California Energy Commission

STAFF REPORT APPENDICES

Appendices of the Assembly Bill 2127 Third Electric Vehicle Charging Infrastructure Assessment

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APPENDIX A: Light-Duty Charging Infrastructure Modeling – Inputs and Parameters

This appendix provides a detailed discussion of the EVI-Pro 4 analysis used to estimate the need for the light-duty charging infrastructure in this report and presents several key inputs and parameters for this analysis.

EVI-Pro 4

The Electric Vehicle Infrastructure Projection tool (EVI-Pro 4) projects the number, locations, and types of charging ports required to meet the needs of California's light-duty EV drivers. The EVI-Pro 4 model uses travel survey data, vehicle characteristics, and charging costs to estimate the charging demand from travel by light-duty EVs and design a supply of shared Level 2 and DC fast charging ports capable of meeting the charging needs without requiring significant changes to people's schedules. The California Energy Commission has worked with National Laboratory of the Rockies (NLR) on the EVI-Pro model since 2016, and it has been a key light-duty vehicle (LDV) charging infrastructure analysis tool in the first and second AB 2127 Assessments, as well as numerous other projects nationwide.[1]

The EVI Pro 4 model simulates a week in the life of California drivers and fits charging into each driver's schedule based on how much they drive, how long they spend at destinations, and what their preference is for each type of charging. As simulated drivers travel from home to other destinations like work, stores, and parks, the state of charge (SOC) of their vehicle depletes. Once the SOC is low enough, drivers decide where to charge, with that choice depending on the cost, speed, and convenience of the charging options available and how much energy they need to recover including the following considerations:[2]

- Many drivers have access to either a Level 1 or a Level 2 charging port at home, and for these drivers, charging at home is generally the cheapest and most convenient option. A Level 2 charging port at home can generally provide enough energy in an overnight charging session to power three days or more of routine driving for most drivers.[3] Level 1 charging at home is also sufficient for many drivers, although drivers may need to plug in more often.

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1 Wood, Eric, Brennan Borlaug, Matt Moniot, Dong-Yeon Lee, Yanbo Ge, Fan Yang, and Zhaocai Liu. 2023. *The 2030 National Charging Network: Estimating U.S. Light-Duty Demand for Electric Vehicle Charging Infrastructure.* National Renewable Energy Laboratory, https://www.nrel.gov/docs/fy23osti/85654.pdf.

2 Appendix A provides specific values for many of the assumptions used in the EVI-Pro model, including the prevalence of home charging, the proportion of vehicles used for commuting, and the proportion of drivers in each charging behavior cohort.

3 A vehicle driven 12,000 miles driven per year would travel roughly 98.6 miles every three days. Assuming 330 Wh/mile vehicle energy efficiency, three days of driving would require 32.5 kWh of charging to recover, which would take 4.9 hours using a 6.6-kW home L2 charging port.

- Some drivers have access to a Level 2 charging port while at work. Charging with Level 2 while at work can provide a similar amount of energy to charging overnight at home, but not all drivers are assumed to commute regularly or to have access to charging while at work.
- Public Level 2 charging ports are available at many destinations, but many drivers do not spend enough time at these destinations for Public Level 2 to be a primary charging option. Public Level 2 charging can supplement other charging options, particularly at locations where EVs remain parked for several hours.
- Finally, drivers can use DCFC to add large amounts of energy relatively quickly. Because DCFC charging events often represent additional stops, the model assumes that drivers will seek to minimize time spent charging by using the highest-powered DCFC option their vehicle can take advantage of. In the main scenario presented in this report, DCFC is the primary charging option away from home for most drivers.

For drivers with multiple available charging locations, EVI-Pro 4 simulates their choices based on ranked charging availability, with different cohorts of drivers having different availability. In the main scenarios, home charging is the first choice for all drivers who have access to it, and these drivers will use it for most of their charging. Most battery-electric vehicle (BEV) drivers in the main scenarios use DCFC if they do not have home charging and on long travel days. Other drivers use lower-cost charging at work L2 or public L2 as an alternative to home charging, although public L2 provides a relatively small share of total charging even for drivers who use it. Most PHEV drivers fall into one of two groups: drivers who charge only at home and rely on their ICE motor when they use up their electric range, and drivers who use non-home charging as much as possible to minimize fuel use.

After simulating the charging behavior of EV drivers, EVI-Pro 4 converts charging events into charging port counts based on assumptions about charging port utilization[4] and peak demand and produces charging load curves for each charging port category. The model outputs these results at a range of spatial scales, including statewide, counties, and census tracts.

Changes to the EVI-Pro 4 Model

For the AB 2127 Third Assessment, NLR and CEC staff made several updates to EVI-Pro 4 to produce higher-quality results at the state and local levels. While these updates affect local results substantially, only the change from daily to weekly travel behavior has a significant directional effect on the statewide estimate of infrastructure needs:

- The model simulates a full week of travel for drivers rather than one day, providing a more realistic representation of driving behavior with a more representative distribution of charging needs per vehicle.

4 This report uses the term *utilization* to describe how much a charging port is used in order to be consistent with the terms used by industry, charging providers, and government entities. Utilization can me measured either in terms of time spent charging or energy delivered. The EVI-Pro model uses *capacity factor*, how much energy a charging port delivers in a week relative to the theoretical maximum amount of energy it could deliver in that time frame, as the primary measure of utilization.

- The model accepts a wider range of inputs at a census tract scale, making it possible to account for local differences in the expected availability of home charging, the number and types of jobs in an area, and seasonality of demand for charging in remote areas.
- The model tracks state of charge for vehicles parked at home and can create scenarios identifying the potential for vehicle-to-home energy transfer during peak hours to minimize utility bills.

Weekly Travel Behavior

The most impactful change to the EVI-Pro 4 model is the switch from daily to weekly simulation of travel behavior, which decreases the incidence of extremely high- and low-mileage vehicles in the simulation and improves the accuracy of estimated charging needs. This change increases the proportion of vehicles that meet most of the respective charging needs with home charging and slightly decreases the number of DC fast charging ports resulting from a given set of behavioral assumptions.

Previous iterations of EVI-Pro simulated a single travel day for each vehicle and tracked vehicle state of charge over several days by repeating that travel day, resulting in an unrealistically large number of vehicles with extremely low or high implied annual mileage. Vehicles assigned a day with only one or two short trips were able to rely on short charging sessions at lower-speed charging ports. Vehicles assigned a day with multiple long trips were modeled as requiring frequent DC fast charging sessions even if they had home charging available.

The EVI-Pro 4 simulates travel behavior by assigning each light-duty EV in the fleet scenario a random selection of seven National Household Travel Survey[5] travel diary days from vehicles in the same region of California. The model resamples these results to ensure that the overall annual mileage of the state's light-duty EV population aligns with the Additional Achievable Transportation Electrification Scenario 3 (AATE3) vehicle population scenario.[6] By simulating a full week of travel, the model now produces a more realistic distribution of vehicle mileage, includes a mix of shorter and longer travel days for most vehicles, and has less variability in charging needs between vehicles.

Census Tract Inputs and Outputs

EVI-Pro 4 uses census tracts as the finest scale of analysis, producing charging infrastructure estimates for each census tract in the state in addition to county-level and statewide results. Census tracts are more widely used and easier to associate with demographic data than California Statewide Travel Demand Model traffic analysis zones, which were the finest scale of analysis in the AB 2127 Second Assessment.[7] In addition to changing the finest resolution of

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5 *The National Household Travel Survey* is a survey of travel patterns intended to support transportation planning throughout the United States. Members of each surveyed household fill out travel diaries, which include a range of information about all the trips that person took on the survey day. Information collected about each trip includes the start and end location, departure and arrival time, and the travel mode (for example, personal vehicle, public transit, bicycle).

6 AATE3 is a managed forecast that post-processes some vehicle fuel types to align with sales proportions or population proportions stipulated by Advanced Clean Cars II and Advanced Clean Trucks.

7 The California Statewide Travel Demand Model, developed by Caltrans, is an advanced multimodal tour-/activity-based travel demand model that can forecast short and long-distance travel by California residents. This

analysis to census tracts, the model now uses local information to better predict local charging needs, which will make it possible to better target charging port deployments to areas where they will be most beneficial.

CEC staff used data about individual housing parcels to produce a statewide estimate of potential home charging access at the census-tract scale. Using this dataset as an input, EVI-Pro 4 can more accurately distribute nonhome charging infrastructure. In areas where home charging access is expected to be lower (because of a higher prevalence of rented homes, smaller electrical panels, or multifamily housing or a combination), there will be more demand for charging infrastructure at work and public destinations. In areas where home charging access is more prevalent, there will be less demand for nonhome charging options.

The model incorporates U.S. Census Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics (LODES) data[8] to identify areas with high levels of retail, entertainment, and food service employment because customer-serving businesses may have higher demand for public charging. Future updates to AB 2127 analysis may link LODES data to home charging analysis to better understand areas where work charging may be most beneficial.

Finally, the model incorporates seasonal travel data to calibrate expected infrastructure needs to peak demand in areas with highly seasonal travel patterns. In areas with low average charging demand but higher demand in peak seasons, a charging network scaled for the average would face severe congestion during the peak.

Vehicle-Grid Integration (VGI)

EVI-Pro 4 includes several minor updates to the charging behavior component of the model that make it possible to develop more informative and realistic scenarios for VGI. The model tracks vehicle state of charge more closely than before and can simulate vehicle-to-home energy discharge based on home electrical load patterns. Tracking vehicle state of charge allows the development of scenarios that explore the potential of vehicle-to-home (V2H) and VGI to decrease consumer energy costs and support the grid during peak periods. The main scenarios do not assume any VGI, but an alternative scenario presented in Appendix D examines the potential benefits of vehicle-to-home bidirectional charging to lower home energy costs and decrease peak loads on the grid.

Additional Models for Light-Duty DCFC Needs

In addition to the EVI-Pro 4 model, which assesses charging infrastructure needs for routine travel within 100 miles of home, this report uses two other models to project the charging infrastructure needs of light-duty electric vehicles:

- The EVI-RoadTrip model, developed by NLR, addresses DCFC needs for travel farther than 100 miles from home. EVI-RoadTrip model structure and assumptions used for this report

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model uses traffic analysis zones as the scale of analysis, which means that all trips simulated by the model start and end at a traffic analysis zone.

8 United States Census Bureau Center for Economic Studies. "Longitudinal Employer-Household Dynamics," https://lehd.ces.census.gov/data.

are consistent with those used in the EVI-RoadTrip report published in 2023.[9] This model projects a need for 1,437–2,432 DCFC charging ports to support 3.6 million–6.1 million BEVs in 2030. These charging ports are included in the totals presented in the body of the report and in Appendices B and C.

- The Widespread Infrastructure for Ride-Hailing EV Deployment (WIRED) model, developed by UC Davis, addresses the DCFC needs for PEVs operated by transportation network companies (TNC). WIRED model structure and assumptions used for this report are identical to those used in the AB 2127 Second Assessment, as the requirements of the Clean Miles Standard have not changed. This model projects a need for 1,000 DCFC charging ports to support TNC vehicles electrifying 90 percent of their miles in 2030. These charging ports are included in the totals presented in the body of the report and in Appendices B and C. TNC-serving charging ports are assumed to be publicly accessible and mixed into the rest of the DCFC infrastructure in California, with a larger concentration of charging ports near locations where TNC trips are most common, like airports and downtown areas. The WIRED model is described in greater in the AB 2127 Second Assessment.

Charging Infrastructure Scenario Behavioral Assumptions

The main scenarios for this report are intended to represent a realistic view of how California's charging environment could look in 2030.

While this scenario shifts a large share of nonhome charging by BEVs to DCFC, there remains a large role for nonhome L2 at longer dwell-time locations (entertainment venues, hospitals, parks, hotels, near home, and so forth) that still have an incentive to install.

In the main scenarios of this report, many drivers still have access to charging at work, and for many of these drivers, charging at work is likely to be cheaper and more convenient than finding time to use DCFC. Finally, the model assumes that PHEV drivers will use internal combustion engines on longer travel days rather than using DCFC. Some PHEV drivers are expected to use nonhome L2 relatively frequently to maximize the share of their miles that are powered by the battery, and as a result, PHEVs make up a large share of nonhome L2 use in this scenario.

Table A-1 summarizes the major parameters under the California Electrification Goals scenario in 2030 and 2035. Values for the Federal Obstacles to EV Adoption scenarios are similar with a few exceptions, but the Federal Obstacles to EV Adoption scenario has fewer BEVs in all years and lower assumed utilization for DCFC and Public L2 in 2030. To generate alternative future scenarios, CEC staff and NLR modify individual parameters of the baseline scenario for 2030, including the parameters listed in Table A-1 and the charging behavior cohorts described later in this section.

9 Alexander, Matt and Dong-Yeon Lee. 2023. *California Electric Vehicle Infrastructure for Long-Distance Travel*. California Energy Commission. Publication Number: CEC-600-2023-065, https://www.energy.ca.gov/sites/default/files/2023-12/CEC-600-2023-065.pdf.

Table A-1: Summary of Input Parameters for the Primary Scenario for 2030

Input	2030	2035
Total number of plug-in EVs	4,448,845	9,463,526
Total number of BEVs	3,707,256	8,401,020
Total number of PHEVs	741,589	1,062,506
Average annual vehicle miles traveled (VMT)	12,410	12,410
Percentage of EVs used for commuting	50%	50%
Percentage of EVs located in large multifamily housing (5 or more units in structure)	12%	12%
Percentage of EVs with access to charging at home	73%	72%
Percentage of EV drivers beginning charging as soon as they arrive at home	33%	33%
Percentage of EV drivers participating in TOU rates and starting to charge at start of lowest-price off-peak period	33%	33%
Percentage of EV drivers starting to charge as late as possible	33%	33%
Work Level 2 utilization (percent of day in use)	15%	15%
Public Level 2 utilization (percent of day in use)	8%	8%
DC50 utilization (percent of peak power delivered throughout day)	9.4%	9.4%
DC150 utilization (percent of peak power delivered throughout day)	6.5%	6.5%
DC250 utilization (percent of peak power delivered throughout day)	5.0%	5.0%
DC350 utilization (percent of peak power delivered throughout day)	3.0%	3.8%

Source: CEC staff and NLR

The EVI-Pro 4 model uses behavioral cohorts to simulate the behavior of BEV and PHEV drivers. All drivers within a single cohort share a relative ranking of preferred charging options, but drivers may use less-preferred options if needed to meet their charging needs. Tables A-2 and A-3 summarizes the behavioral cohorts for BEVs and PHEVs, respectively, and show the size of these cohorts in 2030.

Table A-2: BEV Charging Behavior Cohorts Included in EVI-Pro 4 Main Scenarios

	Work L2 Available and Preferred	Work L2 Unavailable	Use Free Public L2	Avoid Nonhome L2
Charging preferences (first choice to last choice)	*Home L1/L2* Work L2 Public L2 DCFC	*Home L1/L2* Public L2 DCFC	Public L2 *Home L1/L2* *Work L2* DCFC	*Home L1/L2* DCFC *Work L2** Public L2*
Percentage of BEV drivers in this cohort (2030)	10%	10%	10%	70%

The EVI-Pro 4 model simulates EV drivers with a range of charging preferences. Because home charging is generally the cheapest and most convenient option, drivers with access to home charging in all cohorts will use it for most of their charging, although some may take advantage of free public L2 charging where it is available. Charging types in italics (Home L1/L2 and Work L2 in some cohorts) are only used if available. * Drivers in the "Avoid nonhome L2" cohort may occasionally use L2 at work or public locations, but it will make up a very small proportion of their overall charging.

