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Workforce Projections to Support Battery Electric Vehicle Charging Infrastructure Installation

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Acronyms and Abbreviations

Acronym	Abbreviation
AC	Alternating current
ADA	Americans with Disabilities Act
AFDC	Alternative Fuels Data Center
AFV	Alternative Fuel Vehicle
BEV	Battery electric vehicle
BLS	Bureau of Labor Statistics
CalEPA	California Environmental Protection Agency
CALeVIP	California Electric Vehicle Infrastructure Project
CARB	California Air Resources Board
CEC	California Energy Commission
CO_2	Carbon dioxide, also CO_2e, carbon dioxide equivalent
CPUC	California Public Utilities Commission
CRS	Congressional Research Service
CVRP	California Clean Vehicle Rebate Project
DAC	Disadvantaged community
DC	Direct current
DUNS	Data Universal Numbering System
EACH	Electric Access Charging Hub
ECS	Electronic Charging Station
EV	Electric Vehicle
EVITP	Electric Vehicle Infrastructure Training Program
EVSE	Electric Vehicle Supply Equipment
FCEV	Fuel cell electric vehicle
FHWA	Federal Highway Administration
GHG	Greenhouse gas
GVWR	Gross vehicular weight rating. Sometimes just GVW
HDV	Heavy-Duty Vehicle
IOU	Investor-owned utility
LAEDC	Los Angeles Economic Development Corporation
LDV	Light-Duty Vehicle
MDV	Medium-Duty Vehicle
MPGe	Miles per gallon equivalent
MUD	Multi-unit dwelling
NAICS	North American Industry Classification System
NAICS	North American Industry Classification System
NEC	National Electric Code
NFPA	National Fire Protection Association
NOx	Nitrogen oxides
NREL	National Renewable Energy Laboratory
NRG	NRG Energy, Inc

NVE	Nevada Energy
O&M	Operations and maintenance
OCVRP	Oregon Clean Vehicle Rebate Program
OES	Occupational Employment Statistics and Wages
PEV	Plug-in Electric Vehicle
PEV	Plug-in electric vehicles
PG&E	Pacific Gas & Electric
PHEV	Plug-in Hybrid Electric Vehicle
$PM_{2.5}$	Particulate matter 2.5μm or smaller
RMI	Rocky Mountain Institute
SB	Senate Bill
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SO_2	Sulfur dioxide
USAID	U.S. Agency for International Development
USEER	U.S. Energy and Employment Report

Workforce Projections to Support Battery Electric Vehicle Charging Infrastructure Installation

Executive Summary

This report assesses the workforce needs associated with light-duty and medium/heavy-duty battery electric vehicle charging infrastructure build-out and identifies equitable pathways towards "high road" jobs for priority communities within the electric vehicle charging infrastructure landscape. This work provides policymakers and interested stakeholders with an overview of the electric vehicle landscape, discussion of the current state of the workforce, survey-derived bottom-up estimates of workforce needs to support infrastructure buildout, and perspectives on potential pathways to address issues of equity in the burgeoning electric vehicle infrastructure workforce.

Workforce estimates, derived from bottom-up survey elicitation from industry professionals show that California's statewide light-duty electric vehicle program goals, and the associated charging infrastructure would generate workforce needs of ~38,200 to 62,400 job-years over the period from 2021 to 2031 in California, based on the baseline and high electric vehicle adoption scenarios. The greatest workforce needs for light-duty infrastructure would be for electricians (21.3% of job-years), general contractors (21% of job-years), planning and design (20% of job-years), and electrical contractors (15% of job-years). From estimates of projected medium and heavy-duty electric vehicle growth, this work estimates that the associated charging infrastructure in California would generate ~9,100 additional job-years from 2021 - 2030, in addition to the light-duty charging infrastructure workforce needs. Nationwide buildout of 500,000 electric vehicle DC Fast chargers by 2030, announced in 2021 under the Biden administration's infrastructure goals, would generate workforce needs of around 28,950 job-years from 2021 to 2030.

The skills and knowledge gained from charger installation share many common similarities with other job sectors, meaning trained and skilled workers may find additional opportunities for career advancement in other sectors of the economy. With deliberate policies that include job quality, state-certified electrical apprenticeship and equity requirements, coupled with robust and engaged social impact analysis, widespread electric vehicle infrastructure development and the associated creation of high quality jobs can offer a pipeline for those in priority communities toward skilled, well-paying, upwardly mobile jobs and careers.

Workforce Projections to Support Battery Electric Vehicle Charging Infrastructure Installation

1 Purpose and Introduction

This report assesses the workforce needs associated with light-duty and medium/heavy duty battery electric vehicle charging infrastructure build-out and identifies equitable pathways towards "high road" jobs for priority communities within the electric vehicle charging infrastructure landscape. This work provides policymakers and interested stakeholders with an overview of the electric vehicle landscape, discussion of the current state of the workforce, survey-derived bottom-up estimates of workforce needs to support infrastructure buildout, and perspectives on potential pathways to address issues of equity in the burgeoning electric vehicle infrastructure workforce.

Transportation tailpipe emissions make up 28% of total CO_2e emissions in the United States (41% in California), and highway vehicles contribute significant emissions of particulate matter (PM), sulfur dioxide (SO_2), and oxides of nitrogen (NOx), all of which contribute to poor air quality, increased incidence of human health issues (including lung cancer, cardiovascular disease and asthma), and environmental degradation. Decarbonizing the transportation sector promises large climate and environmental health benefits and electrification is seen as one of the primary pathways toward low- and zero- emission transportation fleets. Battery electric vehicles (BEV) reduce tailpipe emissions down to zero, and when coupled with a clean renewable electricity grid BEVs can significantly reduce total emissions of greenhouse gases and other pollutants.

Electric vehicles are highly efficient. Recently produced light-duty vehicle (LDV) BEVs available in the U.S. have a median fuel consumption of ~110 miles per gallon gasoline equivalent (MPGe), and a median all-electric range of ~240 miles[1]. Given efficiency of electric vehicles, lower fuel costs, and lower overall maintenance costs, the overall cost savings of electric vehicle ownership can be significant compared to non-electric vehicles.

There are a number of challenges facing widespread adoption of electric vehicles. Arguably two of the most significant challenges are range and associated charging anxiety (Rauh, Franke, and Krems 2015), which are governed by drivers' concerns over the ready availability of electric vehicle charging infrastructure and charging cycle durations. Due to network effects, electric vehicle ownership and access to reliable charging infrastructure go hand in hand as complementary goods (Green et al., 2014; Skerlos and Winebrake, 2010; Meyer and Winebrake, 2009; Winebrake and Farrell, 1997). Increased availability of public and workplace charging stations can increase trip lengths and decrease range anxiety, while increasing access to charging, therefore supporting greater uptake of electric vehicles. Increased depot, workplace, and public charging can also support the adoption of electric fleet vehicles, including light, medium, and heavy-duty vehicles.

The development of widespread electric vehicle charging infrastructure is likely to generate thousands of new jobs. With the right policies in place to ensure job quality and equity, these new jobs can support pathways into skilled training and careers and can benefit workers in priority communities. *Priority communities* include those that disproportionately suffer from historic health,

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[1] https://afdc.energy.gov/vehicles/search/

environmental, and other social burdens, including, among others, poverty, high unemployment, inadequate access to education and training, air and water pollution, and chronic diseases. Priority communities often include high levels of residents and households with low-income status, seniors, people with disabilities, non-English speakers, and those with limited awareness of or access to clean transportation and mobility. Priority communities include those that may otherwise be referred to as disadvantaged communities (DACs) or low-income communities.

This report begins with a discussion of the current state of knowledge of the electric vehicle charging infrastructure demands, followed by a discussion of the state of the electric vehicle charging workforce. Next, this report discusses available policies, incentives, and programs that support electric vehicle charging infrastructure development, including in the context of employment opportunities for priority communities. The report concludes with an assessment of workforce needs to meet projected infrastructure demand and metrics of success to measure workforce engagement with priority communities.

2 Electric Vehicle Charging Infrastructure

The impacts of electrifying the U.S. transportation sector and associated infrastructure (e.g., truck stops, additional chargers) could have a transformative effect on our nation's economy, with the potential to generate skilled, resilient, and long-term employment opportunities. With proper development of charging infrastructure, electrification of vehicles may proliferate, potentially leading to lower pollution levels, more resilient electricity grids, and growth in employment. However, growth in employment needs to consider potential benefits to priority communities.

The California Energy Commission (CEC) forecasts that by 2025 there will be between 1.5 million and 2.4 million zero-emission vehicles on the roads in California, with the majority being BEVs[2] (Zabin et al. 2020). Though currently less than 10% of the total vehicles on the road in California, alternatively fueled vehicle market penetration on the scale necessary to decarbonize the transportation sector will require significant education, outreach, and supporting infrastructure.

The need for construction and fueling infrastructure is great, as widespread deployment of electric vehicles cannot rely on the conventional network of refueling infrastructure. Supporting electric vehicle adoption across all customer segments requires charging infrastructure across a range of accessible locations including at home, the workplace, along transit corridors, and in urban centers.

The charging needs of LDVs can differ significantly to those of medium and heavy-duty vehicles (M/HDVs). Medium- and heavy-duty vehicle charging infrastructure must be designed and built to handle larger vehicles and electricity loads, with associated safety technology, all of which lead to greater charging station complexity. Additionally, due to the operational characteristics of M/HDVs, their charging cycles may be less flexible than LDVs, thereby introducing grid load-balancing challenges.

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[2] Fuel cell electric vehicles (FCEV) are also available, though not currently as widely distributed as BEVs. FCEVs derive electrical energy from on board fuel cells, including hydrogen, to drive the vehicle's propulsion system. FCEV fueling infrastructure is not covered in this report. This report focuses on workforce needs for installing battery electric charging infrastructure.

2.1 Electric Vehicle Charging Stations

The Alternative Fuels Data Center (AFDC) reports that there are around 42,000 public electric vehicle charging stations in the U.S. with a total of ~102,000 Level 2 and DC Fast charging outlets, as of May 2021 (Figure 1).[3] California leads the way with about 13,000 public charging stations, followed by New York State with ~2,500, Florida with ~2,200, Texas with ~2,000, Massachusetts with ~1,700, and Washington state with ~1,500 charging stations.

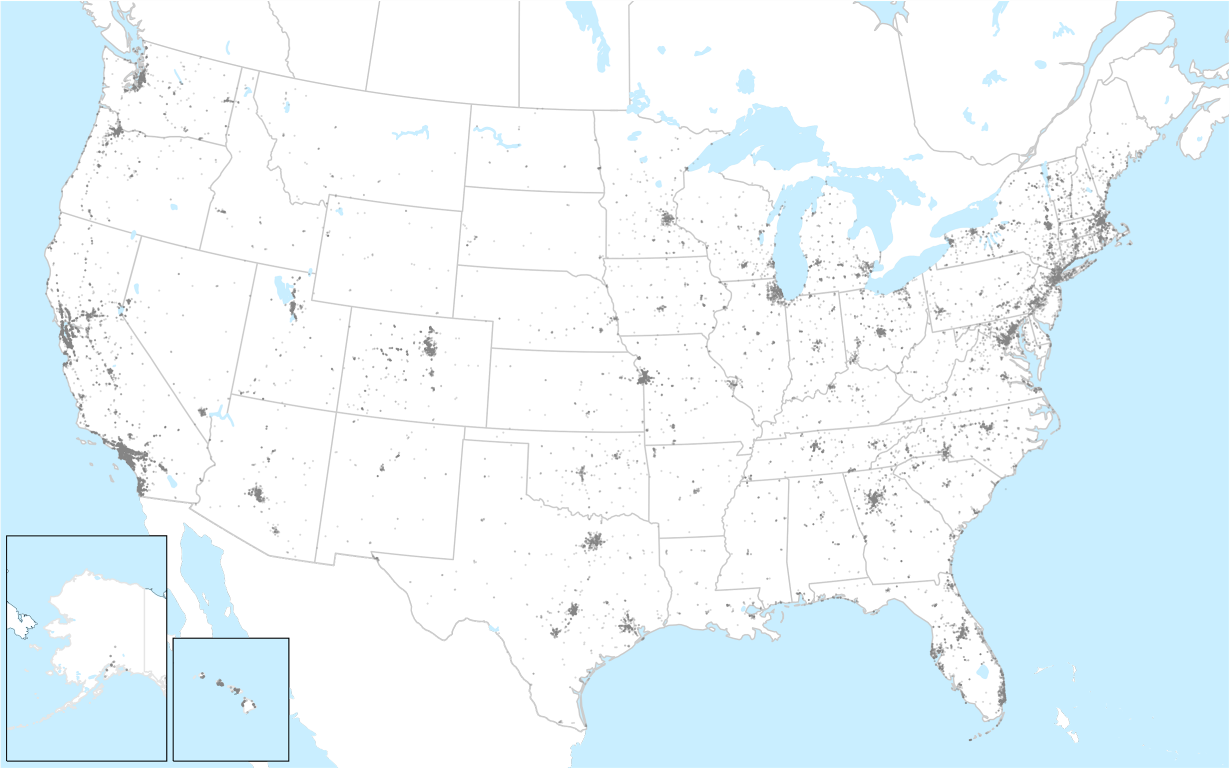

Figure 1: Map of AFDC station locations in the United States. Each grey dot represents a charging station.

The majority of electric vehicle chargers installed in the U.S. at public charging stations are Level 2 type chargers (81.7%), most commonly with SAE J1772 connectors, with DC Fast chargers making up 17.5% of the total.[4] DC Fast chargers are also referred to as DC Level 2 chargers if delivering less than 400kW of power but are typically reported and discussed separately. California also leads the way in the number of public chargers installed in the U.S. with ~27,200 Level 2 chargers, and ~5,500 DC Fast chargers (Figure 2). Data from the California Energy Commission (CEC) show that there are an additional ~40,000 Level 2 and ~620 DC Fast chargers at shared private[5] charging stations in California.[6] New York, the next highest state, has ~5,300 Level 2 chargers and ~630 DC Fast chargers. State totals of electric vehicle charging stations and chargers by type are shown in Figure 2.

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[3] https://afdc.energy.gov/fuels/electricity_locations.html#/find/nearest?fuel=ELEC

[4] Percentages do not sum to 100%. The remaining stations are identified by AFDC as public Level 1 charging stations most commonly with SAE J1772 connectors .

[5] Shared private chargers include those that are located at workplaces or multi-unit dwellings and are accessible to property owners, employees, visitors and residents of the property.

[6] California Energy Commission Zero Emission Vehicle and Infrastructure Statistics. Data last updated April 30, 2021. Retrieved May 20, 2021 from https://www.energy.ca.gov/zevstats

California has a goal of 250,000 charging stations by 2025 (California Governor Brown EO B-48-18),[7] a ~7.6 times increase over May 2021 charging station counts. The National Renewable Energy Laboratory's (NREL) 2017 report "National Plug-In Electric Vehicle Infrastructure Analysis" (Wood et al. 2017) estimates that with 15 million light-duty plug-in electric vehicles (PEV) on the road in 2030, there would need to be 27,500 DC Fast charger plugs and 601,000 Level 2 plugs at public and workplace stations across the U.S. to meet demand for charging. Taking the simple ratio of these estimates, NREL (2017) estimates a need of one public Level 2 plug per 25 light-duty PEVs on the road (40 Level 2 plugs per thousand LDV PEVs), and one DC Fast charger plug per 545 light-duty PEVs (1.8 DC Fast charger EVSE per thousand LDV PEVs). Of course, the demand for Level 2 and DC Fast charging hinges on the purchasing patterns of electric vehicles, and these estimated ratios of needed chargers to electric vehicles should only be taken as indicative, not prescriptive.

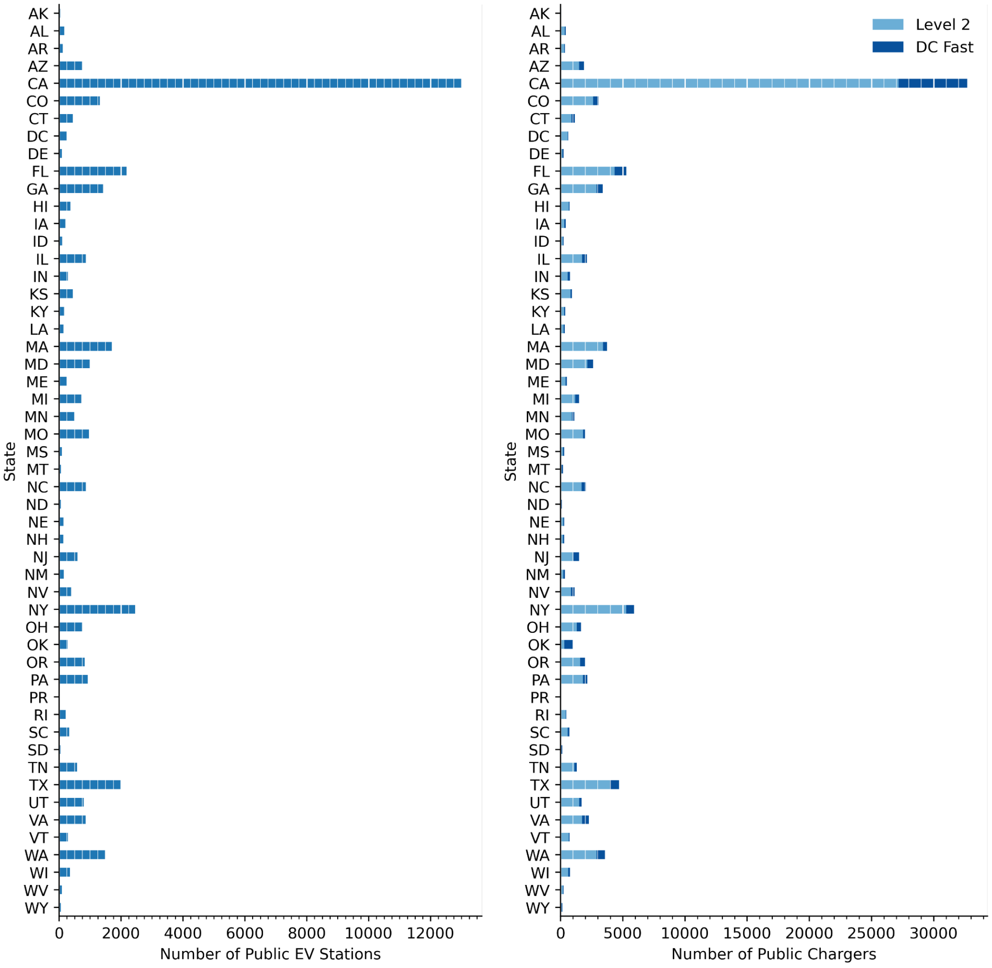

Figure 2: Number of public electric vehicle stations (left) and chargers (right) by state as of May 2020 (Source: AFDC).

The current status of charger installations is equivalent to 12.7% of the NREL projected demand for public Level 2 chargers, and 61.2% of the DC Fast charger demand. Importantly, however, the current mix of DC Fast charging stations listed in the AFDC database (based on the "EV Network Web" field) shows that 25.9% of stations are Tesla Supercharger stations, meaning around a quarter

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[7] https://www.ca.gov/archive/gov39/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/index.html

of the current DC Fast charger infrastructure is unavailable to drivers of vehicles that are not Teslas. DC Fast charging stations that are limited to one particular automaker may also be limiting to the needs of the used vehicle market.

