JANUARY 2024

CHARGING UP AMERICA

The growth of United States electric vehicle charging infrastructure jobs

ANH BUI, LOGAN PIERCE, PIERRE-LOUIS RAGON, ARIJIT SEN, AND PETER SLOWIK (ICCT), AND TAYLOR WAITES (INTERNATIONAL BROTHERHOOD OF ELECTRICAL WORKERS)

ACKNOWLEDGMENTS

This work is conducted with generous support from the Aspen Global Change Institute, the Heising-Simons Foundation, and the Energy Foundation. We thank Sarah Thomason (Movement Economics) for her job estimation, analysis, and review contribution; Gordon Bauer for the valuable advice on the infrastructure needs assessment; Jessie Hammerling and Pamela Egan (University of California Berkeley Labor Center) for their expertise and review on the U.S. labor landscape; Brian Morales (ProCal) on the insight into electrical workforce needs. General reviews on an earlier version of this report were provided by Samantha Houston (Union of Concerned Scientists), Reem Rayef and Roxanne Johnson (Blue Green Alliance), Dale Hall and Marie Rajon Bernard (ICCT). Their reviews do not imply an endorsement, and any errors are the authors' own.

This paper was edited on 27 January 2024 to update acknowledgements and citations.

Edited by Amy Smorodin

International Council on Clean Transportation
1500 K Street NW, Suite 650
Washington, DC 20005

communications@theicct.org | www.theicct.org | @TheICCT

EXECUTIVE SUMMARY

The electric vehicle (EV) transition is underway in the United States. New government policies, in addition to substantial public and private-sector investments, are poised to further accelerate this transition in the years ahead. At the federal level, the Bipartisan Infrastructure Law (BIL) and Inflation Reduction Act of 2022 (IRA) provided large-scale incentives and investments to grow the domestic EV industry. The U.S. Environmental Protection Agency (EPA) has proposed new multi-pollutant emission standards for Model Years 2027 and later (MY2027+) that could result in about two-thirds of new light-duty vehicle (LDV) sales and one-third of all medium- and heavy-duty vehicles (MHDVs) being zero-emission by 2032. Multiple state regulations, led by California, are expected to further increase the sales of zero-emission vehicles in the coming years.

The shift to EVs will create demand for labor for the production and maintenance of the vehicles, in addition to the production, installation, and maintenance of charging infrastructure. Estimating the potential number of jobs that will be needed to carry out this transition is critical for planning strategies to ensure an adequate supply of skilled workers and to maximize the economic benefits of the transition. Jobs related to EV infrastructure installation and maintenance are especially important because these jobs are carried out at site, creating growing opportunity for workers in the United States and spillover economic benefits in local communities.

This paper projects the number of jobs that will be needed to expand electric LDV and MHDV charging infrastructure to meet annual charging needs through 2032. To the best of our knowledge, the number of charging infrastructure jobs associated with EPA's most recent proposed regulations has not yet been assessed at the national scale. In this analysis, we first forecast EV charging infrastructure needs for LDVs and MHDVs consistent with EV projections from the Biden administration's proposed standards. We then project the number of blue-collar jobs from electrical installation, electrical maintenance and repair, domestic charger assembly, and general construction labor, in addition to white-collar jobs from software maintenance and repair, planning and design, and administration and legal, that would be needed to meet our estimates of charging infrastructure needed. We also discuss the potential for additional job creation if the share of chargers that are produced domestically increases. Finally, we discuss key issues that policymakers and industry can address to ensure that enough skilled workers can be recruited to scale the EV charging infrastructure quickly enough to meet goals for EV adoption and maximize job creation and related economic benefits. We draw the following conclusions based on the analysis.

Growth in U.S. charging infrastructure can create about 160,000 jobs by 2032. Table ES1 summarizes various job types ordered by number of jobs. Notably, more than 78,000 jobs, or close to 50% of the total jobs needed, will be electrical installation and electrical maintenance and repair jobs. These jobs will require skilled electricians who meet local licensing requirements and are adequately trained to install and maintain EV chargers safely and accurately. Additional charger assembly and general construction labor would bring the total of blue-collar jobs close to 104,000. White-collar positions—including those in software maintenance and repair, planning and design, and administration and legal—collectively total close to 54,000 jobs by 2032. The electric LDV infrastructure growth would generate most of the jobs (142,000, or 90%)

while a smaller number or proportion of jobs would be needed to support electric MHDV infrastructure growth (16,000, or 10%).

Table ES1. Estimated light-duty and medium- and heavy-duty vehicle charging infrastructure full-time equivalent jobs in 2032

Job type	LDV chargers					MHDV chargers	Total
	Public		Workplace	Multi-family home	Single-family home	Public	
	DC fast	Level 2	Level 2	Level 2	Level 2	DC fast	
Blue-collar jobs							
Electrical installation	1,200	4,900	7,200	6,700	34,200	5,300	**59,500**
Electrical maintenance & repair	500	5,200	5,400	6,100		1,400	**18,600**
Charger assembly	400	400	600	500	9,000	2,100	**13,100**
General construction labor	300	2,700	4,000	3,700		1,600	**12,300**
White-collar jobs							
Software maintenance & repair	800	8,000	8,300	9,300		2,200	**28,600**
Planning & design	400	4,400	6,400	5,900		2,100	**19,200**
Administration & legal	200	1,300	1,900	1,700		900	**5,800**
Total	**3,800**	**26,900**	**33,800**	**33,900**	**43,200**	**15,600**	**157,200**