Source: CEC staff and NLR

Table A-3: PHEV Charging Behavior Cohorts Included in EVI-Pro 4 Main Scenarios

	Work L2 Available and Preferred	Work L2 Unavailable	Use Free Public L2	PHEVs Only Charging at Home
Charging preferences (first choice to last choice)	*Home L1/L2* Work L2 Public L2	*Home L1/L2* Public L2	Public L2 *Home L1/L2* *Work L2*	*Home L1/L2*
Percentage of PHEV drivers in this cohort (2030)	15%	15%	20%	50%

EVI-Pro 4 simulates EV drivers with a range of charging preferences. Because home charging is generally the cheapest and most convenient option, drivers with access to home charging in all cohorts will use it for most of their charging, although some may take advantage of free public L2 charging where it is available. Charging types in italics (Home L1/L2 and Work L2 in some cohorts) are only used if available.

Source: CEC staff and NLR

APPENDIX B:
Light-Duty EV Main Scenario Results

Table B-1: L1 and L2 Charging Ports in the Federal Obstacles to EV Adoption Scenario

Year	Single-Family Home and Small Multifamily L1*	Single-Family Home and Small Multifamily L2*	Large Multifamily Housing L2	Public L2	Work (All locations) L2
2026	267,242	1,703,269	49,247	66,313	88,026
2027	289,191	1,919,566	56,659	70,782	101,495
2028	321,721	2,147,318	65,341	79,454	102,211
2029	350,975	2,404,759	75,422	85,432	106,010
2030	394,054	2,753,944	89,249	97,527	113,840
2031	429,016	3,215,575	106,112	103,596	132,581
2032	479,415	3,764,796	126,317	116,169	154,880
2033	539,584	4,404,406	149,053	128,406	177,421
2034	591,390	5,146,962	174,964	140,320	204,918
2035	655,884	5,979,416	204,479	171,180	238,629

For single-family home and small multifamily L1 and L2, this table shows the number of vehicles with access to that type of charging at home rather than the number of charging ports. Many multi-EV households use a single charger for all their vehicles.

Source: CEC and NLR

Table B-2: DCFC Charging Ports in the Federal Obstacles to EV Adoption Scenario

Year	DCFC 50 kW	DCFC 150 kW	DCFC 250 kW	DCFC 350 kW
2026	2,423	5,066	9,672	11,021
2027	2,667	4,754	10,223	14,036
2028	3,003	4,711	10,161	16,191
2029	3,242	4,819	10,830	19,206
2030	3,426	4,839	11,407	22,144
2031	4,449	5,081	11,666	22,455

2032	4,612	5,708	11,929	24,611
2033	5,474	6,238	13,590	25,779
2034	5,456	6,344	15,210	30,805
2035	6,526	7,530	17,216	36,131

Source: CEC and NLR

Table B-3: L1 and L2 Charging Ports in the California Electrification Goals Scenario

Year	Single-Family Home and Small Multifamily L1*	Single-Family Home and Small Multifamily L2*	Large Multifamily Housing L2	Public L2	Work (All locations) L2
2026	272,594	1,880,381	53,703	67,664	96,128
2027	301,667	2,363,341	68,098	75,511	122,461
2028	344,974	2,937,364	86,385	88,224	135,496
2029	387,284	3,613,336	108,760	97,909	153,581
2030	448,412	4,377,307	135,847	115,548	173,918
2031	495,230	5,257,003	166,312	132,409	208,984
2032	559,425	6,222,165	200,477	161,295	247,557
2033	638,431	7,274,023	237,043	188,961	283,990
2034	703,289	8,431,959	276,921	206,204	325,999
2035	783,071	9,680,314	320,722	252,139	375,948

For single-family home and small multifamily L1 and L2, this table shows the number of vehicles with access to that type of charging at home rather than the number of charging ports. Many multi-EV households use a single charger for all their vehicles.

Source: CEC and NLR

Table B-4: DCFC Charging Ports in the California Electrification Goals Scenario

Year	DCFC 50 kW	DCFC 150 kW	DCFC 250 kW	DCFC 350 kW
2026	2,702	5,648	10,567	10,992
2027	3,346	5,964	12,298	14,573
2028	4,213	6,609	13,145	17,862
2029	5,021	7,464	13,662	21,331
2030	5,618	7,937	14,483	24,466

2031	7,497	8,561	17,394	29,114
2032	7,833	9,693	19,849	36,823
2033	9,262	10,556	22,996	42,257
2034	9,135	10,621	25,465	50,162
2035	10,770	12,426	28,410	58,237

Source: CEC and NLR

Tables B-5 and B-6 show the number of new charging ports needed each year under the California Electrification Goals scenario. Because these tables serve primarily as an input for the JOBS EVSE 2.0 workforce estimation tool (Appendix E), which does not include 250 kW DCFC as a category, these tables also exclude 250 kW DCFC (also referred to as DCFC 250). The DCFC 250 charging ports that appear in other results tables are equally split between DCFC 150 and DCFC 350 for the labor and workforce analysis.

Table B-5: New Charging Ports Needed Each Year 2025–2030 in the California Electrification Goals Scenario

Charging Port Type	Location	Installed charging ports as of 12/31/2025	2026	2027	2028	2029	2030
Level 2	Large Multifamily Housing	17,812	35,891	14,395	18,286	22,375	27,087
Level 2	Workplace	106,266	0	16,195	13,035	18,085	20,337
Level 2	Public	71,084	0	4,427	12,713	9,685	17,639
DCFC 50	Public	2,041	660	644	867	808	596
DCFC 150	Public	8,689	2,242	1,182	1,068	1,114	883
DCFC 350	Public	10,553	5,722	4,447	3,713	3,728	3,545
L2 and DCFC	**Excluding Single-Family Homes**	**216,445**	**44,516**	**41,290**	**49,682**	**55,795**	**70,087**

Source: CEC and NLR

Table B-6: New Charging Ports Needed Each Year 2030–2035 in the California Electrification Goals Scenario

Charging Port Type	Location	Installed charging ports at end of 2030	2031	2032	2033	2034	2035	Total Installations 2026 - 2035
Level 2	Large Multifamily Home	243,180	30,465	34,165	36,566	39,878	43,801	302,910
Level 2	Workplace	167,972	35,066	38,574	36,432	42,010	49,949	269,682
Level 2	Public	82,389	16,861	28,887	27,665	17,243	45,934	181,055
DCFC 50	Public	5,455	1,879	336	1,429	0	1,508	8,729
DCFC 150	Public	12,238	2,080	2,360	2,436	1,300	3,277	17,942
DCFC 350	Public	26,378	6,104	8,937	7,007	9,140	9,547	61,889
L2 and DCFC	Excluding Single-Family Homes	641,964	92,455	113,258	111,536	109,571	154,017	842,207

Source: CEC and NLR

Impact of Improved Batteries by 2035

While the charging landscape in 2030 may look similar to today, changes to vehicle and charger technology mean that charging needs in 2035 are more uncertain. Improvements to battery technology may significantly increase the ranges of light-duty EVs available to consumers and allow faster DCFC charging speeds. To address this, CEC staff developed an alternative scenario for 2035, which includes a lower number of charging ports. This scenario includes the following adjustments from the original scenario:

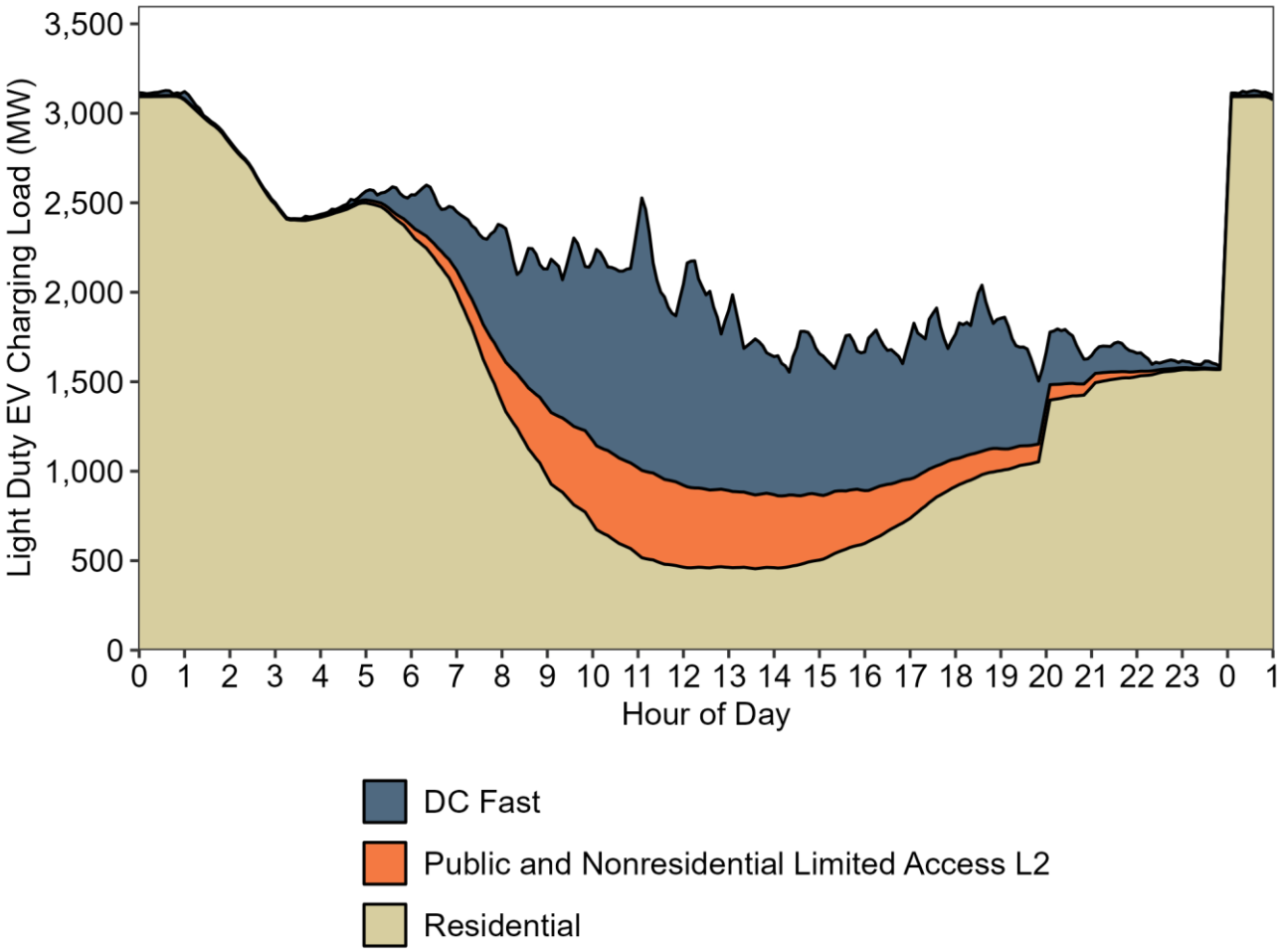
- Larger batteries will decrease the need for charging on long travel days for drivers with charging at home. This result reduces the need for 350 kW charging ports identified by EVI-RoadTrip.
- The ability of some vehicles to charge at 1 MW on DCFC will shift some demand from lower-speed DCFC to higher-speed DCFC, decreasing the number of DCFC ports overall. This shift will be largest for TNC drivers and other drivers needing to charge as fast as possible.
- The increased presence of higher-powered L2 charging (9.9 kW and above) will allow L2 charging needs to be met with a smaller number of ports.

Load Curves for Light-Duty EV Charging

As EV 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. For most drivers, charging at home is the first choice when available, and 69 percent of all charging happens at home in this scenario.

Figure B-1 shows a combined load curve from EVI-Pro 4 and EVI-RoadTrip for all light-duty EV charging for the California Electrification Goals scenario. DCFC is the next most commonly used charging type, accounting for 22 percent of all charging load. Level 2 charging at work and public locations provides 10 percent of all charging load. While the EVI-Pro 4 produces load curves from a full week of travel, this figure presents the average load by time of day for ease of interpretation. There is significant potential to spread and shift the timing of charging events throughout the day, particularly for Level 2 charging at home and work, where people typically spend more time than they need to complete a full charge.

Figure B-1: Light-Duty EV Charging Load Curve in 2030 in California Electrification Goals Scenario



In the main scenarios, TOU rates have the effect of pushing most charging into the hours after midnight, when prices are lowest. Because most people charge at home, the overall peak charging load occurs shortly after midnight.

Source: CEC staff and NLR

APPENDIX C:
Light-Duty EV Alternative Future Scenarios

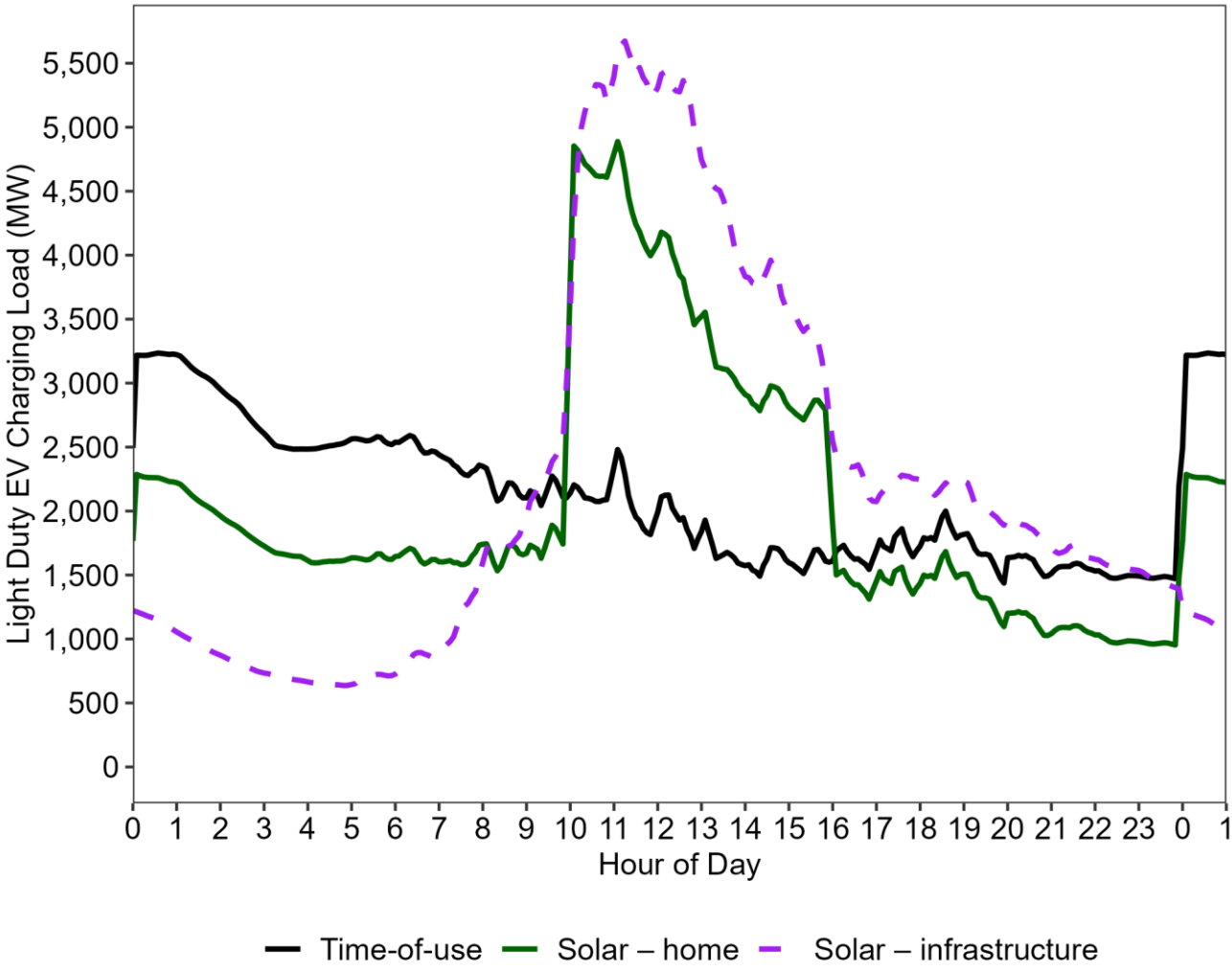
Solar Priority Scenarios

One of the benefits of EVs is the ability to schedule charging for periods when energy is cheapest and cleanest. In the main scenarios of this report, most charging happens at home overnight, since that is the cheapest charging option under most currently available time-of-use rate plans. As more solar capacity is installed, it may be beneficial to prioritize charging during times when solar generation is high and energy demand is relatively low. To explore the potential to shift charging behavior to the daytime, CEC staff worked with NLR to develop two scenarios designed to shift as much charging as possible to the period from 10 a.m. to 4 p.m., both based on the Moderate Adoption fleet size scenario:

- The **solar priority – home scenario** shifts home charging events into the solar priority window, if the vehicle is parked at home during that time. This scenario demonstrates the amount of charging that could be shifted from nighttime to daytime without requiring any changes to charging infrastructure deployment.
- The **solar priority – infrastructure scenario** prioritizes charging at all locations during the solar priority window. In this scenario, drivers prioritize DCFC during the solar period. This scenario demonstrates the maximum potential to shift to the solar window even at the cost of expanded charging infrastructure deployment.