EVgo, a public electric vehicle fast charging network, reported that demand for DC Fast charging may be as high as 45,000 DC Fast chargers by 2025 (Levy, Riu, and Zoi 2020). EVgo notes that the number of DC Fast chargers necessary to meet demand is both a function of the total number of DC Fast charger capable vehicles, and the manner in which those vehicles are driven. Rideshare and delivery drivers, who drive more miles per day than the average driver, need access to fast charging, so as to maximize their profitable operations, whereas office workers may be better able to use Level 2 charging more effectively as their vehicles sit dormant for long periods. Additionally, those without access to home or workplace charging may benefit from better availability of DC Fast chargers. The importance of readily available DC Fast charging towards widespread electric vehicle adoption is also cited by Electrify America (Electrify America, 2021)

2.2 Light, Medium, and Heavy Duty Electric Vehicles

Battery electric vehicles is a collective term for vehicles that are fully battery powered (BEVs or electric vehicles) and vehicles that are plug-in hybrid electric vehicles (PHEVs). These vehicles all connect to the electrical grid to charge the onboard battery, which is then used to drive electric motors. Battery electric vehicles do not have an internal combustion engine (ICE) and rely entirely on energy stored in the battery to drive the motors. Plug-in hybrid electric vehicles have an ICE which can either directly drive the propulsion systems, or be used to charge the battery, which then drives the propulsion system.

The U.S. Energy Information Administration Annual Energy Outlook[8] (AEO, Table 38) projects rapidly rising demand for 200- and 300-mile range light-duty electric vehicles, rising ~7x from total sales (including 100-mile range vehicles) of around 240,000 vehicles in 2019 to 1.7 million light-duty electric vehicles in 2050 (Figure 3). Demand growth is driven by projected demand for 200-mile and 300-mile electric vehicles, with very low, and flat, projected demand for 100-mile electric vehicles.

Light-duty vehicles are defined by the Federal Highway Administration (FHWA) as Class 1 and Class 2 vehicles (Figure 4), with gross vehicular weight ratings (GVWR) less than 10,000 lbs. Light-duty vehicles include conventional family vehicles, including sport utility vehicles (SUVs) as well as full size pickups. The LDV sector accounts for 91% of U.S. vehicles by transportation mode,[9] and most available electric vehicles on the market in the U.S. are in the light-duty sector.

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[8] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=48-AEO2021&cases=ref2021&sourcekey=0

[9] https://www.bts.gov/content/number-us-aircraft-vehicles-vessels-and-other-conveyances

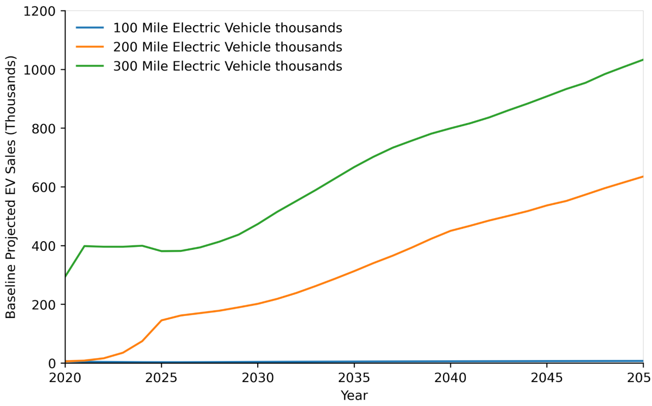

Figure 3: Projected growth in light-duty electric vehicles sales (EIA, 2020)

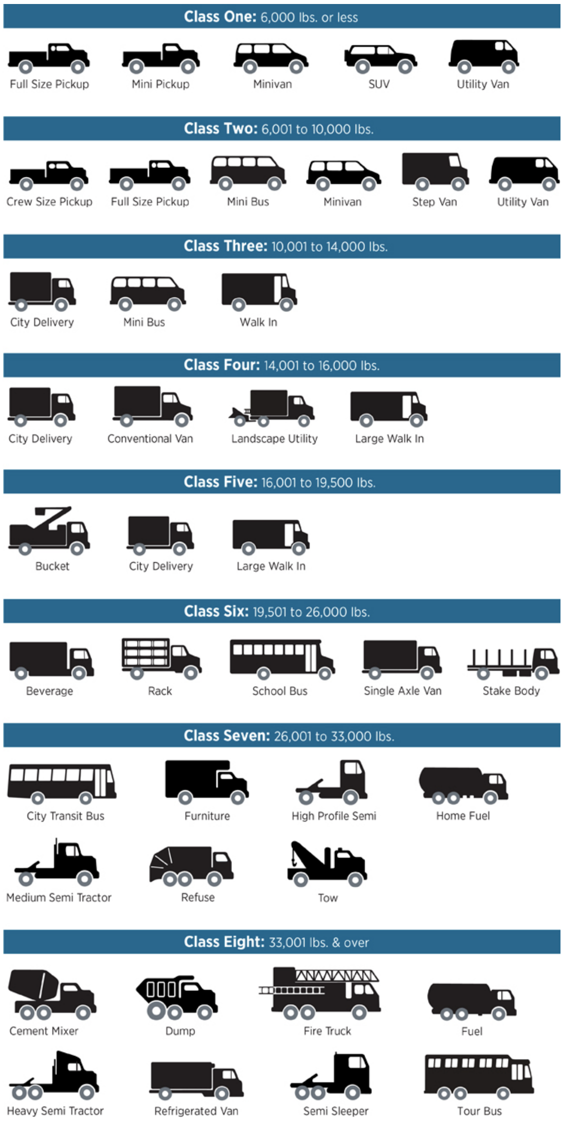

Figure 4: Vehicle types by classification[10]

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[10] https://afdc.energy.gov/data/10381

Medium-duty vehicles (MDVs) are those with GVWRs between 10,001 and 26,000 lbs. Medium-duty vehicles include classes 3-6, encompassing a range of vehicle types including delivery and utility services vehicles. Class 6 vehicles include school buses as well as larger delivery vehicles (Figure 4). Heavy-duty vehicles (HDVs) are those with GVWRs greater than 26,001 lbs., including Class 7 and Class 8 vehicles. Heavy-duty vehicles include tractor-trailers, heavy-duty utility vehicles, including refuse trucks, fire trucks, and fuel tankers, as well as transit buses and coaches.

2.3 Technical Aspects of Charging Infrastructure

Charging stations vary in their applications of three types of chargers: Level 1, Level 2 and DC Fast chargers. DC Fast chargers are sometimes termed DC Level 2 chargers if they deliver less than 400kW of power but are typically referred to as DC Fast chargers and considered separately from AC Level 2 chargers as they utilize direct current. Medium- and heavy-duty electric vehicles are expected to utilize either 50 kW chargers when able to charge more slowly, or 350 kW DC Fast chargers for rapid charging using the SAE J3068 standard.[11]

Since electrical outlets use alternating current (AC) and batteries use direct current (DC), AC power must be converted to DC either within the charger or onboard the electric vehicle. Level 1 and 2 chargers use AC, which is converted into DC by the electric vehicle's power management system. DC Fast chargers convert AC into DC within the charger itself, without using the vehicle's on-board power management system, and directly charge the battery, allowing for a faster and more powerful charge of the vehicle.

2.3.1 Level 1

Level 1 chargers are rarely found publicly and compose less than 2% of U.S. public charging outlets as of 2020,[12] but are common in households. This is because most electric vehicles include Level 1 cords with their purchase. They use a 120V AC plug that can be plugged into a standard outlet and charges at a rate of 2-5 miles per hour, using an SAE J1772 charge port. Level 1 chargers can use existing circuits, but in some cases additional electrical work is required to ensure that the existing circuit can safely handle the load.

2.3.2 Level 2

Level 2 chargers are currently the most common charging ports publicly available. They make up about 80% of all U.S. public charging outlets as of 2020.[13] These outlets use either 208V or 240V alternating current (AC) electrical output that typically charges at a rate of 10-20 miles per hour. The same connector and charge port used in Level 1 charging is employed here (SAE J1772), which allows for a more universal acceptance of stations by most electric vehicles. An individual Level 2 charging port typically falls in the range of $380-$690 for residential chargers, and $2,500-$4,900 for commercial chargers (Nelder and Rogers 2019).

2.3.3 DC Fast Charging

DC Fast chargers, sometimes also termed DC Level 2 and also sometimes incorrectly referred to as Level 3 chargers, charge at a rate of 60-80 miles per 20 minutes. DC Level 2 chargers provide up to 400kW of maximum power. This type of charger has more variation in plug type used, with three

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[11] https://www.sae.org/standards/content/j3068_201804/

[12] https://afdc.energy.gov/fuels/electricity_locations.html#/find/nearest?fuel=ELEC

[13] https://afdc.energy.gov/fuels/electricity_infrastructure.html

different common connecting ports: the Combined Charging System (CCS) connector (or J1772 combo), which is the most common in the U.S., and which can also be used in Level 1 and 2 charging; the CHAdeMO connector; and the Tesla connector which is unique to Teslas. Currently, about 18% of U.S. public charging outlets are DC Fast chargers.[14] DC Fast chargers are more expensive than Level 2 chargers, and prices vary with power outputs. The Rocky Mountain Institute (RMI) estimates that equipment costs range from $20,000-$35,000 for a 50kW DC Fast charger, $75,600-$100,000 for a 150kW charger, and $128,000-$150,000 for a 350kW charger. Estimates reported by Nicholas (2019) indicate that labor costs to install a 350kW DC Fast charger are around 45% greater than for a 50kW DC Fast charger.

Typically the electric utility installs the connection to the grid where new connections are necessary, and electricians and electrical contractors install the charger and associated electrical infrastructure. The need for new grid connections is becoming increasingly common, due to growth of higher powered charging infrastructure. Notable differences exist between installations of different types, with DC Fast chargers requiring more work on the grid side of the meter than Level 2 chargers before the charger can be connected to the system.

2.3.4 Medium and Heavy-Duty Charging

As with light-duty charging, medium- and heavy-duty charging connectors have specific requirements. In addition to the connections used for DC Fast charging (most commonly CCS), three emerging connectors for this sector are the SAE J3068, J3105, and J2954/2. The SAE J3068 connector has been deployed on heavy-duty trucks; the SAE J3105 connector is designed primarily for transit buses and is capable of providing 350 kW DC charging; and the SAE J2954/2 is designed for wireless power transfer for heavy-duty vehicles.

2.4 Grid Integration and Hardening

Electric vehicles draw significant power while charging the vehicle batteries, especially when connected to DC Fast Charging stations, where single charging units may draw up to 350kW, depending on the battery capabilities of the vehicle. However, while connected to smart grids, electric vehicles may behave like a distributed energy resource (DER) (Das et al. 2020), offering vehicle grid integration (VGI) responses and energy transfers that can improve grid resiliency and facilitate bidirectional and smart charging. Grid reliability is a challenge for many priority communities (Federico et al. 2019); as such, increasing deployment of electric vehicles could deliver significant benefits for the grid and communities, but also present challenges.[15]

Grid hardening is a term for increasing the resiliency and security of electrical grids. Shea (2018) identifies a set of subcategories for grid hardening. These include: resilience against extreme events, reliability through grid modernization, protection against malicious attacks, and regulatory and government preparedness for these scenarios. Electric vehicle grid integration has the potential to support grid hardening, by providing a distributed network of batteries with the potential to connect to and support the grid in times of stress, and charge in a manner responsive to grid conditions.

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[14] See footnote 10

[15] This and the following sections section on challenges and benefits benefit greatly from the detailed electric vehicle overview of electric vehicle grid integration provided by Das et al. (2020)

Prior to connecting to the utility grid, the grid on the utility side of the meter needs to be made ready to handle the additional loads of electric vehicle chargers. Make-ready work needs to be completed before the charging station can be connected to the grid and may include line and transformer upgrades as well as additional safety measures. The amount of make-ready work required is a function of the existing local grid parameters and the anticipated needs of charging infrastructure. Make-ready work is an especially important consideration for larger DC Fast charging stations and medium- and heavy-duty fleet charging, where power demands are likely to be large, and could potentially be upwards of a few megawatts.

2.4.1 Grid Integration and Hardening: Challenges

Uncontrolled or unanticipated increases in load during peak electric vehicle charging periods can strain local and regional grids, overload components and reduce the lifespan of the grid management system (Hadley and Tsvetkova 2009; Yong et al. 2015; Yan and Kezunovic 2012). Furthermore, significant increases in power consumption by electric vehicles in one part of the grid may lead to imbalances and power losses in the distribution system, which has real and significant effects on electrical delivery to other grid users if demand remains unbalanced (Pieltain Fernández et al. 2011). Chargers convert grid power to battery power, which can alter voltage and current and cause imbalances with the grid power.

2.4.2 Grid Integration and Hardening: Benefits

Though it comes with a set of challenges, electric vehicle grid integration also has potential benefits to the grid. When electric vehicles are connected to the grid in VGI configurations, they collectively act as a distributed energy resource, essentially acting as a distributed grid of batteries, which happen to also be connected to cars. Electric vehicles can utilize smart charging programs and provide power management when connected in VGI configurations, smoothing surges and flickers, and potentially rapidly providing energy back to the grid in times of high demand. They can also offer low charging demand and act as extra grid storage during periods of excess energy production (Kempton and Tomić 2005). Vehicles providing "vehicle-to-grid" (V2G) services can engage in contracts with the electrical utility to receive compensation for the grid services they provide, offsetting the cost of ownership of the vehicle (Shirazi, Carr, and Knapp 2015). Additionally, public charging often takes place during the day, which aligns with the load profile of solar generation in California.

3 Workforce Needs

Workforce needs associated with BEV charging infrastructure vary across four phases. These phases are (1) knowledge and skills training, including apprenticeships, training programs, and capacity building, (2) planning, (3) construction and installation, and (4) operations and maintenance – and different industries are engaged during different phases of the process.

The electric vehicle industry ecosystem has no set definition, instead falling across a set of existing industries. The Los Angeles Economic Development Corporation (LAEDC) identified the set of industries and their associated North American Industry Classification System (NAICS) codes through a review of a suite of electric vehicle-related companies and their Data Universal Numbering System (DUNS) registrations. LAEDC identified 17 subsectors, identified in Table 1.

Table 1: EV ecosystem job sectors identified by LAEDC

NAICS Code	Description
221	Utilities
238	Specialty Trade Contractors
335	Electrical Equipment, Appliance, and Component
336	Transportation Equipment Manufacturing
423	Merchant Wholesalers, Durable Goods
441	Motor Vehicle and Parts Dealers
485	Transit and Ground Transportation
511	Software Publishers
523	Securities, Commodities Contracts and Other Financial Instruments
524	Insurance Carriers and Related Activities
541	Professional, Scientific and Technical Services
551	Management of Companies and Enterprises
561	Administrative and Support Services
611	Educational Services (Vocational Training)
624	Vocational Rehabilitation
811	Repair and Maintenance
999	Unclassified

The list in Table 1 considers the entire ecosystem associated with the electric vehicle industry, from research and development, vehicle and battery manufacturing, sales, ownership and maintenance, and infrastructure. This list is not limited solely to the charger installation phase, which most likely falls under NAICS sector 238. While there are likely significant workforce benefits to onshoring manufacturing of charging devices and supporting equipment, his report focuses on workforces associated with the installation of charging infrastructure.

As noted by E2 in their 2020 *Clean Jobs Better Jobs* report, most clean energy jobs, including charger installations, are extensions of existing employment sectors, albeit with skills, training, and certification specific to the sector. Many of the essential skills are transferable between similar clean energy and non-clean energy jobs, allowing for robust, “high-road” careers.[16] The work of EVSE installers requires additional training and certification. In the case of charger installation, the foundational skill sets and training required are those already established in the electrical industry.

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[16] This report defined “high-road” careers per the California Workforce Development Board but acknowledges that there may be differences between states: “High-road jobs are jobs created within a high-road economy, which not only centers job quality, but also sustainability and equity. In a “high-road” economy, firms compete by capturing the value of innovation, quality, and worker skill, rather than pursuing a “low-road” race to the bottom based on low wages and environmental externalities. The result is family-supporting jobs, with better wages and benefits, opportunities for entry and advancement, and respect for worker voice. “High-road jobs” is a broader term than “high-quality jobs.” ” “High-quality jobs: The ideal job pays a family-sustaining wage, offers comprehensive employer-provided benefits, values worker voice, and provides security, fair scheduling, a safe and healthy work environment, and pathways for career advancement. There is no single standard for a quality job across regions and industries. A key element of the broader term “high-road jobs.”” Additional discussion may be found at https://cwdb.ca.gov/wp-content/uploads/sites/43/2019/09/High-Road-ECJ-Brief_UPDATED-BRANDING.pdf

California law requires that electrical construction work – including the installation, maintenance and repair of EVSE infrastructure – be performed by state-certified general electricians. California Assembly Bill 841 (AB 841, 2020) additionally requires charging infrastructure to be installed by a licensed contractor and at least one electrician who holds Electric Vehicle Infrastructure Training Program certification (EVITP) certification for charger installations funded or authorized by certain state agencies beginning January 1, 2022.

The majority of jobs associated with expanded electric vehicle infrastructure, while supporting green growth, will likely fall into traditional professional, and technical sectors associated with energy production, transmission and distribution, as well as engineering, planning and construction, and inspection and certification. These jobs fall broadly under the NAICS sector 238, Specialty Trade Contractors. As electric vehicle infrastructure build-out requires state-certified general electricians, electric vehicle infrastructure jobs fall more specifically under NAICS sector 238210 "Electrical Contractors and Other Wiring Installation Contractors." While this sector is not specific to the electric vehicle infrastructure industry, at this time new industry sectors aren't being defined around electric vehicle infrastructure installation, as many of the baseline electrical contracting and electrician skills are transferable from other applications, but instead are enhanced by the addition of jobs and skills related to installing electric vehicle charging.

The Bureau of Labor Statistics (BLS) Occupational Employment Statistics estimate that the "Electrical Contractors and Other Wiring Installation Contractors" sector (NAICS code 238210) employs 950,680 workers in the 50 U.S. states plus the District of Columbia.[17] These jobs are concentrated in the "Construction and Extraction Occupations" with national statistics showing 69.0% of jobs in NAICS sector 238210 falling in this occupational category (Figure 5), with around 60% of those jobs being electrical. The next most common category by occupation under NAICS code 238210 is installation, maintenance, and repair (9.6%), followed by office and administrative support (8.5%), management (4.6%), and business and financial operations (3.0%). Taken together, these top 5 occupational categories account for 94.7% of total employment in the Electrical Contractors and Other Wiring Installation Contractors sector (Figure 5).