Electric vehicle charging infrastructure buildout needs to accelerate in unison with EV uptake. If the development of charging infrastructure falls behind, EV uptake among consumers might not keep up with goals for EV adoption. Both public and home LDV charging infrastructure will need to be scaled significantly to ensure equitable access and to encourage uptake among consumers across all income levels. The rapid development of charging infrastructure for MHDVs will be crucial, as the deployment of this infrastructure has so far lagged behind infrastructure for LDVs. By 2032, we estimate close to 4.1 million workplace and public chargers will be needed, including 2 million workplace Level 2 chargers, 200,000 public DC fast chargers, and close to 1.9 million public Level 2 chargers. We also estimate a cumulative need for approximately 2.2 million multifamily home chargers and 35.2 million Level 2 chargers for single-family homes. By 2032, more than 29,000 opportunity chargers—which include 12,800 ultra-fast and 16,600 fast chargers—and close to 500,000 overnight chargers would be needed to support the MHDV electric fleet.

There is potential for even greater job growth if an increased share of charging infrastructure manufacturing occurs domestically. Based on limited data availability, this analysis estimates that the final assembly of 33% of Level 2 chargers will occur domestically by 2032. Along with 100% domestic assembled DC, this leads to a total of more than 13,000 jobs in charger assembly. This number excludes jobs related to charger component production and assembly, although investments made with National Electric Vehicle Infrastructure (NEVI) Program and Charging and Fueling Infrastructure (CFI) Discretionary Grant Program funding come with requirements that at least 55% of EV charger component costs are manufactured domestically. Wider adoption of these types of requirements by state and local government-funded EV charging infrastructure programs, in addition to increased rates of charger recycling, may increase the share of domestic EV charger assembly and component production, which could significantly increase the number of production jobs generated.

Government policies and industry partnership can help grow a high-road EV charging industry and ensure that work is carried out by appropriately trained workers. In high-road industries, firms compete on quality and innovation, rather than cost-cutting. Jobs in high-road industries are attractive to workers due to good wages and benefits, in addition to employer investment in long-term training and skills upgrading. Government policies that support a high-road EV infrastructure industry, such as wage and benefits standards, skills certification requirements, and support for workers choice to join unions, will be essential to help increase the pool of skilled workers to meet growing labor demand and maximize the economic and social benefits of public investments in charging infrastructure. Government policies that require specific licensing and certification for the EV workforce are important for ensuring the efficient use of public funds, and that infrastructure development and consumer experience are not at risk from inadequate installation or maintenance. Targeted hiring and investments in pre-apprenticeship training can help prepare workers from marginalized communities to gain access to growing career opportunities in the industry.

TABLE OF CONTENTS

INTRODUCTION

The electric vehicle (EV) transition is rapidly spreading across U.S vehicle markets and is expected to accelerate due to recent legislative and regulatory actions. New multi-pollutant standards recently proposed by the U.S. Environmental Protection Agency—for Model Years 2027 and later (MY2027+) light-duty and medium-duty vehicles and greenhouse gas emissions standards for heavy-duty vehicles – Phase 3—could result in about 67% of new light-duty vehicle (LDV) sales and 36% of all medium- and heavy-duty vehicles (MHDVs) sales being zero-emission by 2032 (U.S. Environmental Protection Agency [U.S. EPA], 2023a; U.S. EPA, 2023b; International Council on Clean Transportation [ICCT], 2023). California's Advanced Clean Cars II regulation, either already adopted or intended to be adopted by 14 other states, puts the state on a path toward 100% new light-duty electric vehicle sales by 2035 (California Air Resources Board [CARB], 2023a). California and seven other states have also adopted Advanced Clean Trucks regulations that require manufacturers to sell an increasing percentage of zero-emission trucks (CARB, 2023b). In April 2023, California adopted the Advanced Clean Fleet regulations that phase-in the use of zero-emission vehicles for targeted fleets and require manufacturers to only produce ZEV trucks starting in MY2036 (CARB, 2023c).

The federal government can play a crucial role in the buildout of charging infrastructure needed to support EV adoption while ensuring an equitable transition for all industries and communities involved. Under the Bipartisan Infrastructure Law (BIL), President Biden announced the goal of investing in EV assembly and infrastructure and creating incentives to grow good-paying and union jobs. The National Electric Vehicle Infrastructure Formula Program (NEVI) and Charging and Fueling Infrastructure (CFI) discretionary grant program created under the BIL apportions $7.5 billion to support states' and communities' strategies in deploying EV charging infrastructure (Joint Office of Energy and Transportation, n.d). The administration also recently announced that $100 million from the BIL funding pool will be dedicated to the repair and replacement of existing nonoperational EV chargers to help boost EV charger reliability and support the workforce that will carry out this work (U.S. Department of Transportation, 2021 & 2023).

The Inflation Reduction Act (IRA) provides incentives for EV assembly and infrastructure projects (CALSTART, 2022), including a $10 billion extension of the Advanced Energy Project Credit for projects that establish, expand, or re-equip facilities for the production or recycling of EV components and charging infrastructure (26 U.S. Code §48C). The IRA also extends the Alternative Fuel Refueling Property Credit, which provides a tax credit up to 30% of the cost at a maximum $100,000 for each charging station installed if the project meets prevailing wage and apprentice-utilization requirements (26 U.S. Code §30C).[1] Starting in 2023, only charging stations placed in low-income or rural census tracts are eligible for the Property Credit.

