the Distribution Planning Process to incorporate improved data sharing, EV adoption, dynamic rate development, and load-flexibility utilization.

Relatedly, SB 846 requires the CEC, in consultation with the CPUC and ISO, to "adopt a goal for load shifting to reduce net peak electrical demand." In May 2023, the CEC published the SB 846 Load Shift Goal Report with a target of 7,000 MW statewide load flexibility by 2030.[154]

VGI Advancement 5: Customer Ease, Confidence, and Enrollment

Even though VGI can yield a wide range of customer benefits, Californians may not be accustomed to viewing their vehicle as anything other than a tool exclusively for transportation or adjusting their charging patterns in response to grid signals. For VGI to scale, customers must be confident that participating in VGI rates and programs is beneficial, is easy, does not compromise their mobility needs, and has low barriers for enrollment. In particular, customer-friendly utility processes, increased product choices, and education campaigns can strengthen customer confidence and interest in VGI.

The CEC and CPUC have taken steps to simplify utility processes and lower barriers to customer participation in VGI. In September 2020, the CPUC directed utilities to begin interconnecting DC bidirectional chargers using existing Rule 21 requirements, thus confirming that DC bidirectional chargers do not necessitate special utility policies and should be treated like solar inverters and other generating devices.[155] Further evolving interconnection policies,

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division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/2022-irp-cycle-events-and-materials/iamag09222022.pdf.

152 CPUC staff also proposes using the CEC's IEPR forecasts as the basis for the Freight Infrastructure Planning framework https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/transportation-electrification/fip-draft-staff-proposal_5_22_23-webinar-final_ver2.pdf

153 The annual Transmission Plan then goes before the California ISO Board of Governors for approval. The transmission planning process culminates in a procurement phase which includes a competitive solicitation process.

154 The 7,000 MW goal presented in the report represents an estimated 3,400-3,900 MW incremental increase over current statewide load shift capacity.

155 See Ordering Paragraph 39 in Decision 20-09-035.

for example to support AC bidirectional charging and flexible service agreements, may bolster industry confidence in bidirectional charging and streamline deployment.[156]

In August 2022, the CPUC directed utilities to allow nonutility meters (referred to as "submeters") to measure electricity consumption of vehicle charging for customer billing.[157] Importantly, submetering will make it easier and cheaper for customers to enroll in EV-specific electricity rates, which offer strong off-peak discounts, and will enable V2B and V2H use cases by allowing the vehicle load to be comingled with the facility load.

In early 2023, CEC launched a V2G Equipment List tracking bidirectional charging equipment certified to national safety standards (namely, Underwriters Laboratories 1741). The V2G Equipment List may help streamline utility interconnection of bidirectional chargers and was created in response to repeated industry requests. These agency actions help provide certainty and will simplify the deployment of VGI products and programs.

Beyond state actions, industry plays a crucial role in helping translate these various policy underpinnings into realized customer participation through easy-to-use products and services. The submetering decision is potentially important as it allows industry to offer products that enable customers to enroll in a different electricity rate for charging (separate from the rest of the home or site) and help them automate charging around the lowest-priced hours of that rate.[158] As submetering is likely a novel concept for many drivers, charging providers and other third parties will be important ambassadors for helping customers understand the benefits of and options for submetered vehicle charging. For bidirectional charging, market actors such as Sunrun are already helping customers understand, install, and interconnect bidirectional charging setups that can provide backup power during grid outages. Moving forward, utilities and third-party market actors such as aggregators and charging providers have an essential role in helping customers through utility enrollment and interconnection processes and ensuring customers receive a range of benefits from VGI.

Finally, awareness and education campaigns can also promote customer understanding and interest in VGI. For example, CPUC already directs funding toward statewide Flex Alert media campaigns.[159] Similar efforts can help inform customers about the benefits of smart charging

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156 In a comment responding to the draft staff report, PG&E noted that it is exploring capabilities to "to implement the concept of flexible service connection. A flexible service connection enables EVs that may not be able to interconnect due to capacity constraints, to proceed with interconnection."

157 The CPUC's submetering decision would require submeters used for billing to meet a 1 percent accuracy standard.

158 Submetering permits customers to bill electricity consumed for vehicle charging separately from electricity consumed by the rest of the home. Submetering opens opportunities for customers to consider rates that, without submetering, would require installation of a separate costly utility meter at the site (such as an hourly rate with deep discounts during hours with abundant clean electricity). Because vehicle charging is flexible and can be shifted or paused, submeters enable customers to charge up on deeply discounted off-peak electricity through a grid-friendly rate, while keeping the rest of the home on the existing rate. This gives customers peace of mind and saves them from worrying about higher peak prices or frequent price changes for less flexible home loads such as cooking, space conditioning, and so on.

159 In a December 2021 decision, CPUC directed utilities to continue a statewide Flex Alert media campaign during the summers of 2022 and 2023.

and bidirectional charging (including V2H for backup power during grid outages). As regulations, technology, and products continue to evolve and mature, customer education will be an important component to ensure Californians receive all the benefits electrified transport can offer.

CHAPTER 7:
Labor and Workforce

Introduction

Labor[160] and workforce training and development[161] support for electric vehicle charging infrastructure (EVCI) deployment is critical for ZEVs to be 100 percent of sales in California. Current and projected investments for charger deployments, public and private alike, require the state to consider the range of labor and workforce issues involved in providing this infrastructure to meet the state's ZEV goals and realize other benefits.

EVCI career pathways must be intentionally cultivated with collaboration among the state's workforce entities, employers, training partners, trades, and workers. Furthermore, the state takes an inclusive[162] and high-road approach[163] for businesses and workers and expands workforce opportunities for priority communities and populations that can participate in the EVCI industry.

Senate Bill 589 (Hueso, Chapter 372, Statutes of 2021) requires the CEC to identify workforce training and development resources needed to meet the state's ZEV and climate goals and include this information as part of the AB 2127 assessment starting with this second assessment. This chapter identifies these resources and two other requirements related to the expansion of project eligibility for the manufacturing workforce and expansion of entities the CEC should collaborate with on workforce development.

This chapter also provides a framework to understand the elements of EV chargers and the workforce for each market segment, and a brief overview of key reports and papers about EVCI labor and workforce. These studies provide a useful backdrop and a foundation in understanding analysis of the various roles and occupations needed to install chargers. Estimating the number and types of jobs that will be required is a key step in understanding the EVCI job space. Finally, this chapter will address current state investments and approaches to ensure skills and workforce development prepare workers in all areas of California for the significant investment that lies ahead.

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160 *Labor* refers to the labor required for the projects such as the construction, installation, operations and maintenance, and end-of-life/replacement of EV chargers.

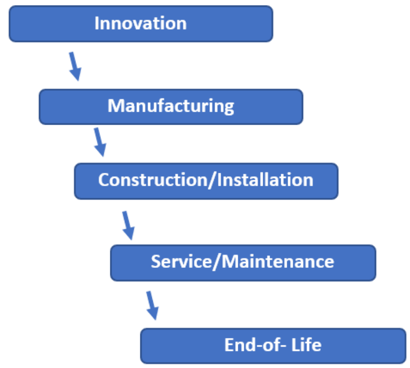
161 *Workforce training and development* refers to the ongoing support structures, institutions, and resources needed to develop the workforce needed to EVSE deployment.

162 Rillera, Larry, Samantha Houston. 2022. *Electric Vehicle Charging in Communities Equity Workgroup Report*. Electric Vehicle Charging Infrastructure Strike Force (ET Community). https://etcommunity.org/assets/files/03-StrikeForceEquityWorkgroupReport-ElectricVehicleCharginginCommunities.pdf.

163 California Workforce Development Board. "High Road Training Partnerships," https://cwdb.ca.gov/initiatives/high-road-training-partnerships.

The *ZEV Market Development Strategy*[164] (ZEV Strategy) provides a framework in understanding the role of the EVCI workforce.[165] The ZEV Strategy describes the role of the CEC with respect to ZEV infrastructure investment and analysis, ZEV-related manufacturing, and workforce training and development. Figure 35 illustrates the EVCI segments needed to support state goals.

Figure 35: EVCI Industry and Workforce Segments



Source: CEC staff

- **Innovation** — The workforce devoted to innovation, research, development, and deployment (RD&D) of EVCI products and services is vast and includes California's higher education systems, community colleges, and private entities. Continuous development and improvements to EVCI technologies are needed to meet market demands and drive down product costs.
- **Manufacturing** — California is home to 55 ZEV-related manufacturers, including ZEV infrastructure companies that commercially manufacture, produce, and assemble hardware. Investment by private capital and state support continues to scale up the ZEV supply chain, creating demand for California workers. Occupations that support manufacturing include engineers, technicians, line manufacturers, materials handlers, assemblers, and supporting roles.
- **Construction and installation** — EVCI labor in the construction and installation segment was presented in the first AB 2127 assessment. This sector includes roles in planning, designing, permitting, construction, installation, inspection, and commissioning technicians.
- **Service and maintenance** — EVCI service, maintenance, and repair were explicitly addressed and discussed in two workshops held on the second AB 2127 Assessment. Ensuring high charger reliability relies on a combination of deliberate efforts for uptime standards, enforcement, and a reliable workforce. Whether EVCI service is on-demand

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164 California Governor's Office of Business and Economic Development. 2021. *California Zero-Emission Vehicle Market Development Strategy*, https://static.business.ca.gov/wp-content/uploads/2021/02/ZEV_Strategy_Feb2021.pdf.

165 The human workforce, including supply chains, needed to design, manufacture, sell, construct, install, service, and maintain ZEV infrastructure.

or scheduled, a trained and skilled workforce is critical to this early stage of charger deployment as EV drivers seek a reliable charging experience.

- **End of life** — EVCI assets reach the end of life (EOL) for various reasons (for example, end of product line, asset degradation or age, technological obsolescence, vandalism) and eventually require replacement. The EVCI workforce plays a significant role in the total asset life cycle of a charger. The same workforce skilled in the construction and installation of EVCIs may find a "second cycle" of employment and jobs in this segment and can help manage the EOL transition per manufacturer milestones and directives.

Senate Bill 589

As part of the CEC's AB 2127 Assessment starting in 2023, Senate Bill 589 requires identification of workforce development and training resources needed to meet EV adoption goals. SB 589:

- Specifies that a project, including a workforce development or training project, that develops in-state production of raw materials and the manufacturing supply chain for zero-emission vehicle components shall be eligible for Clean Transportation Program funding.
- Specifies that CEC shall collaborate with the California Community Colleges, the certified community conservation corps, the California Conservation Corps, and the California Mobility Center to implement the workforce development components of the Clean Transportation Program.
- Requires, as part of the AB 2127 EV charger assessment, the identification of workforce development and training resources needed to meet the ZEV and GHG emission reduction goals. These resources shall include qualified apprenticeships, on-the-job training programs, and other training opportunities that build career pipelines in the zero-emission transportation sector and provide long-term employment in disadvantaged communities.

With respect to provision (1) above, the CEC issued Grant Funding Opportunity (GFO)-21-605 titled "Zero-Emission Transportation Manufacturing" in March 2022 and GFO-21-606 titled "Zero-Emission Vehicle Battery Manufacturing Block Grant" in August 2022. Moreover, the Electric Program Investment Charge (EPIC) in the CEC's Energy Research, Development, and Deployment (ERDD) has a geothermal project that is in the RD&D stage for in-state production of raw materials that may have application for transportation electrification.

The Clean Transportation Program (CTP) has a workforce training and development investment portfolio of nearly $50 million. As noted in provision (2) above, the CTP has recently included new and expanded workforce development partners such as the California Conservation Corps through a $1 million agreement for the Transportation Electrification Training Project focused on classroom and on-the-job training for EV charger construction, installation, and maintenance. In 2022, the CEC issued GFO-21-604 IDEAL ZEV Workforce

Pilot,[166] which provided project funding through a new partnership with the California Mobility Center focused on ZEV manufacturing and service.

On October 18, 2022, the CEC held a workshop titled "Workshop on Labor and Workforce for the Second Assembly Bill 2127 Assessment" to discuss the provisions of SB 589 with respect to workforce training and development resources. Panelists were composed of workforce subject matter experts including the California Labor Federation, International Brotherhood of Electrical Workers (IBEW) Local 569, California Employment Training Panel, SoCal Pre-Apprenticeship, and the California Community Colleges. During the workshop, the information in Table 12 was provided, and panelists and stakeholders commented on the occupations and the volume of approved apprenticeships that can support the ZEV industry.

Table 12: Registered Apprenticeships for Potential ZEV Occupations

Occupation	Number of Apprenticeships
Sheet Metal	14
Manufacturing	41
Electrical and Electronics	41
Laborers	12
TOTAL	**108**

Source: California Department of Industrial Relations, Division of Apprenticeships Standards

The CEC will continue to collaborate with workforce stakeholders to ensure support needed to meet ZEV and EVCI deployment goals.

Estimating Labor for EVCI Installation

Over the past 10 years, various entities have studied labor costs associated with EVCI deployment:

- In 2013, the Electric Power Research Institute (EPRI)[167] published the *Electric Vehicle Supply Equipment Installed Cost Analysis* technical report, which analyzed the cost of EVSE installation and excluded EVSE costs at 637 installation sites from 2009 to 2013.
- In 2019, the Rocky Mountain Institute (RMI)[168] published the *Reducing EV Charging Infrastructure Costs* report, which provided information on EVCI component costs, directed at utility buyers and utility regulators to understand "the best opportunities to

166 California Energy Commission. 2021. "GFO-21-602 – IDEAL ZEV Workforce Pilot," https://www.energy.ca.gov/solicitations/2021-10/gfo-21-602-ideal-zev-workforce-pilot.

167 Electric Power Research Institute. 2013. *Electric Vehicle Supply Equipment Installed Cost Analysis,* https://www.epri.com/research/products/000000003002000577.

168 Nelder, Chris, Emily Rogers. "Reducing EV Charging Infrastructure Costs." Rocky Mountain Institute. https://rmi.org/wp-content/uploads/2020/01/RMI-EV-Charging-Infrastructure-Costs.pdf

reduce the total cost of deploying EV charging infrastructure." While labor was identified as a cost in the report, it was not the subject of analysis or key findings.

- In 2019, the International Council on Clean Transportation published *Estimating Electric Vehicle Charging Infrastructure Costs across Major U.S. Metropolitan Areas*.[169] The study projected estimated capital costs, including installation and hardware, of EVCI in residential and nonresidential markets for the most populous 100 metropolitan areas in the United States from 2019 through 2025. The report found that labor costs represented 50 percent of total EVCI installation costs.
- In 2019, the Avista Corporation[170] published the *Electric Vehicle Supply Equipment Pilot Final Report* that resulted from investments and study of a three-year EVSE pilot launched in 2016. The report identified construction labor and materials as significant cost factors, noting that "installation costs could be expected to gradually rise with labor and material cost inflation."
- In 2021, the Electric Transportation Community Development Corporation published *Workforce Projections to Support Battery Electric Vehicle Charging Infrastructure Installation* (ET Community Jobs Report).[171] The report explored the workforce needs associated with LDV and MDHD EVCI build-out. The report was derived from a "bottom-up" survey designed to elicit information from industry and provides a framework and analysis for EVCI labor and workforce in terms of jobs and skills needed for the installation of chargers in California. Based on survey results, assignment of work phases,[172] job roles,[173] and time requirements, a workforce estimation model was developed, and an estimate of effort needed (multiplier factors) for Level 2 and DCFC installations was determined. The report shows "that California's statewide light-duty electric vehicle program goals,[174] and the associated charging infrastructure would generate workforce needs of approximately 38,200 to 62,400 job-years[175] over the

169 Nicholas, Michael. 2019. "Estimating electric vehicle charging infrastructure costs across major U.S. metropolitan areas." The International Council on Clean Transportation. https://theicct.org/sites/default/files/publications/ICCT_EV_Charging_Cost_20190813.pdf

170 Farley, Rendall, Mike Vervair, Jon Czerniak. 2019. *Electric Vehicle Supply Equipment Pilot Final Report.* Avista Corp. https://www.myavista.com/-/media/myavista/content-documents/energy-savings/electricvehiclesupplyequipmentpilotfinalreport.pdf.

171 Carr, Edward, James Winebrake, Samuel Winebrake. "Workforce Projections to Support Battery Electric Vehicle Charging Infrastructure Installation." Energy and Environmental Research Associates. https://etcommunity.org/assets/files/Workforce-ProjectionstoSupportBatteryElectricVehicleChargingInfrastructureInstallation-Final202106082.pdf.

172 Work phases are 1) knowledge and skills training, 2) planning, 3) construction and installation, and 4) operations and maintenance.

173 Job-roles refers to the typical tasks performed on a project as identified by survey respondents with direct experience in EVCI installation.

174 The goal was based on the estimates provide in the First AB 2127 Assessment.

175 Workforce needs are estimated based on analysis of survey responses, provided in person-days, and converted to job-years assuming a full time equivalent (FTE) of 2080 hours and 8-hour workdays. Note that job-years cannot always be directly translated into a number of jobs created, but instead help to describe the

period from 2021 to 2031 in California, based on the baseline and high electric vehicle adoption scenarios. The greatest workforce needs for light-duty infrastructure would be for electricians (21.3% of job-years), general contractors (21% of job-years), planning and design (20% of job-years), and electrical contractors (15% of job-years)." The report further shows that "[f]rom estimates of projected medium and heavy-duty electric vehicle growth, this work estimates that the associated charging infrastructure in California would generate approximately 9,100 additional job-years from 2021–2031, in addition to the light-duty charging infrastructure workforce needs."

Electric Vehicle Infrastructure Training Program

Assembly Bill 841 (Ting, Chapter 372, Statutes of 2020) requires Electric Vehicle Infrastructure Training Program (EVITP) training and certification to install EV charging infrastructure and equipment that is on the customer side of the electrical meter that is funded or authorized, in whole or in part, by certain state entities. There are certain exceptions.[176] The law requires that certain state agency-funded EV charger installation projects shall be installed by a contractor with the appropriate license classification,[177] and at least one electrician on each crew, at any given time, must hold an EVITP certification. For projects that include installation of a charging port supplying 25 kW or more to a vehicle, at least 25 percent of the total electricians working on the crew, at any given time, must hold EVITP certification. One member of each crew can be both the contractor and an EVITP-certified electrician.

EVITP is a nonprofit organization that provides 20 hours of proprietary training and certification to eligible electricians for a $275 fee in the EV infrastructure installation segment in the United States and Canada. EVITP training and certification is currently offered in an online format until at least December 31, 2024. Online training and certification are critical to ensuring equitable access across the state, especially rural areas of the state where charger deployments are important for ZEV infrastructure goals, the achievement of economic equity, and access to career pathways. There were two physical testing sites in California prior to the availability of online and on-demand training and certification. Those seeking certification were required to travel to one of those two sites. Ongoing online and on-demand options beyond December 2024 will be extremely important to ensuring equity and access for a broad California workforce.

In August 2022, the EVITP training and certification exam went fully on-demand and online. After successful completion of the online training course, an applicant schedules a live

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demand for work. One job-year is equivalent to one person performing a job for one year, or two people performing the same job for half a year, etc.

176 These requirements do not apply to the following:

- EVCI installed by employees of an electrical corporation or local publicly owned electric utility.
- EVCI funded by moneys derived from credits generated from the Low Carbon Fuel Standard Program. (see https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard)
- Single-family home residential chargers that can use an existing 208/240-volt outlet.

177 As determined by the Contractors' State License Board (CSLB).

proctored online examination with applicants notified via email of the examination results. It is important that EVITP training and certification continue to be online and on-demand. Before testing/certification being online and on-demand, there were only two locations in California.

The EVITP website provides a list of electrical contractors where contractors must be currently licensed electrical contractors[178] in good standing and execute an EVITP Approved Contractor Agreement requiring them to use EVITP-certified electricians on jobs. EVITP does not train or certify contractors or employers, only eligible electricians.

As the EVCI industry continues to grow and technology advances, the EVITP curriculum should be updated in collaboration with industry and state agencies that are required to use EVITP-certified electricians. The current EVITP 4.0 curriculum includes DCFC, inductive charging equipment, liquid-cooled conductors, V2G applications, and other installation and maintenance best practices.

EVITP and the National Electrical Contractors Association (NECA) have publicly provided information on the number of electricians and the number of EVITP certified electricians in the nation and the state. In a June 28, 2022, letter from NECA — California Chapters to the CEC docket[179] for the California National Electric Vehicle Infrastructure (NEVI) Deployment Plan, NECA — California Chapters indicated that about 2,300 electricians were identified as EVITP-certified. During the Labor and Workforce Workshop for the Second AB 2127 Assessment on October 18, 2022,[180] a panelist referenced a 2021 NECA report and others[181] regarding the addition of roughly 7,000 electricians nationwide while experiencing the attrition of 10,000 electricians. During the workshop, a representative from EVITP commented there were more than 38,000 California-certified general electricians,[182] more than 7,000 registered electrical apprentices[183] in the state, and more than 2,300 California electricians[184] with EVITP-certified skills.

EVCI Service, Maintenance, and Repair

Reliable and well-maintained chargers are critical to the transition to zero-emission vehicles. Charger availability is fundamental to functionality and reliability as chargers are increasingly subject to environmental, human-caused, technical, and end-of-life (EOL) issues. Ensuring

178 California Department of Consumer Affairs Contractors State License Board. "C-10 – Electrical Contractor," https://www.cslb.ca.gov/about_us/library/licensing_classifications/c-10_-_electrical.aspx.

179 National Electrical Contractors Association. "NECA Comments on California's Draft Deployment Plan for the National Electric Vehicle Infrastructure Program," https://efiling.energy.ca.gov/GetDocument.aspx?tn=243754&DocumentContentId=77654.