Figure C-1 shows the resulting average charging load curves for the Moderate Adoption scenario and for the two solar priority scenarios. In the main scenarios, 22 percent of all charging happens during the solar window from 10 a.m. to 4 p.m., almost all of it at work and public locations. In the solar priority — home scenario, 44 percent of charging happens during the solar window, and the overnight charging peaks are significantly diminished, potentially saving strain on the grid. Finally, in the solar priority — infrastructure scenario, 50 percent of charging happens during the solar window.

Figure C-1: Total Light-Duty EV Charging Load for Solar Priority Scenarios



Under the main scenario, which assumes most drivers schedule their home charging at times when TOU rates are lowest, overnight loads from charging peak at about 2,200 MW shortly after midnight. Under the solar priority scenarios, large amounts of charging are shifted to the window of peak solar generation, from 10 a.m. to 4 p.m. The solar priority — home scenario shifts overnight charging events to the daytime on days when the vehicle is parked at home during the solar window. The solar priority — infrastructure scenario determines the maximum potential for charging during the solar window if additional DCFC charging ports were deployed.

Source: CEC staff and NLR

DCFC Strategy Scenarios

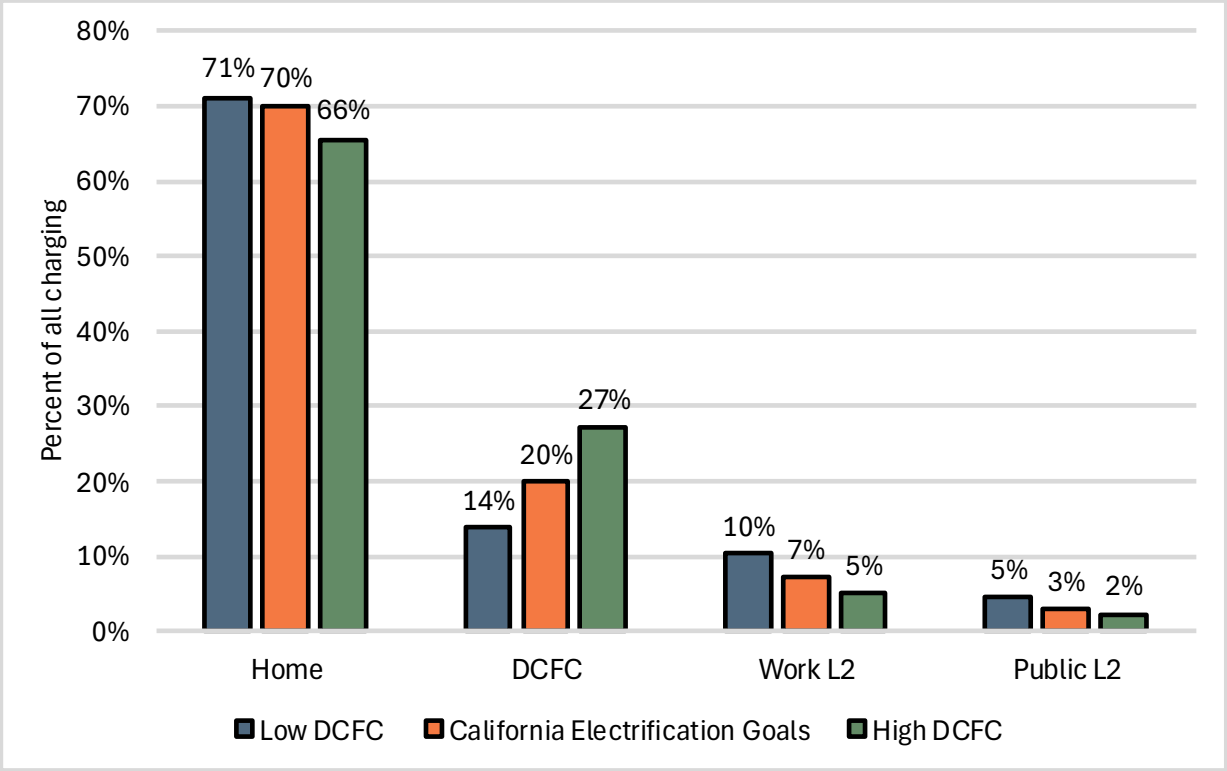
The extent to which DCFC is the dominant type of nonhome charging infrastructure is a key question for the future of transportation electrification. The main scenarios of this report shift BEV charging preferences toward DCFC and away from work and public L2 relative to the second assessment. To better understand the range of potential outcomes, CEC staff worked with NLR to develop two scenarios that bookend a realistic range of outcomes for DCFC deployment, both based on the fleet size from the California Electrification Goals scenario:

- The **low DCFC strategy scenario** uses roughly the same split of charging preferences and charging load from the main scenario of the first and second AB 2127 report assessments. In this scenario, relatively inexpensive and convenient L2 at commute destinations attracts more BEV drivers than DCFC. This scenario has more public and work L2 and less DCFC than the main scenario.
- The **main scenario** assumes DCFC provides most charging away from home for BEV drivers. In this scenario, the speed and availability of DCFC make it more attractive than relying on L2 away from home.
- The **high DCFC strategy scenario** shifts additional charging from home and work L2 to DCFC. Relative to the primary scenario, this scenario has about half as much nonhome L2 by BEVS and slightly less home charging among newer BEVs assumed to have access to a limited amount of free DCFC.[10] This scenario has substantially more DCFC than the primary scenario, and PHEVs are the primary users of remaining nonhome L2.

The behavioral adjustments modeled by the low DCFC and high DCFC scenarios correspond to a respective 6 percentage point decrease and 7 percentage point increase in DCFC charging load relative to the main scenario, as shown in Figure C-2. In all three scenarios, drivers with charging at home do most of their charging at home. Relative to the low DCFC scenario, the main scenario shifts a large share of nonhome L2 charging by BEVs to DCFC. Relative to the main scenario, the high DCFC scenario shifts most remaining nonhome L2 use to DCFC and shifts some charging from home to DCFC to account for free charging available to newly purchased BEVs. In the high DCFC scenario, only 7 percent of all charging is done at nonresidential L2, and most of this is done by PHEVs.

10 For this scenario, new BEVs are assumed to have 1,000 miles of free charging per year for the first two years of ownership. Similar offerings are relatively common for new BEVs sold today.

Figure C-2: Light-Duty EV Charging Allocation in DCFC Strategy Scenarios



The DCFC strategy scenarios provide approximate lower and upper bounds on DCFC charging potential when about 70 percent of EVs have access to charging at home. In the low DCFC scenario, relatively inexpensive and convenient L2 at commute destinations attracts more BEV drivers than DCFC. In the main scenario, the speed and reliability of DCFC make it the preferred nonhome charging source for most BEV drivers. In the high DCFC scenario, DCFC is the main charging option for all BEVs away from home and free DCFC available to newly purchased BEVs draws some charging demand from home to DCFC.

Source: CEC staff and NLR

Table C-1 shows the charging port counts for these two scenarios along with the main scenario for 2030. The main scenario replaces nonhome L2 charging ports with fast charging ports at a rate of about eight L2 charging ports per DCFC, relative to the low DCFC scenario. The high DCFC scenario adds one DCFC per four L2 charging ports removed because most of the increased DCFC use is converted from home charging, and there is little remaining nonhome L2 use by BEVs.

Table C-1: Charging Ports Counts for 2030 in the DCFC Strategy Scenarios

Category and Location	Plug Type	Low DCFC	California Electrification Goals	High DCFC
Public and Nonresidential Limited Access L2 (Work and Public)	**Level 2**	443,361	289,465	211,870
Public, Including Travel Corridors and TNCs	**DCFC**	41,320	52,503	70,152
Total Nonhome	**Level 2 and DCFC**	**484,681**	**341,969**	**282,021**

Source: CEC staff and NLR

APPENDIX D:
Vehicle-Grid Integration

Introduction — What is VGI?

Vehicle-grid integration (VGI) is altering the timing, power, or location of charging to benefit the grid while meeting the driver's needs. From a grid-planning point of view, electric vehicles have two main characteristics. First, they constitute additional load, often unevenly distributed. Second, this load is generally very flexible, which can be beneficial for the grid when properly managed.

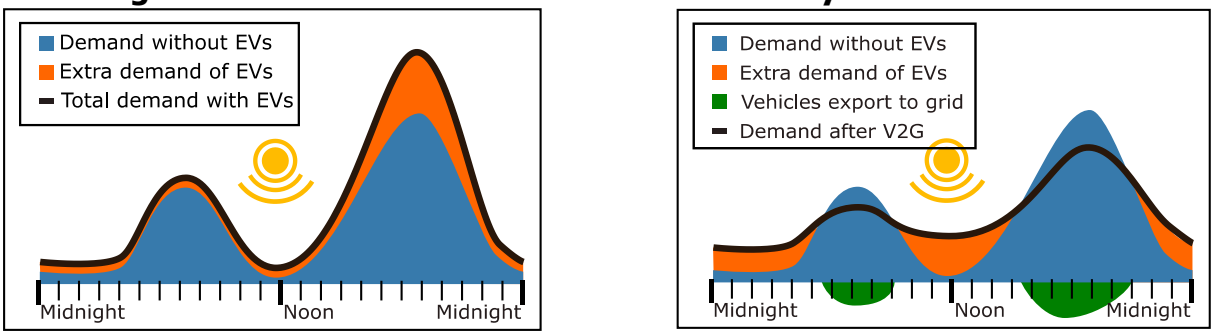
A main challenge of vehicle-grid integration (VGI) is to induce charging behavior that results in a more ideal load profile for California's power generation resources. In practice, this amounts to shaping the "net load"[11] to be as flat as possible. The net load is the total electricity demand minus solar and wind generation. It shows the remaining demand including "ramping" needs that dispatchable resources — such as gas turbines and utility-scale battery energy storage — need to serve. In VGI, shaping the net load is achieved by ensuring that drivers and vehicle operators receive signals that provide economic value for the desired charging and discharging outcomes. VGI use cases include:

- *Smart charging* (optimizing the time and power level of charging to support the grid).
- *Bidirectional charging* (which includes discharging energy from the vehicle back to the grid at beneficial times, or to power local loads).
- *Automated load management (ALM) systems* (which limit facility loads to be below a threshold that could trigger capacity upgrades).
- *Distributed energy resource (DER) supported charging systems* (which use generation systems, such as solar photovoltaics, and/or stationary batteries to reduce or time-shift electric load due to charging).

Figure D-1 shows how different charging behaviors can affect the systemwide profile of electricity delivery. Note the higher peaks and lower troughs in Figure D-1 (a) compared to Figure D-1 (b).

11 California Independent System Operator (California ISO). 2023. *Gross & Net Load Peaks*, https://www.caiso.com/documents/gross-and-net-load-peaks-fact-sheet.pdf.

Figure D-1: Illustrative Effects of EVs on Daily Net Load Profiles



The horizontal axis is time of day. The vertical axis is electricity demand. Both images show an archetypal "net load" curve for California's grid, including low net demand at noon during peak solar and an upward ramp in early evening as the sun sets and electric loads such as air conditioning remain high. In (a), most drivers charge in the early evening. In (b), most drivers charge when net demand is low, and some discharge to the grid when net demand is high (green areas), displacing other energy demands. In both cases, charging and discharging are managed to always meet the driver's transportation needs.

Source: Adapted from the EVerest software project.[12]

A flatter load profile, as shown in D-1 (b), has two advantages. First, it is a more efficient and, hence cheaper, use of power generation resources to deliver a given amount of energy. Net load profiles with greater disparity between peaks and troughs require more generation resources, such as peaker power plants, to meet the higher peak requirements, a situation that puts upward pressure on electricity rates. Second, matching charging to times of high renewable generation reduces greenhouse gas emissions. Fortunately, a charging strategy that minimizes peaks to reduce electricity costs can also maximize the use of renewable generation.

New Emphasis in VGI: Load Flexibility

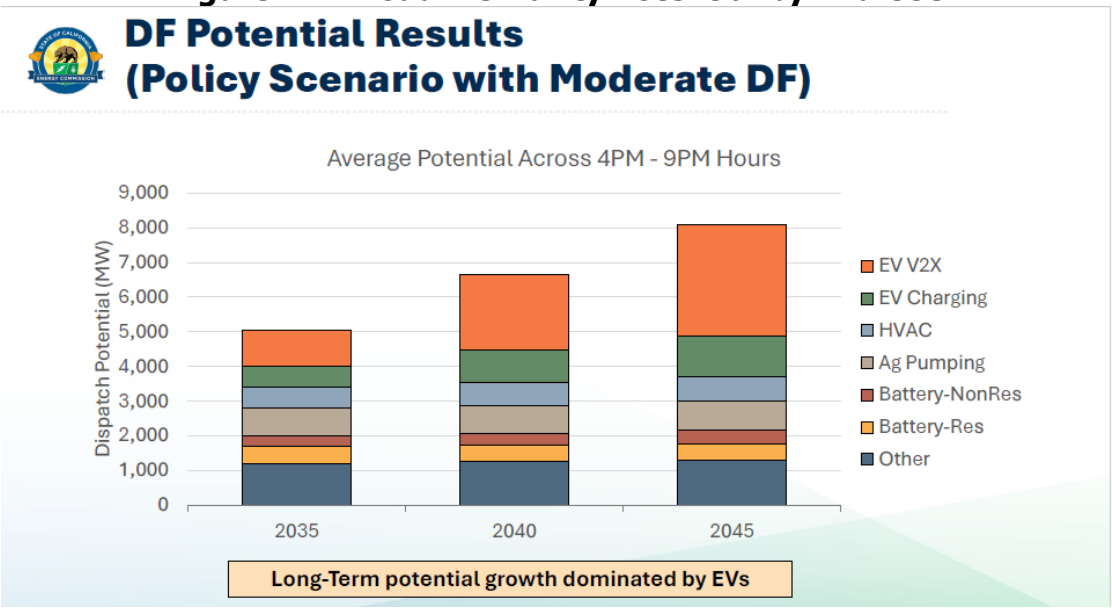
Load flexibility is the ability of electric customers to shift the electricity consumption of devices, appliances, or other loads in response to electricity prices or other signals. This capability offers relief from many of the complications of the energy transition and is increasingly central to state efforts in the power sector. Multiple divisions at the Commission are coordinating load flexibility efforts. The state is increasingly situating its VGI work within the framework of load flexibility, such as dynamic rates and virtual power plants.

In the coming years, rising populations of EVs on the road will provide an increase of EV load flexibility programs, which will become increasingly sophisticated. Figure D-2 shows a scenario

12 Available in de Leeuw, Robert. "EVerest Current Status and How It Can Help Stabilize the Grid." https://static.sched.com/hosted_files/lfenergysummit2024/92/EVerest_%20Current%20Status%20and%20How%20It%20Can%20Help%20Stabilize%20the%20Grid1.1.pdf.

for load-shift potential in future years, based on CEC modeling. Vehicles comprise the largest source of load flexibility, but the amount depends on many factors that are hard to predict.