The shift to EVs will create demand for labor in several different key categories: production of EVs and their components, maintenance of EVs, production of EV charging infrastructure, installation of charging infrastructure, maintenance of that infrastructure, EV and charging infrastructure recycling, and other jobs related to the EV ecosystem. Between 2015 and August 2023, manufacturers reported 179,300 new

1 Prevailing wage rate is an average wage paid to majority of workers engaged in a particular craft in the area of intended employment (U.S. Department of Labor, 2022 & n.d; Wall, Madland, & Walter, 2020). Policymakers often use the prevailing wage law to set the floor for wages and benefits within a jurisdiction.

U.S. EV-related jobs (Environmental Defense Fund & WSP, 2023). Since the passage of the IRA, the U.S. auto industry has announced the creation of more than 32,000 new jobs (Climate Power, 2023). A study by the Economic Policy Institute, produced in coordination with a range of labor unions and environmental organizations, projected that policy actions to onshore the EV industry would lead to a net 150,000 jobs in the auto assembly and auto parts sector (Barrett & Bivens, 2021). Since 2021, manufacturers have announced investments of more than $500 million in U.S.-made EV chargers, which will create more than 3,000 new jobs (U.S. Department of Energy [U.S. DOE], 2023).

Estimating job counts and requirements for the electric transition is essential to help the country secure a sufficient pool of qualified labor and for the economic advancement of the U.S. EV industry. In addition, it will help policymakers assess the increased environmental and social benefits to local communities. Only one study to date has attempted to estimate the number of jobs that will be needed in the EV charger infrastructure industry (Carr, Winebrake, & Winebrake, 2021). The study suggested workforce needs of 38,200 to 62,400 job-years from 2021–2031 in California for both LDV and MHDV infrastructure installation and close to 29,000 job-years based on the Biden administration's goal of 500,000 nationwide EV chargers by 2030 (The White House, 2023),[2] excluding assembly and maintenance. Since this study was published, federal and state EV transition policy goals have increased substantially.

In this paper, we estimate the national job creation potential associated with the expansion of EV charging infrastructure based on recent federal policies designed to advance the market. First, we forecast the EV charger infrastructure needs for LDVs and MHDVs using the ICCT's charging infrastructure models. We then project job creation associated with infrastructure assembly, installation, and maintenance and discuss strategies to ensure a sufficient supply of skilled labor to scale EV charging infrastructure quickly enough to meet the EPA's proposed regulations. We also discuss the potential job creation associated with increased domestic production, assembly, and recycling if policymakers can successfully incentivize manufacturers to shift to domestic production. Lastly, we discuss key issues that policymakers and industry should consider to ensure the rapid expansion of EV charging infrastructure along with high-road career development within the industry.

2 The study assumes all 500,000 EV chargers are public DC fast.

CHARGING INFRASTRUCTURE OVERVIEW AND NEEDS ASSESSMENT

This section provides an overview of the current EV charging infrastructure, based on a review of existing data and literature as of September 2023, and presents our modeling of the number of chargers that will be needed in the future for electric LDVs and MHDVs. In this analysis, a charger is defined as a port that allows one vehicle to charge at a time.[3] The estimates we present in this section are later used as inputs to project the total number of jobs.

LIGHT-DUTY EV CHARGING INFRASTRUCTURE NEEDS

Background

Chargers for LDVs are categorized by levels, a designation defined by automotive engineering association SAE International based on a combination of connector type and power capacity. Level 1 and Level 2 chargers in the United States use the SAE J1772 standard connector which provides slower, alternating current (AC) and about 1–2 kW (Level 1) or between 3 kW and 19 kW (Level 2) of power, depending on the current rating of the charger and the accepted current rating of the EV. Direct current (DC) fast charging can offer 50 kW to 350 kW of power, allowing for a much faster charge. In the United States, several competing standards for DC fast charging exist, including CHAdeMO, the Combined Charging System type 1 (CCS type 1), and Tesla's proprietary standard for its Supercharger network (Doll, 2021).

There have been several developments in the recent months related to charger standardization in the United States. In November 2022, Tesla renamed its charging standard to the North American Charging Standard (NACS) and opened it for use by other automakers. In June 2023, Ford announced that it would use the NACS standard for its vehicles beginning in 2025, becoming the first of many automakers to make similar commitments (Dow, 2022). Buoyed by these market developments, SAE International has begun the process of standardizing NACS, likely under the name "J3400" (Dow, 2022). NACS is unique from other standards in that it uses the same connector to support both AC and DC charging. Given the widespread announcements of its adoption, it seems likely that the forthcoming J3400/NACS standard will become the de facto standard for all chargers, regardless of level, in the United States.

Three main locations are typically associated with light-duty EV charging: at home, in public, and at workplaces. Home charging may often occur overnight using a 120V household outlet for Level 1 charging or a 208/240V appliance outlet for Level 2 charging. Where a Level 1 outlet doesn't already exist, or at multifamily homes (MFH)—housing types with two or more residential units—a hardwired Level 2 charging station can also be installed (Ge et al., 2021). Parking locations typically available in MFHs are less likely to have existing outlets than single family homes (SFHs).

3 This definition is not the same as the NEVI program's definition, which defines a charger as "a device with one or more charging ports and connectors for charging EVs" (87 Fed. Reg. 37262). It is more aligned with the NEVI program's definition of a charging port that is "the system within a charger that charges one (1) EV. A charging port may have multiple connectors, but it can only provide power to charge one EV through one connector at a time". However, to simplify and stay consistent with our previous publications, we use the term "charger" throughout the paper to indicate non-simultaneous charging.