180 October 18, 2022, "Labor and Workforce for the Second AB 2127 Assessment," ChargePoint, Inc. representative. https://www.energy.ca.gov/event/workshop/2022-10/workshop-labor-and-workforce-second-assembly-bill-2127-assessment.

181 Border States. 2022. "The State of the Electrician Shortage in 2022: New Data on the Impact of COVID-19," https://solutions.borderstates.com/the-electrician-shortage.

182 California Contractors State Licensing Board as of February 3, 2020.

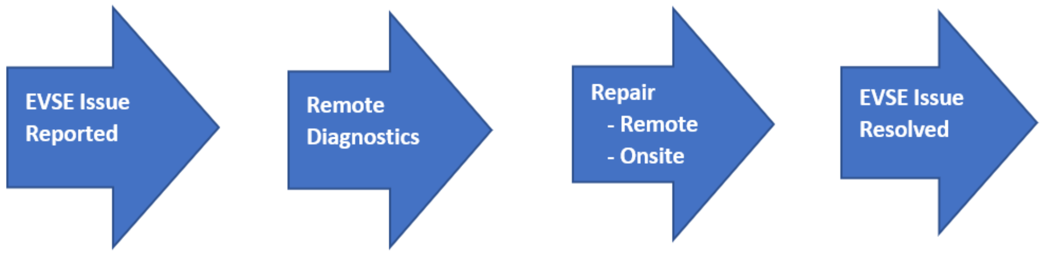
183 California Department of Industrial Relations, Division of Apprenticeship Standards as of February 21, 2020.

184 EVITP as of June 27, 2022.

accessible and operational chargers is paramount in this early adopter period, especially in underserved communities where charging coverage may be sparse and dependable mobility options may be limited.

Maintaining charger uptime requires performance standards and data collection. Restoring chargers to full operational status requires timely actions by skilled and trained personnel. EVCI companies provide a range of essential products in the service, maintenance, and repair of chargers to ensure chargers are available. Figure 36 illustrates how charger issues are identified and the workforce is engaged to resolve issues.

Figure 36: EVSE Service, Maintenance, and Repair Pathway



Issues Identified Support Requested Customer Response Ticket Logged	Remote Diagnostics Troubleshooting Response	Remote Repair Dispatch Onsite Repair	Issue Resolution EVSE Operational

Source: CEC staff

Charger manufacturers provide service, maintenance, and repair products. In addition to certifying charger installers for their products, charger manufacturers also provide general and proprietary training and certification for service, maintenance, and repair. Nonmanufacturers or private companies also provide training and certification. Examples of products and services by companies include:

- ABB, Inc. "E-Mobility Service Offering;"[185]
- ChargePoint, Inc. "ChargePoint University;"
- ChargerHelp! "EVSE Technician Training;"[186]
- Electrify America internal training and certification program;[187]
- and EVITP 4.0 training content for "EVSE Troubleshooting, Maintenance and Repair."

High-Road Principles in the EVCI Workforce

185 ABB. "E-mobility Service Offering," https://new.abb.com/ev-charging/connected-services/emobility-service-offering-service-level-agreement.

186 Charger Help. "Workforce Development," https://www.chargerhelp.com/_files/ugd/30e128_0032898550534e609ce4188fa91bc926.pdf.

187 Electrify America. 2022. "2922 Q2 Report to California Air Resources Board," https://media.electrifyamerica.com/assets/documents/original/918-Q22022ElectrifyAmericaReporttoCARBPublic.pdf.

California strongly supports investments and projects that create good paying jobs, improve job quality, increase access to quality jobs, strengthen local and regional economies, sustain economic equity,[188] and generate opportunities for economic prosperity to develop an equitable and diverse workforce in building out the EVCI.

The High Road Training Partnerships (HRTP) initiative was developed by the California Workforce Development Board (CWDB) and started as a $10 million demonstration project designed to model workforce partnership strategies for the state. The HRTP model embodies a sector approach through industry partnerships, with regional skills strategies designed to support economically and environmentally resilient communities. These partnerships support California's "high road" employers — "companies that compete based on quality of product and service achieved through innovation and investment in human capital and can thus generate family-supporting jobs where workers have agency and voice."[189] Moreover, the High Road Construction Careers (HRCC)[190] initiative partners construction trades councils with workforce boards, community colleges, and community-based organizations. These partnerships create structured career pathways with standard core curricula and supportive services to state-certified apprenticeships in a variety of crafts/trades, and focus on equity by expanding access to high-quality jobs to members of underrepresented populations, including women and persons of color.

The state has cultivated strong partnerships with crafts and trades associated with transportation electrification, specifically with EVCI installations. The state will continue to work with partners to establish a strong labor force of trained workers to support and enhance the EV industry. Specific partnerships with the EVCI-affected workforce and labor groups include those with the NECA, IBEW, Jobs to Move America, and others. State workforce agency partners that support labor, apprenticeships, and training, for EVCI installation, service, and maintenance include the CWDB, the Employment Training Panel (ETP), the Labor and Workforce Development Agency (LWDA), the California Community Colleges Chancellor's Office, and the Department of Industrial Relations Division of Apprenticeship Standards.

Recent CEC solicitations for ZEV and EVCI funding opportunities have required applicants to include ZEV and EVCI Workforce Plans.[191] These workforce plans, submitted as part of competitive solicitation processes, were subject to evaluation and scoring criteria that included job creation and recruitment, training and upward mobility, safe workplace conditions, workforce engagement, workforce accessibility to jobs, prevailing wage pay, supplier diversity, benefits, and other job quality elements. As EVCI funding and incentive programs are

188 Rillera, Larry, Samantha Houston. 2022. *Electric Vehicle Charging in Communities Equity Workgroup Report.* Electric Vehicle Charging Infrastructure Strike Force (ET Community). https://etcommunity.org/assets/files/03-StrikeForceEquityWorkgroupReport-ElectricVehicleCharginginCommunities.pdf.

189 California Workforce Development Board. "High road Training Partnerships," https://cwdb.ca.gov/initiatives/high-road-training-partnerships.

190 California Workforce Development Board. "High Road Construction Careers," https://cwdb.ca.gov/initiatives/hrcc.

191 California Energy Commission. "GFO-21-605 – Zero-Emission Transportation Manufacturing," https://www.energy.ca.gov/solicitations/2022-03/gfo-21-605-zero-emission-transportation-manufacturing.

developed, a high-road approach should be embedded in solicitation requirements, as well as in workforce training and development programs.

The California Department of Transportation (Caltrans) notes in the "California NEVI Deployment Plan" that HRTPs exist in ZEV manufacturing and other transportation fields and could be a model for EVSE manufacturing in California. The California Fiscal Year 2022–2023 budget includes $15 million in HRCC and HRTP per year for the next three years, which could be used to advance economic equity in California's growing EVSE industry.[192]

EVSE Workforce Training and Development

The labor and workforce needed to support the entire EV charger ecosystem (Figure 33), as noted in the tens of thousands of workers, will require ongoing training for new skills development, as well as upskilling and reskilling of the existing workforce including growth in on-the-job, pre-apprenticeship, and apprenticeship programs. Continuous investment and advocacy for apprenticeship programs are critical given the duration of such programs and the clear need for these workers to safely install and maintain this infrastructure. New companies and workers will enter this ecosystem via adjacent[193] clean energy industries and existing technology sectors. The skill sets, training, and work experience acquired in adjacent sectors can be transferred to the EVCI sector workforce. The range of jobs, roles, and wages can also transfer.[194]

Jobs related to charging installations that include training through state-approved apprenticeship programs, payment of prevailing wages, and other labor standards create opportunities for middle-class careers with good wages and benefits through a pipeline for workers to learn specific crafts, skills, and knowledge.[195] From engineering and design jobs to administrative support jobs, EVCI is positioned to create many jobs in all areas of California via billions of dollars in public and private EVCI investments. New partnerships will be formed as businesses develop their company workforces to align and acquire new business opportunities or in developing new business-to-business (B2B) relationships.

As noted above, California has a rich culture of strong workforce development institutions among state agencies, training entities, and employers. Identifying workforce trends, challenges, and training needs will be important going forward. It will also require careful

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192 Fauble, Brian, *et al.* 2022. *California's Deployment Plan for the National Electric Vehicle Infrastructure Program.* California Department of Transportation, California Energy Commission https://dot.ca.gov/-/media/dot-media/programs/sustainability/documents/nevi/2022-ca-nevi-deployment-plan-a11y.pdf.

193 At the October 18, 2022, workshop, EVITP stated that there are "differences in industries such as solar where contractors hold C-10 licensed electrical contractor licenses and C-46 licenses. C-10 licensed contractors can do EV charger work, while C-46 licensed contractors cannot but pathways are available to get workers the certifications needed."

194 For example, companies that provide EVCI construction and installation services will also find work in EVCI service, maintenance, and EOL replacement.

195 Carr, Edward, James Winebrake, Samuel Winebrake. "Workforce Projections to Support Battery Electric Vehicle Charging Infrastructure Installation." Energy and Environmental Research Associates. https://etcommunity.org/assets/files/Workforce-ProjectionstoSupportBatteryElectricVehicleChargingInfrastructureInstallation-Final202106082.pdf.

analysis and awareness of the net migration of jobs between industries and sectors adjacent to EVCI markets.

In addition to supporting apprenticeship programs and HRTP, state and local agencies are also moving forward with innovative projects that accelerate new skills development, on-the-job training, and career acquisition across the state. The CEC's Clean Transportation Program has funded several projects including:

- The "South Valley San Joaquin Valley ZEV Talent Pipeline Project" (Kern Community College District (KCCD) with the Kern County Electrical Apprenticeship Program).
- The "EVITP In-Person Certification Examinations" (EVITP and the KCCD).
- The "EV and EVCI Training Program" (The Latino Equity and Policy Institute (LEAP), ChargerHelp!).
- The "Los Angeles County Clean Transportation Program" (Los Angeles County, Cerritos College, California Clean Cities Coalitions).
- The "Transportation Electrification Training Project" (California Conservation Corp).

CHAPTER 8:
Conclusions

Transportation electrification is key to meeting California's climate change and air pollution reduction goals. Regulations like Advanced Clean Cars II, Advanced Clean Fleets, and Advanced Clean Trucks have begun to set out the path for transitioning to light-, medium-, and heavy-duty ZEVs, but California cannot meet its transportation electrification goals without ensuring there is a sufficient supply of reliable charging infrastructure. To meet the needs of the 7.1 million light-duty PEVs on California's roads in 2030, the state will need 1.01 million public and shared private chargers, including 39,000 public DCFC chargers. By 2035, charger needs will rise to 2.11 million public and shared-private chargers, including 83,000 public DCFC chargers to supporting 15.2 million light-duty PEVs. Medium- and heavy-duty PEVs will require 109,000 depot chargers and 5,500 en route chargers in 2030 and 256,000 depot chargers and 8,500 en route chargers in 2035.

This report assesses the amount of charging infrastructure needed to reach the state's transportation electrification targets and identifies key areas for emphasis:

1. Providing access to home charging is a priority for light-duty vehicles. Home charging is often the most convenient and least expensive charging option, and expansion of home charging reduces the need for public charging. In addition, home charging provides the flexibility to shift charging loads to support the grid.
2. Installing fast and convenient charging at other locations will be necessary to meet the transition from early adopters to a market that's inclusive of all Californians. High-powered DCFC will be particularly important to support an increasing number of long-range BEVs. Level 2 charging deployment should focus on locations of long dwell-time activities, and charging must be available at all workplaces, not just offices.
3. Drivers and fleet operators must be able to reliably charge their electric vehicles. Factors affecting charging reliability include the operative state of the charger and related components, the ability for the electric vehicle to communicate successfully with the make and model of the charger, and whether peripheral payment systems can successfully authorize payment. CEC is taking steps to ensure the reliability of chargers that it funds and will work to harmonize existing reliability requirements with those required by AB 2061.
4. Leverage VGI technologies to manage charging in ways that benefit consumers and move charging to times when there's excess capacity on the grid and the cleanest possible energy. While vehicle charging makes up a small fraction of California energy usage today, the rapid increase in ZEV adoption required by new regulations will increase the amount of grid capacity needed.
5. Panel upgrades and site improvements will be necessary to install chargers in many existing locations. The addition of automated load management systems at sites with many chargers could provide benefits and help increase installation speeds.

6. Prepare for the expansion of high-powered charging required by medium- and heavy-duty vehicles. While the overall charging need may be lower than light-duty vehicles, vehicles will need to draw more power potentially creating bottlenecks to infrastructure deployment at the local grid level.
7. Analyze charging need and grid capacity to prioritize infrastructure upgrades throughout the state. The energy demand from vehicle charging will require upgrades to the physical components of the distribution system such as transformers, primary and secondary circuits, and substations. For the state to meet its GHG emissions goals, vehicle charging must be powered by clean energy when possible.
8. Prioritize labor and workforce training and development in vehicle charging infrastructure construction, installation, and maintenance. The rapid rollout of charging infrastructure through 2035 will require training of tens and thousands of existing and new workers across a range of occupations and geographies.

GLOSSARY

ADDITIONAL ACHIEVABLE TRANSPORTATION ELECTRIFICATION 3 (AATE3) SCENARIO – A planning scenario from the 2022 Integrated Energy Policy Report Update that incorporates the expected impact of the ACC2, ACT, and ACF regulations on ZEV ownership and use. The AATE3 scenario

ADVANCED CLEAN CARS II (ACCII) – A regulation on light-duty vehicles adopted by CARB in 2022. ACCII requires an increasing proportion of new passenger vehicle sales to be ZEVs each year, reaching 100 percent in 2035.

ADVANCED CLEAN FLEETS (ACF) – A regulation on commercial vehicle fleet operators adopted by CARB in 2023. ACF requires fleet operators in certain segments to reach 100 percent ZEVs by 2035 or 2040.

ADVANCED CLEAN TRUCKS (ACT) – A regulation on medium- and heavy-duty trucks adopted by CARB in 2021. ACT requires an increasing fraction of truck sales to be ZEVs through 2035, with specific targets for each vehicle class.

ALTERNATING CURRENT (AC) – The flow of electricity that constantly changes direction. Almost all power produced by electric utilities in the United States moves in current that shifts direction at a rate of 60 times per second.

AUTOMATED LOAD MANAGEMENT (ALM) SYSTEM – ALMs manage charging load with the objective of reducing or eliminating the need for electrical capacity upgrades on the utility and/or customer side of the meter.

BATTERY-ELECTRIC VEHICLE (BEV) – Also known as an "all-electric" vehicle, BEVs use energy that is stored in rechargeable battery packs. BEVs sustain power through the batteries and therefore must be plugged into an external electricity source to recharge.

BIDIRECTIONAL CHARGING – Bidirectional charging, which enables a PEV to export energy from its onboard battery to buildings (vehicle-to-building), homes (vehicle-to-home), or to the grid (vehicle-to-grid). When equipped with the appropriate power electronics and electrical switching, bidirectional charging can provide power to a site during a grid outage.

CALIFORNIA AIR RESOURCES BOARD (CARB) – The state's lead air quality agency consisting of an 11-member board appointed by the Governor and more than 1,000 employees. CARB is responsible for attainment and maintenance of the state and federal air quality standards, California climate change programs, and motor vehicle pollution control. It oversees county and regional air pollution management programs.

CALIFORNIA ENERGY COMMISSION (CEC) – The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The CEC's five major areas of responsibilities are forecasting future statewide energy needs; licensing power plants sufficient to meet those needs; promoting energy conservation and efficiency measures; developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels and infrastructure; and planning for and directing state response to energy emergencies.

CALIFORNIA PUBLIC UTILITIES COMMISSION (CPUC) – A state agency created by a California constitutional amendment in 1911 to regulate the rates and services of more than 1,500 privately owned utilities and 20,000 transportation companies. The CPUC is an administrative agency that exercises legislative and judicial powers; its decisions and orders may be appealed only to the California Supreme Court. The major duties of the CPUC are to regulate privately owned utilities, securing adequate service to the public at rates that are just and reasonable to customers and shareholders of the utilities; and the oversight of electricity transmission lines and natural gas pipelines. The CPUC also provides electricity and natural gas forecasting, and analysis and planning of energy supply and resources. Its headquarters are in San Francisco.

CHAdeMO – A connector standard for fast charging of electric vehicles that can provide up to 62.5 kilowatts of power.

CHARGER – The system within an EVSE that charges one EV. A charging port may have multiple connectors, but it can provide power to charge only one EV through one connector at a time. Also referred to as a charging port.

COMBINED CHARGING SYSTEM (CCS) – A connector standard for fast charging of electric vehicles that can provide up to 350 kilowatts of power.

COMMUNITY CHOICE AGGREGATOR (CCA) – Community choice aggregators procure energy for electricity users in a community or region. CCAs do not operate electric distribution infrastructure, and electricity procured by CCAs is delivered via existing distribution infrastructure typically operated by a utility.

CONNECTOR – A physical socket with a specified pin configuration. A charger may have one or multiple connectors.

DEPOT CHARGER – A depot charger is charger used by an MDHD vehicle at a location where the vehicle returns overnight or stops between trips. These chargers can be provided by the vehicle operator or another party. The models in this report estimate depot charging needs at a range of power levels from 20 kW to 150 kW.

DIRECT CURRENT (DC) – A current of electricity that flows in one direction and is the type of power that comes from a battery.

DISTRIBUTED ENERGY RESOURCE (DER) – DERs are decentralized generation or storage devices connected to the distribution grid. DERs include rooftop solar photovoltaics, on-site batteries and other energy storage systems, and electric vehicles. As noted later in this chapter, the CPUC's High DER Rulemaking (R.21-06-017) is exploring options to ensure the grid can support the growing number of DERs on the grid.

ELECTRIC VEHICLE (EV) – A broad category that includes all vehicles that can be fully powered by electricity or an electric motor.

ELECTRIC VEHICLE CHARGING INFRASTRUCTURE (EVCI) – A broad term covering the design, manufacture, installation, and maintenance of EVSE.

ELECTRIC VEHICLE CHARGING STATION – A charging station is a physical address where one or more chargers are available for use. This is the same usage as for "gas station." A charging station can be public, shared private, or private.

ELECTRIC VEHICLE INFRASTRUCTURE TRAINING PROGRAM (EVITP) – AB 841 requires EVITP training and certification to install EV charging infrastructure and equipment that is on the customer side of the electrical meter that is funded or authorized, in whole or in part, by certain state entities. The EVITP program was designed to provide qualified electricians with the most comprehensive training available in the market today. All EVITP Certified Electricians must pass a certification exam for proof of knowledge and skill.

ELECTRIC VEHICLE SERVICE PROVIDERS (EVSP) – An entity responsible for operating one or more EVSE.

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE) – Equipment designed to supply power to EVs. Most EVSEs can charge BEVs and PHEVs.

EN ROUTE CHARGER – An en route charger is a charger used by an MDHD vehicle to rapidly restore range while on a trip, rather than at an existing destination. The models in this report estimate en route charging needs at a range of power levels from 350 kW to 1500 kW.

GREENHOUSE GAS (GHG) – Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO2), methane (CH4), nitrous oxide (NOx), halogenated fluorocarbons (HCFCs), ozone (O3), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs).

GRID NEEDS ASSESSMENT (GNA) – The grid needs assessment (GNA) presents forecasted load and distributed energy resource (DER) planning assumptions and identified distribution and subtransmission needs in IOU territories. The data include forecasted equipment deficiencies, incremental demand, and incremental DER growth for each circuit and substation with a grid need over a five-year forecasting period.

HYDROGEN FUEL CELL ELECTRIC VEHICLE (FCEV) – A vehicle that uses an electric motor for propulsion, much like a BEV, but powers the electric motor using hydrogen fuel cells rather than a large onboard battery. FCEVs are a subcategory of ZEVs.

INTEGRATED RESOURCE PLAN (IRP) – Large utilities are required by Senate Bill 350 to develop integrated resource plans (IRPs) which are reports that detail how they will meet their customers' resource needs, reduce GHG emissions, and ramp up the use of clean energy resources within their service territories.

INTEGRATION CAPACITY ANALYSIS (ICA) – The integration capacity analysis (ICA) is a complex modeling study that uses detailed information about the electric distribution system, which includes physical infrastructure, load performance, and existing and queued generation. The ICA simulates the ability of individual distribution line sections to accommodate additional DERs without causing issues that would affect customer reliability and power quality.

KILOWATT (kW) – One thousand watts, a measure of power. On a hot summer afternoon, a typical home - with central air conditioning and other equipment in use - might have a power demand of 4 kW.

KILOWATT-HOUR (kWh) – One kilowatt of electricity supplied for one hour, that is, a measure of energy. It is the most used unit of measure telling the amount of electricity consumed over time.

LEVEL 1 (L1) CHARGING – Electric vehicle charging at 120 volts.

LEVEL 2 (L2) CHARGING – Electric vehicle charging at 240 volts.

LIGHT DUTY VEHICLE (LDV) – A vehicle with a GVWR of 10,000 lbs. or less. Most LDVs are privately owned cars and trucks.

LOAD – The amount of energy delivered by the electrical grid at a given time, often measured in MW. The models used in this report estimate the load needed to support EV charging throughout the day.

LOAD FLEXIBILITY – Load flexibility refers to the ability of electric customers to shift the electricity consumption of devices, appliances, or other loads in response to electricity prices or other signals. VGI can be viewed as load flexibility applied to vehicle charging.