Figure D-2: Load Flexibility Potential by End Use



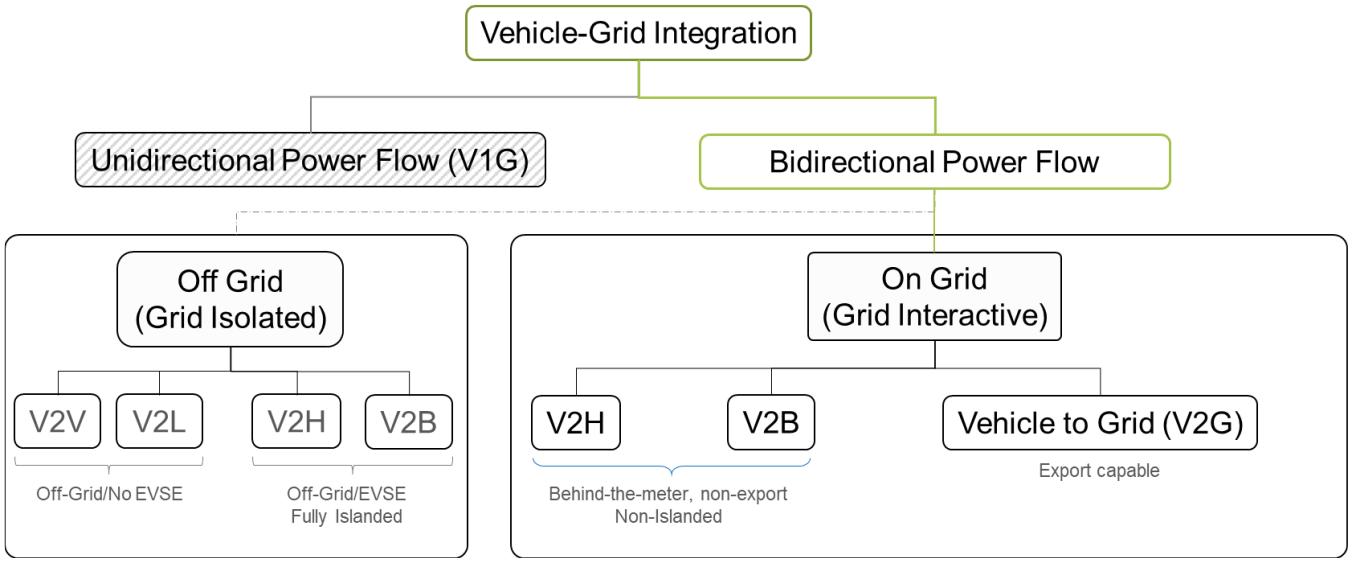
From SB 100 Demand Scenarios Demand Flexibility Resource Potential, Slide 20.

Source: CEC staff[13]

The scenario in figure D-2 categorizes VGI potential into two subcategories: "EV Charging" (unidirectional charging) and "EV V2X" (or bidirectional charging), the latter consisting of different applications, including vehicle-to-grid, vehicle-to-building (V2B), or vehicle-to-home (V2H), vehicle-to-load, and vehicle-to-vehicle. Figure D-3 describes the different categories of VGI and shows that certain bidirectional charging applications (for example, V2H and V2B) can be operated when connected to the grid or when isolated from the grid.

Figure D-3: VGI Categories

13 CEC. 2024. "SB 100 Demand Scenarios: Demand Flexibility (DF) Resource Potential," https://efiling.energy.ca.gov/GetDocument.aspx?tn=258330&DocumentContentId=94343.



Source: CEC staff

The Demand Flexibility Potential analysis further shows that the load-flexibility potential is two to three times higher for bidirectional VGI than for unidirectional charging. This ratio is consistent with the findings from previous studies[14] on VGI benefits.

Vehicle-to-Home Bidirectional Charging Analysis

CEC staff worked with NLR to develop a scenario that assesses a rough market size for a subset of the EV V2X categories, vehicle-to-home (V2H) bidirectional charging, using outputs from the EVI-Pro 4 model and NLR ResStock granular home load data.[15] This scenario explores the potential of bidirectional-capable EVs to supply power to single-family homes during peak TOU rate hours in the hottest week in summer, while EV owners would charge their vehicles when energy prices are lower.

In addition to the assumptions of the 2030 moderate adoption scenario for LDV charging in this report (see "Light-Duty EV Charging Infrastructure Primary Scenarios" in Chapter 2), the V2H analysis includes the following assumptions:

- The maximum discharge power level for V2H is 7.7 kW, which corresponds to a 40-ampere (A) circuit (and a maximum power export of 32A at 240V). This analysis was repeated with a range of other discharge power levels, with results included at the end of this chapter.

14 Electric Power Research Institute. 2019. *Open Standards-Based Vehicle-to-Grid: Value Assessment*. https://www.epri.com/research/products/000000003002014771; "California Framework for Grid Value of Vehicle Grid Integration (VGI)," slide 28, 2019, Energy and Environmental Economics 2019 presentation included in California Joint Agencies VGI Working Group materials.

15 The ResStock data for California includes 37,586 single-family homes simulated based on weather data from Actual Meteorological Year 2018. For the peak-week analysis presented in this section, NLR used July 23 to July 29, 2018. For the simulation, each sampled BEV is assigned to a randomly chosen ResStock load pattern. Source: "ResStock: Highly Granular Modeling of the U.S. Housing Stock." National Lab of the Rockies, https://resstock.nlr.gov/.

- Drivers are assumed to charge daily to 80 percent state of charge (SOC), taking into account automakers' recommendations to preserve battery life. Drivers may charge to 100 percent on unusual travel days.
- Drivers are willing to discharge their battery down to a 30 percent SOC with V2H to preserve battery life and assuming drivers may want to keep an additional margin for unplanned trips.
- No change in travel behavior is assumed relative to the primary LDV charging scenario discussed in Chapter 2.
- Charging behavior is modified to plug in every day.
- The V2H period is 4–9 p.m. or from the arrival time until 9 p.m. if the vehicle returns home after 4 p.m. The vehicle must remain parked at home until 9 p.m. to be included in the simulation.
- The V2H operation consists of a single, continuous discharging cycle to minimize impact on the battery.

The analysis covers "grid-forming" and "grid-interactive" cases. In the grid-forming case, homes are disconnected from the grid, and the vehicle must be able to fully cover home energy needs from 4 p.m. to 9 p.m., limited by the 7.7-kW power maximum and a 30 percent SOC minimum. In the less restrictive grid-following case, the vehicle provides up to 7.7 kW of power and discharges to 30 percent SOC with remaining power coming from the grid. Both are bounding cases to find the potential for V2H, assuming all single-family homes with Level 2 would be able to participate.

Under the grid-forming case, about 85.7 percent of BEV owners with access to charging at a single-family home (3,771,926 BEVs, about 13.7 percent of all LDVs in California) are fully powering their homes from the time the vehicle parked until 9 p.m. in the summer using V2H at least once per week. This means that the home power demand never rose above 7.7 kW, and the number of kWh did not exceed remaining battery capacity with a 30 percent buffer. In the simulation, EV owners shifted an average of 6.9 kWh (median 5.4 kWh, maximum 33.5 kWh) per day from times of peak TOU rates to times when the grid is less congested and costs are lower. If all vehicles able to participate in V2H under this scenario did so, they would serve 17.4 percent of all home electrical load in California in the 4–9 p.m. period and decrease power drawn from the grid by up to 4,100 MW.

Under the grid interactive case, use of V2H expands to 87.8 percent of BEV owners with access to charging at a single-family home (3,863,592 BEVs, about 14.1 percent of all LDVs in California) using V2H at least once per week. In this case, the grid can supply any power greater than 7.7 kW while the EV discharges and satisfy the entirety of the house demand after the EV reaches the 30 percent SOC threshold. The average load shift increases to 8.5 kWh (median 6.4 kWh, maximum 38.5 kWh). In this case, the energy delivered by the vehicle represents 21.8 percent of home load in the 4–9 p.m. period and decreases power drawn from the grid by up to 5,000 MW.

Depending on the utility that serves them and which specific time-of-use rates they participate in, the average EV owner could save more than $250 per year from V2H, as shown by two

example TOU rate plans in Table D-1. Figure D-4 shows the net added load reduction from light-duty EV charging both without V2H and with near-universal V2H participation. Widespread adoption of V2H could also allow light-duty EVs to serve as a large negative load during peak hours. If the benefits of V2H convince drivers to upgrade from L1 to L2 charging, the potential use of V2H would expand to cover nearly all EV owners with home charging.

Table D-1: Results of the V2H analysis in Both the Grid-Forming and Grid-Interactive Cases

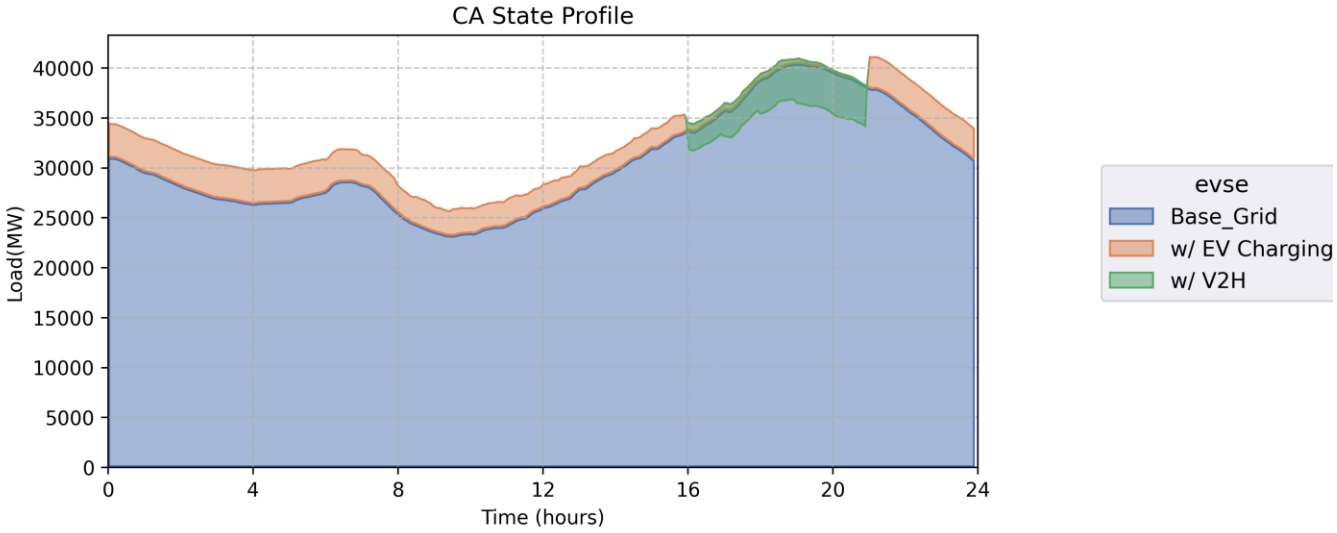
	Grid-Forming — V2H must supply 100% of home power 4–9 PM	Grid-Interactive — grid power can supplement V2H
Vehicles able to participate in V2H	3,771,926 BEVs (55.3% of all EVs)	3,863,592 BEVs (56.6% of all EVs)
Total load shifted if all capable vehicles participate in V2H	26,166 MWh per day	32,840 MWh per day
Mean load shifted per day per vehicle	6.9 kWh	8.5 kWh
Savings per day, assuming difference of 23 cents per kWh between peak and off-peak TOU rates16	$1.60	$1.96
Savings per day, assuming difference of 31 cents per kWh between peak and off-peak TOU rates17	$2.15	$2.64
Savings June 1 to September 30, difference of 23 cents per kWh between peak and off-peak TOU rates	$194.66	$238.51
Savings June 1 to September 30, difference of 31 cents per kWh between peak and off-peak TOU rates	$262.36	$321.47

Source: CEC staff and NLR

16 The 23-cent-per-kWh price premium corresponds to the TOU price premium in summer for EV owners enrolled in the SMUD "Time-of-Day (5–8 p.m.)" rate plan in 2025. These customers pay 36.55 cents per kWh from 5 to 8 p.m. and 13.55 cents per kWh from midnight to 6 a.m. (the midnight to noon summer Off-Peak rate of 15.05 cents per kWh with an additional discount in the rate from midnight to 6 a.m. for EV owners). Source: Sacramento Municipal Utility District. 2025. "Rate Details." https://www.smud.org/Rate-Information/Residential-rates/Time-of-Day-5-8pm-Rate/Rate-details. Accessed on 5/28/2025.

17 The 31-cent-per-kWh price premium corresponds to the TOU price premium in summer for PG&E customers enrolled in the EV2-A rate plan in 2025. These customers pay 62 cents per kWh from 4 to 9 p.m. and 31 cents per kWh from midnight to 3 p.m. Source: Pacific Gas and Electric Company. 2025. "Residential EV Rate Plans." https://www.pge.com/en/account/rate-plans/find-your-best-rate-plan/electric-vehicles.html. Accessed on 5/28/2025.

Figure D-4: Statewide Residential Summer Load Curve, Including EV Charging, Without V2H and With 100 Percent V2H Participation



Under a high rate of V2H participation, light-duty EVs could significantly reduce load during peak hours in summer. While this level of V2H participation may not be necessary every day, it could be beneficial during high load conditions. In addition, some drivers may choose to do V2H charging regularly to save money on their electric utility bills.

Source: CEC staff and NLR

This analysis estimates great potential for V2H to shift load away from peak hours, decreasing stress on the grid and saving EV owners on their utility bills without requiring them to modify their driving habits, electric consumption, or utility tariff. The final section of this chapter includes more detailed results from the V2H analysis, including results for a range of maximum V2H power levels from 3.7 kW to 15.7 KW and a range of more cautious minimum SOC values from 30 percent to 50 percent.

Barriers to Bidirectional Charging

As the analysis above shows, vehicle-to-home discharging has great potential for customers to save on their utility bills by taking advantage of rates designed to reward grid-friendly behavior. However, significant barriers must be solved before California can realize the value of V2H or other forms of bidirectional charging. Among these are:

- **Limited product offering:** Relatively few vehicles offer discharging capability today, although the number of models is rising each year. Some vehicle makers plan to enable bidirectional capability on all their EVs within a few years. Similarly, relatively few bidirectional-capable chargers are available. Most of those that exist today use direct current exported from the vehicle and cost thousands of dollars.[18] It is expected that

18 At the time of writing, at least two early entrant residential DC models are priced above $9000 when islanding backup capability is included.

inexpensive models using alternating current export will become available in a few years as interoperability challenges are overcome.[19]

- **Customer awareness and education:** Vehicle owners may be unaware of the ability to use their vehicle battery for any purpose other than transportation.
- **Interoperability standards maturity:** V2G requires cooperation between vehicle manufacturers, charging equipment manufacturers, and utilities. Industry groups such as EPRI20 and IEA21 are pursuing interoperability initiatives among these stakeholders so V2G can become routine.

Two other major barriers to general V2G may be overcome by the design of the above V2H use case:

- **Interconnection:** It can take months for new equipment to become qualified for interconnection.[22] The V2H use case allows the possibility of disconnecting the house from the grid while using the vehicle battery to cover local load. This use case allows the customer to avoid the utility's interconnection procedure.
- **Compensation:** There are limited ways for customers to be compensated for exporting power back to the grid, and it is uncertain what opportunities will exist in the future. The V2H use case avoids exporting to the grid; instead, money is saved by charging the battery when grid rates are low and using the battery instead of the grid to supply household loads when grid rates are high.

Vehicle-Grid Integration Scenario Detailed Parameters

Tables D-2 and D-3 contain results from the vehicle-to-home (V2H) analysis described above. For this analysis, power from vehicles was used to replace all or most of home electrical load between 4 and 9 p.m. in summer. Table D-2 shows the effect of a range of V2H power levels on the amount of home load that can be served by V2H (assuming a 30 percent minimum state of charge). Table D-3 shows the effect of changing the minimum state of charge EV owners are willing to accept for V2H (assuming 7.7 kW maximum V2H power). Columns in these tables are as follows:

- **V2H Only:** This column identifies whether the values in this row come from a scenario that required the vehicle to supply 100 percent of the home's energy needs from 4 to 9 p.m. (V2H Only) or whether grid power was allowed to supplement vehicle power when

19 For example, Nissan plans to release a bidirectional charger using AC in 2026 "at a price comparable to a monodirectional charger available today." Nissan press release, "Nissan to Launch Affordable Vehicle-to-Grid Technology in 2026," https://global.nissannews.com/en/releases/nissan-to-launch-affordable-vehicle-to-grid-technology-in-2026.