Public and workplace charging can provide charging access to those without home chargers and can alleviate anxieties related to the range that LDVs can travel on a single charge, which are still common among potential EV consumers (Pierce, 2023). Level 2 charging stations are commonly used for public charging at both curbside and off-street locations, while DC fast chargers are usually found only at off-street locations. DC fast chargers are typically located alongside highways and used for quickly recharging an EV during long-distance trips, while public Level 2 chargers are located where people might park for extended periods of time, such as a mall parking lot or workplace. Alternatively, Level 2 chargers may be installed curbside in residential neighborhoods without off-street parking.

Data and results

This section describes our methods used to estimate the number of LDV chargers that will be needed at the national level through 2032. First, we estimate the number of EVs that will be on the road, based on federal policy goals and regulations. We then model the expected energy demand of the U.S. electric passenger vehicle fleet per year. Next, we apply data on charging behavior trends and assumptions of charger utilization and power to estimate the total number of chargers that will be needed each year. Our methods are based on ICCT's Roadmap and EV CHARGE model. More detailed descriptions of these models can be found in the model documentations (ICCT, 2022b; ICCT, 2023b). We include assumptions regarding how frequently chargers must be replaced. The number of new chargers deployed each year is the sum between the replacement chargers and the difference or delta in the total amount of chargers between the two consecutive years.

EV adoption estimates

Our analysis assumes that the BEV share of LDV sales will reach 67% nationally by 2032, which aligns with BEV projections based on the EPA's multi-pollutant emissions standards for MY2027+ light-duty and medium-duty vehicles (U.S. EPA, 2023a). Additionally, we estimate that PHEVs will represent 6% of LDV sales nationally by 2032. The total number of electric LDVs on the road in 2032 is estimated to reach more than 60 million vehicles, increasing from an estimated 4.4 million by the end of 2023. Survival rates for LDVs by age, adopted from the EPA's MOVES3 model, are applied to determine the fleet turnover (U.S. EPA, 2021). Given the relatively young age of the U.S. electric LDV fleet, most EVs sold since 2011 are still expected to be on the road by 2032; growth in the EV stock tracks closely with the growth in sales projected from the EPA's 2027+ multi-pollutant emission standards. We then use ICCT's Roadmap model to estimate the energy needs for the electric LDV fleet based on fleet-weighted mileage and efficiency assumptions (ICCT, 2022b). We update the fleet efficiency assumptions using data from Slowik et. al (2022).

Charger power output and utilization estimates

Next, we estimate the cumulative number of chargers that would be needed each year based on estimates of charger output and charger utilization rates. Our previous analysis of charger usage data found that regions with higher EV penetration saw higher utilization of public and workplace Level 2 and DC fast charging infrastructure, with utilization increasing roughly with the square root of the EV stock share of LDVs (Bauer et al., 2021). We apply a similar logarithmic relationship to our new projections for EV adoption to estimate charger utilization, as shown in Table 1. The EV CHARGE model assumes slightly different utilization for different use cases of public, workplace, and DC fast charging (ICCT, 2023b). If utilization increases at a slower rate than what we model here, the number of required public chargers would be higher than our estimation. Conversely, if utilization increases more rapidly than what we model, each charger will be able to serve more EVs and the number of required public chargers would be lower than what we estimate here.

Table 1 provides an overview of the characteristics of charging stations used by light-duty EVs, including the mile-range per hour of charging and estimated hours of use per charger per day.

Table 1. Overview of light-duty EV charger characteristics

Charger type	Nominal power output	Charging standard	Potential locations	Estimated electric range per hour of charging	Estimated hours utilized per day
Home	Level 1 1-2 kW	SAE J1772 connector, NACS	SFH, MFH	2-5 miles	N/a
Home	Level 2 3-19 kW	SAE J1772 connector, NACS	SFH, MFH	10-20 miles	N/a
Public overnight	Level 2 7.2/14 kW	SAE J1772 connector, NACS	Residential location	10-20 miles	2.9 hours (2025), 4.8 hours (2030), 5.3 hours (2032)
Public destination	Level 2 7.2/14 kW	SAE J1772 connector, NACS	Shopping center, hotel, downtown curbside, etc.	10-20 miles	2.3 hours (2025), 4.6 hours (2030), 5.1 hours (2032)
Public destination	DCFC 50/150 kW	CCS Type 1, CHAdeMO, NACS	Shopping center, hotel, downtown curbside, etc.	180+ miles	2.3 hours (2025), 4.6 hours (2030), 5.1 hours (2032)
Public enroute	DCFC 150/350 kW	CCS Type 1, CHAdeMO, NACS	Highway rest stop, highway charging station	180+ miles	2.3 hours (2025), 4.6 hours (2030), 5.1 hours (2032)
Workplace	Level 2 7.2/14 kW	SAE J1772 connector, NACS	Office, transit hub	10-20 miles	2.6 hours (2025), 3.9 hours (2030), 4.3 hours (2032)

Note: Public en route chargers are alongside highways and are used to support long-distance trips. Public destination chargers are those in any public location other than highways or residential areas. Public overnight chargers are chargers in residential locations that serve EV drivers without home charging.