MEDIUM-/HEAVY-DUTY VEHICLE – A vehicle with a GVWR of over 10,000 lbs. Most MDHD vehicles are used for commercial purposes. The models in this report consider four categories of MDHD vehicles: LHDVs (vehicles with a GVWR of 10,001-14,000 lbs.), class 4-6, class 7, and class 8.

MEGAWATT (MW) – A unit of power equal to 1 million watts.

MEGAWATT CHARGING SYSTEM (MCS) – A connector standard for fast charging of electric vehicles that can provide up to 3.75 megawatts of power.

NITROGEN OXIDES (OXIDES OF NITROGEN, NOx) – A general term for compounds of nitric oxide (NO), nitrogen dioxide (NO2), and other oxides of nitrogen. Nitrogen oxides are typically created during combustion and are major contributors to smog formation and acid deposition. NO2 is a criteria air pollutant and may result in numerous adverse health effects.

ON ROUTE PUBLIC CHARGER – An on route public charger is a high-powered charger operated by an EVSP that is used to charge MDHD vehicles making brief stops during trips. The models in this report estimate on route public charging needs at a range of power levels from 350 kW to 1.5 MW.

PLUG-IN ELECTRIC VEHICLE (PEV) – A general term for any car that runs at least partially on battery power and is recharged from the electricity grid. There are two types of PEVs: pure battery-electric and plug-in hybrid electric vehicles.

PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV) – PHEVs are powered by an internal combustion engine and an electric motor that uses energy stored in a battery. The vehicle can be plugged in to an electric power source to charge the battery. Some can travel nearly 100 miles on electricity alone, and all can operate solely on gasoline (like a conventional hybrid).

PRIVATE CHARGING STATION – A private charging station has parking space(s) that are privately owned and operated, often dedicated for a specific driver or vehicle (for example, a charger installed in the garage of a single-family home).

PUBLIC CHARGING STATION – A public charging station has parking space(s) designated by a property owner or lessee to be available to and accessible by the public for any period.

SHARED PRIVATE CHARGING STATION – A shared private charging station has parking space(s) designated by a property owner or lessee to be available to and accessible by employees, tenants, visitors, and/or residents. Parking spaces are not dedicated to individual drivers or vehicles.

SMART CHARGING – Smart charging, also called managed charging or V1G, adjusts charging time or power level in response to utility rates, demand response events, local site controllers, or other signals.

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) – A global association of more than 128,000 engineers and related technical experts in the aerospace, automotive, and commercial vehicle industries. It is the leader in connecting and educating mobility professionals to enable safe, clean, and accessible mobility solutions.227

TRAFFIC ANALYSIS ZONE (TAZ) – A spatial unit used for the planning of transportation systems. In the models used in this report, charging events are located in TAZs derived from the California Statewide Travel Demand Model.

TRANSPORTATION ELECTRIFICATION (TE) – The conversion of transportation system from the use of internal combustion engines and liquid fuels to ZEVs, particularly PEVs.

TRANSPORTATION NETWORK COMPANY (TNC) – A company that provides prearranged transportation services for compensation using an online-enabled application or platform (such as smartphone apps) to connect drivers using their personal vehicles with passengers.

VEHICLE-GRID INTEGRATION (VGI) – Various technologies and strategies that alter the time, charging level, or location of charging in a manner that benefits the grid while ensuring driver needs are met. VGI may appear in different forms, including but not limited to smart charging, bidirectional charging, automated load management, and integration with local generation or storage.

ZERO-EMISSION VEHICLE (ZEV) – Vehicles that produce no emissions from the onboard source of power (for example, hydrogen fuel cell electric vehicles and battery electric vehicles).

APPENDIX A: List of Related Public Workshops

July 8, 2021: The CEC conducted a workshop to solicit feedback on analysis of public light-duty electric vehicle charging infrastructure access by disadvantaged communities, low-income communities, and rural communities and to seek feedback on components of the Senate Bill 1000 report.[196]

October 21, 2021: The CEC, CPUC, and GO-Biz conducted a workshop on EV charging infrastructure deployment acceleration and grid integration.[197]

January 20, 2022: The CEC conducted a workshop to present and gather stakeholder feedback on the *Zero-Emission Vehicle (ZEV) Infrastructure Plan* (ZIP).[198]

March 11, 2022: The CEC conducted a workshop to discuss and receive stakeholder feedback on how to define, measure, and publish reliability metrics for electric vehicle (EV) charging infrastructure and how to incorporate reliability metrics in EV charging infrastructure funding opportunities.[199]

March 16, 2022: The CEC conducted a workshop to present the Electric Vehicle Infrastructure Projections 3 (EVI-Pro 3) model and analysis. The workshop gathered information for the CEC's second AB 2127 assessment.[200]

May 17, 2022: The CEC conducted a workshop to discuss the design and implementation of a voluntary, CEC-housed Vehicle-to-Grid (V2G) Inverter List.[201]

June 14, 2022: The CEC and California Department of Transportation cohosted a workshop to introduce and discuss preliminary elements of the California State Electric Vehicle Infrastructure Deployment Plan as required by the National Electric Vehicle Infrastructure Formula Funding Program (NEVI).[202]

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196 https://www.energy.ca.gov/event/workshop/2021-07/senate-bill-1000-staff-workshop.

197 https://www.energy.ca.gov/event/workshop/2021-10/joint-agency-workshop-accelerating-electric-vehicle-charging-infrastructure.

198 https://www.energy.ca.gov/event/workshop/2022-01/workshop-zero-emission-vehicle-infrastructure-plan.

199 https://www.energy.ca.gov/event/workshop/2022-03/electric-vehicle-charging-infrastructure-reliability-workshop.

200 https://www.energy.ca.gov/event/workshop/2022-03/electric-vehicle-infrastructure-projections-evi-pro-assembly-bill-ab-2127.

201 https://www.energy.ca.gov/event/2022-05/workshop-vehicle-grid-inverter-list.

202 https://www.energy.ca.gov/event/workshop/2022-06/joint-workshop-california-department-transportation-california-state.

July 28, 2022: The CEC conducted a workshop to discuss the current status of vehicle-grid integration (VGI) in California and present several funding solicitation concepts designed to help advance and prepare for widespread VGI.[203]

September 19, 2022: The CEC conducted a workshop to initiate public discussion of the second biennial AB 2127 Report. Staff shared plans for developing the assessment, introduced scenarios and analysis, and presented the EVI-Pro 3 model.[204]

October 18, 2022: The CEC conducted a workshop to discuss labor and workforce topics and to gather information for the CEC's second Assembly Bill (AB) 2127 assessment.[205]

November 9, 2022: The CEC conducted a workshop to discuss updates to its Medium- and Heavy-duty Electric Vehicle Infrastructure Load, Operations, and Deployment (HEVI-LOAD) and Widespread Infrastructure for Ride-Hailing EV Deployment (WIRED) modeling analyses. The workshop presented inputs, assumptions, and key differences from earlier versions of the analyses and solicited stakeholder feedback on their development.[206]

September 7, 2023: The CEC conducted a workshop to present the draft Staff Report of the second AB 2127 Assessment. The workshop presented assumptions, results, and key differences from the first AB 2127 assessment and solicited stakeholder feedback.[207]

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203 https://www.energy.ca.gov/event/workshop/2022-07/workshop-vehicle-grid-integration-market-status-and-funding-concepts.

204 https://www.energy.ca.gov/event/workshop/2022-09/assembly-bill-ab-2127-assessment-workshop.

205 https://www.energy.ca.gov/event/workshop/2022-10/workshop-labor-and-workforce-second-assembly-bill-2127-assessment.

206 https://www.energy.ca.gov/event/workshop/2022-11/workshop-medium-and-heavy-duty-and-ride-hailing-electric-vehicle.

207 https://www.energy.ca.gov/event/workshop/2023-09/assembly-bill-ab-2127-assessment-workshop-staff-draft-report

APPENDIX B: Text of Assembly Bill 2127 and Senate Bill 589

The scope of this report is defined in part by two state laws and an executive order that require the CEC to assess the charging infrastructure and workforce development and training resources needed to meet the state's transportation electrification goals. Assembly Bill 2127 (Ting, Chapter 365, Statutes of 2018) requires the CEC to prepare a statewide assessment of the charging infrastructure needed to achieve the goal of 5 million ZEVs on the road by 2030 and reduce emissions of greenhouse gases to 40 percent below 1990 levels by 2030. Executive Order N-79-20 directed the CEC to expand this assessment to support higher targets of electric vehicle adoption through 2035. Senate Bill 589 (Hueso, Chapter 732, Statues of 2021) requires as part of the CEC's AB 2127 assessment starting in 2023, to identify workforce development and training resources needed to meet PEV adoption goals.

The text of these laws is included here for reference.

Assembly Bill No. 2127

An act to add Section 25229 to the Public Resources Code, relating to electric vehicles. Approved by Governor September 13, 2018. Filed with Secretary of State September 13, 2018.

THE PEOPLE OF THE STATE OF CALIFORNIA DO ENACT AS FOLLOWS:

SECTION 1.

(a) The Legislature finds and declares all of the following:

(1) Advanced clean vehicles and fuels are needed to reduce petroleum use, to meet air quality standards, to improve public health, and to achieve greenhouse gas emissions reduction goals.

(2) Widespread transportation electrification requires increased access to the use of electricity as a transportation fuel.

(3) Electric vehicles and charging infrastructure with the ability to record consumption and connect by remote communication technology could assist in grid management and the integration of eligible renewable energy resources. Electric vehicles can also reduce fuel costs for vehicle owners, and time-of-use electric rates can encourage charging that is compatible with electrical grid conditions.

(4) Deploying electric vehicle charging infrastructure will facilitate increased adoption of electric vehicles.

(b) It is the policy of the state and the intent of the Legislature to encourage transportation electrification as a means to achieve ambient air quality standards and the state's climate goals.

SECTION 2.

Section 25229 is added to the Public Resources Code, to read:

25229.

(a) The commission, working with the State Air Resources Board and the Public Utilities Commission, shall prepare a statewide assessment of the electric vehicle charging infrastructure needed to support the levels of electric vehicle adoption required for the state to meet its goals of putting at least five million zero-emission vehicles on California roads by 2030, and of reducing emissions of greenhouse gases to 40 percent below 1990 levels by 2030.

(b) The assessment shall expand on the commission's electric vehicle infrastructure projections to consider all necessary charging infrastructure, including, but not limited to, the chargers, make-ready electrical equipment, and supporting hardware and software, all vehicle categories, road, highway, and offroad electrification, port and airport electrification, and other programs to accelerate the adoption of electric vehicles to meet the goals described in subdivision (a). The assessment shall examine existing and future infrastructure needs throughout California, including in low-income communities.

(c) The commission shall regularly seek data and input relating to electric vehicle charging infrastructure from stakeholders, including, but not limited to, the Public Utilities Commission, the State Air Resources Board, electrical corporations, local publicly owned electric utilities, state and local transportation and transit agencies, charging infrastructure companies, environmental groups, and automobile manufacturers.

(d) The commission shall update the assessment at least once every two years.

Senate Bill No. 589

An act to add Section 44272.2 to the Health and Safety Code, and to amend Section 25229 of the Public Resources Code, relating to air pollution. Approved by Governor October 8, 2021. Filed with Secretary of State October 8, 2021.

THE PEOPLE OF THE STATE OF CALIFORNIA DO ENACT AS FOLLOWS:

SECTION 1.

Section 44272.2 is added to the Health and Safety Code, to read:

44272.2.

(a) A project, including a workforce development or training project, that develops instate production of raw materials and the manufacturing supply chain for zero-emission vehicle components shall be eligible to receive funding under the program established pursuant to Section 44272.

(b) In addition to the entities set forth in Section 44272, the commission shall also collaborate with the California Community Colleges, the certified community conservation corps as defined in Section 14507.5 of the Public Resources Code, the California Conservation Corps, and the California Mobility Center to implement the workforce development components of the program established pursuant to Section 44272.

SECTION 2.

Section 25229 of the Public Resources Code is amended to read:

25229.

(a) The commission, working with the State Air Resources Board and the Public Utilities Commission, shall prepare a statewide assessment of the electric vehicle charging infrastructure needed to support the levels of electric vehicle adoption required for the state to meet its goals of putting at least five million zero-emission vehicles on California roads by 2030, and of reducing emissions of greenhouse gases to 40 percent below 1990 levels by 2030.

(b) The assessment shall expand on the commission's electric vehicle infrastructure projections to consider all necessary charging infrastructure, including, but not limited to, the chargers, make-ready electrical equipment, and supporting hardware and software, all vehicle categories, road, highway, and offroad electrification, port and airport electrification, and other programs to accelerate the adoption of electric vehicles to meet the goals described in subdivision (a). The assessment shall examine existing and future infrastructure needs throughout California, including in low-income communities.

(c) As a part of the assessment, the commission, in consultation with stakeholders, shall identify workforce development and training resources needed to meet the goals described in subdivision (a). These resources shall include, but are not limited to, qualified apprenticeships, on-the-job training programs, and other training opportunities that build career pipelines in the zero-emission transportation sector and provide long-term employment in disadvantaged communities.

(d) The commission shall regularly seek data and input relating to electric vehicle charging infrastructure from stakeholders, including, but not limited to, the Public Utilities Commission, the State Air Resources Board, electrical corporations, local publicly owned electric utilities, state and local transportation and transit agencies, charging infrastructure companies, environmental groups, and automobile manufacturers.

(e) The commission shall update the assessment at least once every two years.

APPENDIX C: EVI-Pro 3 Inputs and Parameters

This appendix presents several key inputs and parameters used for the EVI-Pro 3 analysis discussed in this report. Table C-1 provides a summary of the major parameters under the baseline scenario. To generate alternative future scenarios, individual parameters of the baseline scenario for 2030 were modified.

Table C-1: Summary of input parameters for the baseline scenario

Input	2023	2025	**2030**	2035
ZEV Count	1,459,396	2,495,085	**7,063,541**	15,165,466
BEV Count	1,076,462	2,015,881	**6,228,970**	13,613,011
PHEV Count	382,934	479,204	**834,571**	1,552,455
Commuter Share	70%	70%	**50%**	50%
Share of PEVs in Multi-family Housing	5%	8%	**23%**	23%
Residential Charging Access	84%	78%	**66%**	60%
BEV “Rational” Cohort Size	80%	80%	**65%**	65%
BEV “Free Public Level 2” Cohort Size	10%	10%	**20%**	20%
BEV “DCFC dominant” Cohort Size	10%	10%	**15%**	15%
PHEV “Lazy” Cohort Size	60%	60%	**50%**	50%
PHEV “Rational” Cohort Size	30%	30%	**30%**	30%
PHEV “Free Public Level 2” Cohort Size	10%	10%	**20%**	20%
No TOU Cohort Size	50%	50%	**0%**	0%
TOU ASAP (on peak ends) Cohort Size	17%	17%	**33%**	33%
TOU ASAP (off peak starts) Cohort Size	17%	17%	**33%**	33%
TOU ALAP Cohort Size	17%	17%	**33%**	33%
Non-res Level 2 Utilization (events per day)	0.9-1.1	0.9-1.1	**0.9-1.1**	0.9-1.1

DC50 Utilization (events per day)	4.8-6.8	4.8-6.8	**4.8-6.8**	4.8-6.8
DC150 Utilization (events per day)	6.5-8.5	6.5-8.5	**6.5-8.5**	6.5-8.5
DC250 Utilization (events per day)	3.2-5.2	3.2-5.2	**6.1-8.1**	6.1-8.1
DC350 Utilization (events per day)	1.2-3.2	1.2-3.2	**5.1-7.1**	5.1-7.1
DC50 Utilization (percent)	11.5%	11.5%	**11.5%**	11.5%
DC150 Utilization (percent)	10.0%	10.0%	**10.0%**	10.0%
DC250 Utilization (percent)	5.0%	5.0%	**8.5%**	8.5%
DC350 Utilization (percent)	2.5%	2.5%	**7.0%**	7.0%

Source: CEC Staff and NREL

Charging behavior cohorts represent these behaviors:

- **BEV "rational"** is the fraction of BEV drivers that choose to charge where it is cheapest, with home charging being the first choice.
- **BEV "Free Public Level 2"** cohort drivers use free public Level 2 charging when it is available at an activity destination.
- **BEV "DCFC dominant"** cohort drivers prefer to use DCFC whenever possible.
- **PHEV "Lazy"** cohort drivers only charge their PHEVs at home and use the internal combustion engine for the rest of the day if they expend their electric range.
- **PHEV "Rational"** cohort drivers manage their charging to minimize their use of the internal combustion engine, even if this means charging briefly at every destination.
- **PHEV "Free Public Level 2"** cohort drivers use free public Level 2 charging when it is available at an activity destination.

The residential load cohorts behave as follows:

- **No TOU** drivers start charging their car as soon as they arrive home.
- **TOU ASAP (on peak ends)** drivers start charging as soon as the peak TOU rate ends.
- **TOU ASAP (off peak starts)** drivers start charging as soon as the lowest cost off-peak hour TOU rate starts.
- **TOU ALAP** drivers start charging as late as possible while ensuring that they will have sufficient charge for that day's travel.

For this report, CEC and NREL attempted to disaggregate work and public charging events to a more specific range of locations based on business type and charger access. Table C-2 shows the allocation of work charging events to each location type. Other non-home charging events (formerly labeled "public" charging events) are split equally between retail and other locations.

Table C-2: Proportion of chargers from work activity charging events allocated to shared private and public charging locations.

Occupation Type	Shared Private Office	Public Office	Shared Private Retail	Public Retail	Shared Private Other	Public Other
2021	80	20	0	0	0	0
2022	76	20	1	1	1	1
2023	73	20	2	1	2	2
2024	69	20	3	2	4	2
2025	65	20	4	3	5	3
2026	62	20	5	3	6	4
2027	58	20	6	4	7	5
2028	55	20	7	4	8	6
2029	51	20	8	5	10	6
2030	48	20	8	6	11	7
2031	45	20	9	6	12	8
2032	41	20	10	7	13	9
2033	37	20	11	8	14	10
2034	34	20	12	8	16	10
2035	30	20	13.2	8.8	16.8	11.2

Source: CEC Staff and NREL

EVI-Pro 3 models the LDV fleet based on a range of vehicle categories and generations, with vehicles in each category / generation sharing battery capacity, efficiency, and charging characteristics, as shown in Tables C-3. Generation 1 contains vehicles manufactured in 2011-2025. Generation 2 contains vehicles manufactured in 2026-2030. Generation 3 contains vehicles manufactured after 2030. This fleet model was originally designed for the IEPR AATE3 scenario. Table C-4 contains the number of vehicles in each category and generation in the fleet as of 2025, 2030, and 2035.