20 EPRI. *DER Interoperability Guidebook*, https://www.epri.com/research/products/000000003002022065.

21 International Energy Association. "Interoperability of Bidirectional Charging (Task 53)," https://task53.org/.

22 See, for example, SDG&E, *Clean Transportation Annual Report, Program Year 2024*, p. 56. Emailed to the service list of CPUC Rulemaking R.23-12-008 on June 30, 2025.

home load was above the corresponding V2H power level or vehicle SOC dropped below the minimum SOC value (V2H+grid)

- **L1 -> L2 Conversion:** This column identifies whether the values in this row come from a scenario that assumes EV owners with access to L1 at home do not participate in V2H (Drop L1) or that these EV owners upgraded to L2 (L1 -> L2).
- **V2H Power (kW):** This column identifies the maximum power level for V2H, in kW.
- **Minimum SOC %:** This column identifies the lowest state of charge an EV owner is willing to let their vehicle drop to through V2H.
- **Percentage of Vehicles:** This column identifies the percentage of all BEVs in single-family homes with charging that could meet their home energy needs through V2H under this scenario.
- **Mean kWh per week:** This column identifies the mean household kWh of energy provided by V2H during a hot week in summer.
- **Maximum kWh per week:** This column identifies the maximum household kWh of energy provided by V2H during a hot week in summer.
- **% of all Home Load Supplied:** This column identifies the percentage of all statewide home load during provided by V2H during peak hours.

Table D-2: V2H Analysis Results for Range of Power Levels

V2H Only	L1 -> L2 Conversion	V2H Power (kW)	Percentage of Vehicles	Mean kWh per week	Maximum kWh per week	% of all Home Load Supplied
V2H Only	Drop L1	3.7	69.2%	26.45	114.34	7.4%
V2H Only	Drop L1	5.7	81.7%	39.94	181.05	13.5%
V2H Only	Drop L1	7.7	85.7%	48.56	234.69	17.4%
V2H Only	Drop L1	9.7	87.0%	53.15	276.35	19.3%
V2H Only	Drop L1	11.7	87.2%	54.05	336.66	19.6%
V2H Only	Drop L1	13.7	87.2%	54.05	336.66	19.6%
V2H Only	Drop L1	15.7	87.2%	54.05	336.66	19.6%
V2H+grid	Drop L1	3.7	87.8%	49.85	129.50	18.1%
V2H+grid	Drop L1	5.7	87.8%	56.98	199.50	20.9%
V2H+grid	**Drop L1**	**7.7**	**87.8%**	**59.50**	**269.50**	**21.8%**
V2H+grid	Drop L1	9.7	87.8%	60.37	339.50	22.2%
V2H+grid	Drop L1	11.7	87.8%	60.49	359.10	22.2%
V2H+grid	Drop L1	13.7	87.8%	60.49	359.10	22.2%
V2H+grid	Drop L1	15.7	87.8%	60.49	359.10	22.2%
V2H Only	L1 -> L2	3.7	78.7%	26.70	117.08	8.5%
V2H Only	L1 -> L2	5.7	93.0%	40.32	187.66	15.5%
V2H Only	L1 -> L2	7.7	97.6%	49.05	234.69	20.1%
V2H Only	L1 -> L2	9.7	98.9%	53.09	276.35	22.0%
V2H Only	L1 -> L2	11.7	99.1%	53.88	336.66	22.3%
V2H Only	L1 -> L2	13.7	99.1%	53.88	336.66	22.3%
V2H Only	L1 -> L2	15.7	99.1%	53.88	336.66	22.3%
V2H+grid	L1 -> L2	3.7	100.0%	50.52	129.50	20.9%
V2H+grid	L1 -> L2	5.7	100.0%	57.75	199.50	24.1%
V2H+grid	L1 -> L2	7.7	100.0%	60.29	269.50	25.3%
V2H+grid	L1 -> L2	9.7	100.0%	61.06	339.50	25.6%
V2H+grid	L1 -> L2	11.7	100.0%	61.16	359.10	25.6%
V2H+grid	L1 -> L2	13.7	100.0%	61.16	359.10	25.6%
V2H+grid	L1 -> L2	15.7	100.0%	61.16	359.10	25.6%

Source: NLR and CEC staff

Table D-3: V2H Analysis Results for Range of Minium State of Charge Limits

V2H Only	L1 -> L2 Conversion	Minimum SOC %	Percentage of Vehicles	Mean kWh per week	Maximum kWh per week	% of all Home Load Supplied
V2H Only	Drop L1	30%	85.7%	48.56	234.69	17.4%
V2H Only	Drop L1	35%	85.7%	47.33	234.69	16.9%
V2H Only	Drop L1	40%	85.6%	45.58	234.69	16.2%
V2H Only	Drop L1	45%	85.4%	43.36	223.32	15.3%
V2H Only	Drop L1	50%	85.1%	40.73	221.18	14.2%
V2H+grid	Drop L1	30%	87.8%	59.50	269.50	21.8%
V2H+grid	Drop L1	35%	87.8%	58.34	269.50	21.4%
V2H+grid	Drop L1	40%	87.8%	56.76	269.50	20.8%
V2H+grid	Drop L1	45%	87.7%	54.59	269.50	20.0%
V2H+grid	Drop L1	50%	87.7%	51.90	269.15	18.9%
V2H Only	L1 -> L2	30%	97.6%	49.05	234.69	20.1%
V2H Only	L1 -> L2	35%	97.5%	47.72	234.69	19.5%
V2H Only	L1 -> L2	40%	97.4%	45.90	234.69	18.6%
V2H Only	L1 -> L2	45%	97.2%	43.64	228.14	17.6%
V2H Only	L1 -> L2	50%	96.8%	41.01	228.14	16.3%
V2H+grid	L1 -> L2	30%	100.0%	60.29	269.50	25.3%
V2H+grid	L1 -> L2	35%	100.0%	58.99	269.50	24.7%
V2H+grid	L1 -> L2	40%	99.9%	57.29	269.50	23.9%
V2H+grid	L1 -> L2	45%	99.9%	55.04	269.50	23.0%
V2H+grid	L1 -> L2	50%	99.9%	52.32	269.50	21.8%

Source: NLR and CEC staff

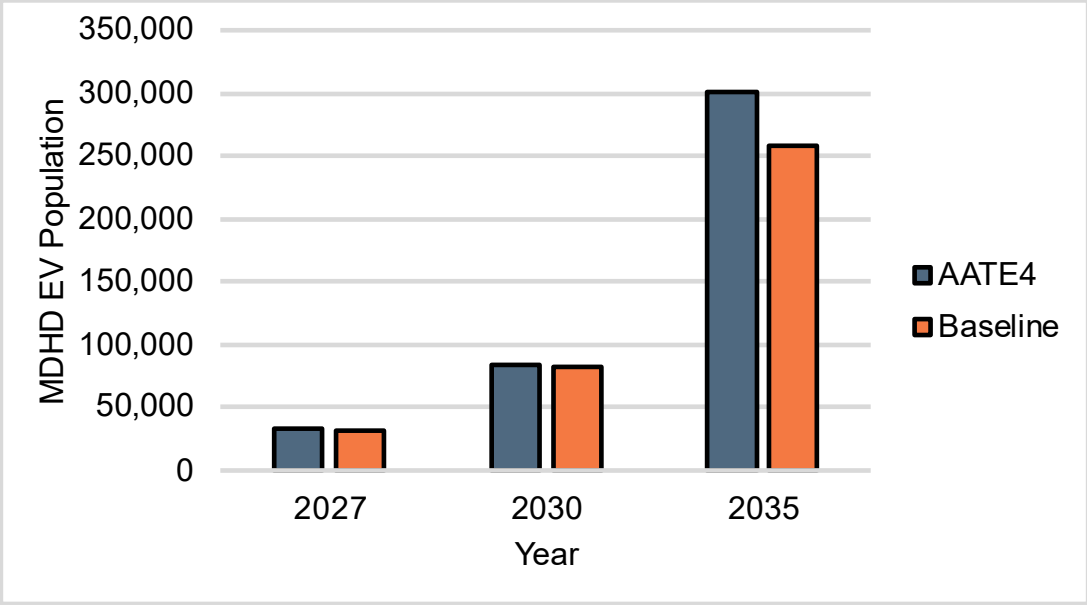
APPENDIX E:
HEVI-LOAD Model

Inputs and Assumptions

Medium- and Heavy-Duty EV Adoption Scenarios in HEVI-LOAD

The AB 2127 Third Assessment uses the medium- and heavy-duty (MDHD) EV populations from the Additional Achievable Transportation Electrification 4 (AATE4) and Baseline scenarios of the *2025 Integrated Energy Policy Report (2025 IEPR)*. Figure E-1 shows the MDHD population used in this assessment. The Baseline scenario has 2 percent less medium-duty (Classes 3–6) vehicle population in 2030 compared to the AATE4 scenario, while the heavy-duty (Classes 7–8) population remains the same. AATE4 has higher populations for both medium-duty and heavy-duty vehicles in 2035.

Figure E-1: MDHD EV Adoption Scenarios in HEVI-LOAD



HEVI-LOAD uses MDHD EV populations in 2027, 2030, and 2035 from the *2025 Integrated Energy Policy Report*. This population does not include battery-electric buses.

Source: CEC

Table E-1: Medium- and Heavy-Duty EV Population by Vehicle Type in Analysis Years

2025 IEPR Scenario	Vehicle Type	2027	2030	2035
AATE4	Classes 3–6	30,635	74,288	200,366
AATE4	Classes 7–8	2,122	9,299	101,325
AATE4	**Total**	**32,757**	**83,587**	**301,691**

Baseline	Classes 3–6	28,930	72,831	164,569
Baseline	Classes 7–8	2,122	9,299	94,063
Baseline	**Total**	**31,052**	**82,130**	**258,632**

Source: CEC

Vehicle Travel Data

HEVI-LOAD takes in trip origin-destination data augmented from the California Department of Transportation's (Caltrans) California Statewide Travel Demand Model (CSTDM) and additional vehicle telematics data to inform the tour-based travel patterns. The shortest possible path through the road network is charted for each pair to generate a trip route that the simulated vehicles travel. Individual trips are stitched together to generate tours. A *tour* is a chain of trips to short-duration intermediate stops ending at a longer-duration destination. This chain of trips provides a more realistic representation of travel behavior, as vehicles are more likely to have dedicated charging time after reaching the final destinations.

The model considers charging between tours at private or public depots and at high-speed public en route locations during the trip, if necessary. Tour start and end locations are considered depot locations, whereas truck parking locations sourced from additional location datasets, including Caltrans's California Statewide Truck Parking Study, are considered en route charging candidate locations.

CSTDM trip data do not provide trip start and end times. These are assigned probabilistically using real-world trip GPS data obtained from the University of California at Riverside, West Virginia University, FleetDNA,[23] INRIX ODs, and so forth, in addition to real-world aggregate commercial vehicle telemetry insights obtained from Altitude by Geotab.[24] The energy consumption of each vehicle is calculated using the simulated travel distance and vehicle class-specific energy consumption per mile. Charging energy consumed during a charging event depends on vehicle SOC. Local daily energy demand for charging is calculated by aggregating charging energy consumed from charging events across a geographic area. Table E-2 shows vehicle and travel behavior assumptions in the model. Statistics from vehicle travel data used as input to the model are shown in Table E-3.

23 National Renewable Energy Laboratory. "Fleet DNA Project Data," https://www.nlr.gov/transportation/fleettest-fleet-dna.

24 Altitude by Geotab. "Altitude by Geotab," https://altitude.geotab.com/.

Table E-2: Vehicle and Travel Behavior Assumptions

Assumption	Classes 3–6	Classes 7–8
%EV population traveling daily	75%	75%
Non-domiciled population	28.6%	9.2%
EV battery capacity	300–400 kWh with 5% yearly growth rate from 2025	600 kWh, with 5% yearly growth rate from 2025 for other market segments 900 kWh for long haul (6.3% vehicle population)
Energy efficiency	1.1 kWh/mile	1.8 kWh/mile

Source: LBNL

Table E-3: Travel Statistics From Input Data

Statistics	Classes 3-6	Classes 7-8
Average trip per tour	1.92 trips per tour	1.04 trips per tour
Average trip distance	28 miles	94 miles
Average tour distance	54 miles	98.06 miles
Average annual vehicle miles traveled (VMT) per vehicle	14,381 miles	24,988 miles

Source: LBNL

Stop Types and Charging

The CSTDM data do not provide the location type of trip destinations. This is assigned in HEVI-LOAD by looking at the stop duration at each location. Short stops (less than 10 minutes) are not considered to provide any charging opportunity. Locations with longer stops can be classified as Origin or Non-Origin. Locations with the longest stops are assumed as the domicile and are labeled as Origin. Locations with smaller but significant stop durations are assumed as destinations and labeled as Non-Origin. This is useful to identify instances where vehicles need to charge at some other fleet's private depot. Such instances can occur if public locations are not available within 3 miles and vehicles are needed to charge. If there are public locations available within 3 miles after a vehicle completes a tour at other fleets' private depot, they charge at those public locations. Charging considerations at stop locations are shown in Table E-4.

Table E-4: Charging Considerations at Stop Locations

Stop Types	Public Depot and En Route Locations	Private Depot Locations
Short stop (less than 10 minutes)	No charging	No charging
Non-origin (Long stop)	Non-origin charging (public)	Non-origin charging (private)
Origin (Longest stop)	Origin charging (public)	Origin charging (private)

Source: LBNL

Vehicles are more likely to charge at depots where they park overnight, spend a long time at a destination between trips, and have a low SOC. Vehicles use en route charging when SOC reaches 20 percent or lower. The power level used for each charging session is determined based on vehicle-specific charging capacity, available charging time, and charging port availability. Sixty percent of depot (private and public) charging is assumed to participate in time-of-use (TOU) pricing-based managed charging by avoiding charging during peak hours. The model considers a TOU schedule with peak hours during 4 p.m.–9 p.m. Resulting charging load for a typical day is shown in Appendix G, Figure G-2.

Defining Vocations

Vocations are defined based on trip data:

- Drayage: Vehicle trips arrived at or departed from a port location at least once in the daily trip chain.
- Regional Domiciled: Daily travel distance less than 300 miles, with frequent stops at same locations.
- Regional Nondomiciled: Daily travel distance less than 300 miles, with no frequent stop locations.
- Long Haul: Daily travel distance more than 300 miles.