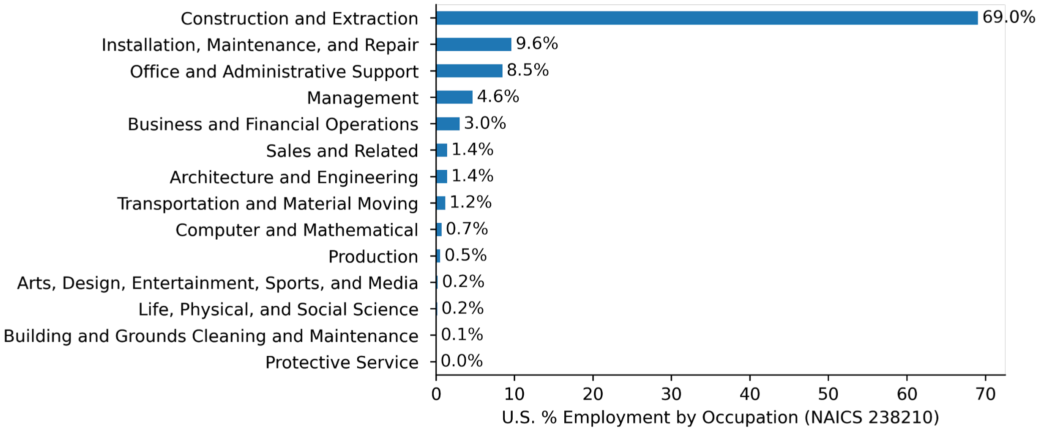

Figure 5: Percent of employment in NAICS sector 238210 by occupation

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[17] https://www.bls.gov/oes/current/oes_research_estimates.htm

3.1 Knowledge and Skills Training

Charging infrastructure draws a significant amount of energy from the grid. Therefore, safety measures are of paramount importance for installers, maintenance staff, operators, and customers of electric vehicle charging stations. While local building, fire, and municipal codes may vary, charger safety measures are standardized under the National Fire Protection Association (NFPA) and National Electric Code (NEC) standards, among others. NFPA 70[18] covers instructions on wiring and installing electrical conductors, while NEC 625 provides standards for charger installation, including connections to circuitry. The set of standards applicable to charger installation requires detailed understanding by installation professionals to ensure the safe install and function of charging devices. Discussion of the whole set of standards falls outside the scope of this work, but merits attention (Das et al. 2020).

In addition to national, state, and local standards, separate training programs are available for installers of electric vehicle infrastructure. For example, the Electric Vehicle Infrastructure Training Program (EVITP) is a national program that provides certification and skill upgrades that enhance electricians' foundational skills (Zabin et al. 2020). State licensure for electricians requires 8,000 hours of training as an apprentice before sitting for certification. The EVITP is an 18-hour continuing education training course and the examination is not overseen or administered by the state. The EVITP provides education that complements electricians' existing skills to better enable them to install charging infrastructure, and its curriculum was designed and developed to address issues of workplace safety during the installation and maintenance of charging equipment (Zabin et al. 2020). To date the EVITP has certified over 4,000 electricians in the U.S. and Canada.[19] California Assembly Bill 841 specifies that projects funded by California state entities have at least 25% of the electricians on the crew be EVITP certified.

3.2 Sales and Marketing Job Roles

The electric vehicle landscape is rapidly changing, with a range of legacy and developing electric vehicle and charging technologies on the market, with varying feature sets and capabilities. Conversations with charger installers (Personal communication, Mike Moser, 2020) identified the sales and marketing phase of charger installation as integral to the overall success of the charging site. Specialized skills and training on charger features, vehicle capabilities, and site host needs and expectations are necessary for sales and marketing professionals to effectively meet the needs of site hosts. Additionally, given that charging needs and vehicle sales are closely linked, automobile salespeople should be trained and knowledgeable about the parameters of the vehicle models they sell, including used vehicles, in order to increase access and exposure to the technology for all potential purchasers (De Rubens, Noel, and Sovacool 2018). Furthermore, sales professionals should be knowledgeable of available incentives and funding opportunities for electric vehicles and charging infrastructure, and how they apply to the specific charging station models they are selling, as public funding opportunities may stipulate that only certain charger types or models are eligible for funding.

3.3 Planning and Permitting Job Roles

Non-residential charging stations often require extensive planning and permitting. First, if the preferred site is not owned by the site host, real estate professionals are involved in drawing up the

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[18] Association NFP. Nfpa 70: national electrical code. National Fire Protection Assoc; 2017.

[19] https://evitp.org/

terms of the site lease, rental, or purchase. A licensed electrical contractor may perform an initial site evaluation that determines the electrical capacity of the selected site, identifies the location of existing electrical lines and potentially other infrastructure, including gas, water, and sewer lines that may affect construction, and determines the optimal location for installing the charger and parking configurations (DOE, 2015). In the case of straightforward installations, for example, where a charger is installed on a parking garage wall with existing spaces close to the necessary electrical circuitry, such an evaluation may be sufficient to determine the appropriateness of the site. With permitting challenges in mind, California's Governor's Office of Business and Economic Development (GO-Biz) has developed a charging station permitting guidebook and does extensive education and outreach to ensure local jurisdictions are implementing expedited and streamlined permitting procedures, in consultation with local fire departments and utilities, as required by California Assembly Bill 1236 (AB 1236, 2015) to facilitate accelerated development of charging infrastructure.[20]

For larger or more complex installations that require additional construction, the planning and permitting phase is more involved. Prior to any trenching and boring to accommodate new electrical lines, the necessary permits must be obtained, existing utility services/infrastructure must be accurately identified and marked by the utility, and if the work will affect traffic in any manner, then road or lane closures and traffic management must be planned for and appropriately permitted through the local authority. Furthermore, larger medium and heavy-duty charging stations may require permitting, inspection, and certification by utilities or government agencies due to their very large capacities.

The planning and permitting phase requires input from a number of different employment sectors. Licensed electrical contractors are involved in all phases of the process. Workers from electrical utilities and municipalities locate and mark infrastructure, and administrative employees process permitting applications, including zoning, fire, and parking ordinances. In the case of large charging stations where modified connections to the grid are required, those plans must be drawn up by electrical engineers and approved by the utility. Engineering drawings of the site may be required depending on the size of the installation and the regulating authority, and the site planning managers should ensure that Americans with Disabilities Act (ADA) compliance requirements are met.

3.4 Construction and Installation Job Roles

The employment requirements for the construction and installation process vary with the complexity of the project. For a straightforward installation, such as in a parking garage with good access to adequate electrical circuitry, the installation process can be completed by a state-certified general electrician and electrical apprentice. Apprentices must be registered in a state-approved electrical apprenticeship program. They must be supervised by a state-certified general electrician using proper ratios according to state law and meet all other requirements as set by state law. Electricians are responsible for installing electrical wiring, equipment, and fixtures, including the charger and necessary electrical panel upgrades.

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[20] Expedited, streamlined permitting procedures for charging station installations in California are specifically defined in AB 1236 and include requiring administration approval of charging station permits, limiting permit review to matters of health and safety, and requiring local jurisdictions to issue one complete deficiency notice if the permit is not approved, among other criteria. For additional details on the requirements of AB 1236 see https://business.ca.gov/industries/zero-emission-vehicles/plug-in-readiness/

Larger or commercial sites may require extensive site preparation prior to the actual installation of the charging units by state-certified general electricians. The site preparation may need trenching or underground work to lay conduit to connect the charging units to the grid, which requires electrical crews with the tools and technical expertise to dig and trench, lay the conduit and electrical lines, backfill the hole, and repave the surface. Trenching effort varies by material, with trenching through soil costing \$10-\$20 per foot and trenching through asphalt or concrete costing \$100-\$150 per foot (DOE, 2015). Longer distances between existing infrastructure and the location of the charger contribute to higher costs both in terms of labor and material. Journey-level Lineworkers then install the cables or wires used to connect the BEV charging station to the grid. In instances where traffic management is necessary, flagger teams are needed to maintain a safe flow of traffic. Once installation is completed, the site must also pass inspection by a certified inspector.

3.5 Operations and Maintenance Job Roles

Charger-related operations and maintenance (O&M) job roles fall under station management and maintenance, billing and accounting, and real estate. This also includes highly skilled technical maintenance by electrical contractors and utilities, often involving interacting with charging software and firmware.

3.6 Job Quality

In California, job quality in the charger installation sector is ensured for charging stations that are installed through investor-owned utility (IOU) programs. State regulations require that charger installation work be performed by state-licensed electrical contractors and electricians who have completed the EVITP program, and that installers on public works projects be paid "prevailing" wages, not less than the wages "prevailing" in the local area for similar classifications of work.

State-certified electrical workers are required to complete apprenticeship programs, which provide the knowledge, skills and training needed to become an electrician or Journey-level Lineworker and allow participants to "earn as you learn." These professions require at least a high school diploma, along with additional training and certifications. Policies and programs that link job quality standards and certifications with occupations associated with electric vehicle charging infrastructure create high-road career opportunities with good pay, benefits and robust potential for growth. Nationally, electrician jobs are projected to grow by 8% or higher from 2019 to 2029, much faster than average job growth rates. In California, electrician jobs are projected to grow by 22% from 2016 to 2022 (Chandler, 2016). Furthermore, electrician and Journey-level Lineworker jobs are resilient, enabling workers to transfer skill sets across multiple industries with minimal barriers to movement.

3.7 Charging Infrastructure Workforce Wages

As discussed above, after the planning and permitting stage of charger site installation, the majority of the effort required falls into two categories: general contracting or civil work, and electrical work. Together, these two types of work account for ~75% of the total expenses for installing electric vehicle charging infrastructure (Chandler, 2016).

Per the Bureau of Labor Statistics (BLS), electricians working in NAICS sector 238210 earn a national average median hourly wage, across states, of \$27.36,[21] and Journey-level Lineworkers earn

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[21] https://www.onetonline.org/link/details/47-2111.00

a median hourly wage of $36.07[22] (Table 2). Within California, electricians earn a median hourly wage of $32.95 and Journey-level Lineworkers earn a median hourly wage of $49.50. Annual wages may be estimated based on full-time equivalency of 2080 hours per year.

Table 2: National average median wage across states for selected occupations under NAICS sector 238210

OCC Code	OCC Title	Average Median Wage ($/hour)
11-9021	Construction Managers	47.06
17-2112	Industrial Engineers	43.49
17-2071	Electrical Engineers	40.55
19-5011	Occupational Health and Safety Specialists	40.03
47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	35.89
49-9051	Journey-level Lineworkers	36.07
47-2051	Cement Masons and Concrete Finishers	33.48
13-1051	Cost Estimators	33.27
17-3012	Electrical and Electronics Drafters	29.33
13-1041	Compliance Officers	27.57
47-2111	Electricians	27.36
47-4011	Construction and Building Inspectors	25.09
17-1022	Surveyors	23.43

3.8 Current Employment Estimates

The increased growth of electric vehicle charging infrastructure means more workers will be needed to fill workforce gaps. Due to the various phases of development, several types of workers are necessary when building electric vehicle charging infrastructure. The stages of development must encompass site planning and permitting, site preparation, electrical work, construction, connection of chargers, testing and deployment, and maintenance.

The "Putting California on the High Road: A Jobs and Climate Action Plan for 2030" report, commissioned as a result of California Assembly Bill 398 (AB 398, 2017), identifies the majority of jobs as "blue-collar" when associated with California's efforts to meet its GHG commitments. The report estimates that jobs in the construction and installation of fueling infrastructure across all fuel types will grow from 69,200 positions in 2014 to 75,000 positions in 2024, equivalent to 8.4% growth over that time period.

The LAEDC estimates the electric vehicle ecosystem in Southern California is experiencing employment growth of 2.8% annually, about 1.5 times higher than the state average employment growth rate (LAEDC 2020). For comparison, data from the BLS show that the tech sector for computer and information technology operations is expected to grow 11% from 2019 to 2029 (or about a 1% annual growth rate). The average job in the electric vehicle ecosystem in Southern

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[22] https://www.onetonline.org/link/summary/49-9051.00

California pays 33% more than the average job in California. Of all jobs in the electric vehicle ecosystem in California, construction jobs account for 23.2% of jobs in 2018.

The LAEDC workforce estimates show more than two-thirds of electric vehicle ecosystem employment in Southern California is held by workers with no degree (24%) or a high school diploma (43.6%), with a trend toward increasing education. Per LAEDC, 5.6% of jobs in the sector are held by workers holding postsecondary non-degree awards, which include trade certification. Electric vehicle jobs requiring at least a high school diploma are anticipated to grow by 0.7% from 2018 to 2023, and jobs requiring at least a bachelor's degree by 1.2%. In balance, jobs needing no diploma or bachelor's degree are forecasted to diminish by 2% over the same time period.

E2 estimated that in total, the clean vehicle sector included 266,000 workers in the fourth quarter of 2019 (E2, 2020). The clean vehicle sector occupations have significant crossover with other technical sectors, and so while these workers may be included in estimates for the clean vehicle sector, it is possible that many workers are also supporting sectors other than clean vehicles. In addition to having the highest total employment in the clean energy sector (~537,000 jobs), California also had the highest employment in the clean vehicles sector with 40,600 people employed in the fourth quarter of 2019. California is followed by Michigan (24,100 jobs), Texas (17,300 jobs), Indiana (16,400 jobs) and Ohio (16,100 jobs). he clean vehicle sector described by the E2 estimates (derived from the U.S. Energy and Employment Report (USEER)), is for the sector as a whole, including vehicle manufacturing. This explains why Michigan, with the motor vehicle output of the Detroit region, ranks second in clean vehicle jobs, while having comparatively fewer charging stations.

4 Policies and Incentives

To enable a vibrant charging infrastructure, planners and policymakers must evaluate workforce needs in order to identify gaps in training or workforce capacity – as well as opportunities for expanding employment and economic activity for a given region. One of the goals of this research is to help planners and policymakers qualitatively and quantitatively understand these potential gaps and opportunities for electric vehicle charging infrastructure systems and engagement with priority communities[23] in several representative geographical locations.

4.1 California Policies Related to Battery Electric Vehicle Charging Infrastructure

The State of California has been actively involved in the development of electric vehicle infrastructure policies. The California Public Utilities Commission (CPUC) has regulatory authority over public utilities, which includes electrical corporations. California law requires that the CPUC direct electrical corporations to develop programs and investments that accelerate cost-effective transportation electrification in the state. Under existing law, the CPUC is required, in consultation with others, to evaluate policies to develop infrastructure necessary to overcome barriers to the widespread deployment and use of plug-in hybrid and electric vehicles. Appendix A details current California policies that relate to the development of charging infrastructure.

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[23] See definition of priority communities discussed above.

4.2 Financial Incentives, Credits, and Instruments Promoting Charging Infrastructure

Electric vehicle uptake is being promoted by a range of economic tools, incentives and public awareness efforts. From federal tax credits to state and local government programs, there exists a set of economic tools that policymakers can engage with to facilitate development of electric vehicle charging infrastructure, and installers and site hosts can use to offset initial investment costs. Appendices B and C provide an overview of relevant federal and state policies in the United States.

5 Issues Related to Battery Electric Vehicle Infrastructure and Equity

Although there are undoubtedly barriers to electric vehicle proliferation throughout the U.S., these barriers are amplified in communities that, among other factors, are characterized by low income, high unemployment, and low education levels. The California Air Resources Board (CARB) identified the most consequential barriers in these "priority communities" as being barriers within the community (such as access, convenience and safety), affordability barriers, funding barriers for electric vehicle and infrastructure investments, and barriers in education and awareness of electric vehicles (CARB 2018). In addition, there is ample evidence in the literature that minority, priority, and low-income communities are disproportionately exposed to poor air quality and environmental conditions than average communities (See Canepa et al 2019 for additional discussion). Proliferation of electric vehicles and infrastructure in priority communities would contribute to improving quality of life of community members as well as environmental justice outcomes through improved air quality, job prospects, and health outcomes. Additional details regarding policies addressing issues of electric vehicles and equity in California and nationwide are available in Appendices D and E, respectively.

5.1 Affordability and Awareness

Canepa et al (2019) find that when a household in a disadvantaged community[24] purchases a personal vehicle, it is unlikely to be an electric vehicle. This is partly due to the high capital costs of electric vehicles, as well as the lack of convenient charging both at home and in the workplace. Even with the current incentives and rebates aiding in electric vehicle purchases, members of low-income communities might not qualify for low-interest loans/leases and might not be able to supply the upfront cost of the vehicle before waiting for their reimbursement. The choice of a non-electric vehicle when purchasing a personal vehicle is also due to the lack of awareness and education these priority communities have with respect to electric vehicles (CARB 2018).

Canepa et al (2019) show that BEV purchases are concentrated in non-DACs, both in terms of absolute vehicle counts and electric vehicles per household. Intuitively, purchasers of electric vehicles in DACs were generally not low-income households, while buyers in non-DACs did have higher average incomes than buyers in DACs. The differences were small, and electric vehicle "buyers in DACs could not be considered 'disadvantaged' in a socioeconomic sense," and are not generally a representative sample of their DAC community. From a charging infrastructure perspective, Canepa et al (2019) find that "DAC census tracts have fewer L2 chargers per household, but more DC fast chargers." While the authors claim that this indicates that infrastructure to support electric vehicle charging does exist, the challenges for DACs are more nuanced. Arguably most significantly, lower income households are more likely to purchase used

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[24] This report uses "priority communities" to discuss issues related to equity but uses the term "disadvantaged communities" here to retain the context, meaning and intention of the original research.

electric vehicles, when purchasing an electric vehicle. Used electric vehicles, although cheaper, may be unable to take advantage of DC Fast Charging infrastructure. This demonstrates that a wide variety of charging stations are needed, especially in priority communities.

The lack of awareness of electric vehicle grants, technologies and future outlooks is another challenge that needs to be addressed when attempting to promote electric vehicle distribution equity. Priority communities in certain areas may lack crucial tools such as the internet which hinders their ability to research before purchasing a personal vehicle. Also, even though there are several funds and grants dedicated to clean transportation, community members may be unaware of these grants' requirements, or even of the grants themselves (CARB 2018). Electric vehicles are a relatively newer technology that haven't been discussed enough in these communities in order for community members to confidently dispense the daunting costs. These issues can be addressed by future outreach and education initiatives within these communities.

5.2 Education and Occupation

Among other factors, priority communities are identified by high unemployment rates, low levels of education, and low incomes. When discussing the necessary increase of equity in future electrification, the participation of priority communities within the electric vehicle charger installation workforce must be considered. As seen previously, the main expenses (~75%) when installing electric vehicle charging infrastructure are accounted for by either contracting or electrical work (Chandler, 2016). Important jobs within these areas include electricians, Journey-level Lineworkers, and urban/regional planners.

The BLS states that electricians and Journey-level Lineworkers typically need a high school diploma when entering the workforce, while urban/regional planners require a master's degree. A high school diploma or equivalent was the most common "typical entry-level education requirement" in the US in 2019,[25] demonstrating that, typically, these electric vehicle infrastructure occupations reflect the average US employment entry-level education requirements. Jobs such as electricians and Journey-level Lineworkers provide good-quality opportunities with median national hourly wages of \$27.36/hour (\$32.95 in California) and \$36.07 (\$49.50 in California) respectively (see Table 2) while still being available to a majority of members within priority communities due to the low entry-level education requirements. This is possible due to the pairing of low entry-level education with apprenticeships and on-the-job training provided in these occupations.

The California Department of Education[26] stated that, in 2020, the high school graduation rate in California was 84.3% while the graduation rate within "socioeconomically disadvantaged" areas was 81.2%. Although fewer members of these "socioeconomically disadvantaged" areas will be able to benefit from electric vehicle-related job openings, the 81.2% graduation rate demonstrates that many members do have the ability to fill these positions.

Figure 6 shows the current distribution of the number of charging stations is skewed towards census tracts where the percentage of people with a high school diploma or higher is greater. Census tracts can vary in size, but generally have a population of around 4,000, but may be as low as 1,200 or as high as 8,000. Presenting figures with counts of stations by census tract serves to normalize the data,

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[25] https://www.bls.gov/emp/tables/education-summary.htm

[26] https://www.cde.ca.gov/nr/ne/yr20/yr20rel101.asp

by both population and geography/area. Figure 6 shows that the availability of chargers is lower in areas with lower educational attainment.