Table C-3: Light duty vehicle fleet characteristics

Vehicle Category	Generation	Battery Capacity (kWh)	Efficiency (Wh/mi)	Charging speed AC (kW)	Charging speed DC (kW)	Electric Range (mi)
Large Car	PHEV	15.0	277	6.5	0	54
Large SUV	PHEV	20.0	376	6.4	0	53
Pickup Truck	PHEV	19.0	378	6.1	0	50
Small Car	PHEV	12.0	275	5.2	0	44
Small SUV	PHEV	17.0	339	6.1	0	50
Sport Car	PHEV	13.0	273	5.7	0	48

Van	PHEV	19.0	353	6.4	0	54
Large Car	Gen 1	136.0	349	12.0	281	390
Large SUV	Gen 1	172.7	500	12.0	311	346
Pickup Truck	Gen 1	179.1	611	12.0	232	293
Small Car	Gen 1	69.9	308	10.9	118	227
Small SUV	Gen 1	139.1	488	12.0	220	285
Sport Car	Gen 1	119.0	389	12.0	224	306
Van	Gen 1	99.9	411	11.6	247	243
Large Car	Gen 2	128.1	349	12.0	410	367
Large SUV	Gen 2	193.4	504	12.0	494	384
Pickup Truck	Gen 2	199.5	582	12.0	397	343
Small Car	Gen 2	79.6	314	12.0	177	254
Small SUV	Gen 2	155.8	487	12.0	363	320
Sport Car	Gen 2	147.4	398	12.0	378	370
Van	Gen 2	118.9	411	11.6	438	289
Large Car	Gen 3	135.7	351	12.0	595	386
Large SUV	Gen 3	208.8	509	12.0	676	410
Pickup Truck	Gen 3	211.9	534	12.0	621	396
Small Car	Gen 3	88.5	319	12.0	245	278
Small SUV	Gen 3	170.9	483	12.0	534	354
Sport Car	Gen 3	155.1	404	12.0	504	384
Van	Gen 3	142.7	425	11.6	681	336

Source: CEC Staff and NREL

Table C-4: Light duty vehicle fleet makeup 2025, 2030, 2035 AATE3 scenario

Vehicle Category	Generation	2025	2030	2035
Large Car	PHEV	2,278	1,494	1,054
Large SUV	PHEV	1,289	6,844	17,695

Pickup Truck	PHEV	8,211	73,471	212,912
Small Car	PHEV	241,543	256,675	333,556
Small SUV	PHEV	212,443	479,317	962,883
Sport Car	PHEV	1,159	1,014	1,834
Van	PHEV	12,280	15,755	22,521
Large Car	Gen 1	520,205	520,205	520,205
Large SUV	Gen 1	7,245	7,245	7,245
Pickup Truck	Gen 1	43,584	43,584	43,584
Small Car	Gen 1	600,956	600,956	600,956
Small SUV	Gen 1	784,036	784,036	784,036
Sport Car	Gen 1	39,753	39,753	39,753
Van	Gen 1	20,101	20,101	20,101
Large Car	Gen 2	0	956,970	956,970
Large SUV	Gen 2	0	30,167	30,167
Pickup Truck	Gen 2	0	339,145	339,145
Small Car	Gen 2	0	967,314	967,314
Small SUV	Gen 2	0	1,632,105	1,632,105
Sport Car	Gen 2	0	218,502	218,502
Van	Gen 2	0	68,886	68,886
Large Car	Gen 3	0	0	1,361,454
Large SUV	Gen 3	0	0	50,479
Pickup Truck	Gen 3	0	0	683,723
Small Car	Gen 3	0	0	1,652,725
Small SUV	Gen 3	0	0	3,003,706
Sport Car	Gen 3	0	0	504,438
Van	Gen 3	0	0	127,516

Source: CEC Staff

Table C-5: Light duty vehicle fleet size by county 2023-2029

County	2023	2025	2026	2027	2028	2029
Alameda	89,170	164,167	204,296	252,551	308,838	372,952
Alpine	40	67	85	108	135	167
Amador	1,013	1,599	2,045	2,617	3,310	4,138
Butte	2,101	3,634	4,476	5,510	6,731	8,145
Calaveras	845	1,355	1,729	2,207	2,784	3,473
Colusa	675	1,050	1,342	1,711	2,156	2,681
Contra Costa	72,197	134,053	167,896	208,719	256,294	310,566
Del Norte	219	411	508	624	758	909
El Dorado	5,366	8,402	10,652	13,510	16,983	21,119
Fresno	10,452	14,958	18,822	23,814	30,004	37,432
Glenn	331	569	704	871	1,067	1,296
Humboldt	5,494	7,861	10,188	13,181	16,856	21,272
Imperial	1,402	2,491	3,050	3,735	4,536	5,454
Inyo	1,002	1,552	2,013	2,616	3,354	4,249
Kern	11,684	17,618	22,129	27,906	34,977	43,414
Kings	1,913	2,918	3,647	4,571	5,698	7,030
Lake	3,688	5,391	7,004	9,070	11,602	14,626
Lassen	255	495	607	740	894	1,067
Los Angeles	406,743	707,084	878,744	1,088,442	1,336,174	1,621,851
Madera	1,653	2,412	3,045	3,865	4,881	6,102
Marin	14,248	20,567	26,324	33,582	42,493	53,113
Mariposa	322	489	623	798	1,013	1,273
Mendocino	4,047	5,796	7,540	9,795	12,566	15,905
Merced	7,977	13,013	16,393	20,632	25,695	31,609
Modoc	70	142	176	216	261	311
Mono	370	589	752	965	1,227	1,544
Monterey	10,414	14,960	19,223	24,686	31,404	39,410
Napa	8,503	12,310	15,769	20,169	25,567	32,003
Nevada	2,003	3,268	4,111	5,179	6,466	7,997
Orange	119,208	216,864	268,865	331,689	405,245	489,366

Placer	12,895	20,484	25,707	32,261	40,178	49,517
Plumas	137	263	322	395	480	578
Riverside	67,679	112,571	140,152	174,343	215,119	262,613
Sacramento	43,132	64,813	81,640	102,939	128,842	159,518
San Benito	6,571	11,115	14,134	17,908	22,392	27,616
San Bernardino	57,268	93,276	115,966	144,243	178,134	217,789
San Diego	123,720	212,634	266,777	332,990	411,281	501,645
San Francisco	33,275	59,881	73,989	91,009	110,990	133,894
San Joaquin	24,058	41,230	51,724	64,597	79,809	97,341
San Luis Obispo	6,799	9,670	12,481	16,108	20,593	25,993
San Mateo	46,434	85,761	106,794	132,115	161,715	195,478
Santa Barbara	16,239	22,364	28,996	37,559	48,159	60,911
Santa Clara	115,752	210,545	262,220	324,531	397,509	480,817
Santa Cruz	13,021	21,311	27,073	34,319	43,000	53,196
Shasta	2,044	3,852	4,701	5,721	6,898	8,232
Sierra	57	105	132	164	201	245
Siskiyou	509	992	1,224	1,498	1,813	2,168
Solano	18,881	28,931	36,660	46,318	57,999	71,723
Sonoma	23,225	32,578	41,916	53,871	68,607	86,267
Stanislaus	9,804	17,075	21,291	26,467	32,562	39,575
Sutter	1,537	2,430	3,054	3,837	4,777	5,881
Tehama	1,206	1,973	2,486	3,124	3,885	4,774
Trinity	173	310	393	497	620	764
Tulare	4,097	6,422	7,964	9,911	12,268	15,051
Tuolumne	1,130	1,809	2,307	2,946	3,720	4,647
Ventura	39,969	56,593	73,169	94,416	120,564	151,872
Yolo	5,100	7,957	10,075	12,717	15,898	19,635
Yuba	1,283	2,051	2,560	3,199	3,965	4,864

Table C-6: Light duty vehicle fleet size by county 2030-2035

County	2030	2031	2032	2033	2034	2035
Alameda	446,532	528,461	616,361	711,411	813,409	921,811
Alpine	204	246	292	342	397	456
Amador	5,115	6,235	7,459	8,810	10,283	11,913
Butte	9,775	11,593	13,541	15,657	17,935	20,390
Calaveras	4,284	5,211	6,223	7,337	8,548	9,886
Colusa	3,299	4,005	4,777	5,633	6,567	7,592
Contra Costa	372,902	442,377	516,910	597,679	684,326	777,162
Del Norte	1,080	1,270	1,472	1,691	1,926	2,173
El Dorado	26,008	31,588	37,694	44,414	51,753	59,805
Fresno	46,263	56,414	67,597	79,966	93,510	108,188
Glenn	1,559	1,853	2,169	2,513	2,884	3,285
Humboldt	26,537	32,606	39,296	46,780	55,063	64,203
Imperial	6,504	7,662	8,895	10,222	11,635	13,128
Inyo	5,312	6,540	7,887	9,392	11,045	12,914
Kern	53,378	64,777	77,257	91,033	106,064	122,430
Kings	8,598	10,382	12,330	14,475	16,809	19,328
Lake	18,230	22,378	26,948	32,053	37,684	43,884
Lassen	1,262	1,476	1,699	1,939	2,194	2,466
Los Angeles	1,952,350	2,322,791	2,722,027	3,156,552	3,625,469	4,127,181
Madera	7,554	9,224	11,060	13,093	15,317	17,749
Marin	65,778	80,280	96,260	114,001	133,633	154,969
Mariposa	1,582	1,938	2,327	2,758	3,230	3,754
Mendocino	19,891	24,491	29,563	35,246	41,535	48,506
Merced	38,499	46,293	54,745	64,036	74,076	84,944
Modoc	367	429	494	563	637	715
Mono	1,921	2,352	2,823	3,345	3,916	4,559
Monterey	48,938	59,772	71,671	84,917	99,482	115,380
Napa	39,671	48,469	58,160	68,940	80,824	93,791
Nevada	9,795	11,837	14,052	16,481	19,125	22,034
Orange	585,972	693,281	808,039	931,937	1,064,761	1,206,407

Placer	60,497	72,961	86,556	101,450	117,658	135,232
Plumas	690	811	939	1,075	1,221	1,380
Riverside	317,951	380,360	447,977	521,693	601,229	686,572
Sacramento	195,762	237,150	282,662	332,811	387,666	446,967
San Benito	33,698	40,565	48,002	56,183	65,023	74,660
San Bernardino	264,125	316,501	373,389	435,561	502,858	575,215
San Diego	606,266	723,534	850,120	987,861	1,136,475	1,295,324
San Francisco	160,259	189,640	221,199	255,257	291,886	330,651
San Joaquin	117,664	140,541	165,303	192,328	221,437	252,643
San Luis Obispo	32,443	39,796	47,880	56,884	66,827	77,785
San Mateo	234,298	277,499	323,851	373,949	427,723	484,991
Santa Barbara	76,188	93,794	113,310	135,158	159,378	186,027
Santa Clara	576,700	683,549	798,382	922,694	1,056,309	1,198,371
Santa Cruz	65,127	78,601	93,222	109,325	126,837	145,944
Shasta	9,742	11,389	13,121	14,970	16,929	19,006
Sierra	295	351	411	475	544	620
Siskiyou	2,568	3,007	3,469	3,964	4,489	5,046
Solano	87,898	106,328	126,522	148,799	173,153	199,384
Sonoma	107,375	131,670	158,495	188,452	221,609	257,844
Stanislaus	47,658	56,703	66,420	76,976	88,282	100,403
Sutter	7,174	8,645	10,249	12,012	13,922	15,988
Tehama	5,811	6,981	8,249	9,646	11,167	12,821
Trinity	931	1,118	1,317	1,536	1,771	2,033
Tulare	18,310	22,005	26,020	30,423	35,195	40,348
Tuolumne	5,740	6,990	8,353	9,855	11,491	13,304
Ventura	189,276	232,503	280,453	334,072	393,447	458,687
Yolo	24,024	29,025	34,499	40,521	47,091	54,197
Yuba	5,913	7,105	8,401	9,822	11,361	13,022

APPENDIX D: EVI-Pro 3 Detailed Results for Primary Scenarios

Table D-1: Statewide totals with lower and upper bounds for 2023 and 2025 AATE3

Charger and Location	2023 – Lower	2023 – Upper	2025 – Lower	2025 – Upper
Single-family housing Level 1	380,533	422,815	666,941	741,045
Single-family housing Level 2	687,437	763,819	1,021,453	1,134,948
Multi-family housing Level 1	10,165	11,295	20,594	22,882
Multi-family housing Level 2	10,202	20,404	17,522	35,045
Shared Private Office	54,389	66,475	91,882	112,301
Public Office	14,901	18,212	28,271	34,554
Shared Private Retail	1,490	1,821	5,654	6,911
Public Retail	12,256	14,980	20,845	25,478
Shared Private Other	1,490	1,821	7,068	8,639
Public Other	13,001	15,890	20,845	25,478
DCFC 150 or less	1,161	1,521	2,149	2,815
DCFC 250	1,965	3,192	4,136	6,721
DCFC 350	697	1,842	2,418	6,447

Source: NREL

Table D-2: Statewide totals with lower and upper bounds for 2030 and 2035 AATE3

Charger and Location	2030 – Lower	2030 – Upper	2035 – Lower	2035 – Upper
Single-family housing Level 1	1,300,797	1,445,330	2,206,323	2,451,470
Single-family housing Level 2	2,584,764	2,871,960	5,416,469	6,018,299
Multi-family housing Level 1	115,555	128,395	186,052	206,724
Multi-family housing Level 2	127,564	255,128	253,752	507,503
Shared Private Office	185,511	226,735	264,323	323,061
Public Office	77,296	94,473	176,215	215,374
Shared Private Retail	30,918	37,789	116,302	142,147
Public Retail	125,231	153,060	291,164	355,867

Shared Private Other	42,513	51,960	148,021	180,914
Public Other	129,096	157,784	312,310	381,712
DCFC 150 or less	3,688	4,847	4,237	5,583
DCFC 250	9,220	12,242	18,439	24,485
DCFC 350	14,909	20,756	38,790	54,002

Source: NREL

Table D-3: Statewide totals with lower and upper bounds for 2030 and 2035 ACCII

Charger and Location	2030 – Lower	2030 – Upper	2035 – Lower	2035 – Upper
Single-family housing Level 1	1,046,015	1,162,239	1,780,618	1,978,464
Single-family housing Level 2	2,078,496	2,309,440	4,371,374	4,857,082
Multi-family housing Level 1	92,825	103,138	150,075	166,750
Multi-family housing Level 2	102,471	204,942	204,684	409,367
Shared Private Office	152,234	186,063	215,071	262,865
Public Office	63,431	77,526	143,381	175,243
Shared Private Retail	25,372	31,011	94,631	115,661
Public Retail	108,637	132,778	244,713	299,094
Shared Private Other	34,887	42,640	120,440	147,204
Public Other	111,808	136,655	261,919	320,123
DCFC 150 or less	2,088	2,750	2,463	3,254
DCFC 250	6,707	8,906	14,044	18,648
DCFC 350	11,992	16,695	31,092	43,285

Source: NREL

Table D-4: County-by-county results for total Level 1 and Level 2 chargers at Multi-Family Housing

County	2023	2025	2030	2035
Alameda	1,119	2,980	20,854	37,252
Alpine	0	0	2	4
Amador	3	4	52	105
Butte	7	8	239	431
Calaveras	3	3	44	87
Colusa	2	2	40	80
Contra Costa	237	311	10,130	18,269
Del Norte	1	1	10	18
El Dorado	18	19	361	719
Fresno	34	35	1,423	2,880
Glenn	1	1	19	35
Humboldt	18	18	618	1,295
Imperial	5	6	171	299
Inyo	3	4	54	114
Kern	38	41	1,223	2,427
Kings	6	7	228	444
Lake	12	12	285	594

Lassen	1	1	12	20
Los Angeles	13,602	23,273	115,526	211,318
Madera	5	6	97	198
Marin	47	180	2,550	5,198
Mariposa	1	1	16	33
Mendocino	13	13	311	657
Merced	26	30	740	1,414
Modoc	0	0	3	6
Mono	1	1	20	40
Monterey	34	46	1,662	3,391
Napa	28	29	889	1,819
Nevada	7	8	93	181
Orange	2,047	4,645	28,985	51,635
Placer	42	48	1,139	2,203
Plumas	0	1	6	11
Riverside	222	261	6,260	11,697
Sacramento	142	150	6,123	12,097
San Benito	22	26	657	1,259
San Bernardino	188	216	7,219	13,604
San Diego	2,493	5,002	31,066	57,433
San Francisco	3,075	4,466	15,123	27,000
San Joaquin	79	96	2,420	4,496
San Luis Obispo	22	22	847	1,757
San Mateo	689	1,695	11,261	20,171
Santa Barbara	79	284	3,208	6,779
Santa Clara	1,259	3,572	26,357	47,391
Santa Cruz	43	49	1,958	3,798
Shasta	7	9	169	285
Sierra	0	0	3	5
Siskiyou	2	2	24	41
Solano	62	67	2,200	4,318
Sonoma	76	76	2,806	5,830
Stanislaus	32	40	905	1,650
Sutter	5	6	136	262
Tehama	4	5	71	136
Trinity	1	1	11	21
Tulare	13	15	309	589
Tuolumne	4	4	59	118
Ventura	131	131	5,239	10,987
Yolo	17	86	973	1,899
Yuba	4	5	112	213

Source: NREL

Table D-5: County-by-county results for total Level 2 chargers at work and public sites

County	2023	2025	2030	2035
Alameda	6,323	10,928	36,817	86,082
Alpine	2	6	9	17
Amador	68	61	347	808
Butte	123	224	931	1,865
Calaveras	32	59	216	535
Colusa	38	57	151	233
Contra Costa	3,457	5,605	24,235	54,297
Del Norte	9	14	54	82
El Dorado	281	384	1,646	3,603
Fresno	762	1,037	4,984	11,725
Glenn	17	34	100	198
Humboldt	351	476	2,323	6,104
Imperial	76	157	295	784
Inyo	33	55	393	886
Kern	718	1,350	3,970	9,320
Kings	181	281	977	1,909
Lake	167	212	1,048	2,738
Lassen	13	28	76	113
Los Angeles	34,191	62,746	201,464	435,764
Madera	161	201	577	1,456
Marin	1,027	1,423	4,918	10,522
Mariposa	18	15	88	290
Mendocino	285	338	1,545	3,818
Merced	443	620	1,887	5,252
Modoc	5	1	7	26
Mono	13	21	187	383
Monterey	621	973	4,232	11,042
Napa	524	937	3,802	8,109
Nevada	68	136	577	1,507
Orange	10,457	20,788	66,026	143,044
Placer	713	1,111	4,557	10,314
Plumas	3	5	27	64
Riverside	3,681	7,158	22,944	51,171
Sacramento	3,067	4,498	17,111	40,327
San Benito	386	422	2,412	4,552
San Bernardino	3,706	6,987	21,076	51,913
San Diego	11,418	20,869	70,112	153,300
San Francisco	2,204	3,874	12,625	27,537
San Joaquin	1,397	2,491	8,154	18,790
San Luis Obispo	573	823	2,879	7,365
San Mateo	2,851	6,305	18,693	41,352

Santa Barbara	1,132	1,679	6,713	17,278
Santa Clara	9,338	17,822	59,680	126,726
Santa Cruz	476	933	4,230	9,359
Shasta	142	277	870	1,664
Sierra	1	3	3	22
Siskiyou	30	53	159	282
Solano	1,297	2,020	7,202	15,525
Sonoma	1,549	2,052	10,103	20,564
Stanislaus	506	819	3,038	6,914
Sutter	44	60	321	867
Tehama	40	50	298	538
Trinity	3	8	37	80
Tulare	283	414	1,689	3,162
Tuolumne	46	79	320	886
Ventura	2,618	3,338	15,012	35,956
Yolo	278	475	1,759	4,135
Yuba	118	173	276	553

Source: NREL

Table D-6: County-by-county results for total DC fast chargers

County	2023	2025	2030	2035
Alameda	355	893	2,059	4,196
Alpine	0	1	1	4
Amador	7	13	39	89
Butte	4	11	36	80
Calaveras	5	6	18	43
Colusa	5	11	28	76
Contra Costa	147	425	1,391	2,873
Del Norte	1	1	4	9
El Dorado	9	28	120	266
Fresno	28	52	203	516
Glenn	1	3	4	6
Humboldt	19	40	124	349
Imperial	7	17	37	78
Inyo	6	10	40	127
Kern	44	105	230	559
Kings	8	32	60	153
Lake	14	27	125	287
Lassen	1	3	6	16
Los Angeles	1,277	3,284	8,601	20,201
Madera	8	13	36	82
Marin	53	51	295	690
Mariposa	2	1	7	21
Mendocino	5	18	100	205

Merced	27	62	127	362
Modoc	0	0	0	1
Mono	0	0	4	10
Monterey	32	87	251	644
Napa	47	84	321	644
Nevada	6	11	43	78
Orange	407	1,204	3,331	6,401
Placer	38	91	236	664
Plumas	0	1	2	6
Riverside	252	597	1,258	2,669
Sacramento	125	290	817	1,904
San Benito	35	96	206	487
San Bernardino	164	367	1,116	2,516
San Diego	437	999	3,184	6,658
San Francisco	123	285	692	1,431
San Joaquin	114	273	556	1,153
San Luis Obispo	21	35	188	432
San Mateo	164	374	1,032	2,224
Santa Barbara	83	134	391	988
Santa Clara	543	1,284	2,490	5,609
Santa Cruz	47	88	260	593
Shasta	5	12	47	86
Sierra	0	0	1	2
Siskiyou	2	6	11	26
Solano	148	282	435	1,111
Sonoma	109	220	738	1,688
Stanislaus	53	93	255	536
Sutter	7	11	31	59
Tehama	3	6	18	49
Trinity	2	4	2	9
Tulare	16	23	79	166
Tuolumne	2	7	18	51
Ventura	149	202	1,012	2,286
Yolo	13	45	94	238
Yuba	1	25	22	59

Source: NREL

Table D-7: Statewide annual charger totals 2025-2028 AATE3

Charger and location	2025	2026	2027	2028
Single-family housing Level 1	703,993	706,874	848,494	1,011,034
Single-family housing Level 2	1,078,200	1,462,310	1,764,791	2,085,154
Multi-family housing Level 1	21,738	27,156	40,569	59,845
Multi-family housing Level 2	26,284	44,350	66,616	97,440

Shared Private Office	102,091	124,766	154,123	174,920
Public Office	31,413	40,247	53,146	63,607
Shared Private Retail	6,283	10,062	15,944	22,263
Public Retail	23,161	34,648	48,341	66,756
Shared Private Other	7,853	12,074	18,601	25,443
Public Other	23,161	36,661	50,998	73,117
DCFC 150 or less	2,482	3,105	3,319	3,304
DCFC 250	5,428	6,978	7,304	8,005
DCFC 350	4,432	8,201	10,417	12,965

Source: NREL

Table D-8: Statewide annual charger totals 2029-2032 AATE3

Charger and location	2029	2030	2031	2032
Single-family housing Level 1	1,189,007	1,373,064	1,396,499	1,619,066
Single-family housing Level 2	2,407,927	2,728,362	3,430,800	3,966,763
Multi-family housing Level 1	86,430	121,975	122,957	141,213
Multi-family housing Level 2	138,185	191,346	238,476	273,139
Shared Private Office	186,602	206,123	243,017	255,798
Public Office	73,177	85,885	108,008	124,780
Shared Private Retail	29,271	34,354	48,603	62,390
Public Retail	95,365	139,146	165,050	201,842
Shared Private Other	36,589	47,237	64,805	81,107
Public Other	99,024	143,440	175,851	214,320
DCFC 150 or less	3,498	4,268	4,442	4,629
DCFC 250	9,288	10,731	12,776	14,526
DCFC 350	15,059	17,832	22,853	27,842

Source: NREL

Table D-9: Statewide annual charger totals 2033-2035 AATE3

Charger and location	2033	2034	2035
Single-family housing Level 1	1,850,110	2,088,838	2,328,896
Single-family housing Level 2	4,531,599	5,116,389	5,717,384
Multi-family housing Level 1	159,717	178,328	196,388
Multi-family housing Level 2	308,847	344,838	380,628
Shared Private Office	269,260	285,847	293,692
Public Office	145,546	168,145	195,795
Shared Private Retail	80,050	100,887	129,225
Public Retail	235,210	280,771	323,516
Shared Private Other	101,882	134,516	164,468
Public Other	249,765	297,586	347,011
DCFC 150 or less	4,599	4,774	4,910
DCFC 250	16,622	19,434	21,462
DCFC 350	32,483	39,250	46,396