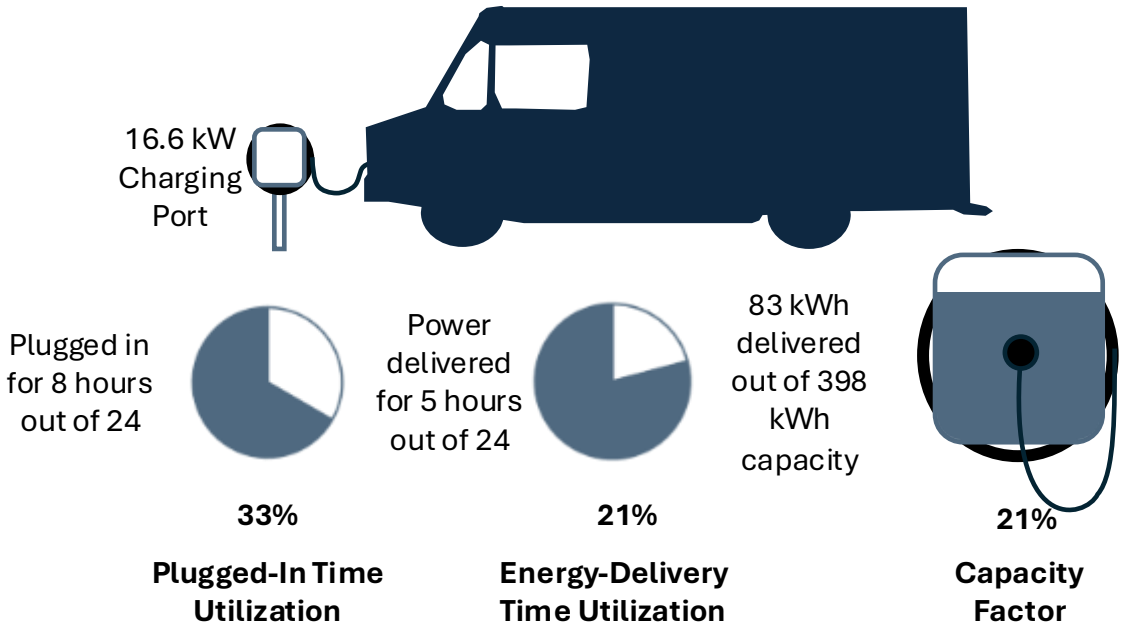
MDHD Charging Infrastructure Scenarios

The HEVI-LOAD model generates charging events, which are assigned to charging ports to produce charging port counts. Charging port utilization is a key consideration in modeling infrastructure needs. A low utilization means fewer charging events per charging port per day, which means high availability, less chance of queueing, and less revenue for the station operator. Conversely, high utilization means more events per charging port, lower availability, more probability for queueing, and higher station revenue. For HEVI-LOAD, low utilization would mean distributing the charging events over more charging ports, and higher utilization would result in fewer charging ports.

There are several ways to calculate utilization, each potentially producing a different utilization rate. Plugged-in time-based utilization considers the duration of occupancy for a given period (for example, a day).[25] Energy-delivery time utilization considers only the duration of dispensing energy. Capacity factor considers the ratio of the dispensed energy over a specific period to the theoretical energy delivery capacity. The capacity factor metric for utilization is most relevant to HEVI-LOAD as it can be calculated from the model and can be directly related to real-world charging ports. "Capacity factor" is in line with the use of this terminology for electricity generating units.[26]

Charging station owners might monitor utilization through other metrics, such as queueing time and transformer load factor. Capacity factors are generally higher for lower-powered charging ports (for example, Level 2 AC) as vehicles receive energy for longer durations at the maximum power level. Whereas for faster charging ports, charging power is generally below the maximum power of the charging port for a period at the start and end of the charging event due to charging power curves. Figure E-2 demonstrates utilization concepts.

Figure E-21: Different Ways to Measure Charging Port Utilization



Vehicles may not draw power for the whole duration they are plugged in, resulting in differences between plugged-in time utilization and energy-delivery time utilization. Faster charging ports generally achieve less utilization as charging takes less time, and vehicles not charging at the rated power level.

Source: CEC staff

25 Pritchard, Ewan, Brennan Borlaug, Fan Yang, and Jeff Gonder. 2023. *Evaluating Electric Vehicle Public Charging Utilization in the United States Using the EV WATTS Dataset.* National Renewable Energy Laboratory, https://www.nrel.gov/docs/fy24osti/85902.pdf.

26 EIA. "Capacity Factor," https://www.eia.gov/tools/glossary/index.php?id=Capacity_factor. Accessed December 31, 2024.

For the 2030 MDHD charging port counts estimated in the AB 2127 Second Assessment, the overall capacity factor was 5 percent. The California Transportation Commission's SB 671 Assessment,[27] published in December 2023 and investigated charging needs along major freight corridors, assumed about 20 percent utilization. This difference in utilization assumption yields substantially different charging port deployment requirements.

Limited data available to the CEC show that current MDHD charging stations can experience about 1 percent capacity factor, with operators aiming to reach 5–9 percent in a developed market. Based on these data, this report primarily considers a 2.5 percent overall capacity factor in 2030, with an alternative future scenario with a higher capacity factor of about 4.8 percent. The 2027 capacity factor is lower at 2.2 percent (4.1 percent for higher capacity factor alternative future scenario), while for 2035 it is higher at 3.7 percent (7.1 percent for higher capacity factor alternative future scenario), representing a market maturing with time with more vehicles accepting higher charging power.

The lower capacity factor consideration is applied with the two MDHD EV adoption scenarios from the *2025 IEPR* (AATE4 and Baseline), producing two scenarios. The higher capacity factor is used with the AATE4 adoption scenario to create an alternative future scenario.

All three scenarios assume that because of grid capacity, cost, operational, and other constraints, many private depots will not have charging ports powered 350 kW and above and will use nearby public depots for higher powered charging. To reflect this, 40 percent of 350 kW, and 50 percent of 500 kW–1.5 MW charging port needs generated at private depots from the simulation are shifted to public depots in these two scenarios. The scenarios can be summarized as follows:

- California Electrification Goals Scenario: MDHD population meets California electrification goals (based on AATE4). 2.5 percent capacity factor in 2030.
- Federal Obstacles to EV Adoption Scenario: Federal obstacles and market conditions prevent California from meeting state electrification goals, resulting in 2 percent smaller medium-duty EV population (based on Baseline). 2.5 percent capacity factor in 2030.
- Higher Capacity Factor Alternative Future Scenario: MDHD population meets California electrification goals (based on AATE4). Capacity factor scales to 4.8 percent in 2030.

Charging ports needed for buses are generated separately. (See Appendix F.) These capacity factor considerations are not applied for bus charging ports.

27 California Transportation Commission. December 6, 2023. *SB 671 Clean Freight Corridor Efficiency Assessment*, https://catc.ca.gov/-/media/ctc-media/documents/programs/sb671/sb671-final-clean-freight-corridor-efficiency-assessment-dor.pdf.

Detailed Results

California Electrification Goals Scenario

Table E-5: Statewide Medium-Duty Vehicle Charging Port Totals From HEVI-LOAD for the California Electrification Goals Scenario

Location Type	Power (kW)	2027	2030	2035
En Route	350	410	819	1,503
En Route	500	25	53	82
En Route	750	8	11	22
En Route	1,000	2	3	7
En Route	1,500	1		2
Private Depot	19.2	2,003	3,711	7,094
Private Depot	50	6,392	11,929	23,470
Private Depot	100	4,759	8,842	17,319
Private Depot	150	2,426	4,613	8,949
Private Depot	350	949	1,892	3,496
Private Depot	500	201	381	740
Private Depot	750	75	168	303
Private Depot	1,000	35	59	112
Private Depot	1,500	8	25	41
Public Depot	150	2,912	5,735	11,138
Public Depot	350	322	626	1,183
Public Depot	500	147	300	614
Public Depot	750	41	74	145
Public Depot	1,000	13	21	42
Public Depot	1,500	3	4	12
Grand Total		**20,731**	**39,265**	**76,274**

Source: CEC staff

Table E-6: Statewide Heavy-Duty Vehicle Charging Port Totals From HEVI-LOAD for the California Electrification Goals Scenario

Location Type	Power (kW)	2027	2030	2035
En Route	350	233	807	6,318
En Route	500	16	81	571
En Route	750	6	20	163
En Route	1,000	1	6	43
En Route	1,500		1	10
Private Depot	50	565	1,780	15,030
Private Depot	100	353	1,003	8,549
Private Depot	150	166	595	5,097
Private Depot	350	95	355	3,089
Private Depot	500	29	63	581
Private Depot	750	8	38	262
Private Depot	1,000	6	8	109
Private Depot	1,500		2	28
Public Depot	150	217	594	4,850
Public Depot	350	38	116	886
Public Depot	500	20	47	472
Public Depot	750	2	17	124
Public Depot	1,000	2	5	31
Public Depot	1,500			7
Grand Total		**1,759**	**5,538**	**46,220**

Source: CEC staff

Federal Obstacles to EV Adoption Scenario

Table E-7: Statewide Medium-Duty Vehicle Charging Port Totals From HEVI-LOAD for the Federal Obstacles to EV Adoption Scenario

Location Type	Power (kW)	2027	2030	2035
En Route	350	387	803	1,235
En Route	500	24	52	67
En Route	750	8	11	18
En Route	1,000	1	3	5
En Route	1,500	1		1
Private Depot	19.2	1,892	3,639	5,827
Private Depot	50	6,037	11,695	19,277
Private Depot	100	4,494	8,669	14,225
Private Depot	150	2,291	4,523	7,351
Private Depot	350	896	1,855	2,872
Private Depot	500	190	374	608
Private Depot	750	71	165	248
Private Depot	1,000	33	58	92
Private Depot	1,500	7	24	34
Public Depot	150	2,750	5,622	9,148
Public Depot	350	304	613	972
Public Depot	500	139	294	504
Public Depot	750	39	72	119
Public Depot	1,000	12	21	35
Public Depot	1,500	2	4	10
Grand Total		**19,577**	**38,495**	**62,647**

Source: CEC staff

Table E-8: Statewide Heavy-Duty Vehicle Charging Port Totals From HEVI-LOAD for the Federal Obstacles to EV Adoption Scenario

Location Type	Power (kW)	2027	2030	2035
En Route	350	233	807	5,865
En Route	500	16	81	530
En Route	750	6	20	151
En Route	1,000	1	6	40
En Route	1,500		1	9
Private Depot	50	565	1,780	13,953
Private Depot	100	353	1,003	7,936
Private Depot	150	166	595	4,732
Private Depot	350	95	355	2,868
Private Depot	500	29	63	539
Private Depot	750	8	38	244
Private Depot	1,000	6	8	101
Private Depot	1,500		2	26
Public Depot	150	217	594	4,502
Public Depot	350	38	116	823
Public Depot	500	20	47	438
Public Depot	750	2	17	115
Public Depot	1,000	2	5	28
Public Depot	1,500			6
Grand Total		**1,759**	**5,538**	**42,908**

Source: CEC staff

Higher Capacity Factor Alternative Scenario

Table E-9: Statewide Medium-Duty Vehicle Charging Port Totals From HEVI-LOAD for the Higher Capacity Factor Alternative Future Scenario

Location Type	Power (kW)	2027	2030	2035
En Route	350	214	426	783
En Route	500	13	28	43
En Route	750	4	6	12
En Route	1,000	1	1	3
En Route	1,500			1
Private Depot	19.2	1,043	1,933	3,695
Private Depot	50	3,329	6,213	12,224
Private Depot	100	2,479	4,605	9,021
Private Depot	150	1,264	2,403	4,661
Private Depot	350	494	985	1,821
Private Depot	500	105	199	385
Private Depot	750	39	87	158
Private Depot	1,000	18	31	58
Private Depot	1,500	4	13	21
Public Depot	150	1,517	2,987	5,801
Public Depot	350	168	326	616
Public Depot	500	77	156	320
Public Depot	750	21	38	76
Public Depot	1,000	7	11	22
Public Depot	1,500	1	2	6
Grand Total		**10,797**	**20,450**	**39,726**

Source: CEC staff

Table E-10: Statewide Heavy-Duty Vehicle Charging Port Totals From HEVI-LOAD for the Higher Capacity Factor Alternative Future Scenario

Location Type	Power (kW)	2027	2030	2035
En Route	350	121	421	3,291
En Route	500	9	42	297
En Route	750	3	11	85
En Route	1,000	1	3	23
En Route	1,500			5
Private Depot	50	294	927	7,828
Private Depot	100	184	522	4,453
Private Depot	150	86	310	2,655
Private Depot	350	49	185	1,609
Private Depot	500	15	33	302
Private Depot	750	4	20	137
Private Depot	1,000	3	4	57
Private Depot	1,500		1	14
Public Depot	150	113	309	2,526
Public Depot	350	20	60	462
Public Depot	500	11	24	246
Public Depot	750	1	9	64
Public Depot	1,000	1	2	16
Public Depot	1,500			4
Grand Total		**916**	**2,885**	**24,073**

Source: CEC staff

Table E-11: Vehicles per Port in HEVI-LOAD Results for 2030

Scenario	Vehicle Class	Vehicle per Port
California Electrification Goals	Medium-Duty	1.89
California Electrification Goals	Heavy-Duty	1.68
Federal Obstacles to EV Adoption	Medium-Duty	1.89
Federal Obstacles to EV Adoption	Heavy-Duty	1.68
Higher Capacity Factor Alternative Future	Medium-Duty	3.63
Higher Capacity Factor Alternative Future	Heavy-Duty	3.22

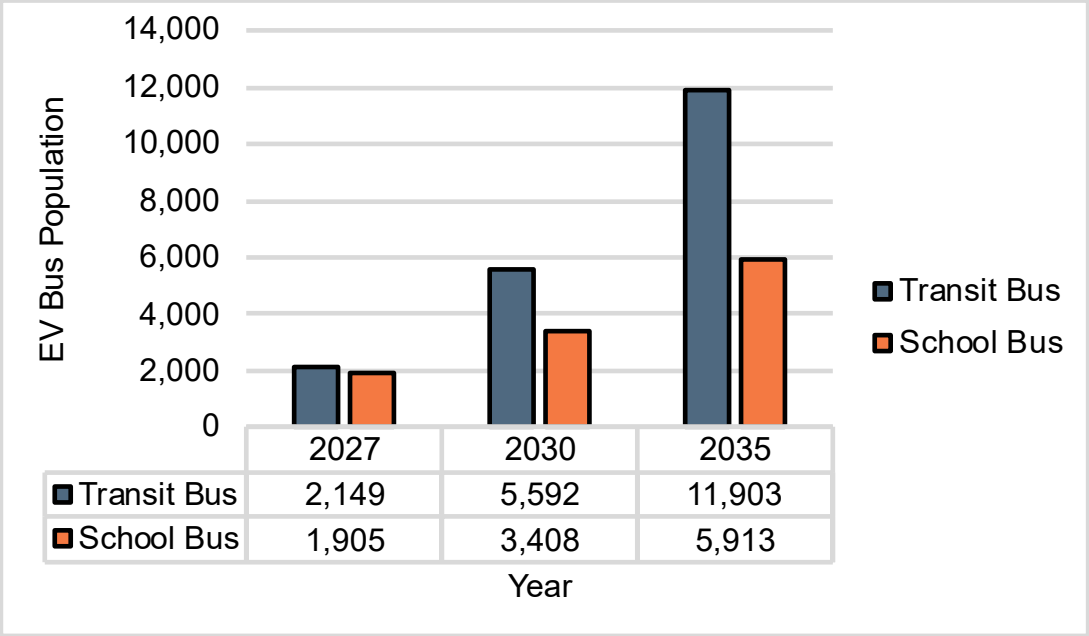
Source: CEC staff

APPENDIX F:
Bus Model

The bus model estimates charging needs for battery-electric transit and school buses. It is top-down and disaggregates, or breaks down, statewide bus travel demand to estimate regional infrastructure needs at the scale of counties. It derives total statewide bus mileage from EMFAC, Altitude by Geotab, and supporting literature such as the *Electric School Bus U.S. Market Study* and the *Zero-Emission Bus Blueprint* to calculate total charging load, which is then distributed across counties using data from Altitude by Geotab.[28] Statewide battery-electric transit and school bus populations used in this analysis are from the *2025 IEPR* (Figure F-1). Buses are assumed to charge only after completing routes and returning to the depot, utilizing private access depot charging. Allowing nonbus vehicles to charge at their depots would introduce liability and safety issues. For this reason, bus charging ports are counted as private depot charging ports when combining MDHD charging port counts.

28 California Air Resources Board. "EMFAC," https://arb.ca.gov/emfac/emissions-inventory/5e1f30f1f47ccf578757a37b96e89bb720272063. Accessed June 12, 2025; Wang, Jessica, Vishant Kothari, Emmett Werthmann, Eleanor Jackson, Lidia Henderson, and Alissa Huntington. 2024. *Electric School Bus US Market Study.* World Resource Institute, https://electricschoolbusinitiative.org/sites/default/files/2024-08/Electric%20School%20Bus%20U.S.%20Market%20Study%20(August%202024).pdf; Martinez, Sofia S. and Constantine Samaras. February 19, 2024. "Electrification of Transit Buses in the United States Reduces Greenhouse Gas Emissions." *Environmental Science & Technology* 58, no. 9: 4137-4144, https://pubs.acs.org/doi/10.1021/acs.est.2c07296; Santa Clara Valley Transportation Authority. November 2024. *Zero-Emission Bus Blueprint,* https://www.vta.org/sites/default/files/2025-04/VTA_ZEB_Blueprint_0.pdf.