For public DC fast charging, we consider three different nominal power ratings: 50 kW, 150 kW, and 350 kW. DC fast charging speeds are known to fluctuate depending on the state of charge of the battery, and vehicle limitations mean that not all EVs can take full advantage of the fastest chargers. The average DC fast charger power output during a charging session is therefore often less than what a station is rated for. As battery and charging technology improves and EV drivers better understand their vehicle's capabilities, EVs will achieve average power output that is closer to the nominal rated power of chargers. We consulted Hackmann (2022) on charge acceptance curves (i.e. power output versus state of charge) and specifications for a diverse set of EVs to estimate the power delivery ratio, or the actual power that an EV receives from a charger during a charging session. Based on this research, we assume a 75% ratio for a 50-kW charger (37.5 kW) in 2023, which improves to 86% (43 kW) by 2032, a 65% ratio for a 150-kW charger (97.5 kW) in 2023, which improves to 76% (114 kW) by 2032, and 50% ratio for a 350-kW charger (175 kW) in 2023, which improves to 65% (228 kW) by 2032.

For public and workplace Level 2 charging we consider two nominal power ratings: 7.2 kW and 14 kW. Similar to DC fast charging, the on-board charger in the EV, which converts AC power from the charger into DC power to charge the battery, limits the power entering in the battery pack during Level 2 charging. As on-board charger technology improves, more vehicles will be able to accept higher power from Level 2 chargers. As such, we assume that workplace and public destination Level 2 chargers have an 80% power delivery ratio in 2023, which improves to 88% by 2035. Public overnight chargers are assumed to have 80% power delivery ratio for all years within the analysis.

As EV technology improves, we expect that lower-rated power chargers will become decommissioned over time and be replaced by higher-rated chargers to better match vehicle technical specifications. Likewise, we anticipate that in each subsequent year, a greater share of newly installed chargers will have higher power ratings. Table 2 shows the share of newly installed chargers by rated power for each charger type in 2023 and 2032; shares increase or decrease linearly between 2023 and 2032.

Table 2. Assumed share of newly installed chargers by type and rated power in 2023 and 2032

Charger type (Level)	Share of newly installed chargers in 2023 (nominal power)	Share of newly installed chargers in 2032 (nominal power)
Workplace (Level 2)	60% (7.2 kW), 40% (14 kW)	46% (7.2 kW), 54% (14 kW)
Public overnight (Level 2)	70% (7.2 kW), 30% (14 kW)	53% (7.2 kW), 47% (14 kW)
Public destination (Level 2)	20% (7.2 kW), 80% (14 kW)	23% (7.2 kW), 77% (14 kW)
Public destination (DCFC)	80% (50 kW), 20% (150 kW)	73% (50 kW), 27% (150 kW)
Public enroute (DCFC)	80% (150 kW), 20% (350 kW)	73% (150 kW), 27% (350 kW)

Estimates of additional new and replacement charger need

To estimate the number of jobs each year, we rely on the number of additional new and replacement chargers. The EV CHARGE model output shows the cumulative number of chargers needed from 2023 to 2032. We then project the total number of new chargers that will need to be installed each year, based on the difference between the two consecutive years and how frequently chargers will need to be replaced. In other words, the total number of new chargers needed each year are the sum of additional new and replacement chargers. We assume that each charger will need to be replaced every 10 years on average, based on industry expert predictions (Enphase O&M Marketplace, 2022; GNY Insurance Companies, n.d.).

Estimates of the historical number of multifamily home and single-family home chargers are as follows. For MFH Level 2, we assume a CAGR for chargers from roughly 1,000 in 2013 to our model projection of 87,000 in 2023. For Level 2 SFH chargers, the number is calculated as 40% of total new EV sales in 2013 from U.S. DOE (n.d.), whereas the rest are Level 1. This is consistent with the home charger split between Level 1 and 2 SFH charging in 2020 used by Bauer et al. (2021). At that early stage of the EV transition, these vehicles were likely to be purchased by consumers who live in SFH with access to Level 1 or 2 charging. We assume the CAGR results in the number of Level 2 SFH chargers going from close to 40,000 in 2013 to more than 2 million in 2023.

Results

Figure 1 shows the resulting number of non-home chargers (workplace, public Level 2, public DC fast). By 2025, our model estimates the need for close to 914,000 workplace and public chargers, including 359,000 workplace Level 2 and 488,000 public Level 2 (259,000 public destination Level 2 and 229,000 public overnight Level 2) to support daily travel needs, and 67,000 from public DC fast chargers (50,000 public destination DCFC and 17,000 public enroute DCFC). By 2030, we estimate around 2.9 million workplace and public chargers are needed. This includes almost 1.6 million public Level

2 and DC fast chargers, more than tripling the Biden administration's goal of 500,000 by 2030. By 2032, we estimate close to 4.1 million workplace and public chargers will be needed, including 2 million workplace Level 2 chargers, along with more than 1.9 million public level 2 chargers (689,000 public destination Level 2 and 1.2 million public overnight Level 2), and 200,000 public DC fast chargers (154,000 public destination DCFC and 46,000 public enroute DCFC).