Source: NREL

APPENDIX E: EVI-Pro 3 Alternative Futures

Table E-1: Summary of Alternative Future scenarios

Scenario Name	Modification from Baseline Scenario
Higher home access	Home charging access increased to 76% (66% in baseline)
Lower home access	Home charging access decreased to 56% (66% in baseline)
Gas station model	Drivers without home charging use DCFC as first choice
Low work access	Work charging access decreased to 40% (50% in baseline)
More free public Level 2	Free public Level 2 increased to 40% (20% in baseline)
Solar priority	Daytime charging prioritized by all drivers
Home grid: unmanaged	All home charging events start immediately upon arrival at home
Home grid: pure TOU	All home charging events start at beginning of off-peak rate
Home grid: as late as possible	All home charging events start as late as possible

Source: CEC Staff and NREL

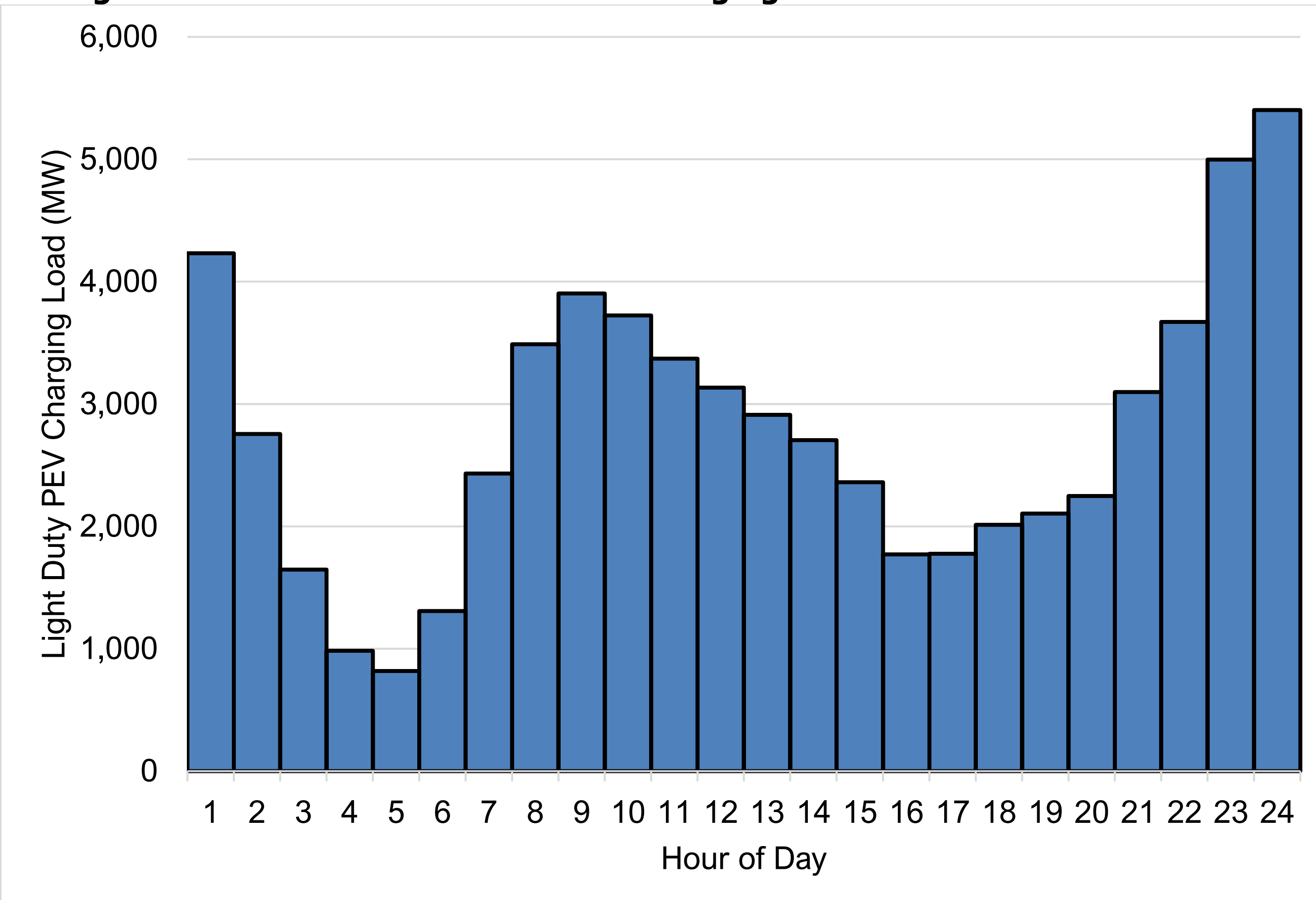
Table E-2: Alternative Future results for 2030

Location	Multi-Family Home Level 1 and Level 2	Public and Work Level 2	DCFC
Baseline	313,321	656,184	32,831
Higher home access	443,779	616,333	28,677
Lower home access	182,624	723,687	35,201
Gas station model	313,748	253,755	96,082
Low work access	313,322	578,357	36,883
More free public Level 2	312,442	899,381	30,511
Solar priority	310,000	1,052,338	59,581
Home grid: unmanaged	313,293	659,837	32,123
Home grid: pure TOU	313,321	656,184	32,831
Home grid: as late as possible	313,321	656,184	32,831

Source: CEC Staff and NREL

This appendix contains load curves for all alternative future scenarios. For reference, Figure E-1 shows the load shape on a typical summer day in 2030 for the CAISO planning area using the CEC's Energy Demand Forecast's Electric Vehicle Infrastructure Load Model. The EV Load Model distributes charging load over the course of a forecast year based on time-of-use rates and changes in the type of charging over time (e.g., home charging vs. away-from-home charging). These load shapes are used as part of the broader IEPR planning forecast to inform utility plans for resource procurement, distribution planning, and transmission planning.

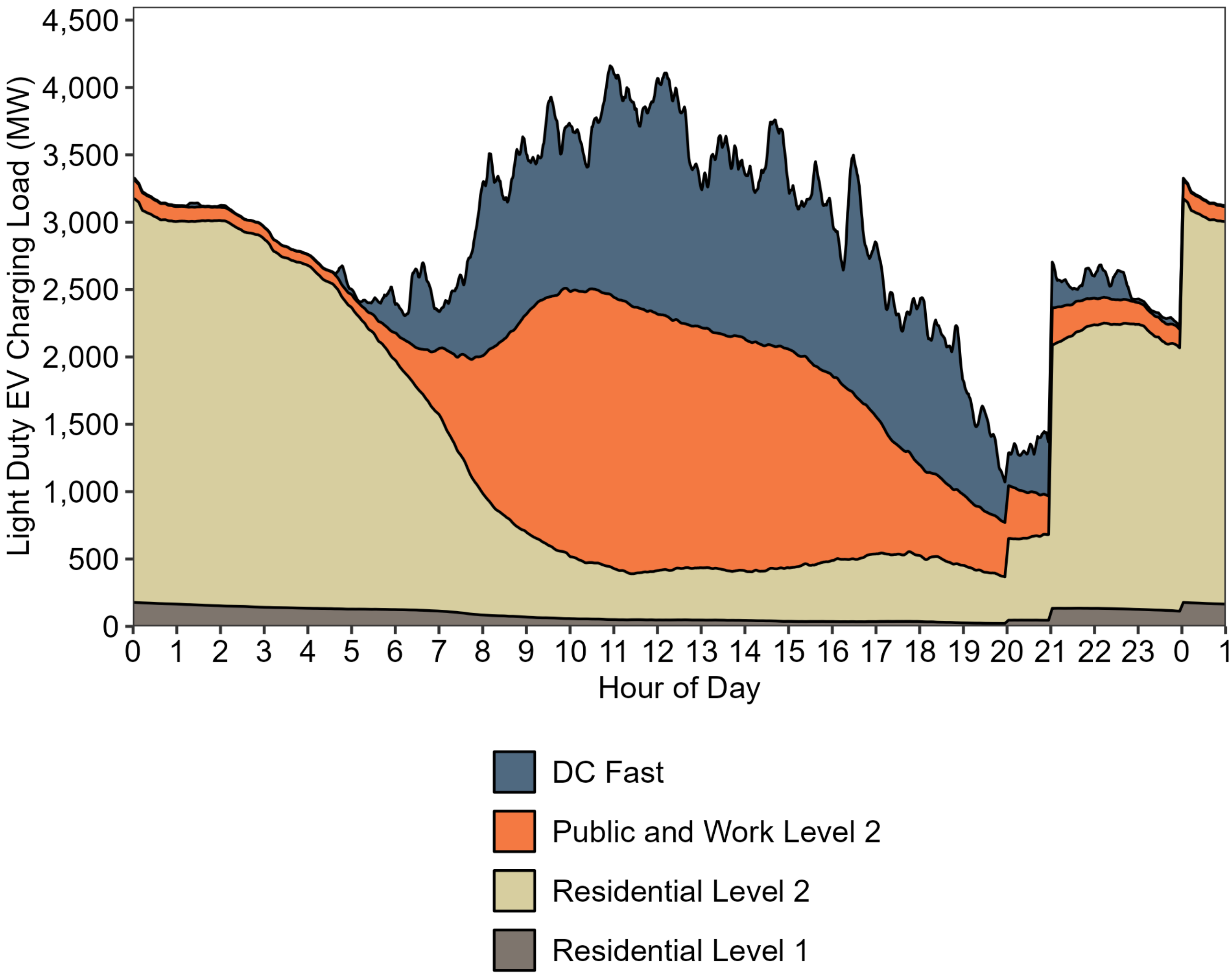
Figure E-1 EAD load curve from PEV charging in 2030 under AATE3 scenario



LDV charging load modeled by the CEC's Energy Assessment Division for the IEPR shows a large proportion of charging moved away from late afternoon and early evening to minimize strain on the grid and California's energy supply.