Figure F-1: EV Bus Populations in the Model



The bus model uses EV bus populations from the CEC's *2025 Integrated Energy Policy Report*. Bus populations remain unchanged in both Additional Achievable Transportation Electrification 4 and Baseline scenarios.

Source: CEC

Hourly distribution of the number of operational buses is based on FleetDNA and EMFAC data, which provide estimates of when buses return to the depot throughout the day. This information is then used to allocate hourly charging load. Bus charging load combined with other MDHD vehicles are shown in Figure G-2 in Appendix G.

Modeling Assumptions

Table F-1: Vehicle and Travel Behavior Assumptions

Assumption	Transit Bus	School Bus
Average daily vehicle miles traveled (VMT) per bus	72.83 miles in 2027 68.87 miles in 2030 67.01 miles in 2035	27.56 miles in 2027 29.18 miles in 2030 30.32 miles in 2035
Energy efficiency	2.19 kWh/mile in 2027 2.22 kWh/mile in 2030 2.23 kWh/mile in 2035	1.8 kWh/mile
EV battery capacity	400 kWh	200 kWh
Charging Power	50 kW, 150 kW, 350 kW	19.2 kW, 50 kW

Source: CEC staff and LBNL

Results

Table F-2 shows statewide bus charging port counts. The overall capacity factor for transit bus charging ports stays at 3 percent for 2027 and 2030, rising to 5 percent in 2035. For school bus charging ports, it is 7 percent in 2027, 8 percent in 2035, and 13 percent in 2035. Results for 2030 show one vehicle per port for both transit and school buses.

Table F-2: Projected Charging Port Needs for Buses in 2027, 2030 and 2035

	Power (kW)	2027	2030	2035
Transit Bus	50	367	895	1,282
Transit Bus	150	1,474	3,598	5,156
Transit Bus	350	552	1,347	1,930
Transit Bus	**Total**	**2,393**	**5,840**	**8,368**
School Bus	19.2	1,484	2,628	2,865
School Bus	50	505	895	976
School Bus	**Total**	**1,989**	**3,523**	**3,841**

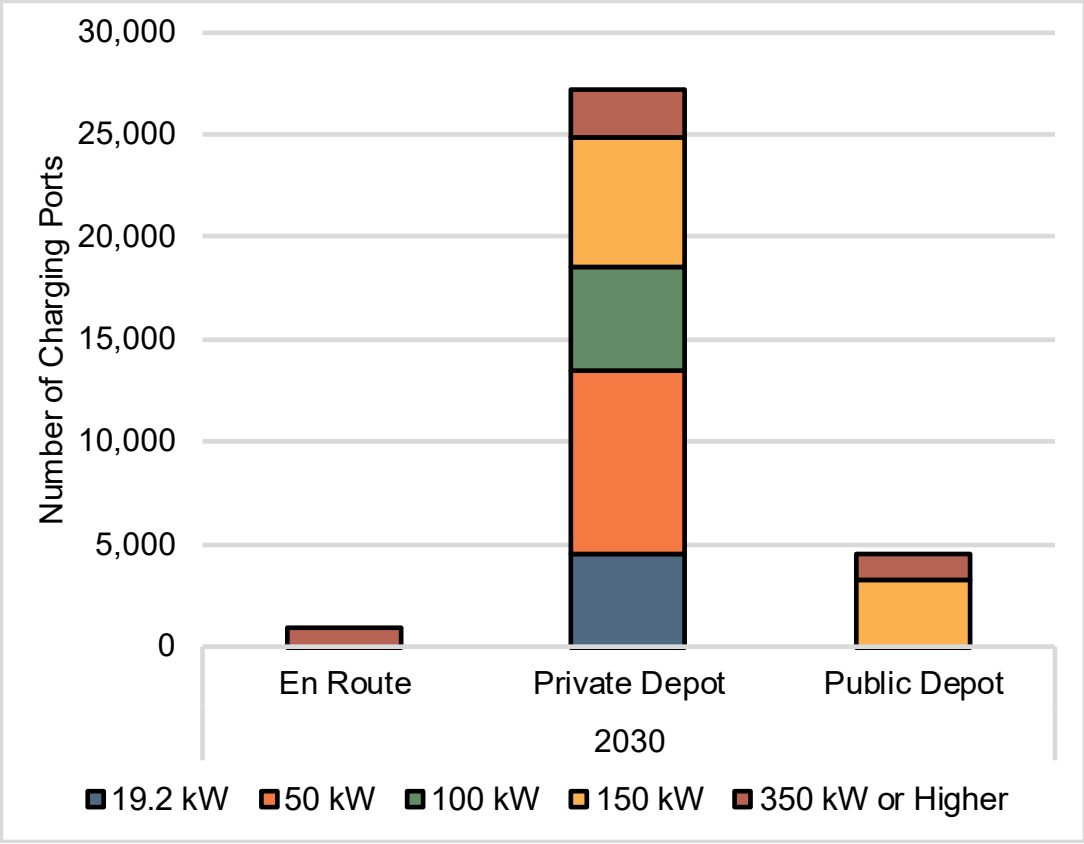
Source: LBNL

APPENDIX G:
Additional Results For Medium- and Heavy-Duty Electric Vehicle Infrastructure Needs

Higher Capacity Factor Alternative Future Scenario

The California Electrification Goals Scenario considers an overall capacity factor of 2.5 percent for the MDHD charging network in 2030 (excluding charging ports for buses). If utilization is higher than expected, a smaller number of charging ports would be able to serve the same number of vehicles. This alternative future scenario estimates the size of the required charging network assuming 4.8 percent overall capacity factor in 2030. In this scenario, about 33,000 charging ports will be needed to serve 93,000 MDHD EVs in 2030. About 27,000 of these charging ports will be needed at private depots. Bus charging ports are assumed to be installed only at private bus depots. Figure G-1 shows charging port needs in 2030 under this scenario.

Figure G-12: Projected Medium- and Heavy-Duty Charging Infrastructure Needs in 2030 Under the Higher Capacity Factor Alternative Future Scenario



Under the higher capacity factor alternative scenario, about 33,000 charging ports will be needed in 2030 for almost 93,000 vehicles. About 27,000 of these charging ports will be needed at private depots.

Source: CEC staff

Table G-1 shows by how much the number of required charging ports in 2030 under each scenario change from the California Electrification Goals Scenario.

Table G-1: Difference in 2030 Charger Counts Under Different Scenarios Compared to the California Electrification Goals Scenario

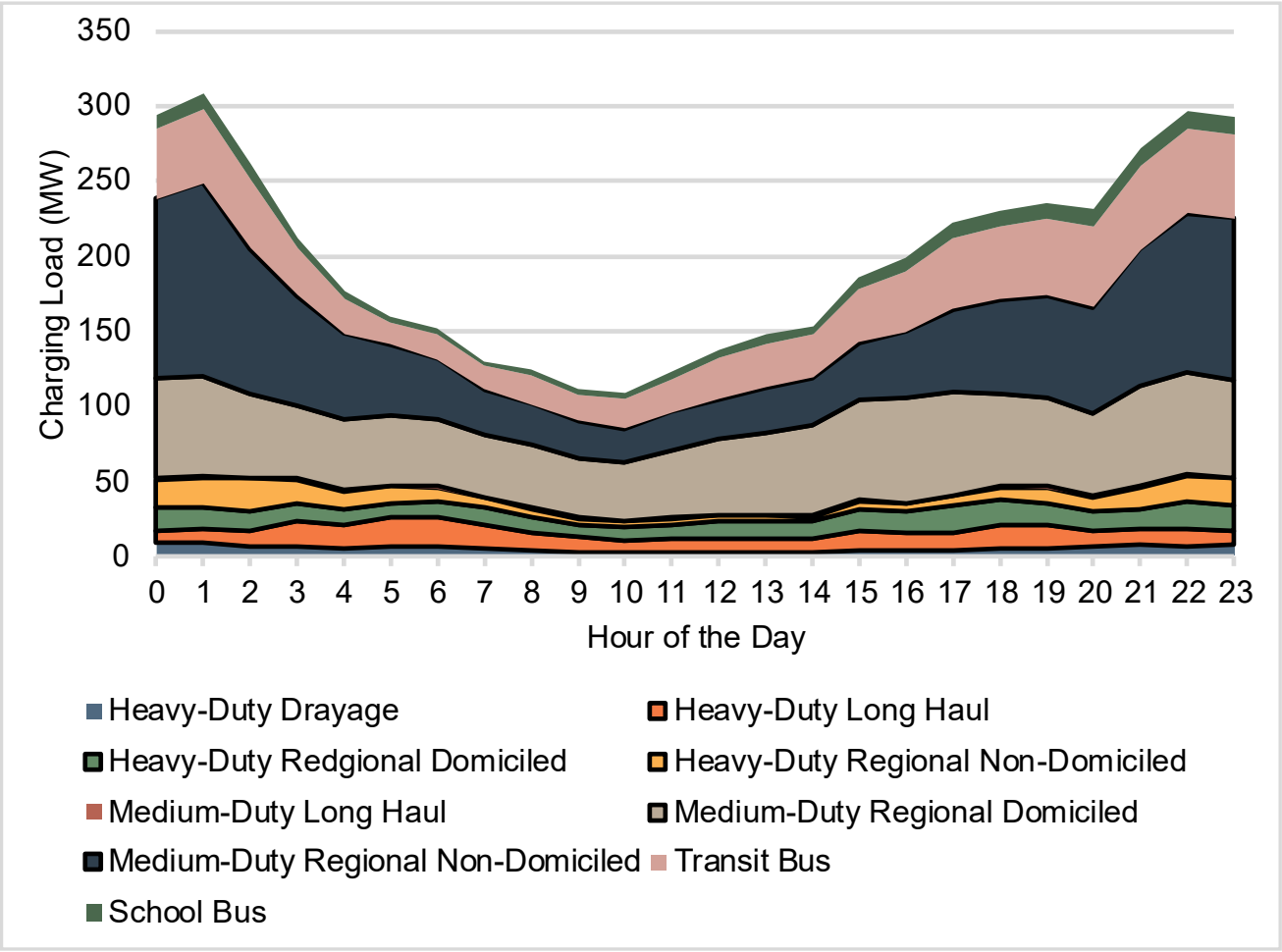
Scenario	Private Depot	Public Depot	En Route
Federal Obstacles to EV Adoption	-598	-153	-17
Higher Capacity Factor Alternative Future	-16,384	-4,220	-863

Source: CEC staff and LBNL

MDHD Charging Load

Figure G-2 shows statewide MDHD charging load for the California Electrification Goals Scenario. In addition to buses, vehicles are broken down by vocation (drayage, regional, long-haul), and vehicle class (medium-duty and heavy-duty). Furthermore, regional MDHD vehicles with and without access to a private depot are classified as domiciled and nondomiciled, respectively. Sixty percent of charging for all vehicle types, except buses, at both private and public depots is considered TOU-responsive and shifted to off-peak hours. Buses are assumed to charge after returning to the depot and can charge several times a day as necessary. With these considerations, the peak is observed at 1 a.m.

Figure G-23: Medium- and Heavy-Duty EV Charging Load Curve in 2030



In 2030, battery-electric MDHD vehicle charging will generate an aggregate demand peak of about 300 MW at 1 a.m., assuming 60 percent depot charging will be TOU-sensitive for all vehicles except the buses.

Source: LBNL and CEC staff

New Charging Ports Needed Each Year Under the California Electrification Goals Scenario

Tables G-2 and G-3 show the number of new MDHD charging ports needed each year under the California Electrification Goals scenario. These numbers are used as an input for the JOBS EVSE 2.0 workforce estimation tool (Appendix E), which does not include 100 kW ports as a category. Because of this, the 100 kW ports generated from the modeling are aggregated with 150 kW ports. In addition, 350 kW and 500 kW ports are combined under one category (DCFC 100, 150); so are 750 kW, 1,000 kW, and 1,500 kW ports (DCFC 750, 1000, 1500) that appear in other result tables. Also for aligning with the location types in the JOBS EVSE 2.0 workforce estimation tool, private depot locations are considered as "workplace," while public depot and en route locations are naturally considered to be "public" locations.

Most recent MDHD charging port deployment data available to the CEC shows about 20,000 ports operational or under development as of September 16, 2025, with no information on the

share of different charging power levels. For the labor and workforce analysis, this number is assumed to be the ports available by the end of 2025. The number of ports for each type is derived from this aggregate number by applying the distribution of 2027 port types obtained from the modeling: if DCFC 50 ports are 20 percent of the total port count in 2027, the number of DCFC 50 ports in 2025 is taken as 20 percent of the 2025 total of 20,000.

HEVI-LOAD and the Bus Model produced charging port needs for 2027, 2030, and 2035. Port counts for intermediate years are obtained using linear interpolation: 2027 and 2030 port counts are used to generate counts for 2028 and 2029, while 2030 and 2035 counts produced port needs in 2031-2034. Finally, 2026 port counts are generated by averaging the number of ports in 2025 and 2027.

Table G-2: New MDHD Charging Ports Needed Each Year 2025–2030 Under the California Electrification Goals Scenario

Charging Port Type	Location	Operational or under development charging ports as of 9/16/2025	2026	2027	2028	2029	2030
Level 2	Workplace	2,595	446	446	966	877	1,009
DCFC 50	Workplace	5,828	1,001	1,001	2,453	2,429	2,786
DCFC 100, 150	Public	2,329	400	400	1,039	1,041	1,119
DCFC 100, 150	Workplace	6,831	1,173	1,173	2,981	2,987	3,505
DCFC 350, 500	Public	1,299	223	223	598	686	940
DCFC 350, 500	Workplace	962	165	165	454	492	679
DCFC 750, 1000, 1500	Public	107	18	18	48	52	67
DCFC 750, 1000, 1500	Workplace	49	8	8	24	27	33
Level 2 and DCFC		**20,001**	**3,435**	**3,435**	**8,564**	**8,592**	**10,139**

Source: CEC staff

Table G-3: New MDHD Charging Ports Needed Each Year 2031–2035 Under the California Electrification Goals Scenario

Charging Port Type	Location	Installed charging ports at end of 2030	2031	2032	2033	2034	2035	Total charging ports added 2026 - 2035
Level 2	Workplace	6,339	956	801	686	624	553	7,364
DCFC 50	Workplace	15,469	4,242	5,449	5,617	5,126	4,826	34,930
DCFC 100, 150	Public	6,328	1,605	2,087	2,163	1,980	1,826	13,659
DCFC 100, 150	Workplace	18,651	4,645	5,654	5,755	5,311	5,056	38,240
DCFC 350, 500	Public	3,969	1,752	2,495	2,559	2,182	1,968	13,626
DCFC 350, 500	Workplace	2,917	715	786	762	689	672	5,579
DCFC 750, 1000, 1500	Public	312	118	164	167	144	129	926
DCFC 750, 1000, 1500	Workplace	150	46	62	64	55	49	378
Level 2 and DCFC		**54,166**	**14,078**	**17,497**	**17,772**	**16,110**	**15,079**	**114,702**

Source: CEC staff

APPENDIX H:
JOBS EVSE 2.0

Estimating the number and types of jobs that will be required to support electric vehicle charging infrastructure is key to understanding the related labor market supply and future demand. The following estimate focuses on supply chain[29] jobs, reported in job-years, needed for the development and operations of public and limited access charging ports. Jobs for private charging stations and chargers installed at single-family homes are not included in the analysis. Induced impact jobs associated with the spending of wages by job holders elsewhere in the economy are also excluded from the workforce estimate.