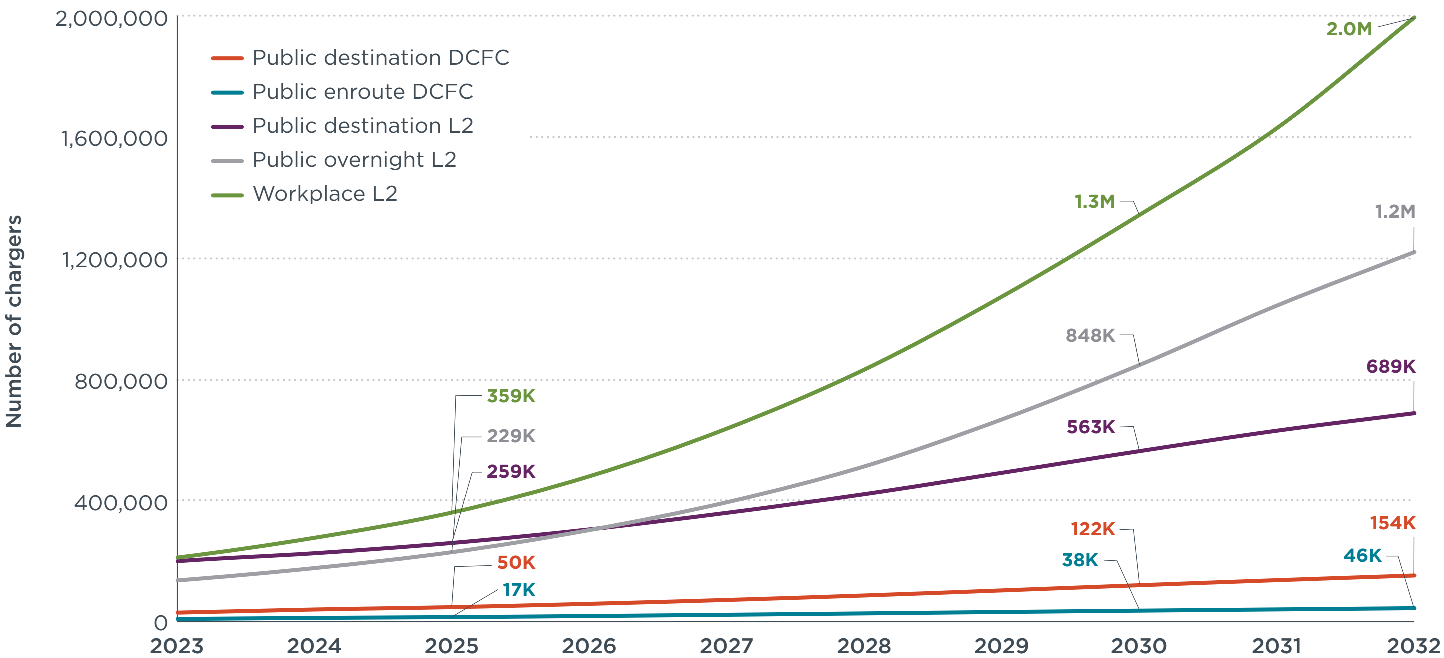

Figure 1. Cumulative U.S. workplace Level 2, public overnight Level 2, public destination Level 2, public destination DC, and public enroute DC fast chargers needs through 2032

Growth of public destination Level 2 chargers and both DC fast enroute and destination chargers will gradually decrease as battery and charging technology improves, utilization rates increase, and EVs are able to accept higher power output from chargers. Growth will occur more rapidly for workplace and public overnight Level 2 chargers, as these charger types will be increasingly needed as long as a significant portion of EV drivers lack home charging access. However, if there is a concerted effort and collaboration among governments and industry to provide access to and increase the utilization of workplace and home charging, especially at MFHs, more of the energy needs would be met at these locations rather than at charging at public locations.

Figure 2 shows our estimates for total new (sum of additional new and replacement) public DC fast and public and workplace Level 2 chargers. The total of new chargers grows from 140,000 in 2023 to more than 720,000 in 2032, a CAGR of 20%. In 2025, the total new charger installation includes 12,000 public DC, 94,000 public Level 2, and 86,000 workplace Level 2. These numbers in 2030 are 25,000, 270,000, and 290,000, respectively. In 2032, the total new charger installation includes 26,000 public DC, 282,000 public Level 2, and 411,000 workplace Level 2. Workplace Level 2 will be increasingly significant for drivers without home charging access and will make up 36% of total new workplace and public chargers in 2023 and 57% by 2032.