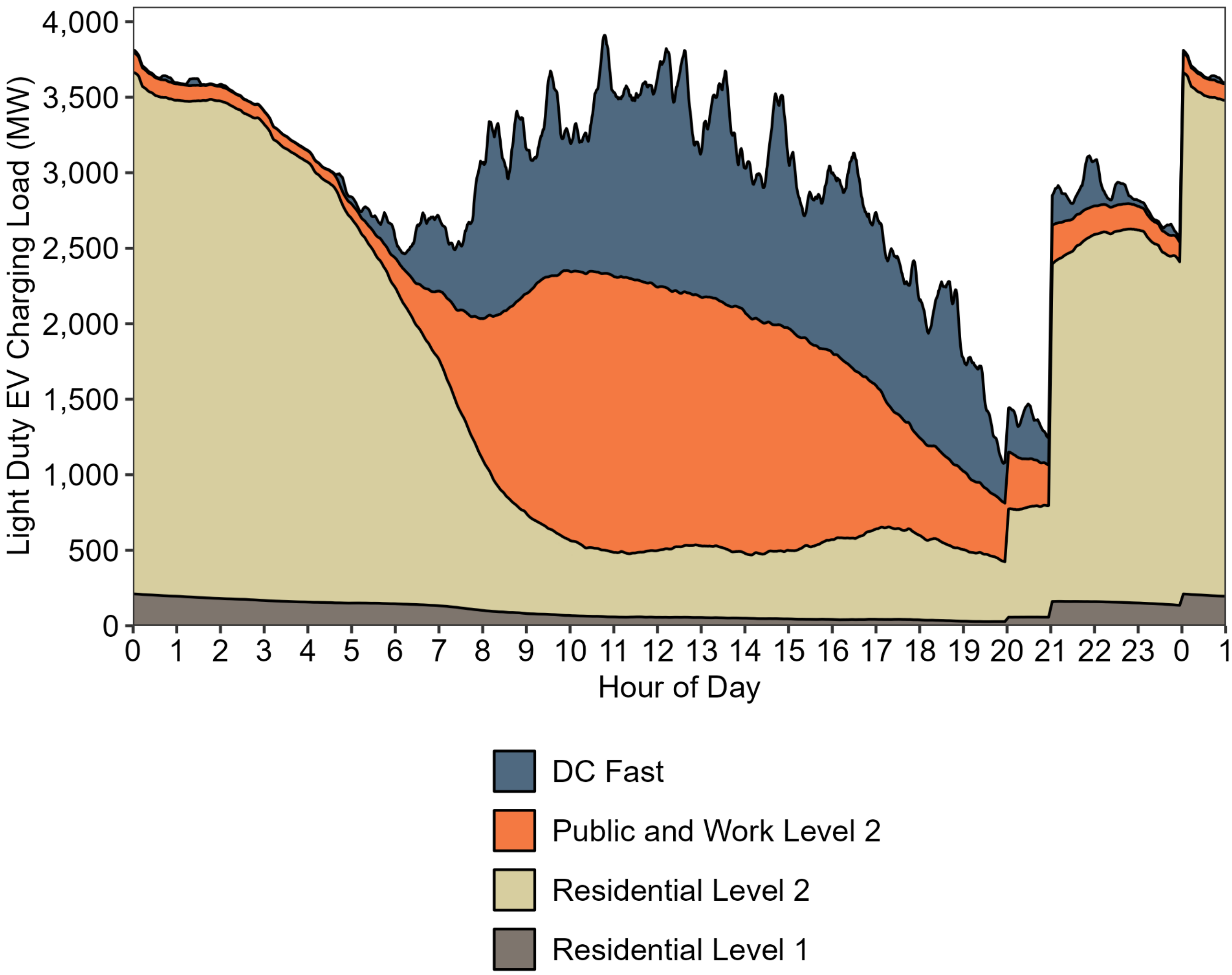
Source: CEC Staff

Figure E-2: LDV charging load under the primary scenario



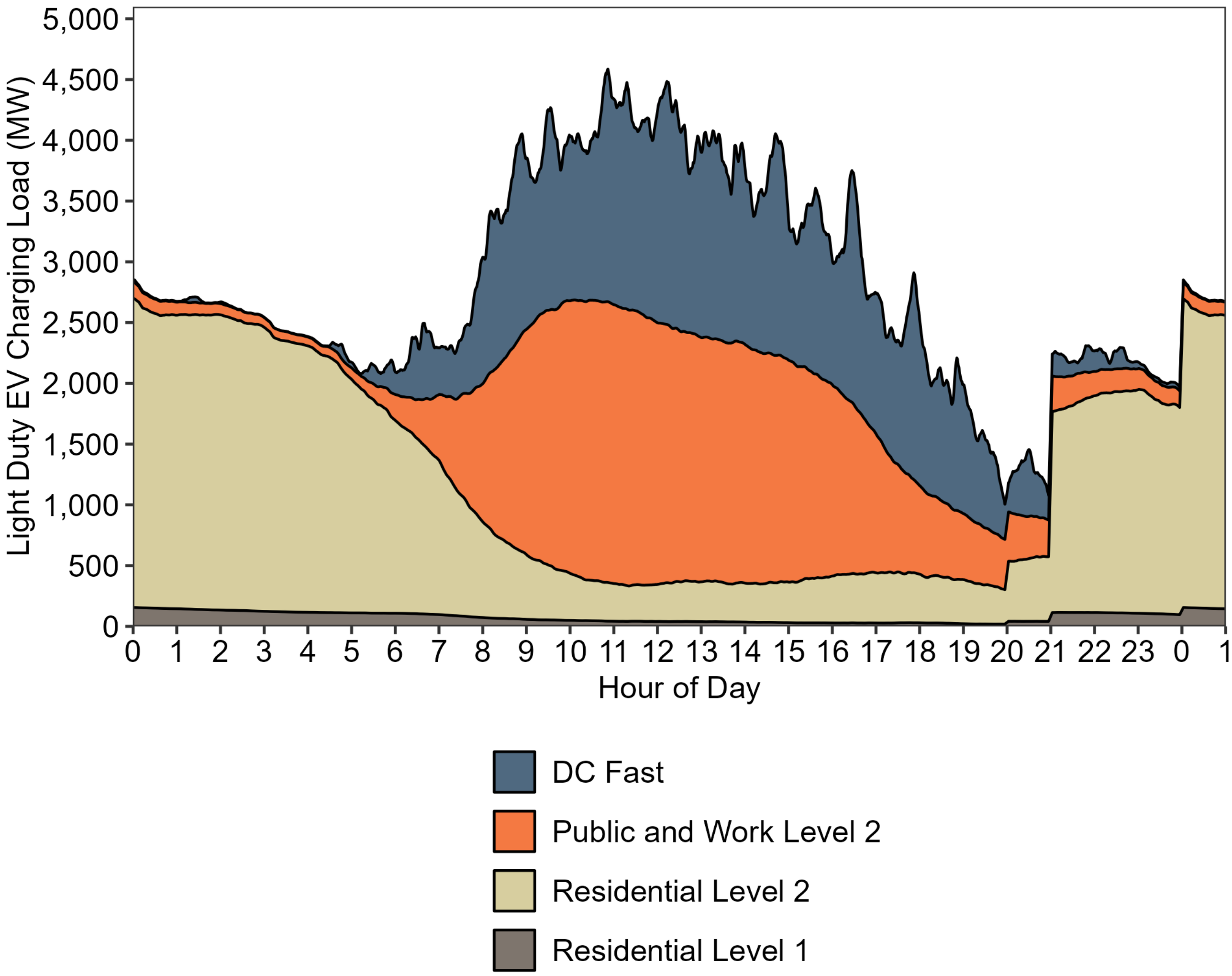
Source: CEC Staff and NREL

Figure E-3: LDV charging load curve under high home access scenario



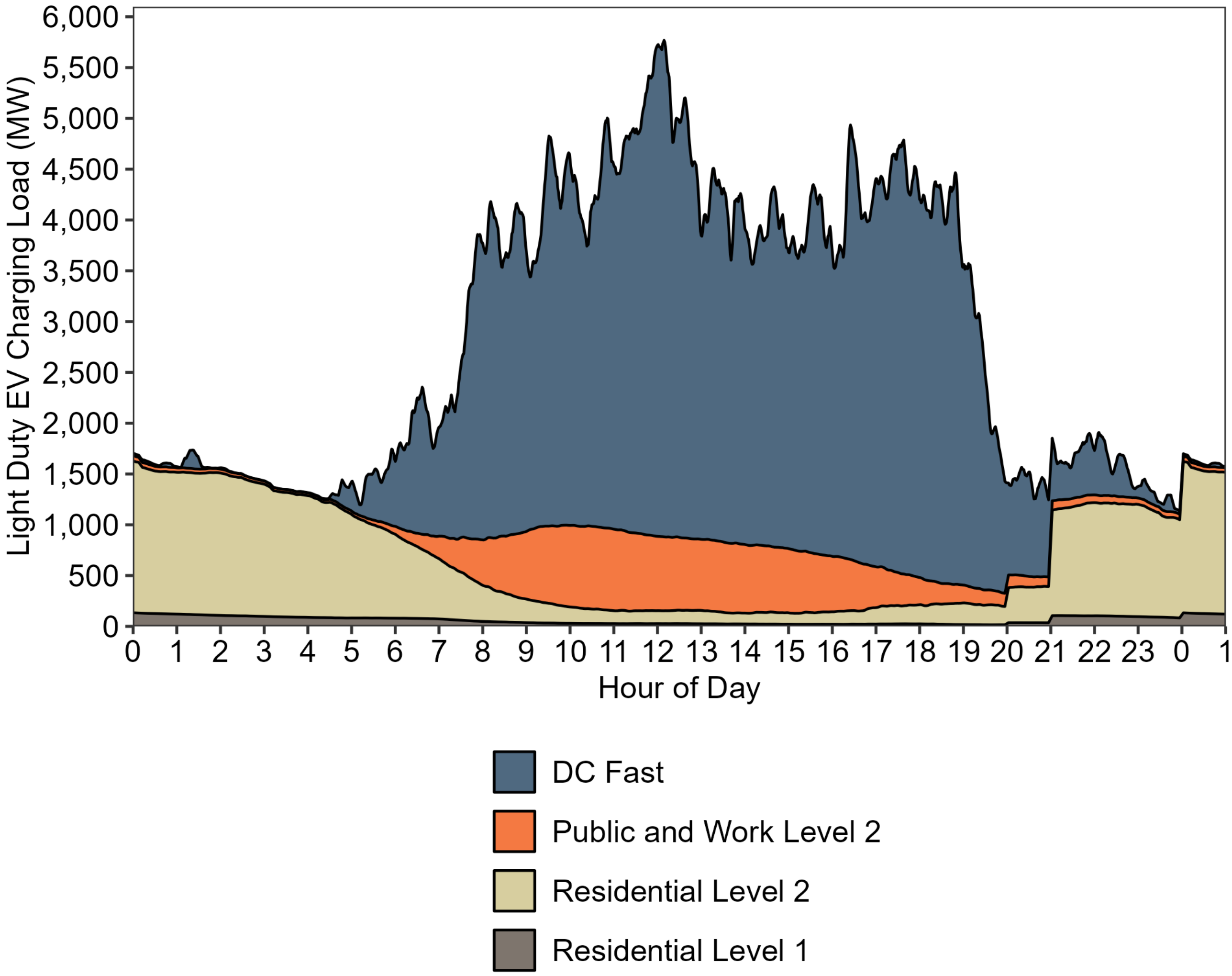
Source: CEC Staff and NREL

Figure E-4: LDV charging load curve under low home access scenario



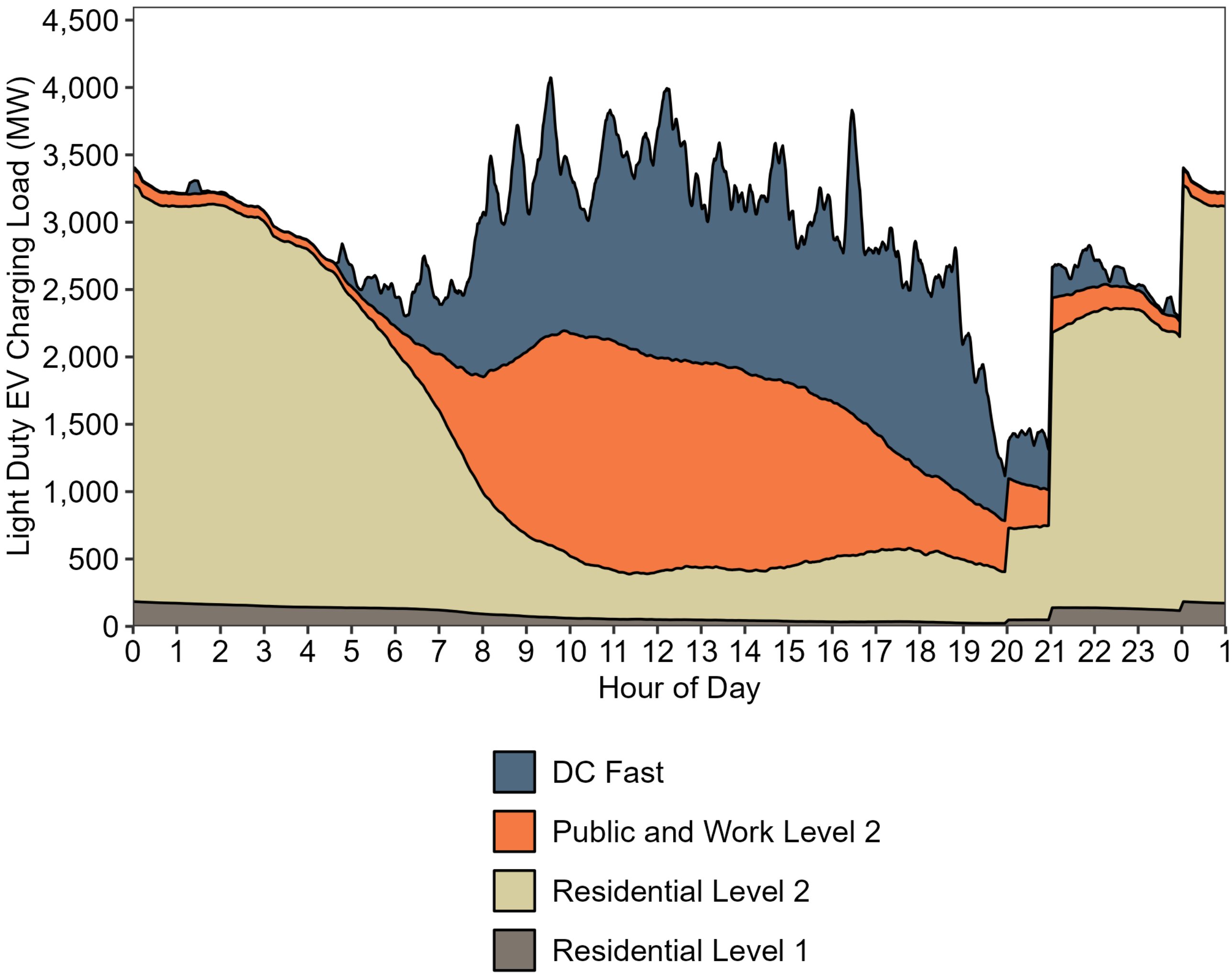
Source: CEC Staff and NREL

Figure E-5: LDV charging load curve under gas station model scenario



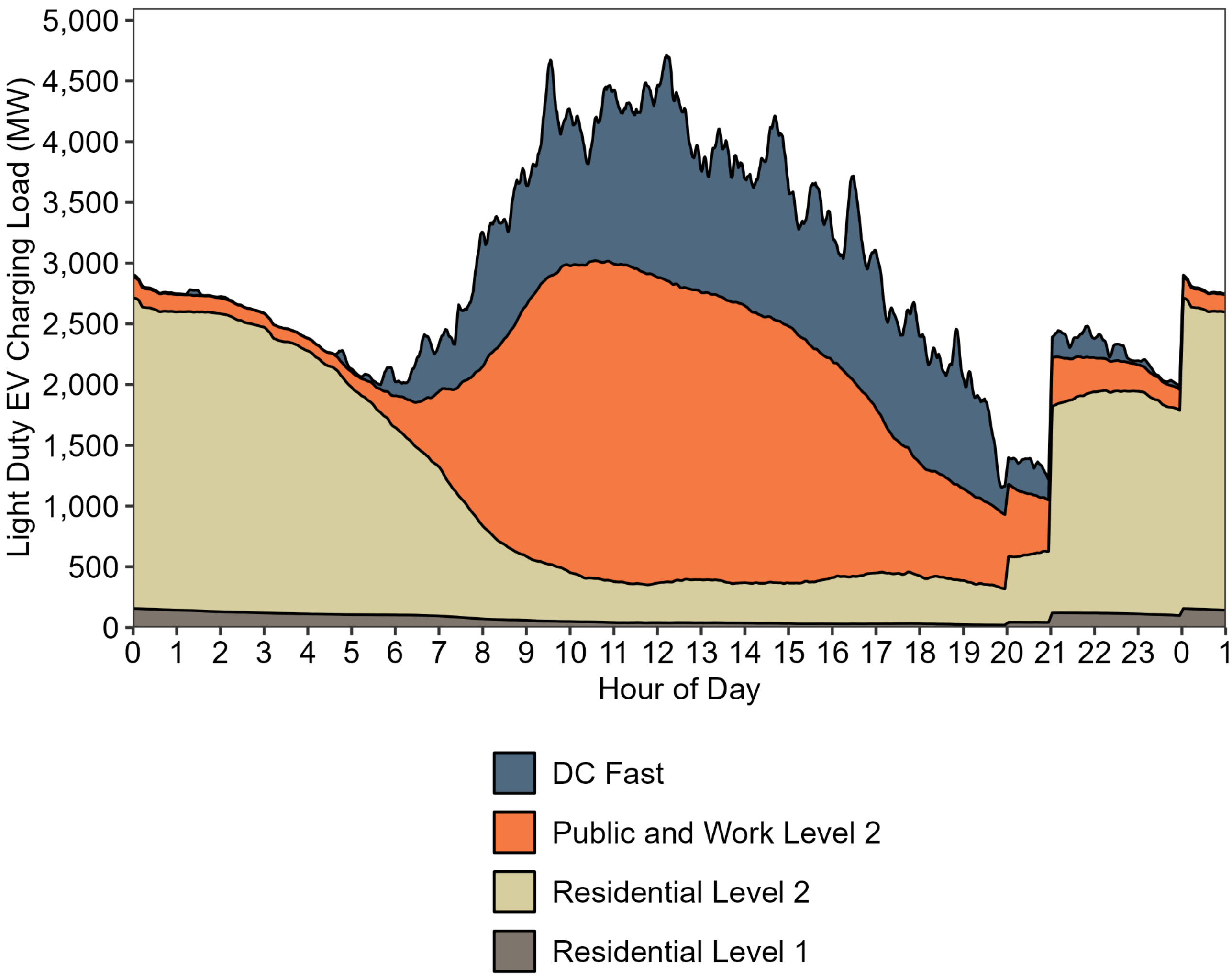
Source: CEC Staff and NREL

Figure E-6: LDV charging load curve under low work access scenario



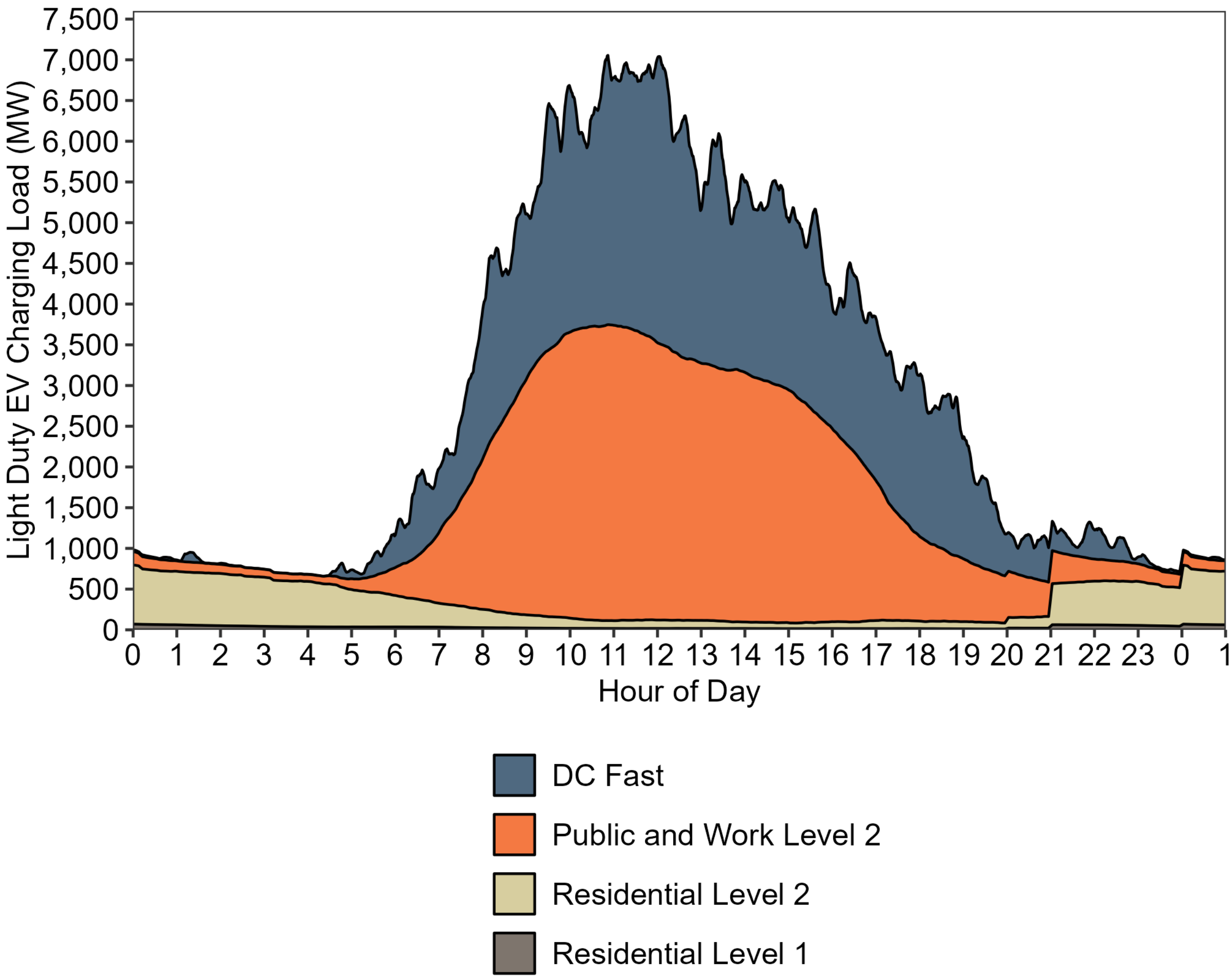
Source: CEC Staff and NREL

Figure E-7: LDV charging load curve under more free public Level 2 scenario



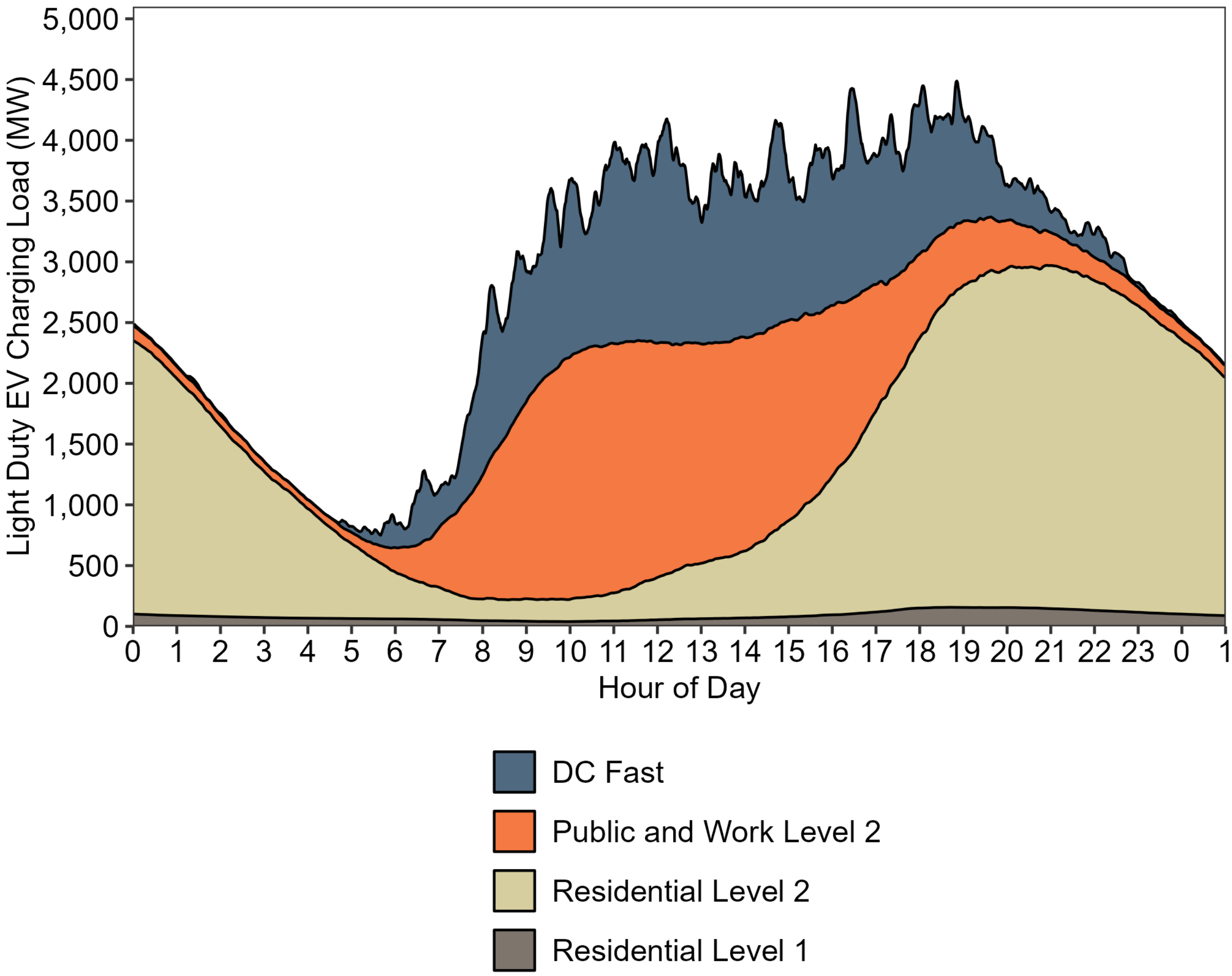
Source: CEC Staff and NREL

Figure E-8: LDV charging load curve under solar priority scenario



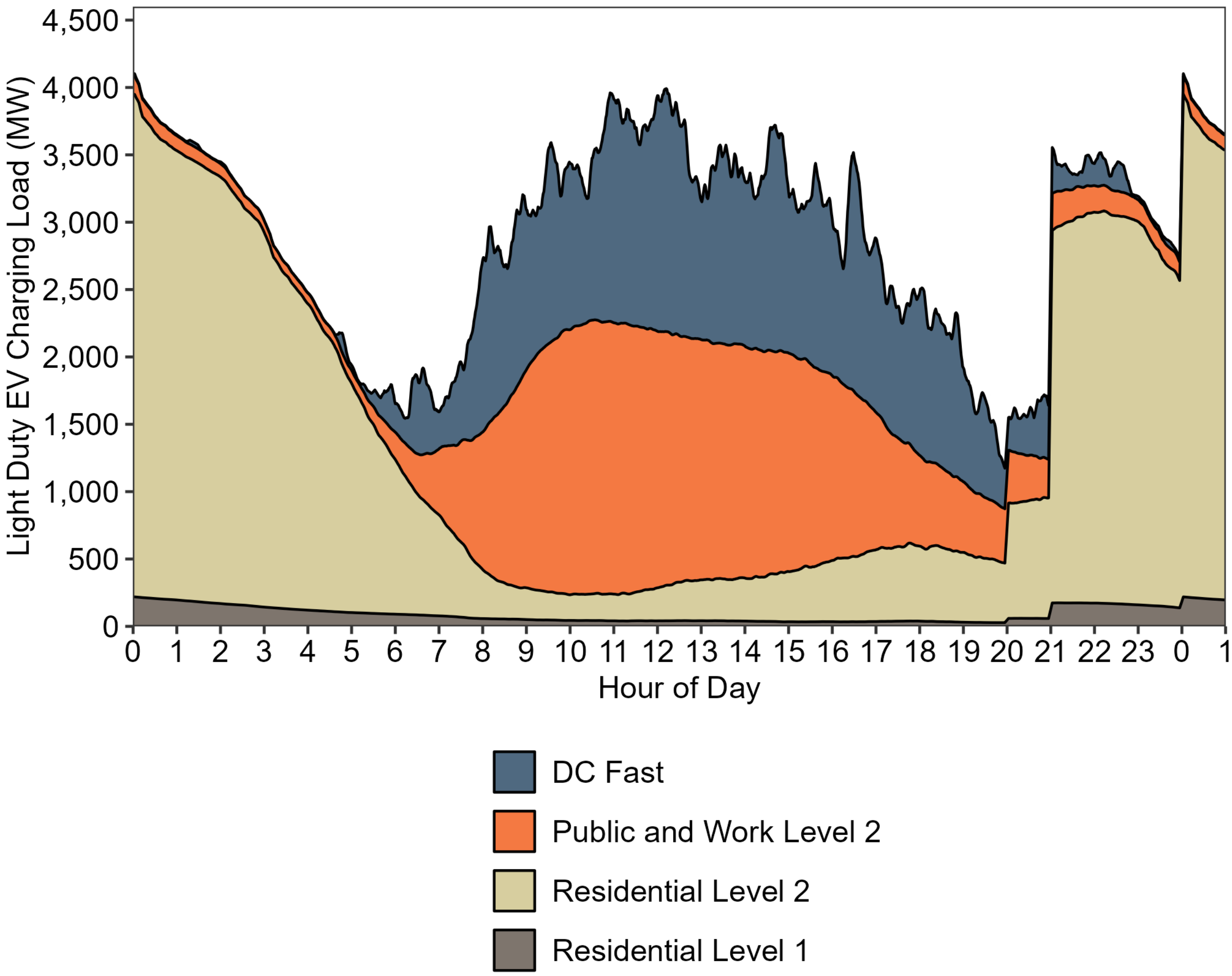
Source: CEC Staff and NREL

Figure E-9: LDV charging load curve under home grid: unmanaged scenario



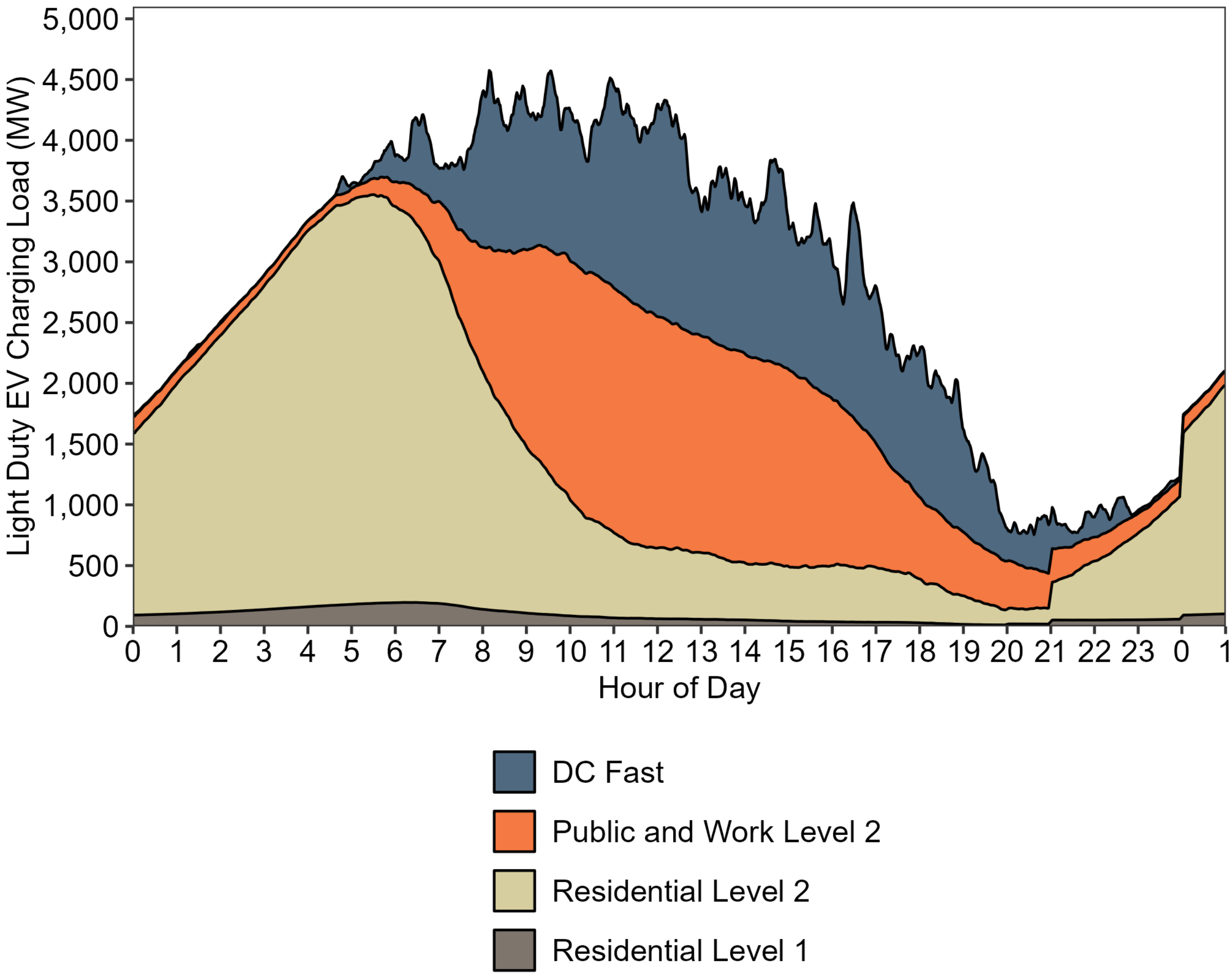
Source: CEC Staff and NREL

Figure E-10: LDV charging load curve under home grid: pure TOU scenario



Source: CEC Staff and NREL

Figure E-11: LDV charging load curve under home grid: as late as possible scenario



Source: CEC Staff and NREL

APPENDIX F: WIRED Annual Results and Regional Maps

This appendix provides detailed results from the WIRED model on DCFC infrastructure needed to support PEVs driving for TNCs under the Clean Miles Standard through 2035. This model is introduced in Chapter 5. Table F-1 contains the total number of DC fast chargers needed to support PEVs driving for TNCs statewide and in each of the three areas of interest.