Method

The Argonne National Laboratory JOBS EVSE 2.0© model[30] provides a gross, input-output, economic impact analysis to calculate employment gains associated with charging infrastructure manufacturing, installation, operations, and maintenance. Input-output analyses are most often used for regional planning and track economic transactions between industries over time. The model uses regional input-output modeling[31] tables and economic employment multipliers[32] specific to California.

Employment impacts, or jobs, are calculated from a percentage of uninstalled equipment costs. Equipment costs include charger assemblies, onsite battery storage, mounting hardware, and safety and traffic control supplies such as bollards. Upstream equipment used to obtain power from the existing utility's distribution network is also included, such as switch gear, transformers, conduit, and cables. JOBS EVSE 2.0 assesses direct jobs such as charging equipment manufacturing, transportation, construction, and maintenance, as well as indirect jobs such as raw material production, prefabricated materials, electrical generation, and administration. Warranty, maintenance, administration, data networking, and power generation are included in the following analysis as operations jobs. Jobs are reported in the number of job-years, defined as one year of work for one person; it does not account for part-time employment or employees who are serving more than one industry through their occupation.

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29 *Supply chain* jobs are direct and indirect impacts from initial expenditures.

30 JOBS EVSE 2.0 was developed by the Argonne National Laboratory with funding from the Vehicle Technologies Office of the U.S. Department of Energy. Available at https://www.anl.gov/esia/jobs-evse.

31 The U.S. Department of Commerce's Bureau of Economic Analysis produces annual input-output tables (Regional Input-Output Modeling System; RIMS II) for the United States that provide an economic snapshot of about 500 industries.

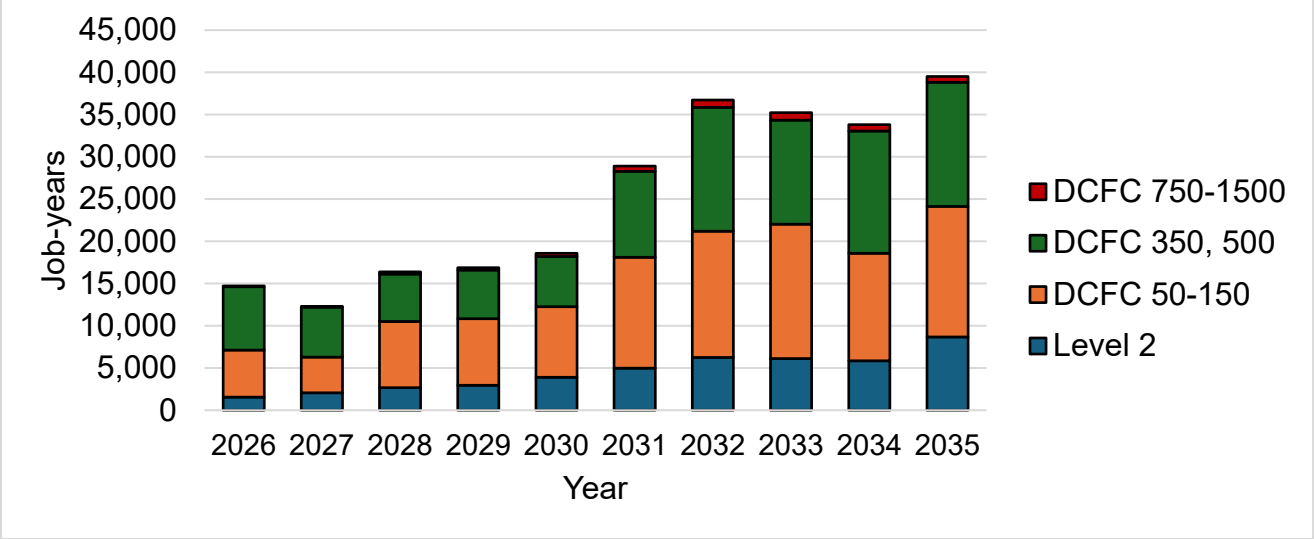
32 *Economic employment multipliers* are used to estimate the total increase in employment across the economy for every new job created in specific industries, which are categorized by North American Industry Classification System codes.

Charging Development and Deployment Jobs

The workforce estimates to support equipment manufacturing is driven primarily by charger and on-site electrical storage production, as this equipment includes some of the most expensive components and has the largest employment multipliers. Although equipment manufacturing may take place prior to the year in which charger installation occurs, all charger manufacturing and installation jobs including construction are counted the same year.

EVI-Pro 4 primary scenario estimates that 842,207 new public and limited access charging ports including for multifamily homes will need to be installed in California between 2026 and 2035 to support light-duty vehicles (Tables B-5 and B-6). The HEVI-LOAD and Bus Models estimate 114,702 ports will need to be installed at public depots, private depots, and en route for medium-, heavy-duty, transit, and school bus applications (Tables G-2 and G-3). JOBS EVSE 2.0 estimates that up to 253,069 job-years (Figure H-1) will be needed to manufacture and install these new charging ports. Not included in this total are additional job-years needed to manufacture and install more than 8.3 million charging ports in single-family homes.

Figure H-14: Charging Development and Deployment Jobs



Source: CEC staff

About 45,070 job-years will be needed to manufacture and install Level 2 chargers; 105,994 job-years for 50–150 kW DCFC, 97,059 job-years for 350 kW DCFC, and 4,946 job-years for 750–1500 kW DCFC that will be installed at public and limited access locations (Table H-1).

Table H-1: Yearly Development Jobs by Charging Port Type (job-years)

Year	Level 2	DCFC 50-150 kW	DCFC 350, 500 kW	DCFC 750-1500 kW	Total
2026	1,549	5,577	7,497	100	14,723
2027	2,070	4,220	5,908	100	12,297
2028	2,667	7,848	5,612	267	16,394
2029	2,954	7,877	5,761	290	16,882

Year	Level 2	DCFC 50-150 kW	DCFC 350, 500 kW	DCFC 750-1500 kW	Total
2030	3,904	8,364	5,947	371	18,587
2031	4,989	13,129	10,168	624	28,911
2032	6,263	14,929	14,662	865	36,718
2033	6,120	15,903	12,324	884	35,232
2034	5,866	12,712	14,474	761	33,813
2035	8,688	15,435	14,706	683	39,512
Total	**45,070**	**105,994**	**97,059**	**4,946**	253,069

Source: CEC staff, output from JOBS EVSE 2.0

Direct and indirect manufacturing jobs to support vehicle charging development include production of raw materials, component or prefabricated material production, equipment assembly, and transportation. Charging equipment installation includes engineering, design, permitting, site preparation, electrical infrastructure make-ready[33], and construction jobs. About 68,387 job-years will be needed for manufacturing, transportation, and installation; 145,167 job-years will be needed for civil and electrical (Figure H-2).

Table H-2: Charging Development Job-Years by Job Type

Year	Manufacturing, Transportation, Installation	Civil, Electrical Construction	Total Job-Years
2026	4,709	10,014	14,723
2027	3,969	8,329	12,297
2028	5,244	11,149	16,394
2029	5,437	11,445	16,882
2030	6,058	12,529	18,587
2031	9,243	19,668	28,911
2032	11,683	25,035	36,718
2033	11,229	24,003	35,232
2034	10,816	22,997	33,813
2035	12,888	26,624	39,512
Total	**68,387**	**145,166**	**253,069**

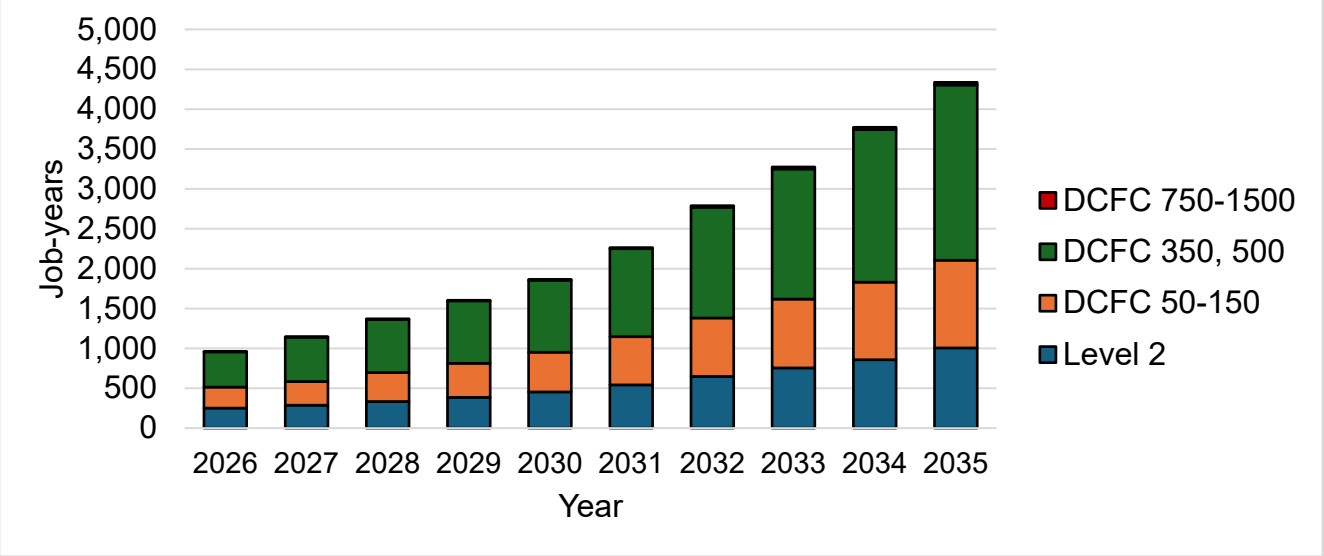
Source: CEC staff, output from JOBS EVSE 2.0

33 *Make ready* refers to work needed to modify or upgrade to existing electrical infrastructure to handle the increased power demand from EV charging ports. Examples include increasing the capacity of transformers, replacing or increasing the capacity of existing transmission power lines, installing new electrical panels or upgrading existing with additional circuits, and installing conduit and wiring to connect the electrical system to the charging stations.

Charging Operations Jobs

EVSE JOBS 2.0 assumes that jobs pertaining to electric vehicle charging operations begin the year following installation, that is, operational jobs for the light-, medium- heavy duty, transit and school charging ports installed as of 2025 (Appendix Tables B-5, B-6, G-1 and G-2) are counted in 2026. Operations jobs are based on the cumulative number of installed charging ports. For example, operational jobs for 2027 include jobs to maintain and operate charging ports installed as of 2025 and charging ports installed in 2026. Up to 23,389 (Figure H-2) job-years are estimated to be needed to support the 236,446 public and limited access charging ports installed as of 2025 and 956,909 new charging ports installed between 2026 through 2035.

Figure H-25: Charging Operations Jobs



Source: CEC staff

About 5,527 job-years will be needed to support operations and maintenance of Level 2 chargers; 6,117 job-years for 50–150 kW DCFC, 11,586 job-years for 350–500 kW DCFC, and 159 job-years for 750–1500 kW DCFC that will be installed at public and limited access locations (Table H-3).

Table H-3: Charging Operations Job-Years by Charging Port Type

Year	Level 2	DCFC 50-150 kW	DCFC 350, 500 kW	DCFC 750-1500 kW	Total Job-years
2026	252	262	443	4	961
2027	288	297	556	5	1,146
2028	335	362	667	7	1,371
2029	387	427	782	8	1,605
2030	455	497	903	11	1,865
2031	542	605	1,104	15	2,265
2032	649	731	1,390	20	2,790
2033	755	864	1,631	25	3,275

Year	Level 2	DCFC 50-150 kW	DCFC 350, 500 kW	DCFC 750-1500 kW	Total Job-years
2034	858	972	1,912	30	3,773
2035	1,006	1,101	2,198	34	4,338
Total	**5,527**	**6,117**	**11,586**	**159**	**23,389**

Source: CEC staff, output from JOBS EVSE 2.0

The workforce needed to support charging port operations can be categorized by industry sector: electrical generation; data and networking; and warranty, maintenance, and administrative jobs. About 18,684 job-years will be needed for electrical generation; 2,570 job-years for data and networking; and 2,134 job years for warranty, maintenance and administrative work as summarized in Table H-4.

Table H-4: Charging Operations Job-Years by Job Type

Year	Electrical Generation	Data and Networking	Warranty, Maintenance, Administrative	Total Job-Years
2026	758	110	93	961
2027	911	128	108	1,146
2028	1,092	152	127	1,371
2029	1,279	178	148	1,605
2030	1,483	209	174	1,865
2031	1,804	252	209	2,265
2032	2,233	305	252	2,790
2033	2,623	357	295	3,275
2034	3,029	408	337	3,773
2035	3,474	472	391	4,338
Total	**18,685**	**2,570**	**2,134**	**23,389**

Source: CEC staff, output from JOBS EVSE 2.0

JOBS EVSE 2.0 Summary

Input-output models, such as EVSE JOBS 2.0, are best suited for policy or program planning at the industry level to estimate employment impacts and may overestimate actual labor demand for project or worksite applications. Input-output economic models like JOBS EVSE 2.0 assume productivity to be static, or industry inputs and outputs do not change over time. Since technological advancements and economies of scale can change over time, especially for new technologies, the manufacturing workforce effect for charging infrastructure is difficult to estimate over long periods.[34] Comparatively, a bottom-up workforce analysis approach may

34 Ke, Y., M. Mintz, and Y. Zhou. 2022. "Estimating Potential Employment Impact of the Charging Infrastructure Used to Support Transportation Electrification in the United States." *Transportation Research Record*, *2676* (12), 436-444. https://doi.org/10.1177/03611981221095750.

overlook smaller tasks and potentially underestimate workforce needs; a bottom-up approach is most effective for project level workforce planning for specific occupations.

For example, the 2021 *Workforce Projections to Support Battery Electric Vehicle Charging Infrastructure Installation*[35] report, a bottom-up analysis, estimated 71,510 job-years could install 1,624,000 charging ports. The 2021 report did not include jobs for raw material production, equipment component production, assembly, and transportation jobs, which are all included in the JOBS EVSE 2.0 model. Only installation jobs (engineering, design, permitting, electrical infrastructure make ready, civil and electrical construction) were included in the 2021 report.

JOBS EVSE 2.0, a top-down input-output model, estimates 253,069 job-years would be needed to support development, manufacturing, and installation of 956,909 public and limited access Level 2 and DCFC ports for light-duty, medium-duty, heavy-duty, and bus applications. An additional 23,389 job-years will be needed to support operations of charging ports installed as of 2025 and between 2026 to 2035 (Table H-5).

Table H-5: EVSE JOBS 2.0 Summary (job-years)

Job Type	Level 2	DCFC 50-150 kW	DCFC 350, 500 kW	DCFC 750-1500 kW	Total
Manufacturing, Transportation, Installation	20,032	31,925	29,102	217	**81,276**
Civil, Electrical Construction	25,038	74,069	67,957	4,729	**171,793**
Electrical Generation	2,392	5,218	10,924	150	**18,684**
Data and Networking	1,537	591	435	6	**2,570**
Warranty, Maintenance, Administrative	1,598	307	226	3	**2,134**
Total Development and Operations	**50,597**	**112,111**	**108,645**	**5,105**	**276,458**

Source: CEC staff, output from JOBS EVSE 2.0

Modeling the existing labor market supply is critical for identifying gaps in between workforce supply and demand. In addition to estimating gross demand for jobs associated with charging infrastructure, future workforce assessments should carefully analyze the net migration of jobs between industries and adjacent sectors. The CEC has contracted the University of California, Los Angeles, Labor Center to conduct an in-depth workforce assessment of the zero-emission vehicle charging infrastructure labor market focusing on installation and maintenance occupations. The workforce assessment will include information about workforce supply and

35 Carr, Edward, James Winebrake, and Samuel Winebrake. June 2021. *Workforce Projections to Support Battery Electric Vehicle Charging Infrastructure Installation*. Energy and Environmental Research Associates, https://www.etcommunity.org/wp-content/uploads/2024/03/Workforce-ProjectionstoSupportBatteryElectricVehicleChargingInfrastructureInstallation.pdf.

demand, project job growth, and identify any regional workforce supply or training gaps. This workforce assessment is expected to be completed by early 2027.