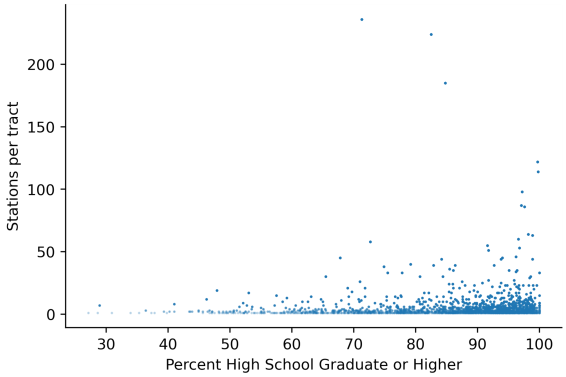

Figure 6: Amount of charging stations vs. high school graduation rate by census tract in California.

5.3 EV Infrastructure and Electrification Funding in Priority Communities

The distributional effects of tax credits for clean energy have disproportionately benefited higher-income Americans, with households in the top quintile, in terms of income, receiving around 60% of all clean energy tax credits. When considering programs aimed at electric vehicles through 2013 the top income quintile has received around 90% of all credits (Borenstein and Davis 2016). These issues persist, though the share of rebates distributed to low income and priority groups has increased in recent years (Guo and Kontou, 2021). Borenstein and Davis, and Guo and Kontou's findings shed important light on the distributional effects resulting from policy choices and mechanisms. Crediting citizens for making clean energy purchases may be politically more palatable than alternative mechanisms, such as carbon taxes, but credits are shown to disproportionately benefit higher income Americans. Furthermore, if credits offered don't actually incentivize sales beyond what would have occurred under the baseline, without the credits, then the credit simply becomes a mechanism for transferring economic rents to higher income groups. The need for thoughtful and deliberate design of incentive programs to benefit all consumers is clear.

From an environmental perspective, electric vehicles cause non-exhaust emissions from facilities generating the electricity used to charge the batteries, though this will diminish as electrical grids rely more on renewable or non-emitting energy sources. Conversely, gasoline and diesel vehicles generate tailpipe emissions along the routes that they travel. The literature indicates that electric vehicles generally reduce emissions of greenhouse gases, though the delta in emissions of greenhouse gases and criteria pollutants (in particular, SOx, PM, NOx) can be highly variable depending on the local mix of generation facilities and their primary generation fuels (Holland et al. 2019).

Several programs funding charging infrastructure and EV rebates throughout California and select other states allocate funds to priority communities in order to promote electrification equity. These programs normally achieve a balanced spread of funding by establishing a percentage of projects/funds that will go solely to low-income and priority areas. As shown in Figure 7, access to public charging stations is greatest in areas with greater educational attainment, while Figure 7 (left) shows that regions with lower unemployment have greater access to charging stations. Considering employment, Figure 7 (right) shows that census tracts with a greater number of people employed in the construction sectors generally have lower numbers of charging stations. Though the patterns in charging stations per census tract are similar, percent unemployment and percent employment in the construction sector are not correlated (Pearson's R = -0.069).

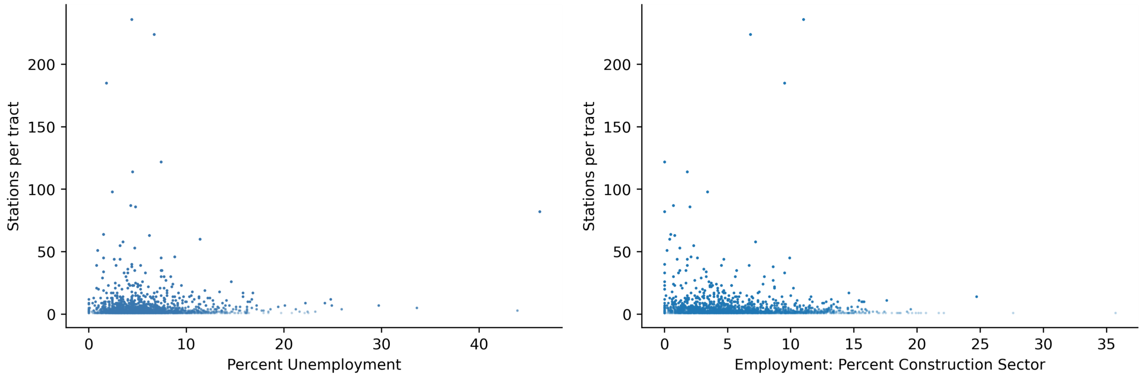

Figure 7: Charging stations vs. unemployment rates by census tract (left) and charging stations vs. employment rates within the construction sector by census tract in California (right).

5.3.1 Efforts to Address Equity in California

California is progressive when compared to other states in providing beneficial incentives, rebates and charging station funding for priority communities. See Appendix D for examples of funded electric vehicle infrastructure and rebates that have been scattered throughout priority regions of California. These examples provide a glimpse of what is currently happening to increase equity of electric vehicle benefits in California. It is important to note that several of the incentives and rebates targeting electric vehicle customers are able to stack onto each other, allowing for a larger total rebate when purchasing an electric vehicle.

5.3.2 Policies Affecting Priority Communities Nationwide

Although California leads the way in providing incentives, rebates and charging station funding within priority communities, many similar policies can be found scattered throughout the United States. These policies typically focus on two areas: providing larger rebates when purchasing electric vehicles and expanding the amount of charging stations within disadvantaged communities. See Appendix E for examples of these actions being taken in various states.

6 Electric Vehicle Infrastructure Workforce Estimation Analysis

This section presents results from analysis of a survey distributed to 386 individuals identified as stakeholders in the electric vehicle industry, with a focus on stakeholders engaged in electric vehicle infrastructure. The goal of this survey was to collect bottom-up information on the amount of effort (by job category) necessary to build out electric vehicle charging infrastructure. This section begins with a quantitative summary of the survey results, followed by estimation of the level of effort, by job role, required for electric vehicle charging infrastructure installation, split out by Level 2 and DC Fast charging infrastructure. This section concludes with a qualitative and quantitative discussion of open-ended responses related to policies that benefit and increase engagement with workers from priority communities.

6.1 Survey Results Summary

A survey instrument (available in the Appendix F to this document) was distributed via Qualtrics to 386 individuals and we received 92 responses, a rate of 23.8%. The survey was extensively tested, and went through multiple iterations, including comments and suggestions from the project team, before being deployed. Respondents received two personalized follow up emails and the collection period was extended by two weeks to allow for additional responses for a total response period of one month.

Depending on the role identified and the organization type, some respondents were not asked questions related to workforce estimation. Only respondents who did identify as having direct experience planning, contracting, managing, or installing electric vehicle charging infrastructure were asked to identify the level of effort by job role for a typical station. Respondents who did not have direct experience were not shown the workforce estimation questions. The geographic distribution of respondents leaned towards California, with 71% of respondents listing California as their state of operation.

6.1.1 Organization Type

Overall, 58% of respondents identified as construction companies or electrical contractors with experience installing charging infrastructure (Figure 8). The next largest group, state or federally approved electrical apprenticeship programs, accounted for 9% of respondents. Of the electrical contractors and construction companies that responded, reported revenues linked to installing electric vehicle charging infrastructure ranged from 1% to 100% of total revenues, with a mean of 19.6% and a median of 10%. As such, these data indicate that, of the firms surveyed, EV infrastructure installation comprises only part of their business, and the majority of firms have business revenue streams alongside EV infrastructure installations. For the majority of firms, EV infrastructure installation accounts for 10-20% of business revenues.

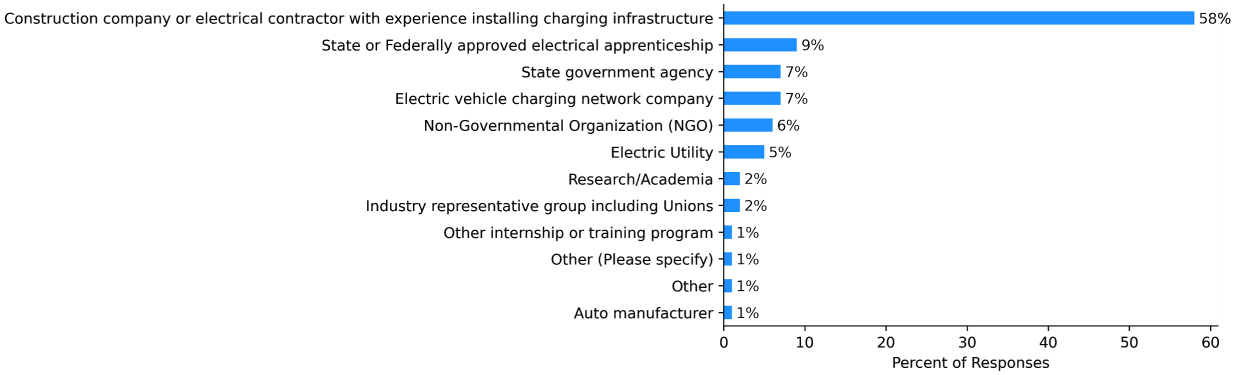

Figure 8: Percent of survey respondents by organization type

6.1.2 Experience

When asked about direct experience planning, contracting, managing, or installing EV infrastructure, 77.2% of respondents responded that they did have experience in one or more of those fields (Figure 9). Survey "skip logic" was applied to the 22.8% of respondents that did not have experience in any of those fields, and those respondents were then asked to answer the questions related to policies later in the survey without seeing the experience-related workforce estimation questions. Among respondents that reported direct experience with installing electric vehicle charging stations, half of all respondents reported 7.5 years or less of experience, and 90% reported fewer than 13.1 years of experience with charging infrastructure.

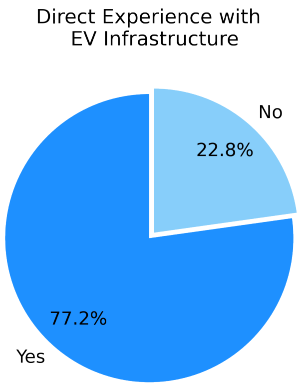

Figure 9: Direct experience of respondents with relation to planning, contracting, managing, or installing EV infrastructure.

Among respondents with direct experience installing, managing, contracting, or planning EV infrastructure, respondents identified the greatest experience with planning and permitting and installation and supporting site modifications, with 80.8% of respondents reporting at least moderate levels of experience with planning and permitting, and 90.5% of respondents reporting at least moderate experience with installation and supporting site modifications (Figure 10).

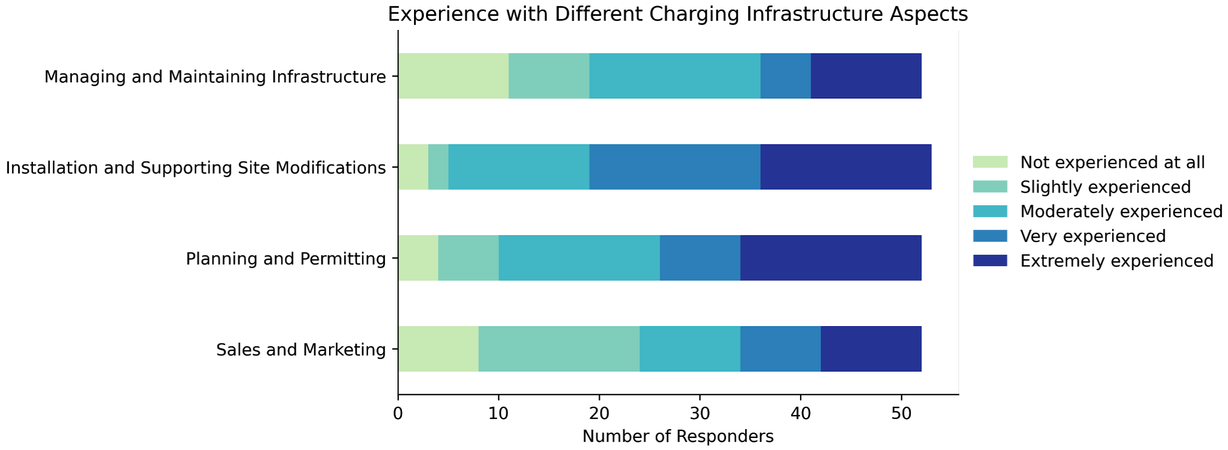

Figure 10: Experience levels of respondents with regards to various charging infrastructure aspects.

6.1.3 Charging Station Installations

Most of the firms surveyed performed fewer than 50 installations of any of the charging station types over the last three years (Figure 11). Estimates of the mean are skewed by a few firms with large numbers of installations, with four firms reporting over 250 Level 2 charging stations in the past three years. The median number of Level 2 charging station installations was 20, and the 75th percentile was 137.5. For DC Fast charging stations, the median reported was 4 charging stations, and the 75th percentile was 12. The pattern for Level 2/DC Fast charging stations was similar to the DC Fast charging stations, with a median of 3, and a 75th percentile of 10 charging stations over three years.

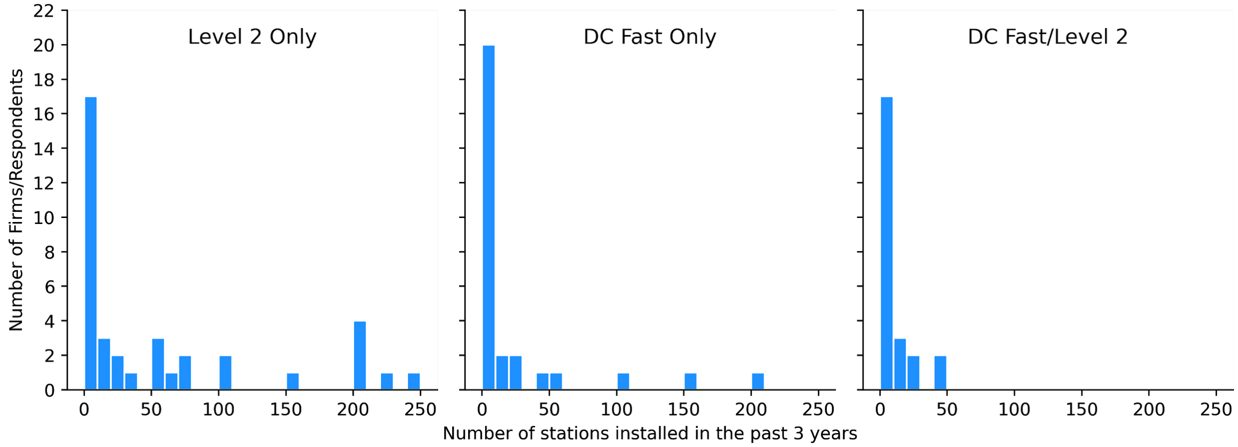

Figure 11: Level 2, DC Fast, and combination DC Fast/Level 2 charging station installations by survey respondents in the past three years(y-axis scales are consistent).

6.2 Level 2 Charging Stations

This section provides details of the typical Level 2 charging station characteristics reported by respondents to the survey. Respondents were then asked to provide their workforce estimates based on the parameters of the "typical" station they reported. As such, the survey design captured workforce estimates for heterogeneous project parameters, but also enabled respondents to provide workforce estimates for the types of projects with which they were most familiar.

6.2.1 Characteristics of Typical Level 2 Charging Stations Installed by Respondents

The median of the typical number of Level 2 chargers reported was 5 chargers per station, and the 75th percentile was 27.5 (Figure 12). The mean reported was 36.8, which is positively skewed due to the presence of two respondents reporting over 100 chargers per station.

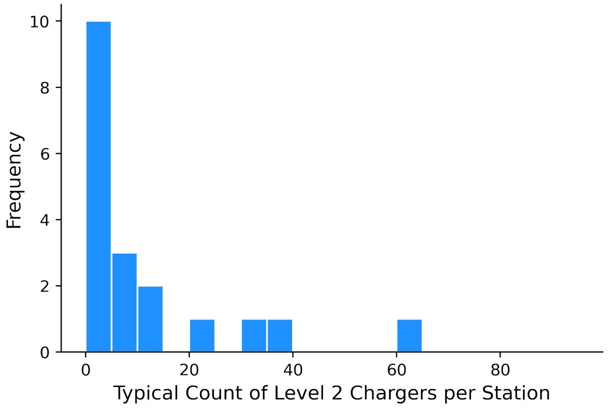

Figure 12: Frequencies of typical number of Level 2 chargers per station installed by respondents.

Nearly all respondents (90%) reported needing to trench through either soil or concrete/asphalt, with median trenching distances of 80 feet and 77.5 feet, respectively. As with many of the data in this survey, the results are positively skewed, with a mean of 336.8 feet and 234.3 feet, for trenching in soil and concrete/asphalt, respectively.

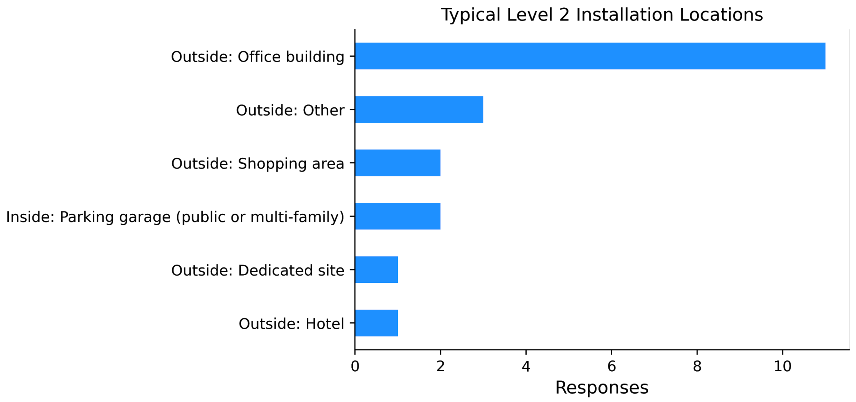

Figure 13: Frequencies of locations of typical Level 2 station installations of respondents.

Among the respondents surveyed, the typical location for public or shared private charging stations was outside (Figure 13), with the most typical exterior location being at office buildings. Two firms responded that their most typical charging station installation location was inside -- either in a parking garage or multi-unit dwelling (MUD).

Half of the respondents reported installing additional lighting or safety measures at their typical Level 2 stations, and nearly two-thirds (65%) reported installing networked stations. Three quarters of respondents reported typically installing stations as part of a pre-existing build, and 22% of respondents indicated that their charging station installations are typically co-located with small-scale renewable energy sources.

6.2.2 Workforce Estimation: Level 2

Respondents were asked to estimate the level of effort associated with a set of job roles and phases of charging station infrastructure development, in person-days, considering the parameters of the "typical" project they described earlier in the survey. The survey instructed respondents to leave blank effort in areas or job-roles where they were unsure. As such, estimates of total labor could not be generated from the data, as not all respondents had perfect information regarding all job-roles. The data were cleaned, removing outliers, and exploratory data analysis was performed to identify patterns in the data. Respondents were treated independently and estimates of effort were estimated by job-role.