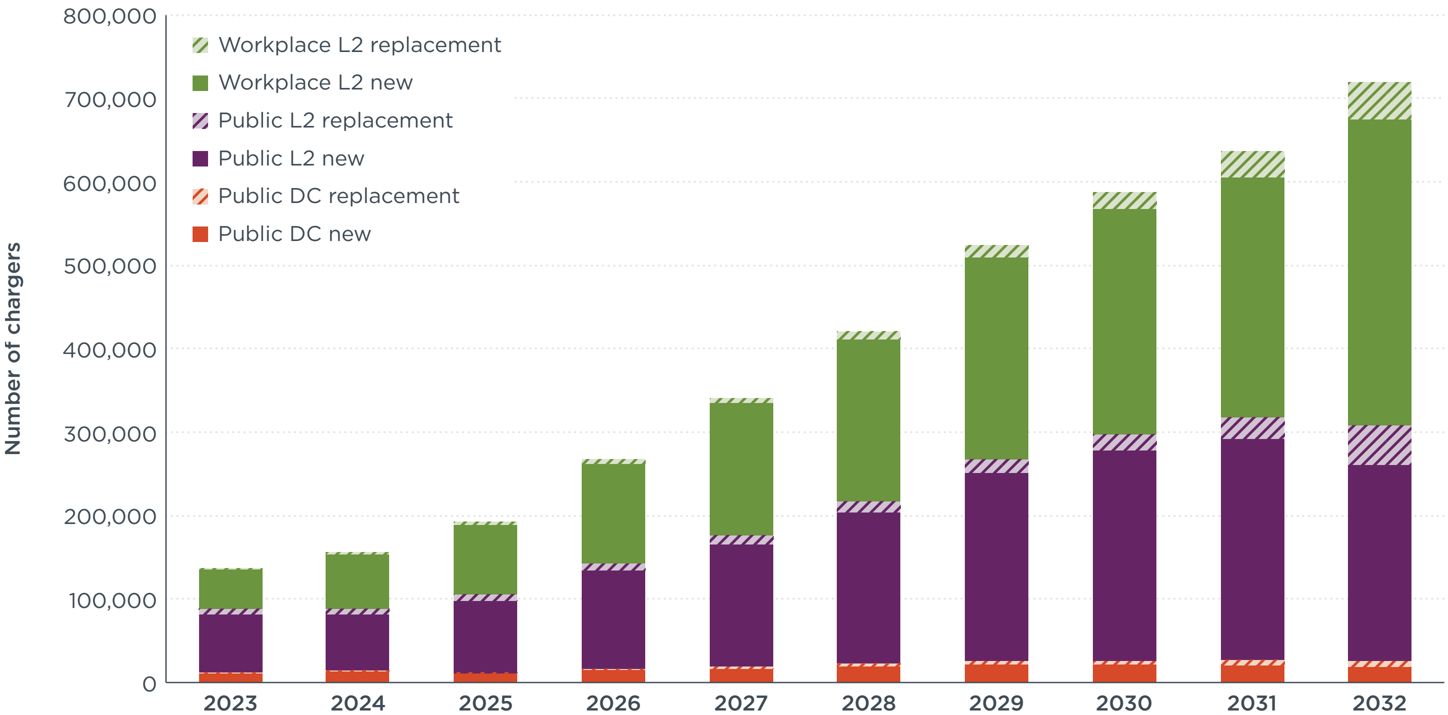

Figure 2. Estimated additional new and replacement light-duty vehicle public and workplace Level 2 and DC fast chargers from 2023 to 2032

Because overnight home charging is the most affordable and convenient way to charge, home charger installations make up the bulk of new chargers that will be needed by 2032. While EV owners have been disproportionately SFH dwellers in the past, higher EV uptake rates will mean that MFH dwellers, who make up 20% of all U.S. residents, will become a larger proportion of EV owners in the future (U.S. Census Bureau, 2021).

Figure 3 indicates that by 2025, approximately 8.9 million electric LDVs will be on the road and will require around 4.8 million home chargers, including about 200,000 MFH chargers and 4.6 million SFH chargers. By 2030, we estimate a more than fourfold increase in the electric LDV stock to 41.7 million, which would need 25.2 million Level 2 home chargers, including 1.4 million MFH and 23.8 million single-family home chargers. By 2032, the electric LDV stock will be close to 60.5 million and the home Level 2 charger count is expected to be 37.4 million, which includes around 2.2 million MFH chargers and 35.2 million SFH chargers.