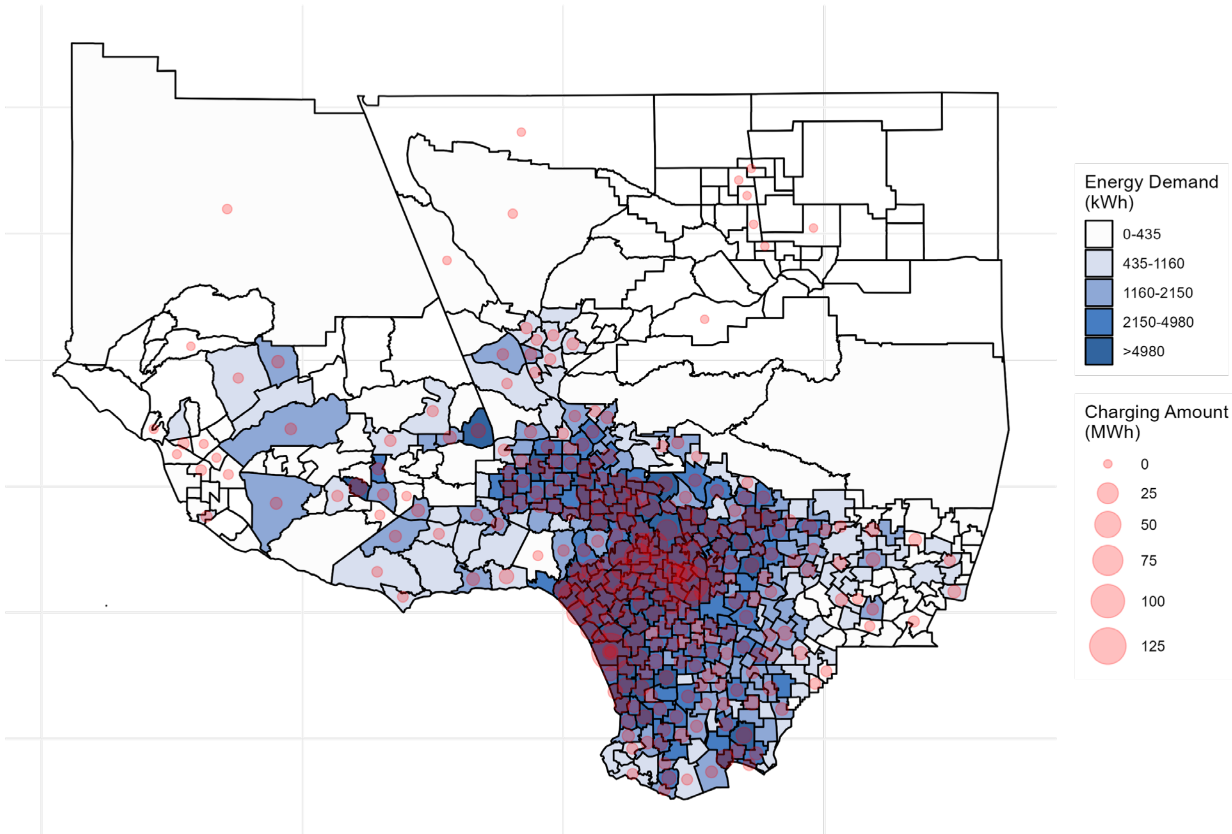
Table F-1: WIRED model assessment of annual DCFC charger needs for PEVs driving for TNCs under the Clean Miles Standard

Year	Los Angeles	San Diego	San Francisco	Statewide Total
2023	0	0	0	0
2024	0	0	0	0
2025	2	0	0	3
2026	15	3	32	63
2027	63	8	103	218
2028	141	14	182	421
2029	253	25	292	713
2030	392	36	410	1,048
2031	520	43	519	1,353
2032	636	70	624	1,663
2033	759	89	728	1,970
2034	799	103	775	2,096
2035	820	106	781	2,134

Source: CEC and UC Davis

Figures C-1, C-2, and C-3 show energy demand and total amount of charging performed in each aggregated traffic analysis zone in the Los Angeles, San Diego, and San Francisco Bay Areas. The model assigns charging events to existing chargers where possible, and identifies new charger needs where none are available.

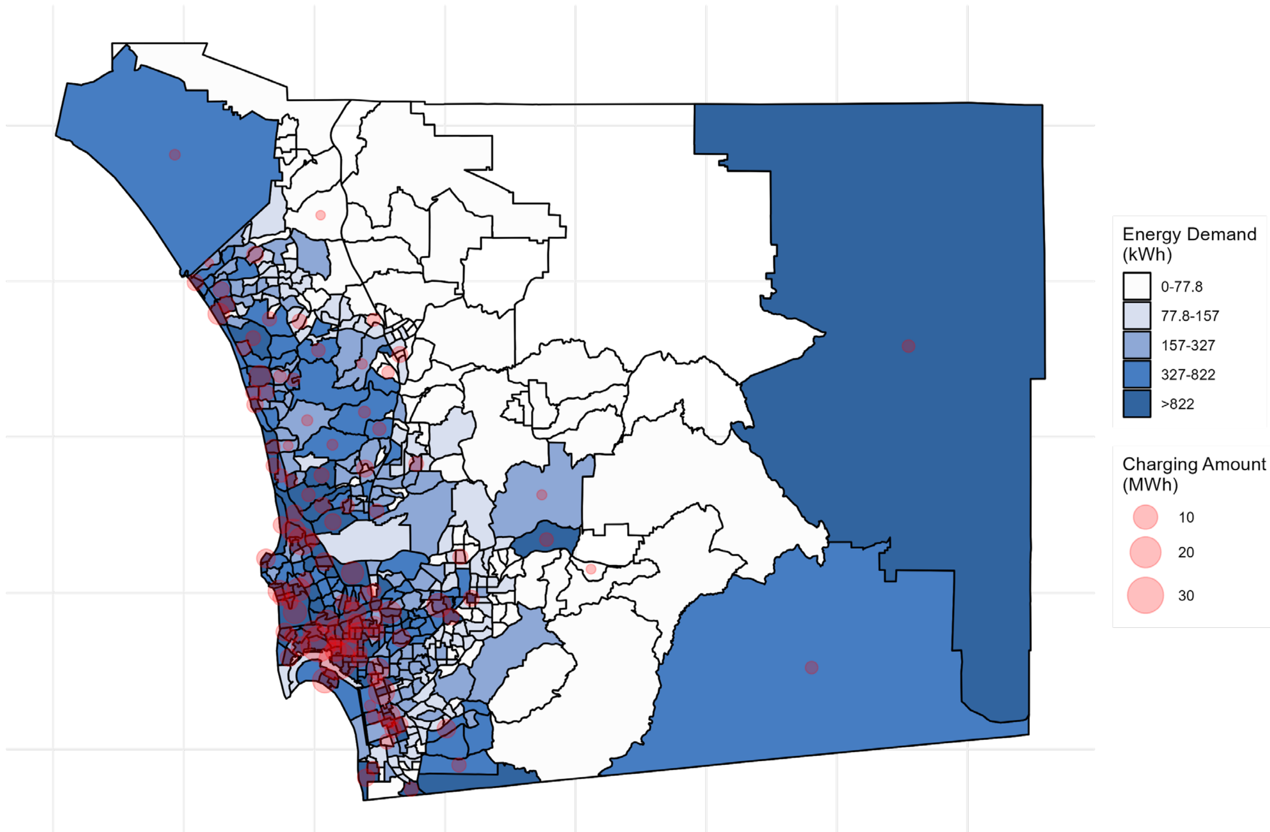
Figure F-1: Energy demand from TNC PEVs and total charging amount provided to these vehicles in the Los Angeles area



TNC use is concentrated in central part of Los Angeles, and TNC vehicles will require the most new chargers in this area, but TNCs are used throughout the region and chargers may need to be installed for these vehicles throughout the region.

Source: UC Davis

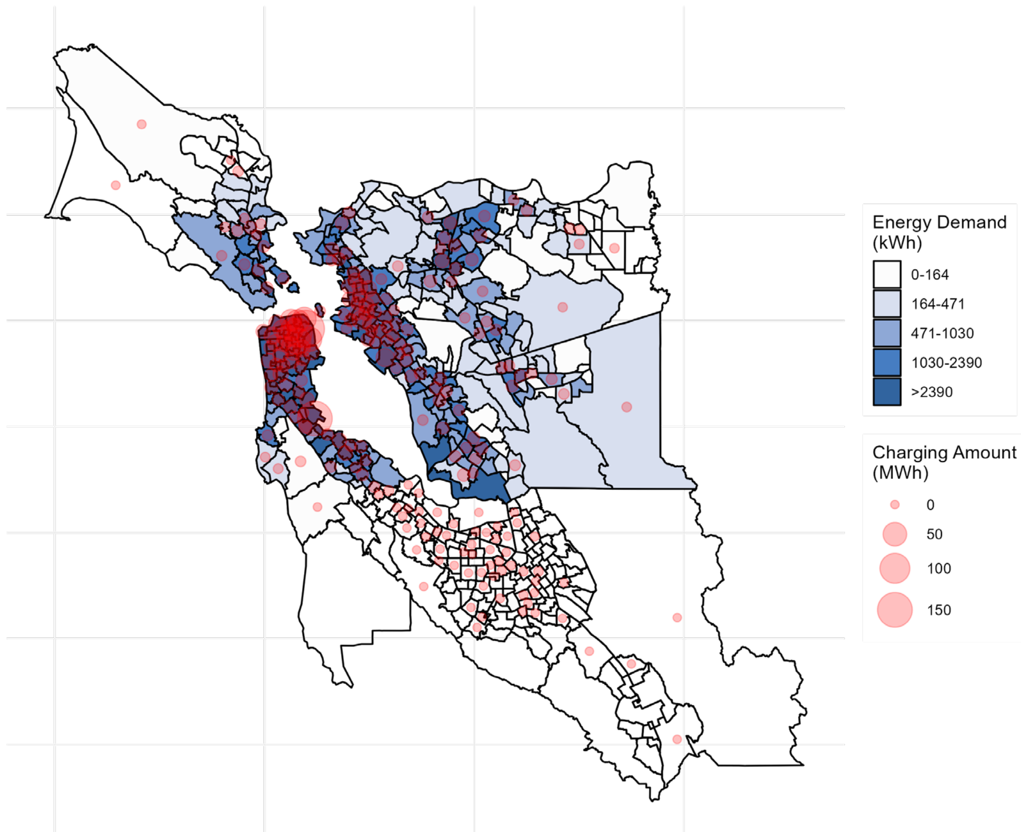
Figure F-2: Energy demand from TNC PEVs and total charging amount provided to these vehicles in the San Diego area



TNC use is concentrated in the coastal part of San Diego County, and TNC vehicles will require the most new chargers in this area. The eastern part of the county also has considerable TNC energy demand and may require additional charging.

Source: UC Davis

Figure F-3: Energy demand from TNC PEVs and total charging amount provided to these vehicles in the San Francisco Bay Area

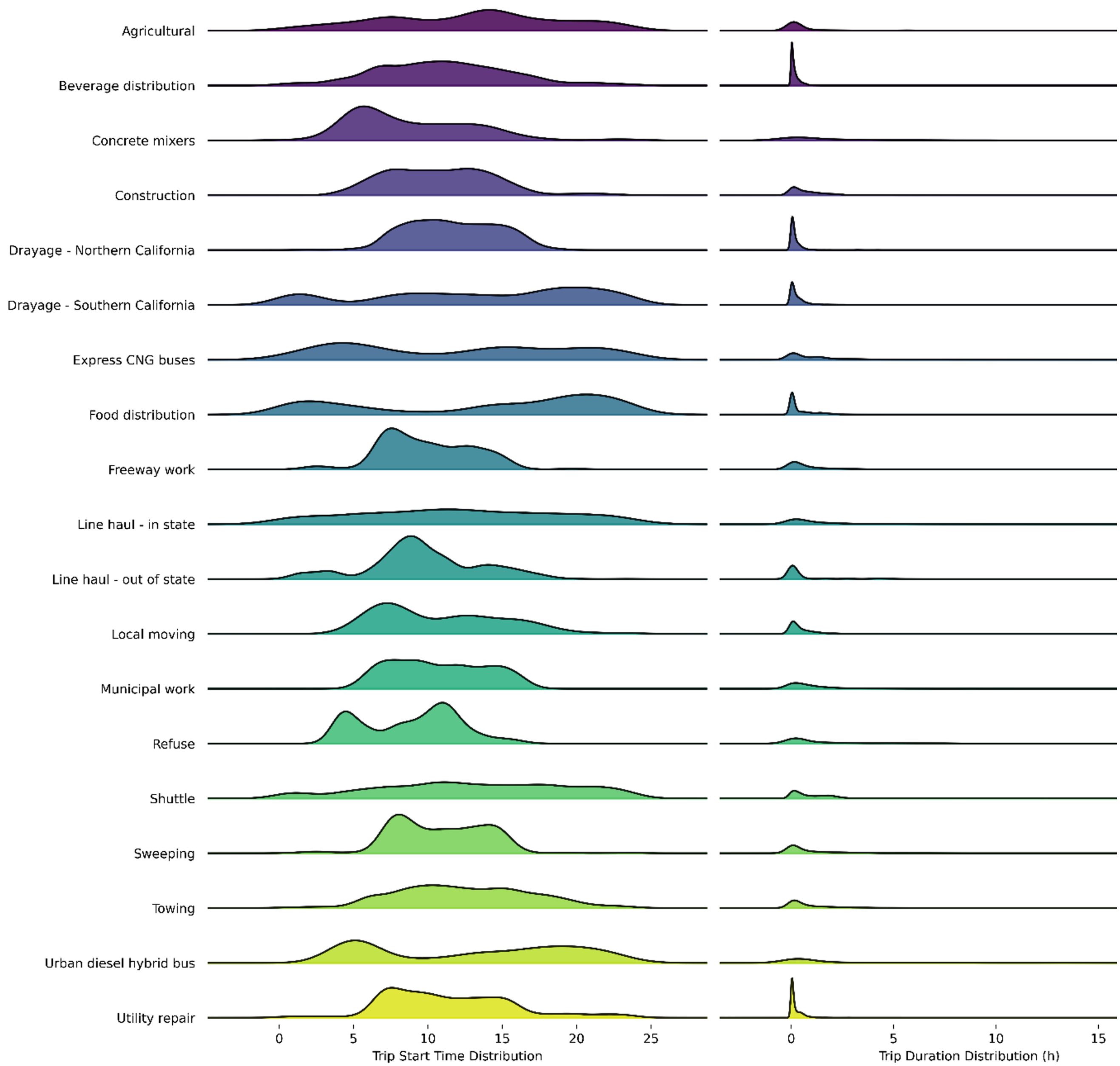


TNC use in the San Francisco Bay Area is highest in San Francisco. TNCs are used throughout the region and chargers may need to be installed for these vehicles throughout the region.

Source: UC Davis

APPENDIX G:
HEVI-Load Inputs and Parameters

Figure G-1: Statistical Distribution of Start Times and Durations for Trips in HEVI-LOAD



Statistical distribution of real-world GPS location data used to calibrate the CSTDM trips. Trip start times are shown on the left-hand side and trip durations are shown on the right-hand side.

Source: LBNL

Table G-1: Energy efficiency, daily miles, and vehicle counts by vehicle class

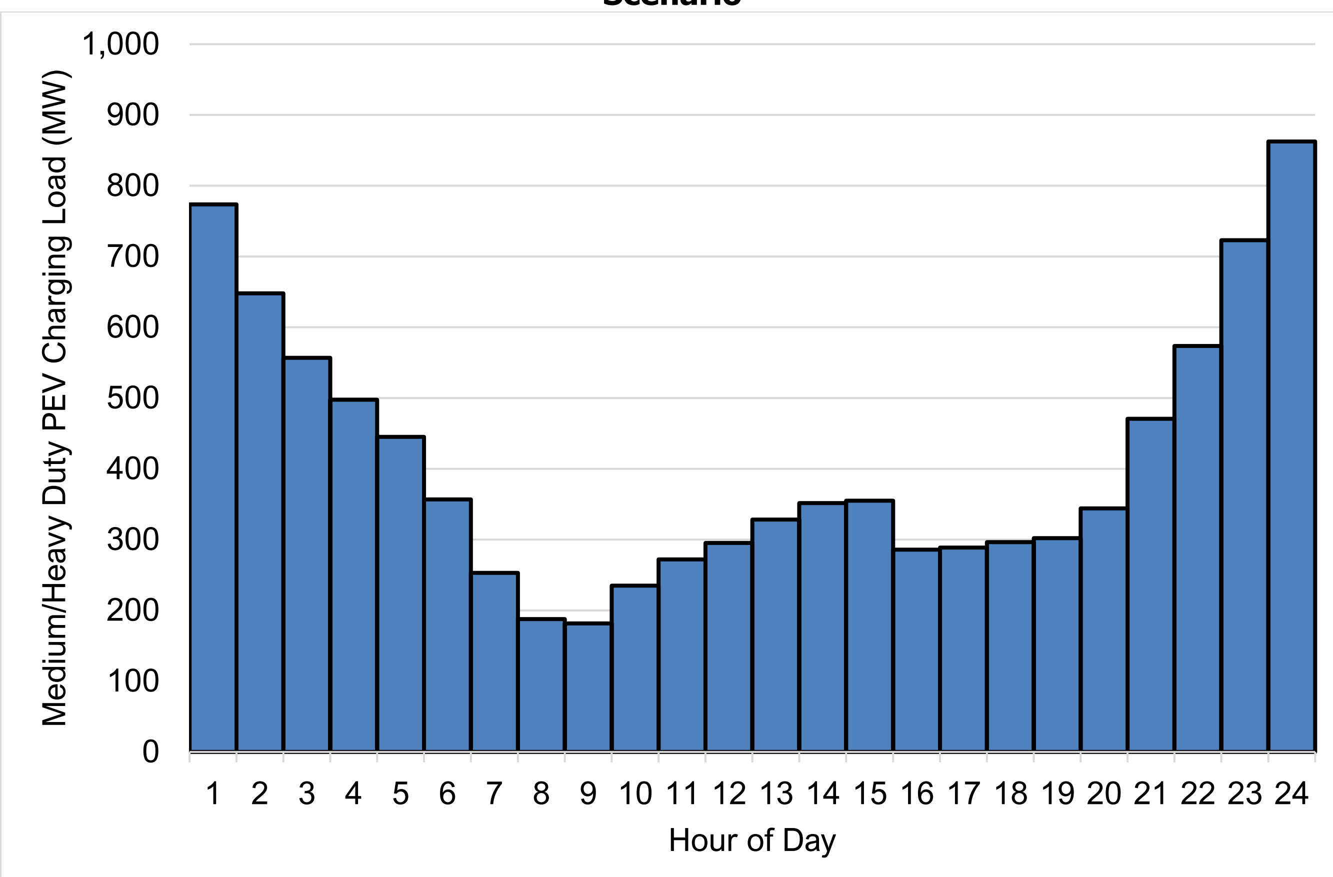
EMFAC Class	Daily miles per vehicle	kWh / mile	kWh per vehicle per day	AATE3 vehicles 2025	AATE3 vehicles 2030	AATE3 vehicles 2035
LHD2 (Class 3)	51.8	0.6	31.1	6,196	26,932	71,755
T6 CAIRP Class 4	83.0	1.1	89.2	3	30	84
T6 CAIRP Class 5	92.2	1.1	99.1	4	57	159
T6 CAIRP Class 6	53.7	1.1	57.7	13	129	342
T6 CAIRP Class 7	219.2	1.1	235.7	28	281	793
T6 Instate Delivery Class 4	38.6	1.1	40.8	583	2,908	6,840
T6 Instate Delivery Class 5	38.6	1.1	40.8	473	2,860	7,046
T6 Instate Delivery Class 6	38.6	1.1	40.7	2,465	12,937	23,789
T6 Instate Delivery Class 7	52.7	1.1	55.6	1	1,466	4,221
T6 Instate Other Class 4	47.3	1.1	50.0	727	3,817	10,951
T6 Instate Other Class 5	47.7	1.1	50.3	2,007	15,505	38,061
T6 Instate Other Class 6	47.5	1.1	50.1	1,237	7,809	18,236
T6 Instate Other Class 7	65.1	1.1	68.7	255	3,155	8,672
T6 Instate Tractor Class 6	63.2	1.1	66.7	4	44	113
T6 Instate Tractor Class 7	78.8	1.1	83.2	0	1,982	4,892
T6 Public Class 4	42.3	1.1	48.0	301	1,660	3,033
T6 Public Class 5	42.3	1.1	48.7	447	2,948	5,270
T6 Public Class 6	41.9	1.1	47.8	215	1,393	2,511
T6 Public Class 7	56.7	1.1	64.5	531	2,643	5,239
T6 Utility Class 5	42.6	1.1	46.4	281	1,543	3,354
T6 Utility Class 6	42.6	1.1	46.5	31	181	372
T6 Utility Class 7	57.2	1.1	62.2	11	86	248
T6TS (Class 7)	82.9	1.1	91.5	4,159	12,389	20,949
T7 CAIRP Class 8	220.9	1.8	400.3	0	0	8,288
T7 Other Port Class 8	325.5	1.8	591.3	232	426	618
T7 POAK Class 8	111.6	1.8	203.1	654	1,236	1,921
T7 POLA Class 8	171.8	1.8	306.9	2,858	6,188	7,637
T7 Public Class 8	56.8	1.9	107.9	446	2,962	5,371
T7 Concrete Mix Class 8	78.4	1.8	141.4	0	319	1,936
T7 Single Dump Class 8	76.2	1.8	137.8	40	1,418	5,035
T7 Single Other Class 8	63.3	1.8	114.3	45	5,162	15,236
T7 SWCV Class 8	64.3	1.8	117.1	120	3,037	10,209
T7 Tractor Class 8	77.2	1.8	139.5	2,298	30,498	67,191
T7 Utility Class 8	56.3	1.8	103.5	11	188	489
T6 OOS Class 4	47.3	1.1	50.0	4	45	125
T6 OOS Class 5	47.7	1.1	50.3	4	56	155
T6 OOS Class 6	47.5	1.1	50.1	16	145	386
T6 OOS Class 7	65.1	1.1	68.7	0	129	369
T7 NNOOS Class 8	77.2	1.8	139.5	0	0	11,129
T7 NOOS Class 8	77.2	1.8	139.5	0	0	3,643