Estimates of effort (by job-role as measured in person-days) were generated through ordinary least squares regression. Here, "Effort" is defined as the dependent variable and various charging station parameters (defined as a vector, X) as the independent variables. Independent variables (i.e. explanatory variables) tested include: number of level 2 chargers, location (inside or outside), lighting and signage upgrades (yes or no), co-location with small-scale renewable energy generation (yes or no), length of trenching in soil/asphalt/concrete/other (in feet), whether the site was a new build or an add-on to an existing site, and whether the chargers were networked (yes or no). The most powerful explanatory variable was commonly the number of level 2 chargers in a typical project and in many cases was the only explanatory variable used based on standard goodness of fit and explanatory power metrics used.

The general form of the regression is shown in Equation 1, where X represents a vector of independent variables, and β_x represents the coefficient on the variable, which is interpreted as the number of person-days of effort per unit change in the variable.

Equation 1

$$Effort = \beta_x X + \epsilon$$

We tested models with the intercept both fixed at zero or estimated in the regression, and generally found that setting the intercept to zero produced better goodness of fit estimates, as well as improved the significance of the coefficients.

The following sections discuss the results of our regression analysis for each of the job-roles identified in the survey.

6.2.3 Level 2: Planning and Design

Planning and design is a broad term that encompasses job-roles associated with planning and design for electric vehicle charging infrastructure installation, including: designing and drafting detailed site plans in consultation with the client, identifying and analyzing charging needs and parameters, surveying, and obtaining permits, among other related job roles.

Planning effort shows a nonlinear relationship with the number of Level 2 chargers in a typical station (Figure 14). Regression model (1) in Table 3 shows the coefficient on the linear treatment of number of Level 2 chargers. The coefficient is significant at the 99% confidence level, but the adjusted R^2 fit is much greater when planning effort is regressed against the square of the number of Level 2 chargers with a coefficient of 1.08 planning days of effort per Level 2 charger squared.

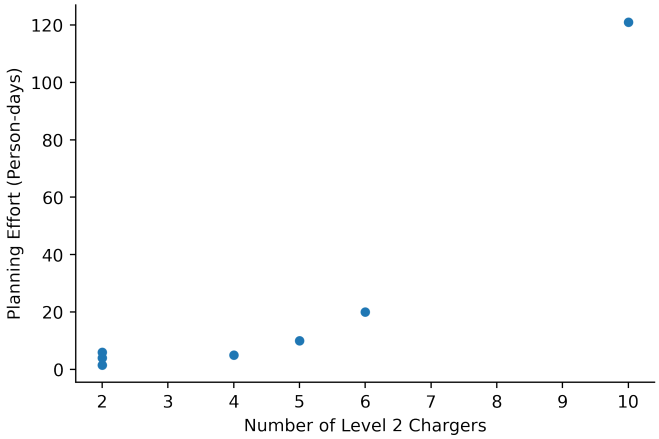

Figure 14: Planning effort in person-days vs. the number of Level 2 chargers of a typical Level 2 station.

The non-linearity identified in the planning effort indicates that as stations become larger they become increasingly complex to plan. This result is intuitive but should be considered in the context of these results. As shown in Figure 14, these estimates are based on effort for stations with 10 or fewer chargers, and the non-linear relationship between planning effort and number of chargers may not extrapolate beyond the bounds of stations with 10 or fewer chargers.

Table 3: Regression model of planning effort in person-days vs. the number of Level 2 chargers in a typical Level 2 station.

	(1)	(2)
Number of Level 2 Chargers	7.529*** (2.216 - 12.842)	
(Number of Level 2 Chargers)^2		1.079*** (0.832 - 1.327)
Adj-R^2	0.655	0.925

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
(values in parentheses represent 95% confidence intervals)

6.2.4 Level 2: General Contracting

General contracting is a broad term that captures job roles associated with construction-related jobs, which may include general laborers, heavy-equipment operators, construction project management and supervision, grading and paving, inspectors, and traffic management around the site.

The number of responses regarding effort related to general contracting was low (n=4) and so modeling of any statistical relationships was not possible. However, summary statistics of these responses show estimates of 0.5 to 6 person days of effort per charging station, with central estimates of 2.3 (mean) and 1.4 (median) days per Level 2 charger.

6.2.5 Level 2: Electrical Contracting

Electrical contractor is a specific occupation. Job-roles associated with electrical contracting include construction-related jobs that are specific to electrical work and may also include effort related to the planning and the design of the site. Electrical contractors are generally responsible for coordinating and overseeing the electrical work at a site and are responsible for hiring electricians.

Electrical contractor effort shows a linear relationship with the number of Level 2 chargers in a typical station. Our regression model (1) in Table 4 shows the coefficient on the linear treatment of the number of Level 2 chargers. The coefficient is significant at the 99% confidence level, and the adjusted-R^2 fit is greater when considering stations with fewer than 15 chargers. There are only 2 data points for stations with more than 15 chargers (Figure 15), and regression model (2) in Table 4 shows a lower adjusted-R^2 value, as well as a lower coefficient on the number of chargers. If the data point at 30 chargers is omitted, the coefficient increases to 2.408 (95% confidence interval = 1.955 - 2.862, adj-R^2 = 0.897).

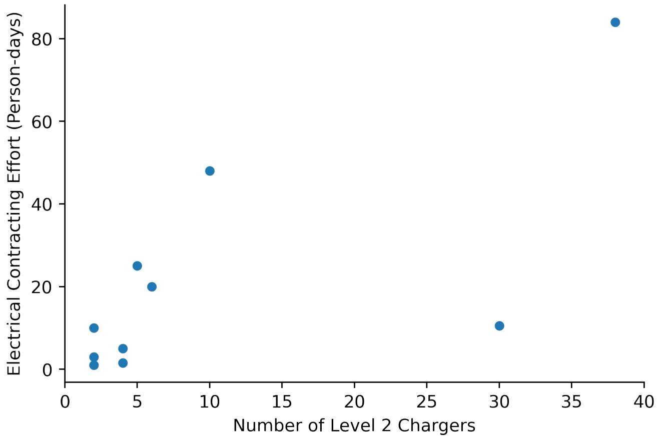

Figure 15: Electrical contracting effort in person-days vs. the number of Level 2 chargers in a typical Level 2 charging station.

The sample size of stations greater than 15 chargers is small (n=2), but including those data produces a lower coefficient than when looking only at smaller stations, indicating that there may be efficiencies of scale for electrical contractors, with the additional unit effort per charger diminishing as stations become larger. This result was tested by fitting a log-linear model (3), for which the coefficient was also significant at the 99% significance level, though the goodness of fit was only slightly improved over the linear model, and the fit was best for the linear model applied to smaller stations (< 15 chargers).

Table 4: Regression model of electrical contracting effort in person-days vs. the number of Level 2 chargers in a typical Level 2 charging station.

	(1)	(2)	(3)
Number of Level 2 Chargers (< 15)	3.800*** (2.586 - 5.014)		
Number of Level 2 Chargers (< 40)		1.681*** (0.560 - 2.803)	
log(Number of Level 2 Chargers (< 40))			13.271*** (4.573 - 21.968)
Adj-R^2	0.833	0.642	0.647

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
(values in parentheses represent 95% confidence intervals)

6.2.6 Level 2: Electricians

Electrician is a specific occupation. Electricians are trained and certified to conduct work on electrical wiring and are responsible for connecting chargers to the lines that connect the site to the grid. Electricians have to complete a comprehensive apprenticeship program before they can be certified.

Electrician effort shows a linear relationship with the number of level 2 chargers in a typical station (Figure 16). Our regression model (1) in Table 5 shows the coefficient on the linear treatment of the number of Level 2 chargers. The coefficient is significant at the 99% confidence level, and the adjusted-R^2 fit is greater when considering stations with fewer than 15 chargers. There are only 2 data points for stations with more than 15 chargers (Figure 16), and regression model (3) in Table 5 shows a lower adjusted-R^2 value, as well as a lower coefficient on the number of chargers.

The sample size of stations greater than 15 chargers is small (n=2) but, as with electrical contractors, including those data produces a lower coefficient than when looking only at smaller stations, indicating that there may be efficiencies of scale for electricians, with the additional unit effort per charger diminishing as stations become larger. This effect is tested by fitting a log-linear model (4), which shows a positive and significant coefficient on log(Number of Level 2 chargers) of 4.522 ($p < 0.001$).

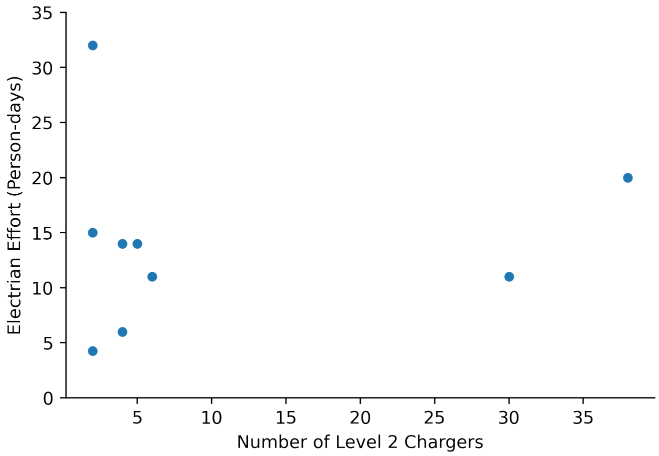

Figure 16: Electrician effort in person-days vs. the number of Level 2 chargers of a typical Level 2 station.

The addition of a binary variable ("New Build") for whether or not the charging infrastructure was installed as part of a new build improves the goodness of fit and estimates a positive and significant coefficient on New Build. This result indicates that when building an electric vehicle charging station at a new build site, the electrician effort is increased by 10.37 person-days, relative to a charging station installation at an existing site. Factors influencing this result may include additional effort pulling conduit and wires to the new site, whereas they may be able to more easily tie in to the infrastructure already in place at an existing site

Table 5: Regression model of electrician effort in person-days vs. the number of Level 2 chargers in a typical Level 2 station.

	(1)	(2)	(3)	(4)
Number of Level 2 Chargers (< 15)[27]	2.520*** (1.751 - 3.289)			
Number of Level 2 Chargers (< 15)		2.314*** (1.683 - 2.946)		
Number of Level 2 Chargers (< 40)			0.392*** (0.211 - 0.573)	
log(Number of Level 2 chargers (< 40))				4.522*** (2.745 - 6.298)
New Build		10.371*** (9.108 - 11.635)	9.664*** (2.390 - 16.939)	7.709** (0.782 - 14.636)
Adj-R^2	0.772	0.910	0.545	0.829

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
(values in parentheses represent 95% confidence intervals)

6.2.7 Level 2: Administration

Administration (i.e., “Admin”) is a broad term that describes occupations related to the administrative process of electric vehicle infrastructure installation. Admin roles may include clerical staff responsible for filing and processing permits and project management tasks including bookkeeping, billing, and payroll.

Admin effort (in person-days) associated with electric vehicle charging infrastructure shows a linear relationship between the number of Level 2 chargers and estimated administrative effort (Figure 17). The coefficient on the number of Level 2 chargers is positive and significant ($p < 0.001$) and indicates an increase of 0.914 person-days of administrative effort per additional Level 2 charger (Table 6).

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[27] Note that these coefficients are estimated with the outlier value removed at 30 person-days of electrician effort for a 2 charger station. With that value included the coefficient for model (1) is 3.033*** (95% CI: 1.639 - 4.428, adj-R^2: 0.454)

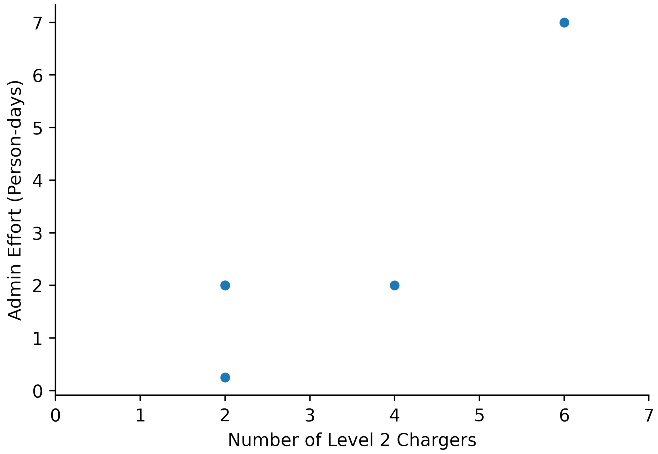

Figure 17: Admin effort in person-days vs. the number of Level 2 chargers of a typical Level 2 station.

Table 6: Regression model of admin effort in person-days vs. the number of Level 2 chargers in a typical Level 2 station.

	(1)
Number of Level 2 Chargers	0.914*** (0.556 - 1.272)
Adj-R^2	0.845

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
(values in parentheses represent 95% confidence intervals)

6.2.8 Level 2: Legal, Other, and Utility Linework

Legal effort refers to work performed by lawyers, paralegals, or legal assistants. Utility linework refers to work performed by trained and licensed electrical Lineworkers, performing work on the grid, or connections to the grid from the electric vehicle charging station.

The survey received limited responses related to the level of effort for legal services (n=1) and “other” effort (n=1). These estimates showed one person-day of legal effort for a 6 charger station (or 0.167 person-days per charger) and 4 person-days of “other” effort for a 6 charger station (or 0.667 person-days per charger).

The survey also only received a single response for utility linework effort, which indicated 160 person-days of effort for a 10 charger station (or 16 person-days per charger). We provide this estimate for transparency, however, it may be an outlier, as the person-days of effort estimated are considerably greater than the largest estimate in any of the other fields, and far outweigh effort estimated for DC Fast charging.

6.3 DC Fast Charging Stations

This section provides details of the typical DC Fast charging station characteristics reported by respondents to the survey. As with Level 2 charging stations, respondents were then asked to provide their workforce estimates based on the parameters of the “typical” station they reported. As such, the survey design captured workforce estimates for heterogeneous project parameters, but also enabled respondents to provide workforce estimates for the types of projects with which they were most familiar.

6.3.1 Characteristics of Typical DC Fast Charging Stations Installed by Respondents

The median of the typical number of DC Fast chargers reported was 4 chargers per station, and the 75th percentile was 5. The mean reported was 4.1 (Figure 18).

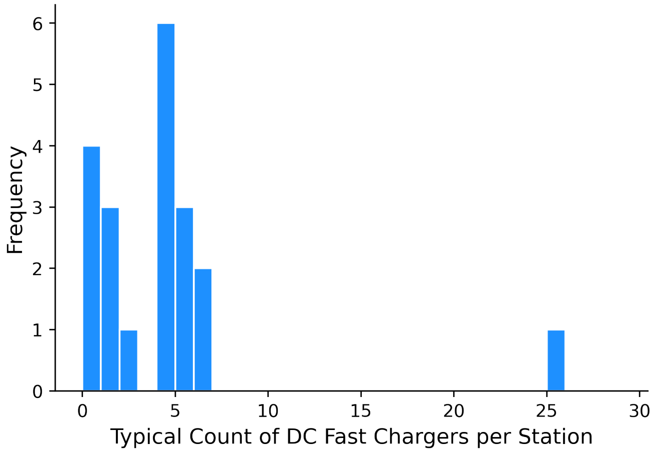

Figure 18: Frequencies of typical number of DC Fast chargers per station installed by respondents.

The majority of respondents (> 76%) reported needing to trench through either soil or concrete/asphalt, with median trenching distances of 60 feet and 80 feet, respectively. As with many of the data in this survey, the results are positively skewed, with a mean of 468.8 feet and 345.8 feet, for trenching in soil and concrete/asphalt, respectively.

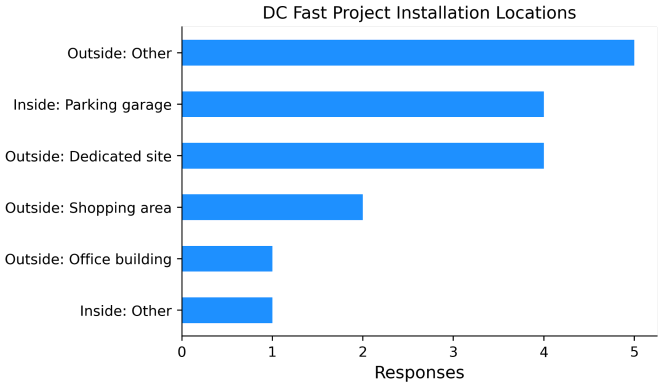

Figure 19: Frequencies of locations of typical DC Fast station installations of respondents.

Among the respondents surveyed, the typical location for public or shared private charging stations was outside, with the most typical location being outside at "other" locations (Figure 19). The sample for DC Fast charging station respondents was smaller than for Level 2 charging stations, with parking garages and dedicated outside sites the next most common locations.

Approximately two-thirds (65%) of respondents reported typically installing additional lighting or safety measures at their DC Fast stations. Respondents reported that typically DC Fast charging stations were installed at existing locations, though the fraction of typical DC Fast charger stations at new builds is higher than for Level 2 charging stations (35%, versus 25% for Level 2). Just under one fifth (19%) of respondents indicated that their DC Fast charging station installations are typically co-located with small-scale renewable energy sources.

6.3.2 Workforce Estimation: DC Fast Charging

As with the Level 2 charging estimates, respondents were asked to estimate the level of effort associated with a set of job-roles and phases of charging station infrastructure development, in person-days, considering the parameters of the "typical" DC Fast charging project they described earlier in the survey. The survey instructed respondents to leave blank effort in areas or job-roles where they were unsure. As such, estimates of total labor could not be generated from the data, as not all respondents had perfect information regarding all job-roles. The data were cleaned, removing outliers, and exploratory data analysis was performed to identify patterns in the data. Respondents were treated independently and estimates of effort were estimated by job-role.

Estimates of effort were generated through ordinary least squares regression analysis of person-days estimated by job-role as the dependent variable and charging station parameters as the independent (i.e., "explanatory") variables. Explanatory variables tested include: number of DC Fast chargers, location (inside or outside), lighting and signage upgrades (yes or no), co-location with small-scale renewable energy generation (yes or no), length of trenching in soil/asphalt/concrete/other (in feet), whether the site was a new build or an add-on to an existing site, and whether the chargers were networked (yes or no). The most powerful explanatory variable was commonly the number of DC Fast chargers in a typical project and in many cases was the only explanatory variable used based on analysis of goodness of fit and explanatory power metrics. Note that the estimates derived in this work are high-level estimates designed to capture the average reported level of effort associated with DC Fast charging infrastructure installation. The project requirements for 350kW chargers are notably different to those of 50kW chargers, including significant additional effort for make-ready, utility service, and equipment pads. Detailed project planning should always take into consideration the parameters of the site being developed.

The general form of the regression modeling is the same as for Level 2 charging infrastructure, shown in Equation 1, where X represents a vector of dependent variables, and β_x represents the coefficient on the variable, which is interpreted as the number of person-days of effort per unit change in the variable.

Equation 1

$$Effort = \beta_x X + \epsilon$$

6.3.3 DC Fast: Planning and Design

Planning and design is a broad term that encompasses job roles associated with planning and design for electric vehicle charging infrastructure installation including designing and drafting detailed site plans in consultation with the client, identifying and analyzing charging needs and parameters, surveying, and obtaining permits, among other related job-roles.

Planning effort shows a nonlinear relationship with the number of DC Fast chargers in a typical station (Figure 20). Regression model (1) in Table 7 shows the coefficient on the linear treatment of the number of DC Fast chargers. The coefficient is non-significant at the 90% confidence level, and the adjusted R^2 fit is low. When testing for nonlinearity, regressing the planning effort against the number of DC Fast chargers squared, the goodness of fit improves (adj.-$R^2 = 0.304$), but the coefficient is not significant.

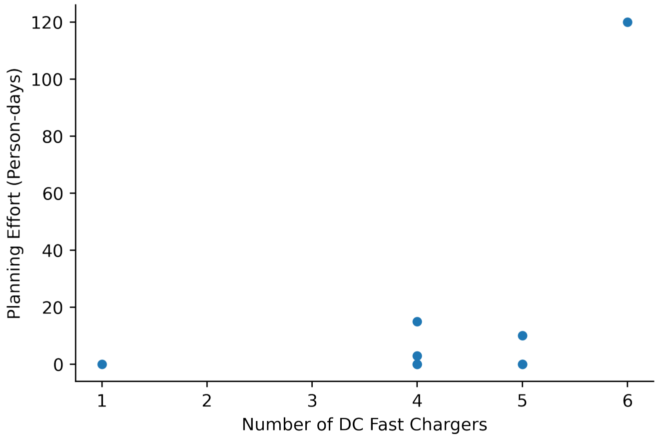

Figure 20: Planning effort in person-days vs. the number of DC Fast chargers of a typical DC Fast station.

Observation of the data points in Figure 20 indicates that the data point at 6 DC Fast chargers may be an outlier, as the effort estimated per charger is greater than 5x the other estimates. With that possible outlier removed, the coefficients become significant at the 90% significance level, though the goodness of fit is reduced when compared to the fit in model (2). Though the coefficient in model (2) is not significant at the 90% significance level ($p = 0.114$), the specification produces the best goodness of fit, and the coefficient on the number of DC Fast chargers squared is very similar to the coefficient for planning effort for Level 2 chargers (Level 2: 1.079, DC Fast: 1.158).

Table 7: Regression model of planning effort in person-days vs. the number of DC Fast chargers in a typical DC Fast station.

	(1)	(2)	(3)
Number of DC Fast Chargers	4.784 (-1.801 - 11.369)		
(Number of DC Fast Chargers)^2		1.158 (-0.279 - 2.595)	
Number of DC Fast Chargers (< 6)			0.871* (-0.042 - 1.785)
Adj-R^2	0.183	0.304	0.221

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
(values in parentheses represent 95% confidence intervals)

6.3.4 DC Fast: General Contracting

General contracting is a broad term that captures job roles associated with construction-related jobs, which may include general laborers, heavy-equipment operators, construction project management and supervision, grading and paving, inspectors, and traffic management around the site.

The number of responses regarding effort related to general contracting was low (n=5) and modeling of statistical relationships did not identify any relationships. However, summary statistics of these responses show estimates of 1 to 16 person days of effort per charging station, with central estimates of 2.98 (mean) and 0.75 (median) days per DC Fast charger.

6.3.5 DC Fast: Electrical Contracting

Electrical contractor is a specific occupation. Job roles associated with electrical contracting include construction-related jobs that are specific to electrical work and may also include effort related to the planning and the design of the site. Electrical contractors are generally responsible for coordinating and overseeing the electrical work at a site and are responsible for hiring electricians.

Electrical contracting effort shows a linear relationship with the number of level 2 chargers in a typical station (Figure 21). OLS regression model (1) in Table 8 shows the coefficient on the linear treatment of the number of DC Fast chargers. The coefficient is significant at the 90% confidence level, and the adjusted-R^2 is 0.319. As shown in the regression model (2) in Table 8, co-location with renewables was a positive and significant variable, increasing the significance on the coefficient capturing the effect of number of chargers ($p = 0.042$), while also significant itself ($p < 0.001$).

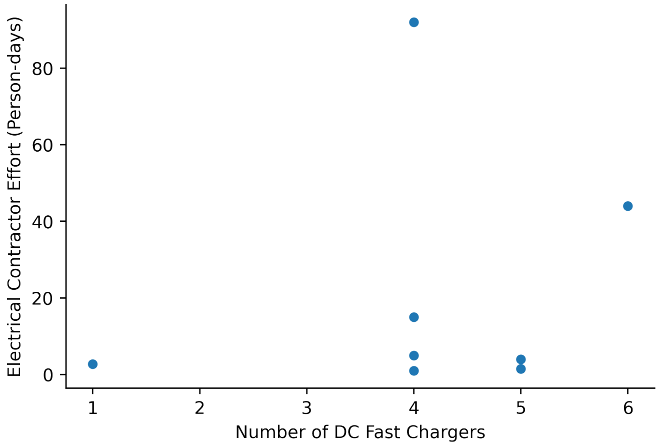

Figure 21: Electrical contracting effort in person-days vs. the number of DC Fast chargers in a typical DC Fast charging station.

The addition of a binary variable for whether or not the charging infrastructure was co-located with small-scale renewables (i.e., "Renewables" in model 2) improves the goodness of fit and estimates a positive and significant coefficient on the renewables variable (binary). This result indicates that when building an electric vehicle charging station at a site co-located with small-scale renewables, the electrician effort is increased by 37.875 person-days, relative to a charging station installation at a site without small-scale renewables.

Table 8: Regression model of Electrical contracting effort in person-days vs. the number of DC Fast chargers in a typical DC Fast charging station.

	(1)	(2)
Number of DC Fast Chargers	2.364* (-0.136 - 4.864)	1.021** (0.039 - 2.003)
Renewables		37.875*** (31.981 - 43.769)
Adj-R^2	0.319	0.897

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
(values in parentheses represent 95% confidence intervals)

6.3.6 DC Fast: Electricians

Electrician is a specific occupation. Electricians are trained and certified to conduct work on electrical wiring and are responsible for connecting chargers to the lines that connect the site to the grid. Electricians have to complete a comprehensive apprenticeship program before they can be certified.

Electrician effort shows a linear relationship with the number of DC Fast chargers in a typical station. OLS regression model (1) shows the coefficient on the linear treatment of the number of DC Fast chargers. The coefficient is significant at the 95% confidence level, and the adjusted-R^2 fit is 0.441.

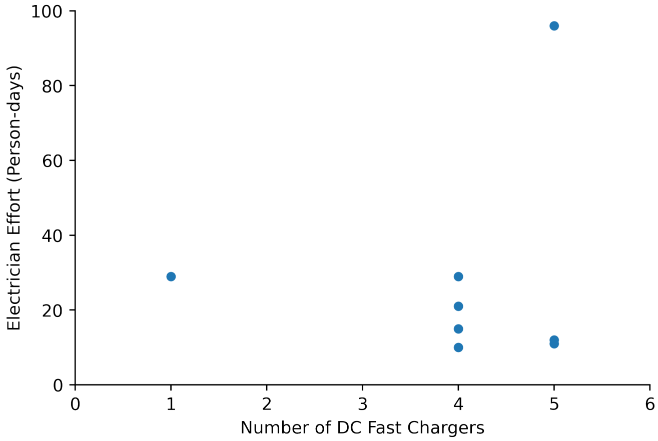

Figure 22: Electrician effort in person-days vs. the number of DC Fast chargers of a typical DC Fast station.

The data in Figure 22 show a possible outlier, with 96 person-days estimated for a 5 charger station. With this data point removed, as shown in model (2) (Table 9), the goodness of fit improves (adj-R^2 = 0.570), and the significance of the coefficient improves ($p < 0.001$). Considering the specification in model (2), these data indicate 3.86 person days of electrician effort per DC Fast charger installed.

Table 9: Regression model of electrician effort in person-days vs. the number of DC Fast chargers in a typical DC Fast station.

	(1)	(2)
Number of DC Fast Chargers	6.600** (1.556 - 11.644)	
Number of DC Fast Chargers (outlier removed)		3.861*** (2.375 - 5.347)
Adj-R^2	0.441	0.570

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
(values in parentheses represent 95% confidence intervals)

6.3.7 DC Fast: Administration

Administration, or "Admin," is a broad term that describes occupations related to the administrative process of electric vehicle infrastructure installation. Admin roles may include clerical staff responsible for filing and processing permits and project management tasks including bookkeeping, billing, and payroll.

Survey responses including estimates of admin effort (in person-days) associated with electric vehicle charging infrastructure were only provided for charging stations with 4 or 5 DC Fast chargers. Due to the limited heterogeneity in the independent variable, admin effort was estimated based on summary statistics, rather than regression modeling. Central estimates for admin effort were well aligned at 1.04 (mean) and 1.05 (median) person-days per DC Fast charger, with the range in estimates from 0.2 to 2.0 person days of admin effort per DC Fast charger.

6.3.8 Level 2: Legal, Other, and Utility Linework

Legal effort refers to work performed by lawyers, paralegals, or legal assistants. Utility linework refers to work performed by trained and licensed electrical Lineworkers, performing work on the grid, or connections to the grid from the electric vehicle charging station.

The survey received limited responses related to the level of effort for legal services (n=1) and "other" effort (n=3). These estimates showed two person-days of legal effort for a 4 charger station (or 0.5 person-days per charger) and 0.2 - 1.75 person-days of "other" effort per charger.

The survey also only received 2 responses for utility linework effort, which indicated 3-6 person-days of effort for a 4 charger station (or 0.75 - 1.5 person-days per charger).

6.4 Workforce Estimation Summary

This section presents a summary of effort associated with electric vehicle infrastructure development and installation by the job-roles involved. While effort per-charger is the primary explanatory variable, workforce estimation modeling has shown that other site-specific factors affect the level of effort associated with charging infrastructure planning and installation.

Table 10 shows the breakdown of estimated effort by job role in terms of the number of chargers and other explanatory variables, described in Section 6.2 and 6.3. The results presented in Table 10 present the model evaluated for the best goodness of fit and significance of coefficients, or the mean in cases where small samples did not allow for regression modeling (denoted with a double dagger ‡). Though sample sizes were generally not large ($n < 15$), regression analysis identified significant coefficients and high adjusted R^2 values, demonstrating good explanatory power.

Table 10: Estimated effort by job-role in person-days for Level 2 and DC Fast charger installation (2 d.p.).

Job-Role	Level 2	DC Fast
Planning and Design	1.08 x $\#Chargers^2$	1.16 x $\#Chargers^2$
General Contracting	2.31 x #Chargers ‡	2.98 x #Chargers
Utility Linework[28]	0.75 x #Chargers ‡	0.75 x #Chargers ‡
Electrical Contracting	1.68 x #Chargers	1.02 x #Chargers + 37.88 if co-located w. renewables
Electrician	2.31 x #Chargers + 10.37 if new build	3.86 x #Chargers
Admin	0.91 x #Chargers	1.04 x #Chargers ‡
Legal	0.17 x #Chargers ‡	0.50 x #Chargers ‡
Other	0.67 x #Chargers ‡	0.92 x #Chargers ‡

‡ Small sample size/summary statistics

As discussed in Section 6.2 and 6.3, these estimates are best applied to charging stations with fewer than 40 chargers, which, based on data from the AFDC, accounts for 99.9% of current public charging stations with Level 2 or DC Fast chargers.

As expected, given the technical demands of DC Fast charging relative to Level 2 charging, the estimated effort associated with DC Fast charging infrastructure is greater than for Level 2 charging, with the exception of estimates for electrical contractors, which are higher for Level 2 charging infrastructure unless DC Fast stations are co-located with renewables.

6.5 Workforce Projections

This section presents estimates of workforce needs based on estimates of effort from the expert survey and estimates of projected charger needs estimated both nationally and by the California Energy Commission (Crisostomo et al, 2021) and presented as a draft staff report[29] in response to Assembly Bill 2127 (AB 2127, 2018).

While this section describes workforce needs associated with electric vehicle charging infrastructure development, it does not address the potentially displaced jobs that may occur in other industries. As electrification of transportation grows, demand for gasoline fuels will decline, with impacts on upstream, downstream, and associated workforces. As the electric vehicle charging industry grows,

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[28] Level 2 utility linework estimates were not available from the survey sample. As such, utility linework effort for Level 2 infrastructure was assumed to be equivalent to the estimates for DC Fast charging infrastructure.

[29] Additional details may be found at https://www.energy.ca.gov/programs-and-topics/programs/electric-vehicle-charging-infrastructure-assessment-ab-2127

workforce programs may wish to consider the training needs of workers displaced from other sectors by the electric vehicle sector.

6.5.1 NREL National Demand for Electric Vehicle Charging Infrastructure

NREL's 2017 analysis estimates around 15 million light-duty plug-in electric vehicles on the road in 2030 (Wood et al., 2017). NREL estimates that to meet charging demand for these vehicles, charging infrastructure will need to be developed such that there are 27,500 DC Fast chargers, and 601,000 Level 2 chargers available nationwide. The current status of charger installations is equivalent to 12.7% of the NREL projected demand for public Level 2 chargers, and 61.2% of the DC Fast charger demand. Therefore meeting NREL's estimated national demand, with no consideration for the geographic distribution of chargers and charging station, would require an additional 10,670 DC Fast chargers, and 524,670 Level 2 chargers.

The workforce needed to meet demand projected by NREL is estimated to be on the order of 22,720 job-years nationwide, from 2021 to 2030 (Table 11). An important caveat to these estimates is that they are based on survey responses that may be more representative of workforces in California than the rest of the country. However, the electric vehicle charging industry in California is larger than the rest of the country, with 20.6% of all public charging stations installed in California. As such, the electric vehicle charging industry in California is likely to be more mature than the rest of the country, on average, and thus are more likely to have identified and built operational efficiencies into their business practices. Another important caveat is that differences in planning and permitting may exist across states, and local ordinances should be considered. However, outside of the planning and permitting phase, infrastructure installation effort in California is likely to be similar to effort in other states. Therefore, from the perspective of experience, and given the nature of the installation work, the workforce estimates described here may be considered to be conservative for the remainder of the country.

Table 11: Workforce estimates in job-years in order to meet 2030 charger demand estimated by NREL.

NREL Estimate	**Level 2 (Job-years)**	**DC Fast (Job-years)**	**Sum (Job-years)**
Planning and Design	4,350	160	**4,520**
General Contracting	4,640	120	**4,760**
Utility Linework	1,510	30	**1,540**
Electrical Contracting	3,390	40	**3,430**
Electrician	4,670	160	**4,830**
Admin	1,840	40	**1,890**
Legal	340	20	**360**
Other	1,350	40	**1,380**
Sum	**22,100**	**620**	**22,720**

6.5.2 Biden Administration Federal Electric Vehicle Charger Goal

In March 2021, the Biden Administration announced a goal to build more than 500,000 EV chargers across the United States.[30] Recent research indicates that around 250,000 public 350kW DC Fast chargers will be required to meet 2030 light-duty public charging demand.[31] If lower powered (50kW+) DC Fast chargers are installed, similar to the current mix of DC Fast chargers, then significantly more than 250,000 chargers will be needed to meet projected demand. With the assumption that all chargers installed to meet the administration's goal are DC Fast chargers, Table 12 presents results for workforce estimates to install 500,000 public DC Fast chargers.

Table 12: Workforce estimates in job-years in order to build 500,000 public DC Fast chargers from 2021 to 2030.

Biden Administration Goal	DC Fast (Job-years)
Planning and Design	7,660
General Contracting	5,730
Utility Linework	1,440
Electrical Contracting	1,960
Electrician	7,430
Admin	2,000
Legal	960
Other	1,770
Sum	28,950

The workforce needs to facilitate the Biden administration goal are estimated to be on the order of 28,950 job-years nationwide (Table 12), from 2021 to 2030. These results assume that all 500,000 chargers are public DC fast chargers, installed to meet projected light-duty demand. If medium and heavy-duty vehicle public charging demand is also considered then the charger needs, and associated workforce demand, would be greater. Similarly, the workforce estimates for DC Fast charging are based on a survey of installers considering the current mix of DC Fast chargers. If the DC Fast chargers actually installed generally have a higher capacity than the current mix, then workforce demand will likely be higher due to increased complexity in planning, permitting and design, increased demand for make-ready and utility connections, and greater site preparation and general contracting needs associated with higher powered charging infrastructure.

6.5.3 California Electric Vehicle Infrastructure Projections

The AB 2127 projected charger needs were developed using a suite of modeling tools, most notably EVI-Pro 2. Three scenarios regarding projected electric vehicle uptake were analyzed, low, baseline, and high, corresponding to 1.9 million, 5 million, and 7.9 million zero-emission vehicles in 2030. Furthermore, each scenario included a low, average, and high estimate for the number of chargers needed to meet demand. These estimates for the baseline and high scenarios are summarized in Table 13.

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[30] https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/02/readout-of-the-white-houses-meeting-with-electric-vehicle-charging-infrastructure-leaders/

[31] https://atlaspolicy.com/rand/u-s-passenger-vehicle-electrification-infrastructure-assessment/

Table 13: Scenarios regarding projected vehicle uptake charger needs for 2030. Excerpted from Table 6 (Crisostomo et al. 2021)

	Baseline (1000 Chargers)			High (1000 Chargers)		
	Low	Average	High	Low	Average	High
All Level 1 and 2	891	933	975	1414	1476.5	1539
DC Fast	30.5	31.3	32.1	53.1	54.5	55.9
Total	921.5	964.3	1007.1	1467.1	1531	1594.9

Per Crisostomo et al (2021), as of September 30, 2020, there were currently around 62,000 Level 2 chargers and 5,400 DC Fast chargers in California. Analysis of allocated funding indicates that an additional 117,000 Level 2 and 4,100 DC Fast chargers are planned or projected for installation by 2025. Considering the average estimates, these data indicate that an additional 871,000 Level 2 and 25,900 DC Fast chargers will be needed under the baseline scenario, and an additional 1,414,500 Level 2 and 49,100 DC Fast chargers will be needed under the high scenario from 2020 to 2030.

Workforce estimates to meet additional electric vehicle infrastructure demand are shown in Table 14 (Baseline scenario) and Table 15 (High scenario). These estimates show workforce needs by job-role to meet projected electric vehicle infrastructure demand from 2021 to 2030. Workforce needs are estimated based on analysis of survey responses, provided in person-days and converted to job-years assuming a full time equivalent (FTE) of 2080 hours and 8 hour workdays. It is important to note that job-years cannot always be directly translated into a number of jobs created, but instead help to describe the demand for work. One job-year is equivalent to one person performing a job for one year, or two people performing the same job for half a year, and so on. The skills required are largely identical to existing trades and likely additive to existing work.

As shown in shown in Table 14 (Baseline scenario) and Table 15 (High scenario), the majority of workforce needs are anticipated to be installing Level 2 charging infrastructure, corresponding to the projected demand for Level 2 charging described in Crisostomo et al (2021). General contracting and electricians are the two largest job-roles, with technical work (general contracting, utility line work, electrical contracting, and electricians) accounting for 64% of effort, in terms of job-years, for Level 2 charger installation and 57% for DC Fast charging infrastructure. In total, estimates for light-duty charging infrastructure range from 38,190 - 62,420 total job-years over the period from 2021 to 2030.

Table 14: Baseline scenario workforce estimates to meet light-duty electric vehicle infrastructure demand in California from 2021 to 2030.

Light-Duty Baseline - No New Build, No renewables	Level 2 (Job-years)	DC Fast (Job-years)	Sum (Job-years)
Planning and Design	7,230	400	**7,630**
General Contracting	7,710	300	**8,000**
Utility Linework	2,510	70	**2,590**
Electrical Contracting	5,630	100	**5,730**
Electrician	7,750	380	**8,140**
Admin	3,060	100	**3,170**
Legal	560	50	**610**
Other	2,230	90	**2,330**
Sum	**36,690**	**1,500**	**38,190**

Table 15: High scenario workforce estimates to meet light-duty electric vehicle infrastructure demand in California from 2021 to 2030.