Source: CEC Staff and LBNL

APPENDIX H: HEVI-Load Detailed Results

Managing the charging loads from an increasing number of MDHD vehicles will be critical for utility investments in grid planning and readiness. The load shape shown in Figure H-1 is for a typical summer day in 2030 for the CAISO planning area using the CEC's Energy Demand Forecast's Electric Vehicle Infrastructure Load Model. The EV Load Model distributes charging load over the course of a forecast year based on time-of-use rates and changes in the type of charging over time. These load shapes are used as part of the broader IEPR planning forecast to inform utility plans for resource procurement, distribution planning, and transmission planning. In this model, the total daily MDHD charging power amounts to 12,135 MW while HEVI-LOAD projects a total daily amount of about 14,100 MW. The 17% difference between the two models is due to their inherent design and overall goal. The EV Load Model is used in the Energy Assessment Division's Transportation Energy Demand Forecast and Integrated Energy Policy Report process for utility grid planning, while HEVI-LOAD's approach centers around truck travel and charging behavior. HEVI-LOAD uses existing trip data to determine granular energy demand and optimal locations for charging infrastructure without disrupting a vehicle's normal operational duty-cycle.

Figure H-1: EAD Load Curve from MDHD BEV Charging in 2030 under AATE3 Scenario



The CEC's EV Load Model shows a MDHD charging load shape that is similar to the unmanaged charging case modeled by HEVI-LOAD.

Source: CEC staff

Table H-1: Statewide charger totals from HEVI-Load under the AATE3 primary scenario

Power (kW)	Location Type	2025	2030	2035
20	Depot	3,714	19,001	45,510
50	Depot	6,567	32,940	76,964
100	Depot	6,157	30,473	70,318
150	Depot	5,406	27,083	63,502
Total	**Depot**	**21,844**	**109,497**	**256,294**
350	Public	1,658	4,226	6,553
500	Public	287	542	829
750	Public	177	338	478
1000	Public	106	236	339
1500	Public	90	185	256
Total	**Public**	**2,318**	**5,527**	**8,455**
Total	**All**	**24,162**	**115,024**	**264,749**

Source: LBNL

Table H-2: Statewide charger totals for 2025, 2030, and 2035 under the High-Speed Depot alternative future scenario

Charger Type	2025	2030	2035
20 kW Depot	2,971	15,201	36,408
50 kW Depot	5,254	26,352	61,571
100 kW Depot	4,926	24,378	56,254
150 kW Depot	4,325	21,666	50,802
350 kW Depot Replacement	1,198	3,754	6,800
500 kW Depot Replacement	207	481	860
750 kW Depot Replacement	128	300	496
1000 kW Depot Replacement	77	210	352
1500 kW Depot Replacement	65	164	266
350 kW En Route	1,658	4,226	6,553
500 kW En Route	287	542	829
750 kW En Route	177	338	478
1000 kW En Route	106	236	339
1500 kW En Route	90	185	256

Table H-3: County-by-county results for depot chargers (up to 150kW)

County	2025	2030	2035
Alameda	778	3,835	8,960
Alpine	0	12	33
Amador	28	156	295
Butte	139	621	1,488
Calaveras	23	134	332
Colusa	23	98	226
Contra Costa	568	2,727	6,392
Del Norte	12	57	136
El Dorado	84	477	1,032
Fresno	641	3,331	7,584

Glenn	37	195	461
Humboldt	60	250	587
Imperial	85	462	1,141
Inyo	16	60	159
Kern	730	3,760	8,789
Kings	154	697	1,652
Lake	24	190	402
Lassen	15	81	175
Los Angeles	5,351	26,932	63,496
Madera	150	824	1,780
Marin	101	617	1,497
Mariposa	17	72	165
Mendocino	42	238	617
Merced	205	880	2,148
Modoc	12	74	138
Mono	16	63	125
Monterey	250	1,082	2,506
Napa	80	385	927
Nevada	45	224	553
Orange	1,599	7,956	18,577
Placer	189	1,044	2,450
Plumas	15	63	153
Riverside	1,090	5,440	12,585
Sacramento	1,085	5,127	11,903
San Benito	50	223	483
San Bernardino	1,217	6,260	14,415
San Diego	1,727	8,628	20,522
San Francisco	719	3,523	8,324
San Joaquin	375	1,929	4,619
San Luis Obispo	112	623	1,487

San Mateo	445	2,189	5,308
Santa Barbara	224	1,060	2,458
Santa Clara	1,183	5,700	13,320
Santa Cruz	112	600	1,425
Shasta	81	442	974
Sierra	6	27	86
Siskiyou	23	137	287
Solano	250	1,212	2,808
Sonoma	293	1,357	3,397
Stanislaus	333	1,843	4,106
Sutter	42	327	661
Tehama	43	211	466
Trinity	5	31	41
Tulare	292	1,569	3,601
Tuolumne	32	160	371
Ventura	390	2,219	5,078
Yolo	147	692	1,725
Yuba	79	371	868

Source: LBNL

Table H-4: County-by-county results for public chargers (350kW to 1500kW)

County	2025	2030	2035
Alameda	92	223	476
Alpine	0	0	0
Amador	0	0	0
Butte	0	0	0
Calaveras	0	0	0
Colusa	18	49	73
Contra Costa	10	23	41
Del Norte	1	2	3
El Dorado	0	0	0
Fresno	99	231	362

Glenn	18	46	62
Humboldt	24	68	84
Imperial	37	89	140
Inyo	9	26	53
Kern	254	667	1,005
Kings	4	12	22
Lake	0	0	0
Lassen	7	18	30
Los Angeles	158	283	347
Madera	48	112	164
Marin	15	43	58
Mariposa	0	0	0
Mendocino	49	120	207
Merced	102	245	384
Modoc	0	0	0
Mono	1	4	4
Monterey	27	69	119
Napa	0	0	0
Nevada	3	8	15
Orange	23	60	66
Placer	23	58	111
Plumas	5	14	14
Riverside	144	377	582
Sacramento	35	94	144
San Benito	0	0	0
San Bernardino	280	589	935
San Diego	161	387	503
San Francisco	0	0	0
San Joaquin	167	359	514
San Luis Obispo	18	50	95

San Mateo	17	47	58
Santa Barbara	42	78	129
Santa Clara	27	65	97
Santa Cruz	0	0	0
Shasta	24	84	122
Sierra	0	0	0
Siskiyou	5	20	33
Solano	60	148	210
Sonoma	0	0	0
Stanislaus	56	128	215
Sutter	11	41	56
Tehama	49	118	222
Trinity	18	47	78
Tulare	131	295	447
Tuolumne	0	0	0
Ventura	0	0	0
Yolo	46	130	175
Yuba	0	0	0

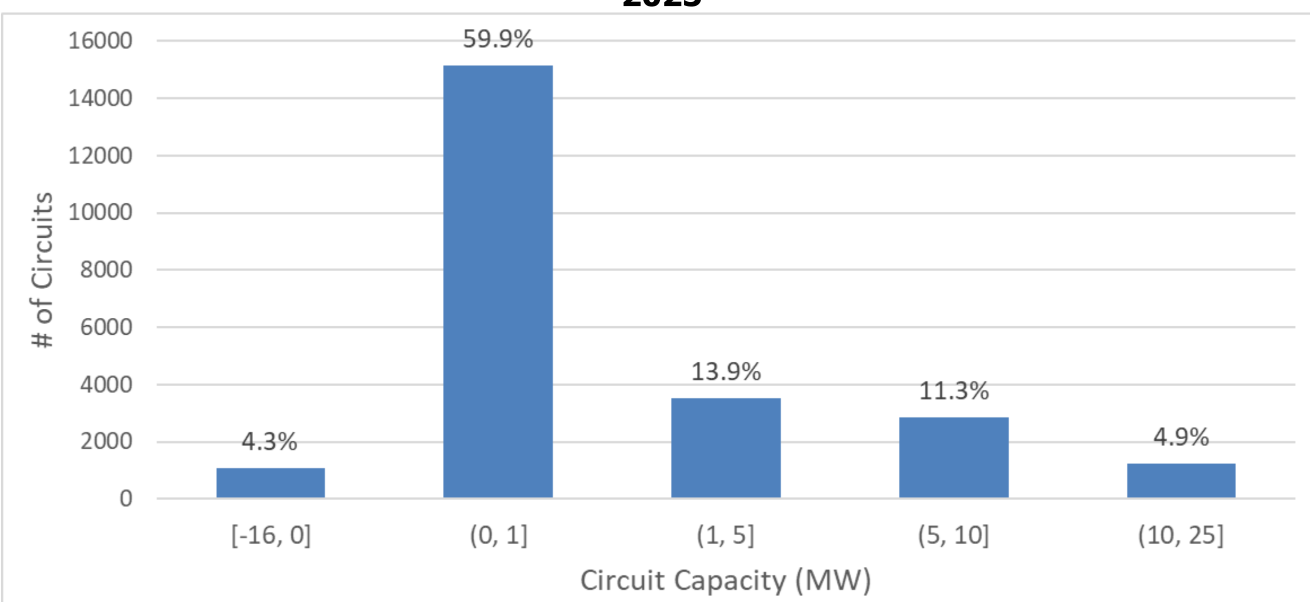
Source: LBNL

APPENDIX I:
EDGE Detailed Results

To calculate capacity indicator metric, EDGE uses GNA circuit capacities and the expected peak load of combined load profiles generated by EVI-Pro and HEVI-LOAD. Figure I-1 shows the distribution of capacity among individual circuits in IOU territories in 2025. Nearly 60 percent of GNA circuits have up to 1 MW of additional capacity and over 4% of the circuits have 0 MW or less of capacity to host additional load. Many of the chargers projected earlier in this report exceed 150 kW, especially in the context of MDHD vehicles. If multiple high-powered chargers were installed together at the same location, such as at a depot where trucks are domiciled or a public fast charging plaza, they could easily exceed 1 MW on an individual circuit. About 3% of California's 5,454 TAZs (i.e. approximately 164 TAZs) are expected to have an EV charging peak load between 1 MW and 5 MW in 2025 with another 21% (i.e. approximately 1,145 TAZs) expected to have an EV charging peak load between 0.5 MW and 1 MW in 2025. These peak load values are expected to continue growing through 2030 and 2035. Although EDGE cannot currently assess charging impact on individual circuits, these types of cases could likely require grid upgrades in order for those chargers to operate properly.

Of the circuits with potentially no additional capacity, 70% of them are in PG&E's service territory, 29% are in SCE's service territory, and the other 1% are in SDG&E's service territory.

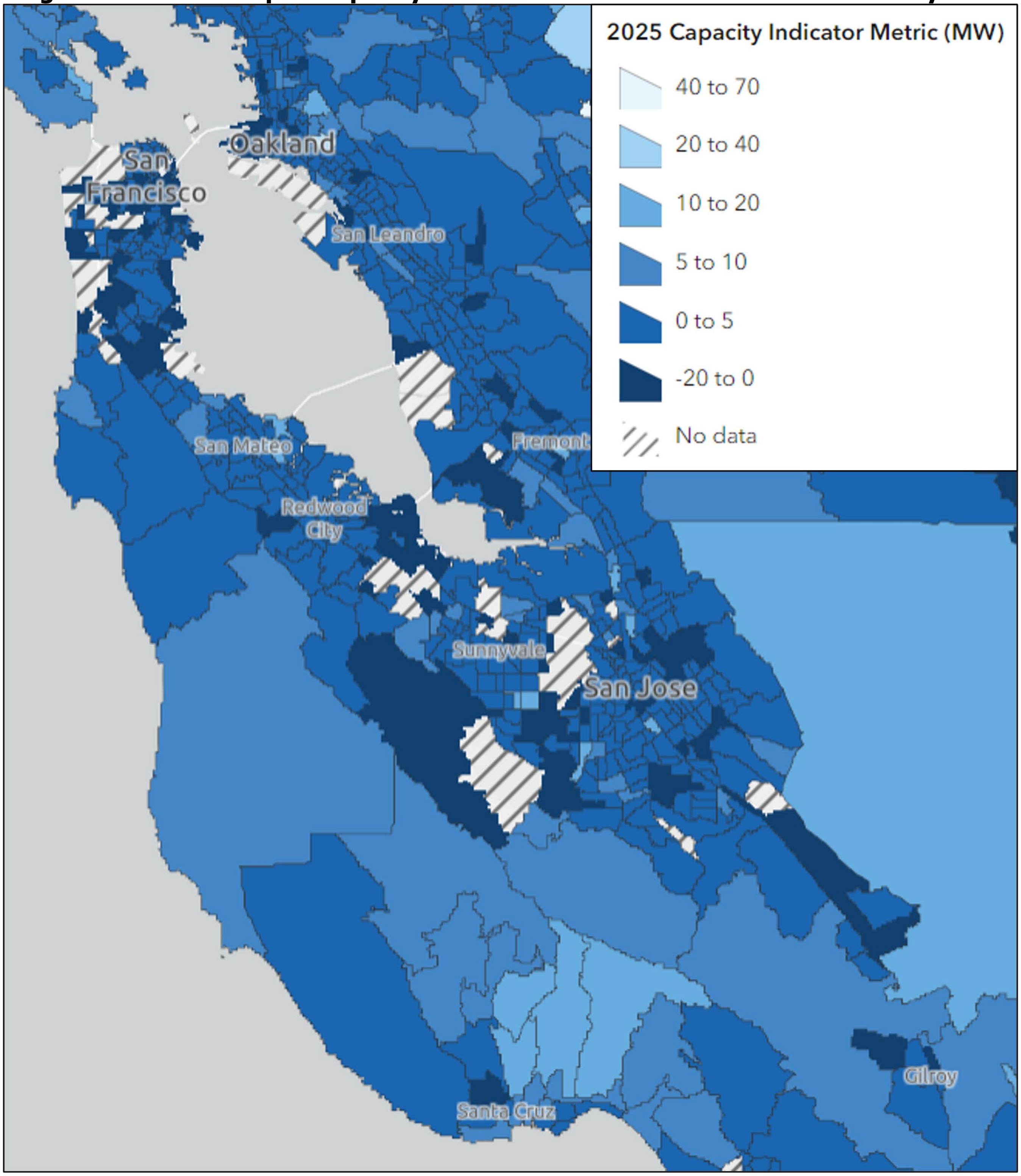
Figure I-1: Distribution of IOUs' GNA Circuit Capacity Forecasts in California in 2025



Source: CEC Staff

Many TAZs in the Bay Area and along the I-5 corridor, especially in the San Joaquin Valley, show positive capacity indicator metric values, indicating areas where particular attention should be paid in the upcoming years. The same is true for locations around the San Pedro Bay ports. These areas have expected EV charging load that exceeds the available circuit capacity in 2025 and could be regions in which grid planning should focus on addressing near-future grid equipment constraints. Figures I-2 and I-3 show maps of these areas in detail.

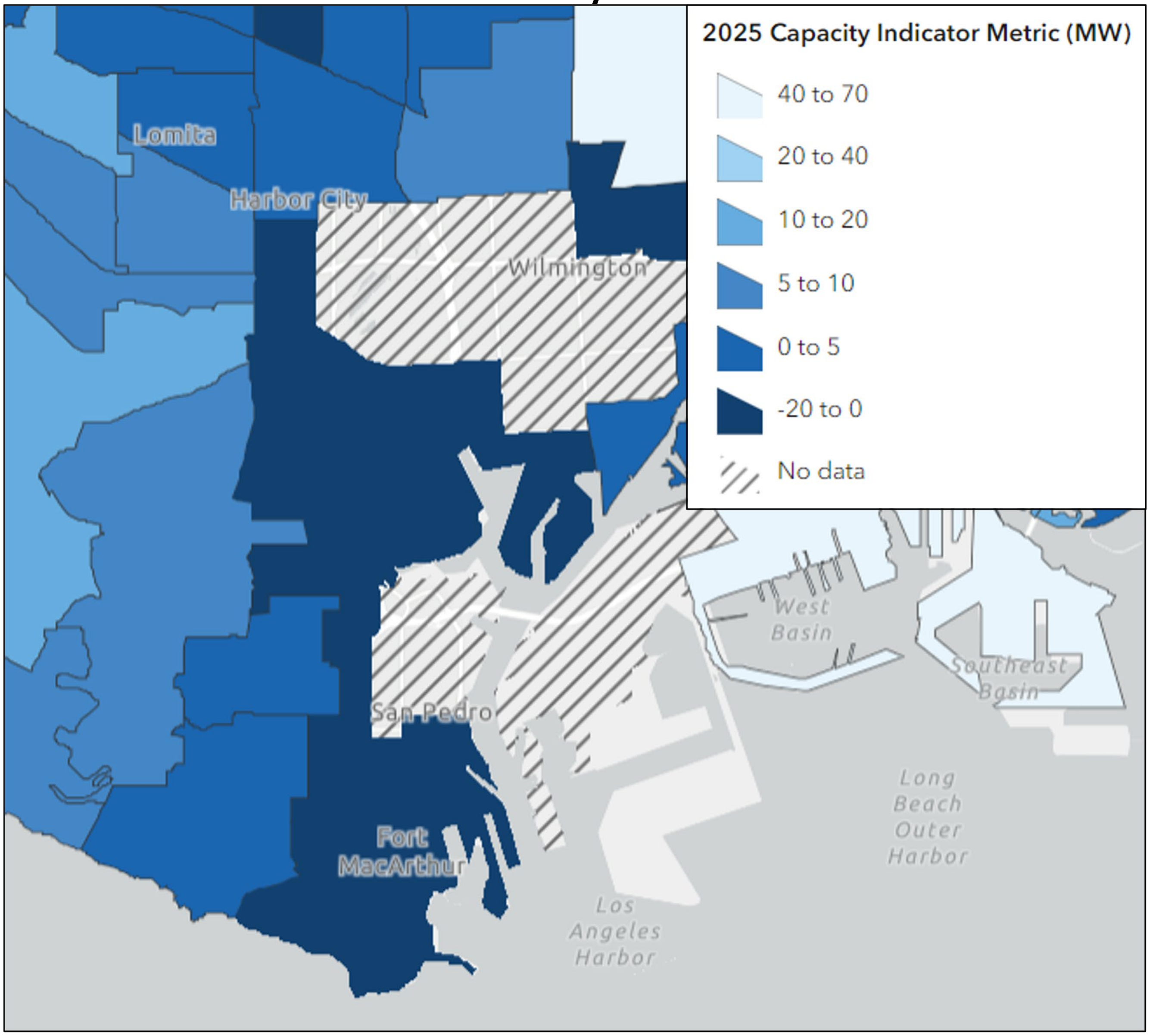
Figure I-2: EDGE Map of Capacity Indicator Metric Values in TAZs in the Bay Area



This map shows capacity indicator metric values in TAZs in the San Francisco Bay Area. These areas have a high density of TAZs with a negative capacity indicator metric value and TAZs with 5 MW or less of additional capacity.

Source: CEC Staff

Figure I-3: EDGE Map of Capacity Indicator Metric Values in TAZs near the San Pedro Bay Ports



This map shows areas near San Pedro Bay ports with clusters of TAZs with negative capacity indicator metric values and TAZs with 5 MW or less of additional capacity.

Source: CEC Staff