Light-Duty High - No New Build, No renewables	Level 2 (Job-years)	DC Fast (Job-years)	Sum (Job-years)
Planning and Design	11,740	750	**12,490**
General Contracting	12,510	560	**13,080**
Utility Linework	4,080	140	**4,220**
Electrical Contracting	9,150	190	**9,340**
Electrician	12,590	730	**13,320**
Admin	4,970	200	**5,170**
Legal	910	90	**1,000**
Other	3,630	170	**3,800**
Sum	**59,580**	**2,840**	**62,420**

6.5.4 California: Medium and Heavy-Duty Infrastructure

Survey respondents mainly had experience with installations in the LDV sector. When asked about the differences between light-duty and medium/heavy-duty charging infrastructure the most commonly referenced difference was the need for a system designed for larger electrical demand, and the associated equipment to handle larger loads (73% of respondents) as well as larger space and weight requirements (36%).

M/HDV estimates are derived based on estimates for LDVs for DC Fast charging, which is designed for larger loads than Level 2 charging. As indicated, requirements for M/HDV infrastructure are likely larger, and therefore these estimates can best be considered to represent the conservative lower bound for the workforce requirements associated with medium and heavy-duty electric vehicle charging infrastructure. As there are comparatively few medium and heavy-duty charging stations, the results here may underestimate effort, including when considering utility make-ready in order to accommodate large station loads associated with medium and heavy-duty vehicle and fleet charging.

Crisostomo et al. (2021) estimate demand for around 141,000 50kW and 16,000 350 kW DC Fast chargers to support 180,000 battery electric medium- and heavy-duty vehicles in California in 2030. Due to the limited buildout of medium- and heavy-duty electric vehicle charging infrastructure at this stage, the estimates in Table 16 assume that the workforce needs for medium- and heavy-duty charging infrastructure, which require higher capacity lines and heavy-duty equipment, are more closely aligned with DC Fast charging infrastructure workforce needs and thus employ the same assumptions from Table 10 in terms of the relationship between the number of chargers and workforce needs. These estimates are based on survey responses from active charging station installers.

Table 16: Workforce estimates to meet demand for buildout of medium- and heavy-duty electric vehicle charging infrastructure in California from 2021 to 2030.

CA M/HDV	Sum (Job-years)
Planning and Design	2,410
General Contracting	1,800
Utility Linework	450
Electrical Contracting	620
Electrician	2,330
Admin	630
Legal	300
Other	560
Sum	**9,090**

The estimates for medium and heavy duty electric vehicle charging infrastructure indicate workforce needs totaling 9,090 job-years from 2021 to 2030, in addition to the light-duty charging infrastructure workforce needs.

6.6 Survey Responses: Challenges and Policies Affecting Equity Communities

When asked to identify the frequency with which they encountered a selected set of challenges during the infrastructure development process, respondents most frequently identified planning and permitting restrictions as a challenge, with two thirds of respondents encountering planning and permitting issues at least somewhat frequently. Funding and vendor availability were the next most frequently encountered challenges. Availability in the employment pool was either not an issue, or infrequently encountered for 72% of respondents, and challenges relating to employee skill sets were either not encountered or infrequently encountered by 83% of respondents (Figure 23).

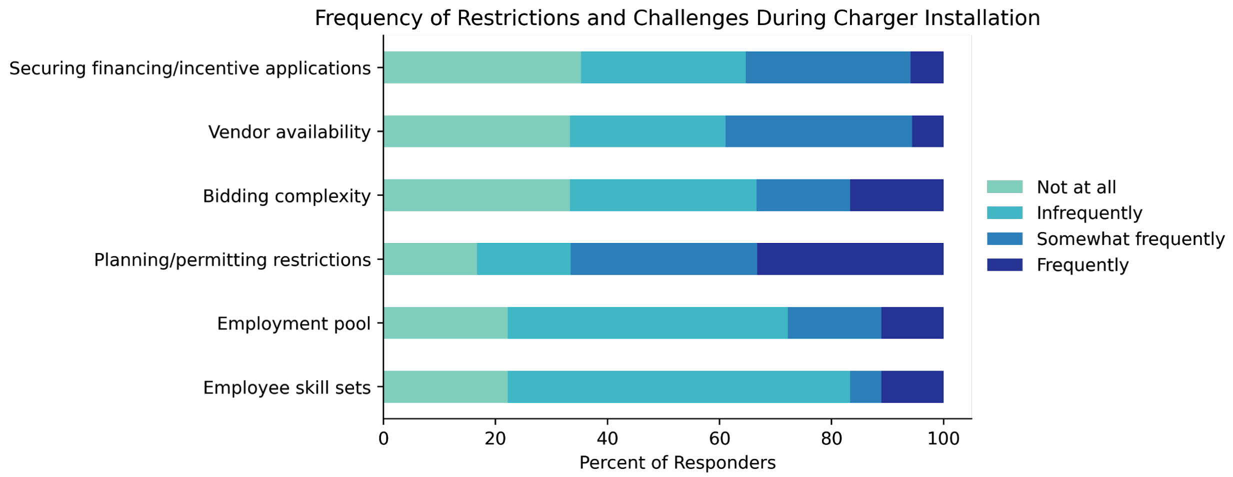

Figure 23: Frequencies of respondents experiencing various restrictions and challenges during charger installations.

When considering the response to the frequency of challenges and restrictions, respondents most commonly identified challenges/restrictions related to employee skill sets as the biggest challenge they encountered (Figure 24). Taking these results in context with the response above, these data indicate that while challenges related to employee skill sets may be infrequently encountered, when they are encountered they represent the biggest challenge to infrastructure development.

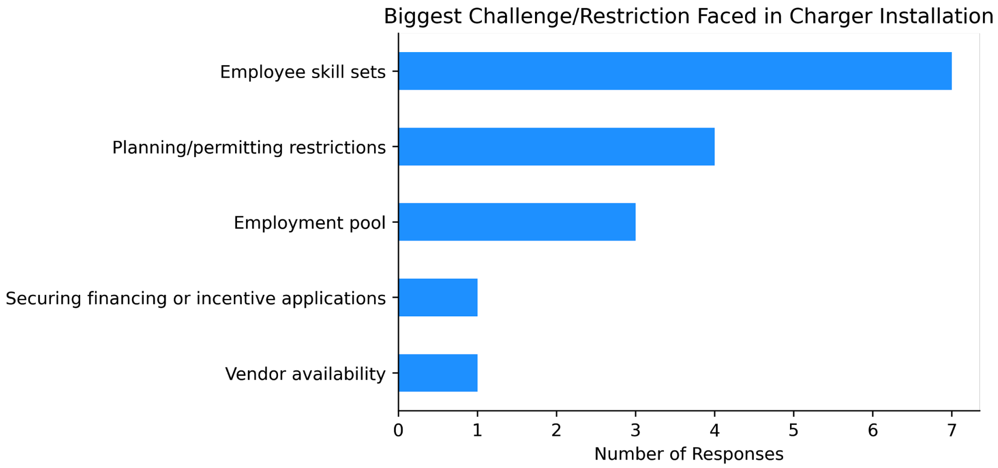

Figure 24: Frequencies of the biggest challenge/restriction faced during charger installations of respondents.

Eighty percent (80%) of respondents in California identified special training requirements for charger installers, beyond state licensure. Among those that responded “yes,” all but one respondent (94%) identified that their installers must have completed EVITP training.

Among respondents from California, over half of respondents (52%) identified apprenticeships as important avenues for developing skills and training to increase access to high quality EV infrastructure jobs for priority communities. 34% of respondents specifically identified joint labor management electrical apprenticeships (or joint apprenticeship and training committee, JATC apprenticeships) and 38% identified the EVITP. Other programs identified include Charge Ready, Ecotality, and community/technical college training programs.

The responses from firms in the rest of the country are similar to those from California. For example, 42% of respondents identified the EVITP as important, along with 38% of respondents who identified apprenticeships as important programs for attracting workers from priority communities, including references to joint labor management electrical apprenticeships. Apprenticeships are a required part of the training and certification process for electricians, with apprentices completing 8,000 supervised hours before they can sit for state-administered licensing exams. These results highlight the importance of the role of electrical apprenticeships as an avenue to high road jobs for priority communities.

When asked how their organization currently addresses issues related to equity and priority communities, 44% of respondents identified outreach and recruiting efforts by apprenticeship programs as central to their efforts to address issues of equity. 38% of respondents identified outreach to veterans and 34% identified outreach to formerly incarcerated individuals as components of their efforts to engage with priority communities. 16% of respondents specifically identified that by hiring through their local union hall they have access to a diverse workforce. These results again highlight the pivotal role that electrical unions and affiliated apprenticeship programs play in engaging with priority communities and stress the importance of the efforts of those organizations to engage with priority communities.

7 Social Impact Assessment

Section 6 identified the potential for tens of thousands of job-years associated with electric vehicle infrastructure buildout. As discussed in Section 3, the types of jobs associated with electric vehicle infrastructure fall across a set of industry classifications, including technical jobs such as electricians, electrical contractors, general contractors, utility Lineworkers, administrative jobs, and jobs related to legal and professional services, including electrical engineering and planning and design. As demand for electric vehicle infrastructure grows, and associated workforce needs grow to meet demand, there is great potential for employment opportunities for priority communities. Many of the technical jobs associated with electric vehicle infrastructure require trained and skilled workforces but are accessible to those that do not have college degrees. These jobs offer a pathway to high road, resilient careers for all of the workforce, particularly priority communities that have disproportionately suffered from historic environmental, health, and other social burdens.

Social Impact Assessment (SIA) can be used to measure the effects of large-scale infrastructure build-out on priority communities. Whether publicly or privately funded, infrastructure expenditures can lead to a suite of social outcomes, including access to said infrastructure upon completion, improved local air quality where electric vehicles displace internal-combustion vehicles, as well as access to high road and resilient employment opportunities related to infrastructure installation. In the context of electric vehicle infrastructure build out and workforce development, including engagement with priority communities, considering the framework of SIA can be instrumental for measuring the social benefits of infrastructure buildout and reassessing and aligning program goals.

SIA is commonly carried out in tandem with public fund expenditures and has been widely applied and incorporated into best practices by government agencies.[32] Arguably most importantly, SIA is a

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[32] See, for example https://www.usaid.gov/sites/default/files/documents/1866/USAID-Social-Impact-Assessment-508.pdf and

participatory process, engaging priority communities, policymakers, and industry stakeholders in an informed process including aspects of planning and developing programs that affect communities.

7.1 Recommended Steps for Robust Social Impact Analysis

Recommended steps for robust SIA in the context of electric vehicle infrastructure workforce development and priority communities are listed below, adapted from USAID guidelines[33] and best practices outlined by Esteves et al. (2012).

Step	Phase	SIA Activity Description in the Context of Electric Vehicle Workforce Needs and Priority Communities
1	**Planned Program/Activity and Goals**	The first phase of SIA is to identify, delineate, and describe the program/activity to be studied and to identify program/activity goals. This phase should include participation from all relevant stakeholders, including priority communities, to facilitate discussion and consideration of relevant viewpoints.
2	**Context of the Activity**	This phase of SIA extends discussion of the program/activity goals, placing the social impacts of the program/activity in the context of the communities being affected, including priority communities. Stakeholder engagement is an important component of this phase, enabling discussion of differing perspectives and possible outcomes.
3	**Initial Screening**	The screening phase of SIA involves engagement with stakeholders to determine the suite of possible outcomes of the activity and identify potential positive and unintended outcomes.
4	**Assess the Baseline**	Data describing the pre-program/activity baseline conditions is collected under the baseline assessment phase of the SIA. Useful data to collect in the context of electric vehicle infrastructure workforce development may include workforce and apprenticeship demographics and socioeconomic parameters, including geographic data relevant to priority and other communities. Though not specifically related to workforce employment, tracking access to electric vehicle infrastructure for priority communities would also provide an important indicator for changing access. Furthermore, qualitative or quantitative assessment of community organization and engagement in the context of workforce development and priority communities could benefit future assessment of activity outcomes. Best practices suggest that data metrics collected be identified prior to assessment through a participatory stakeholder process.
5	**Assess Impacts on Identified Groups**	Through ongoing monitoring and tracking of metrics assessed in Step 4, this phase of SIA involves regular data collection and analysis to determine activity-related impacts on priority and other groups, including analysis of expenditures of public and private funds. This ongoing data collection phase allows for direct comparison with the baseline assessed in Step 4. Best practices suggest that data should be collected, analyzed, and reported at least annually.

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https://repository.library.noaa.gov/view/noaa/6208/noaa_6208_DS1.pdf

[33] https://www.usaid.gov/sites/default/files/documents/1866/USAID-Social-Impact-Assessment-508.pdf

6	**Reassess and Reevaluate**	Informed by analysis of data collected under Step 5, this phase of SIA involves critical assessment and evaluation of the social impacts of the activity, including benefits to the communities of interest in the context of social program goals identified under Step 1. This phase of analysis offers an opportunity to institute new programs that enhance benefits and opportunities. The SIA process is iterative and living, with Step 5 and Step 6 remaining in progress until the completion of the period of program activity or analysis. New data collected should inform critical assessment and evaluation of success in terms of meeting program goals, including those pertaining to vocational training such as apprenticeships and pre-apprenticeship programs. As necessary, new and updated goals should be considered, informed by the data, and developed through an informed stakeholder engagement process.

Areas where SIA may be applicable to workforce demand and priority communities might include analysis of the potential for stranded workforces, whereby workers train and earn qualifications to meet short-run demand, but when demand shifts are left with qualifications that are mis-aligned with demand. Another potential area for SIA might be to evaluate the workforce that is hired local or operated by minority and women-owned businesses.

Many agencies regularly conduct robust social impact analyses, and in the context of evaluating the benefits to priority communities of large-scale electric vehicle infrastructure buildout there is a wealth of information and guidance available to practitioners interested in evaluating social impacts. Community engagement is imperative for successful analysis and evaluation of social impacts and informed stakeholder participation and systematic tracking of relevant metrics can inform regular evaluation and realignment of program goals.

8 Conclusions

Rapid and expansive development of electric vehicle infrastructure, coupled with access, education, and outreach efforts, will be required to meet projected demand for charging and promote statewide uptake of electric vehicles. Light-duty battery electric vehicle sales alone are expected to increase seven times from 2020 to 2050. The relationship between electric vehicle sales and charger installations is bidirectional, with growth in demand in either segment spurring demand in the other, and efforts to improve education and access further boosting demand. Furthermore, the types of chargers necessary to meet anticipated demand are determined by a suite of factors, not just electric vehicle (BEV) sales, but also including driving practices, and the distribution of electric vehicles across different residence types, where those without access to charging at home using Level 1 or 2 chargers would benefit from the ability to charge quickly using DC Fast charger infrastructure.

From a workforce perspective, electric vehicle charging infrastructure buildout will result in the expansion of training and job opportunities in existing sectors. In order to best serve priority communities, programs to increase access to state-approved apprenticeships will be instrumental to increasing access to high-road jobs for priority communities. While charger installer jobs may be considered green jobs, the set of skills necessary to safely plan, permit, and install electric vehicle charging stations are not significantly different from those of the existing electrical sector. Jobs range across a series of sectors, from sales and marketing to planning and permitting and construction and installation. After the charging station is commissioned, operations and maintenance job roles by qualified electrical personnel are necessary to maintain the function of the station and ensure that the site is properly administered. Jobs related to charging installations that include training through state-certified electrical apprenticeship, payment of prevailing wages, and other labor standards and job quality provisions create opportunities for high-road, middle-class careers with good wages and benefits and a pipeline for workers to learn electrical skills and knowledge. Many of these jobs are available to workers with high-school degrees, offering a potential pipeline to high road jobs for workers from priority communities. Including workers from priority communities requires a targeted approach and inclusionary policies. Partnership and recruitment programs benefit all communities, and recruitment efforts in communities of concern, high schools, veteran organizations and organizations serving vulnerable populations can help connect workers in priority communities with apprenticeship training and high road jobs.

The range of policies and incentives supporting charger installation is broad. While the federal government has implemented policies in the past, much of the recent activity around vehicle and charger incentives has occurred at the state level. California has led the way in incentivizing uptake of electric vehicles in many respects, but many other states have also implemented policies aimed at offsetting the costs of charger installation, either through grants, tax credits, or rebates. These incentives offer thousands (or tens of thousands) of dollars toward the charger installation, depending on the type of charger and the site.

Workforce estimates, derived from bottom-up survey elicitation from industry professionals show that California's statewide light-duty electric vehicle program goals, and the associated charging infrastructure would generate workforce needs of ~38,200 to 62,400 job-years over the period from 2021 to 2031 in California, based on the baseline and high electric vehicle adoption scenarios. The greatest workforce needs for light-duty infrastructure would be for electricians (21.3% of job-years), general contractors (21% of job-years), planning and design (20% of job-years), and electrical contractors (15% of job-years). From estimates of projected medium and heavy-duty electric vehicle growth, this work estimates that the associated charging infrastructure in California would generate ~9,100 additional job-years from 2021 - 2030, in addition to the light-duty charging infrastructure workforce needs. Nationwide buildout of 500,000 electric vehicle DC Fast chargers by 2030, announced in 2021 under the Biden administration's infrastructure goals, would generate workforce needs of around 28,950 job-years from 2021 to 2030.

Survey respondents identified employee skill sets as the biggest challenge faced in charger installation. Respondents commonly identified state or federally approved apprenticeships as pathways through which they engage with workers, stressing the central role of unions and apprenticeships for community outreach and engagement with workers from priority communities.

The skills and knowledge gained from charger installation share many common similarities with other job sectors, meaning trained and skilled workers may find additional opportunities for career advancement in other sectors of the economy. With deliberate policies that include job quality, state-certified electrical apprenticeship and equity requirements, coupled with robust and engaged social impact analysis, widespread electric vehicle infrastructure development and the associated creation of high quality jobs can offer a pipeline for those in priority communities toward skilled, well-paying, upwardly mobile jobs and careers.

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Appendix A: California Policies Related to Battery Electric Vehicle Charging Infrastructure

Governor Newsome's Executive Order N-79-20

Governor Newsome issued Executive Order N-79-20[34] in September of 2020. Under this executive order, the Governor announced that in California 100% of new vehicle sales of light-duty cars and trucks, as well as drayage trucks, will be zero emission by 2035. The Executive Order further states that 100% of medium and heavy-duty truck sales in the state shall by zero emission, where operationally feasible, and the same holding for non-road vehicles and equipment by 2035.

Putting California on the High Road

The "Putting California on the High Road: A Jobs and Climate Action Plan for 2030" was commissioned as a result of Assembly Bill 398 (AB 398, 2017) and required that the California Workforce Development Board present a report detailing strategies to help industry, workers, and communities transition and conform with the changes related to the state's greenhouse gas emissions reduction goals. The "Putting California on the High Road" report is broad in scope, detailing the changes and opportunities for clean technologies across a swath of industries in California. Focusing on sustainable transportation infrastructure, the "Putting California on the High Road" report advocates that charging stations funded by state-wide incentive programs be installed by EVITP-certified electricians. With a view toward creating a pipeline of good quality, skilled jobs, pairing the EVITP with state-certified apprenticeships is aimed at creating pathways for supporting entry-level jobs.

California Assembly Bill 841

Beginning on January 1, 2022, Assembly Bill 841 (AB 841, 2020) requires EV infrastructure on the customer side of the electric meter that is funded or authorized, in part or whole, by California state agencies to be installed by state licensed contractors, with at least one electrician on each crew having been certified by the Electric Vehicle Infrastructure Training Program. If the project is for a charging port that supplies 25kW or more to a vehicle, then at least 25% of the total electricians must be certified by the EVITP.

AB 841 also requires that 35% of the investments in transportation electrification, including electric vehicle charging infrastructure programs by electrical corporations and other entities regulated by the CPUC be in underserved communities. AB 841 defines underserved communities as those that are defined as meeting one of the following criteria:

- Disadvantaged community
- Low-income community,
- is within the most disadvantaged 25% in the state,
- at least 75% of public school students are eligible for free or reduced meals,
- is a community located on federally recognized tribal lands.

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[34] Full text available at https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf

Appendix B: Federal Policies to Promote Charging Infrastructure

In the U.S., the federal government offers tax credits for new electric and plug-in hybrid vehicles[35]. In addition to the well-known production tax credits for electric vehicle purchases, which cover the first 200,000 electric vehicles produced by each automaker, the federal government offered up to $1,000 in a tax credit for private residence charger installation, and up to $30,000 for business installations. The tax credit for alternative fuel vehicle refueling property, which was allowed to expire in 2017, was for 30% of the qualifying costs for charger installations (CRS, 2019). The credit was first enacted in 2005, and was extended six times, and was recently extended again to 2021 under the Taxpayer Certainty and Disaster Tax Relief Act of 2020.[36]

The Congressional Research Service (CRS) recognizes the benefits of expanded investment in Level 2 infrastructure, as increasing the availability of infrastructure in homes, at workplaces, and in public places offers a bridge toward more widespread deployment of electric vehicle infrastructure. However, the CRS also recognizes that while the tax credits offered may be substantial for helping defray the costs of Level 2 chargers, the costs of DC Fast Charging infrastructure, which is necessary if electric vehicles are to become viable on longer journeys, are considerably greater and the tax incentives offered offset a smaller portion of the costs. The Securing America's Clean Fuels Infrastructure Act,[37] if implemented, would increase the tax credits available for clean vehicle infrastructure deployment from $30,000 to $200,000.

Electric vehicle demand has been shown to be correlated with charging station availability (Narassimhan and Johnson 2018). Demand for charging stations is not simply being driven by the purchase of electric vehicles. The converse is also true: greater availability and awareness of charging infrastructure leads to increased electric vehicle purchases as potential users become more familiar with the technology. The CRS suggests that alternative financing mechanisms may be appropriate or necessary to spur investment in charging infrastructure, with incentives and rebates used in concert with "green bank" mechanisms supported by the federal government and public bond issues.

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[35] https://www.fueleconomy.gov/feg/taxevb.shtml

[36] https://www.irs.gov/instructions/i8911

[37] Summary and full text may be found at https://www.epw.senate.gov/public/index.cfm/2021/3/carper-burr-cortez-masto-stabenow-introduce-legislation-to-spur-investments-in-clean-vehicle-charging-and-refueling-stations

Appendix C: State Policies to Promote Charging Infrastructure

This appendix presents an overview of the recent activity at the state and regional level in the United States regarding charger installation incentive programs and policies. Table C-1 contains a selection of recent updates to state charging station incentives pulled from the Alternative Fuels Data Center. These incentives typically cover a percentage of installation/charger costs depending on where the charging site is and who is taking advantage of the rebate. Additional details on selected programs and policies related to priority communities in California and other states can be found in Appendices D and E respectively.

Table C-1: Recent and selected laws, incentives, and regulations related to electric vehicle infrastructure. More details available from the Alternative Fuels Data Center (https://afdc.energy.gov/laws, Accessed January 2021)

State	Description	Incentive
AZ	EVSE rebates through the Salt River Project for Level 2 EVSE costs.	$1,500/Level 2 port
AZ	Residential and commercial rebate programs through Tucson Electric Power for Level 2 and DC fast EVSE.	Residential: up to 75% or $500 of EVSE installation cost Commercial Level 2: 75 - 85% or $4,500 - $9,000 of project costs (depending on income level and location) Commercial DC fast: $24,000 - $40,000 per port or up to 75% of the project cost (depending on income level)
CA	EVSE rebates available through the Los Angeles Department of Water and Power for Level 2 and DC Fast chargers.	Level 2: $5,000 with additional $500/extra charge port DC fast: up to $75,000, $125,000 for MDV and HDV use
CA	EVSE rebates available through the California Electric Vehicle Infrastructure Project (CALeVIP) in San Joaquin County, Peninsula-Silicon Valley, San Diego County, Sonoma Coast, Central Coast and Northern California toward Level 2 or DC fast EVSE.	Level 2: $3,500-$6,000 (more for multi-unit dwelling and DAC residents) DC fast: typically covers 75% ($50,000-$70,000) of total project cost (more for multi-unit dwelling and DAC residents, discussed below in 5.3.1.5)
CA	Santa Barbara County Air Pollution Control District distributes grants for installing projects including EVSE.	80% of project cost or up to $150,000
CA	Vouchers from the California Clean Mobility Options Voucher Pilot Program for electric vehicles, EVSE and other related projects.	Up to $1,000,000 for new projects and up to $600,000 for existing service projects
CA	EVSE rebates through San Diego Gas & Electric's Power Your Drive for Fleets program.	80 - 100% of installation cost covered for customers 50% cost of chargers for some transit agencies, school districts and private fleets
CO	EVSE grants from the Colorado Energy Office and Regional Air Quality Council that provide support for Level 2 and DC Fast chargers.	80% of the cost of EVSE Level 2: up to $6,000 for fleet-only, $9,000 for dual port DC fast: up to $30,000, up to $50,000 for station w/ 100kW or greater charging
DE	The Delaware Clean Transportation Incentive Program offers rebates for Level 2 EVSE.	75-90% of charger cost up to $3,500 for single port and $7,000 for dual port
GA	Income tax credits for businesses that	10% of the EVSE cost, up to $2,500

	purchase/install EVSE accessible to the public.	
HI	Electric Vehicle Charging Station rebate program through Hawaii Energy provides rebates for Level 2 and DC Fast chargers.	Level 2: $1,500 - $5,000 depending on location and first-time installations vs. retrofits DC fast: $35,000 for first time-installations, $28,000 for retrofits
ID	Commercial EVSE funding from Idaho Power for various types of vehicles.	Passenger vehicles and forklifts: 50% of project costs or $7,500/EVSE (with limits) Buses, trucking, other: 50% of project costs or up to $20,000/site
MD	Infrastructure grants for businesses offered by the Clean Fuels Incentive Program (CFIP) based on alternative fuel type.	DC Fast: up to 50% of project cost or $55,000
MI	Funding for DC Fast chargers and installation is provided by the Charge UP Michigan Placement Project.	Up to 33.3% of project cost or $70,000
MI	EVSE rebate from the Holland Board of Public Works (HBPW) for Level 2 charger.	$300 rebate
NH	Commercial EVSE rebates through the New Hampshire Electric Co-op that contribute to up to two Level 2 or DC Fast chargers.	50% of installation costs as well as $2,500/charger
NV	EVSE rebates from Nevada Energy contributing toward purchasing and installing Level 2 and DC Fast chargers.	Level 2: Up to 75 - 100% of project cost ($3,000 - $10,000 per port) depending on site of EVSE DC Fast: up to 50% of project cost ($400/kW or $40,000/station)
PA	Level 2 EVSE rebates from the Pennsylvania Department of Environmental Protection for purchase, installation, operation and maintenance of EVSE.	$3,500 - $4,500 or 50 - 90% of project costs depending on public accessibility, network and property owners
TX	EVSE workplace rebates provided by Austin Energy facilitate Level 1, Level 2, and DC Fast charger installation.	Level 1/Level 2: 50% of installation cost (up to $4,000) DC Fast: up to $10,000
VA	EVSE rebates offered by Dominion Energy for Level 2 and DC Fast charger stations.	Level 2: $2,700 - $4,000 for dual port stations, $11,000 toward make-ready costs DC Fast: $35,000 - $53,000 for dual port stations, $73,000 toward make-ready costs
VT	Customers of Green Mountain Power are eligible to receive a Level 2 EVSE for free after purchasing a new electric vehicle.	100% of EVSE cost
WY	Rebate offered from Yellowstone-Teton Clean Cities for EVSE that is publicly accessible.	$5,000 rebate

Appendix D: Policies Addressing Equity in California

SDG&E 'Power Your Drive'

The SDG&E 'Power Your Drive' program[38] completed in September of 2019. Originally, the program set out to install charging ports in San Diego and southern Orange County, with at least 10% of these projects in disadvantaged communities. SDG&E installed roughly 3,040 charging ports - 32% of these being in disadvantaged communities. The average cost per port installation for this program ended up being approximately $20.8k.

SCE 'Charge Ready'

SCE's 'Charge Ready' program[39] both deployed EV infrastructure and spread awareness of EVs in various communities. Similar to the 'Power Your Drive' program, the 'Charge Ready' program had a starting goal of building over 10% of their projects in disadvantaged communities. Of the 2,720 charge ports already installed by SCE in their pilot and bridge programs, 47% are in disadvantaged communities. The average cost per port installation in this program was approximately $14.2k.

PG&E 'EV Charge Network'

PG&E's 'EV Charge Network' program[40] started with a goal of installing EV charging-infrastructure throughout California, with 15% of these installations occurring in disadvantaged communities. PG&E ended up installing 38%, or 1,864 ports, within disadvantaged communities at an average cost of about $18.5k per port installation.

CPUC/NRG Settlement Agreement

NRG Energy and the CPUC reached an agreement in 2012 that required NRG to fund $102.5 million worth of electric vehicle charging infrastructure across the state of California. Within the NRG Settlement, there are several defined areas that the investments must cover, one being an increase in EV access for priority communities.

$50.5 million of this budget was dedicated to building public charging stations, referred to as "Freedom Stations". Each "Freedom Station" is composed of either one DC Fast charging port and a Level 2 charging port, or two DC Fast charging ports. The agreement required that at least 20% of these stations were constructed in priority community locations, spread throughout the LA Basin, San Diego, San Francisco Bay Area, and San Joaquin Valley. The locations of these stations are shown in Figure D-1.

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[38] https://www.sdge.com/residential/electric-vehicles/power-your-drive

[39] https://www.sce.com/business/electric-cars/Charge-Ready

[40] https://www.pge.com/en_US/large-business/solar-and-vehicles/clean-vehicles/ev-charge-network.page

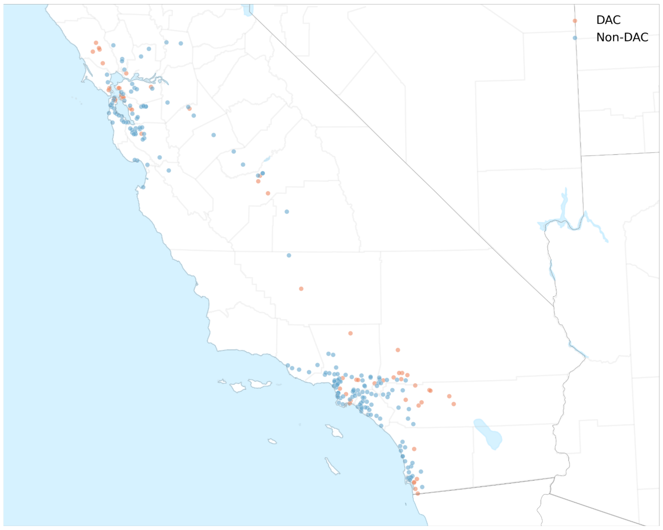

Figure D-1: Locations of "Freedom Stations" built as a result of the CPUC/NRG Settlement. Stations built within disadvantaged communities are plotted in red, stations within non-disadvantaged communities are plotted in blue.

The NRG Settlement also allocated funding into the Electric Access Charging Hub (EACH) project which used about $3.5 million to create seven different EV charging hubs in priority communities. Each of these hubs was outfitted with at least four DC Fast chargers. This project also contributed shared electric vehicles through car sharing programs that were made available to low-income customers in these areas.[41]

California Clean Vehicle Rebate Project (CVRP)[42] and the Clean Cars 4 All Program[43]

The CVRP and Clean Cars 4 All programs both allow for increased rebates in DACs. CVRP offers rebates up to $2,500 for new/leased BEV purchases and $1,500 for PHEV purchases based on household income caps. Households classified as low-income can take advantage of an increased rebate of $4,500 for BEV purchases and $3,500 for PHEV purchases. Clean Cars 4 All allows for low-income participants to retire their current vehicle and upgrade to a cleaner vehicle with large incentive amounts. Eligible households can receive up to $9,500 when purchasing a new or used PHEV, BEV, or FCEV, or they have the choice of up to $7,500 in incentives "to access public, private and shared mobility options."

State Senate Bill 535 and State Assembly Bill 1550

Senate Bill 535 (SB 535, 2012) established that 25% of the Greenhouse Gas Reduction Fund must be designated toward projects that benefit disadvantaged communities in California. Assembly Bill 1550 (AB 1550, 2016) modified the distribution of these funds to include an additional 10% toward low-income households/communities. This legislation has increased the amount of funding that may contribute to charging infrastructure and plug-in electric vehicle uptake in priority communities.

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[41] https://www.cpuc.ca.gov/General.aspx?id=5936

[42] https://cleanvehiclerebate.org/eng

[43] https://ww3.arb.ca.gov/msprog/lct/vehiclescrap.htm

Decisions regulated by the California Public Utilities Commission (CPUC)

The CPUC works to aid in the increased uptake of plug-in electric vehicles in disadvantaged communities[44]. Decision 19-08-026 from August 2019 authorized San Diego Gas & Electric (SDG&E) to allocate more than $107 million toward charger installations dedicated to electric MDVs and LDVs. Thirty percent of this allotment is reserved for projects in disadvantaged communities. Decision 19-09-006 from September 2019 authorized Pacific Gas and Electric Company (PG&E) to allocate up to $4 million in order to supply lower-income residents with charging infrastructure rebates. These funds are meant to aid in compensation for home chargers and contribute toward electrical panel upgrades for charger installations. Decision 19-11-017 from November 2019 aimed to increase charging infrastructure in disadvantaged communities by approving programs from Southern California Edison (SCE), Liberty Utilities, SDG&E and PG&E that would build chargers at parks, beaches and schools. Of the $55 million these companies aimed to spend, anywhere from 25%-100% of it is targeted at disadvantaged communities.

California Electric Vehicle Infrastructure Project (CALeVIP)

This project, funded by the California Energy Commission (CEC), has aided in more widespread electric vehicle charging infrastructure throughout California. In its Central Coast Incentive Project[45] launched in October of 2019, the CEC partnered with Monterey Bay Community Power to provide $7 million in incentives for the purchase and installation of certain electric vehicle chargers. These rebates are larger for projects in disadvantaged communities. For DC Fast chargers, the rebate covers either $80,000/charger or 80% of the project cost (whichever is less). For Level 2 chargers, the rebate normally covers up to $5,500/connector and up to $6,500/connector for multi-unit dwellings. In Monterey County, 38% of its allocated funds were set aside for disadvantaged communities while San Benito County allocated 93% of its funds, and Santa Cruz County allocated 10% of its funds to these communities. CALeVIP has incentive projects like this all over California, including projects in Southern California ($29 million in funding), Northern California ($4 million in funding), and Sacramento County ($14 million in funding). All of these regional projects must reserve a minimum percentage requirement (25%) of funding to allocate toward disadvantaged communities (Hsu and Fingerman, 2020).

Community Housing Development Corporation Financing Assistance Pilot Project[46]

This project is a part of California Climate Investments, an initiative in California that, among other things, aims to improve public health and the environment, especially in disadvantaged communities. This project runs from November of 2015 to March of 2026, with a grant amount of about $3.1 million. Applicants of funds must reside in low-income/disadvantaged communities throughout twelve Bay Area counties. The pilot provides participants with up to $5,000 for hybrid or plug-in vehicle purchases, as well as $2,000 for in-home Level 2 charger purchases. Also, this initiative allows low-income participants who may not normally qualify for a loan to receive loans at beneficial rates.

Electrify America Community Efforts

As mentioned in their 2020 California Annual Report[47], Electrify America makes continual efforts to invest and install charging infrastructure within priority communities. Over 50% of their DC Fast

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[44] https://www.cpuc.ca.gov/General.aspx?id=5597

[45] https://calevip.org/incentive-project/central-coast

[46] https://ww3.arb.ca.gov/msprog/lct/pdfs/financeassist.pdf

[47] https://media.electrifyamerica.com/assets/documents/original/678-Summary2020AnnualReporttoCARB.pdf

Charging station installations and about 42% of their Level 2 station installations occurred in low income and disadvantaged communities across California. Electrify America also targets 35% of all their marketing spending in these communities, while investing and collaborating with other community-based organizations.

Appendix E: Policies Addressing Equity Nationwide

New York's "Make Ready" Program

The New York Public Service Commission (PSC) approved the Make-Ready Program[48] on July 16, 2020, which is a package that aims to expedite the installation of more than 50,000 charging stations and strengthen the number and range of electric vehicles. Within this program, $206 million has been reserved to benefit disadvantaged communities. These communities will also be eligible for larger incentives that will help finance up to 100% of costs to ready an electric vehicle-charging site.

Oregon Clean Vehicle Rebate Program (OCVRP)

This rebate program[49] launched in 2018 and allows for $10.8 million annually from 2018 through 2024 to be used as incentives toward purchasing and leasing new and used electric vehicles. Within this program, there is the Charge Ahead rebate option that benefits residents from low-income households. When purchasing or leasing a new or used electric vehicle, the Charge Ahead rebate is $2,500.

Eversource Charging Infrastructure Plan in Massachusetts

In November 2017, a plan from Eversource (New England's largest energy provider) was approved by Massachusetts' Department of Public Utilities that pledged $45 million to electric vehicle charging infrastructure[50]. A minimum of 10% of the Level 2 and DC Fast chargers built with these funds will be located in lower-income communities.

Pennsylvania's Alternative Fuel Vehicle (AFV) Rebate

Pennsylvania's AFV Rebate Program[51] allows residents to receive certain rebates when purchasing new or used alternative fuel vehicles. For an electric vehicle, the rebate amount is set to $750, but this increases to $1,750 if the resident meets a certain low-income threshold.

Nevada Energy's (NVE) EVSE Rebates

NVE currently employs rebates that benefit those who purchase Level 2 and DC Fast chargers[52]. Level 2 rebates are typically in the range of $3,000-$5,000 or up to 75% of the installation project cost (unless for a government agency). For low-income multi-unit dwelling charging sites, the rebates per port are $10,000 or up to 100% of the installation. To receive these rebates, the low-income multi-unit dwelling must qualify for the Federal Low Income Housing Tax Credit.

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[48] https://www.governor.ny.gov/news/governor-cuomo-announces-nation-leading-initiatives-expand-electric-vehicle-use-combat-climate

[49] https://www.oregon.gov/deq/aq/programs/pages/zev-rebate.aspx

[50] https://www.eversource.com/content/docs/default-source/community/sustainability-report-n.pdf

[51] https://afdc.energy.gov/laws/5812

[52] https://afdc.energy.gov/laws/12118

Appendix F: Survey Questions

[Attached]