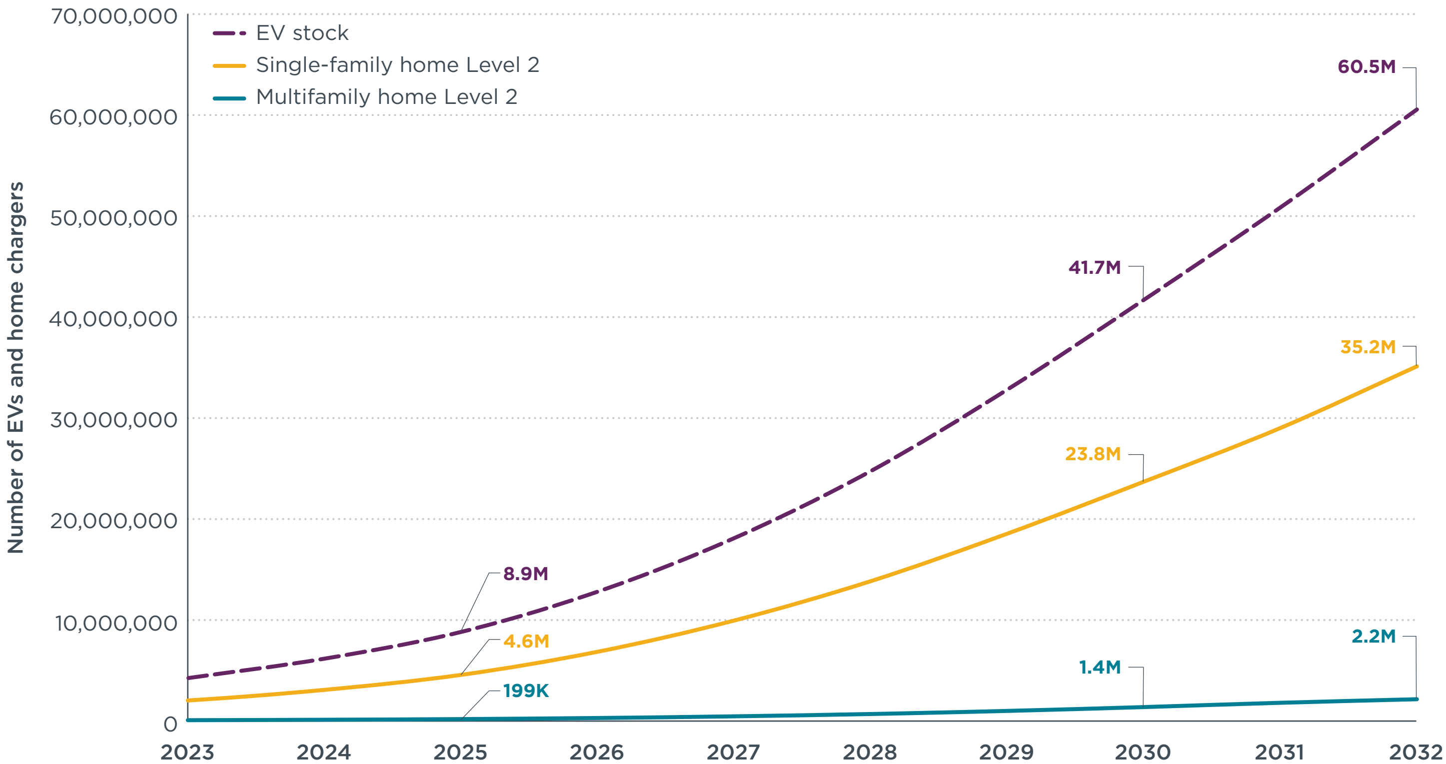

Figure 3. Cumulative U.S. EV stock, single-family home and multifamily home Level 2 charging needs through 2032

Figure 4 shows our estimates for total new single-family home and multifamily home Level 2 chargers. We estimate that total new home chargers will grow from close to 370,000 in 2023 to close to 7 million in 2032, with a CAGR of 40%. In 2025, total new charger installation includes 1.5 million SFH and close to 70,000 MFH chargers. In 2030, these numbers are more than 5.3 million and 400,000, respectively. In 2032, total new charger installation includes 6.6 million SFH and 390,000 MFH chargers. The increasing significance of workplace and public chargers for those residing in MFHs helps to explain the slight slowdown in the installation of new MFH chargers for those without access to home charging.

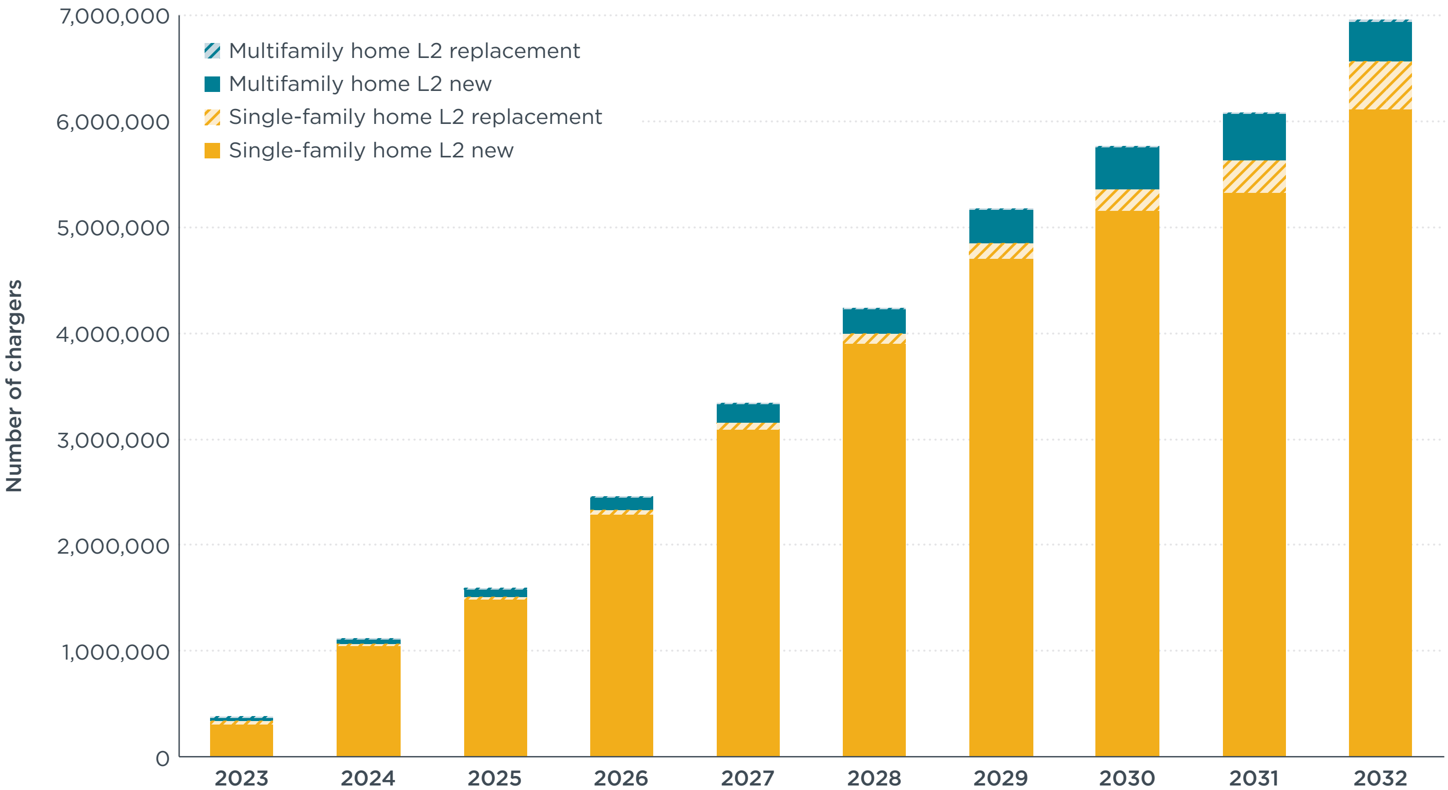

Figure 4. Estimated additional new and replacement light-duty vehicle single-family home chargers from 2023 to 2032

MEDIUM- AND HEAVY-DUTY EV AND CHARGING INFRASTRUCTURE

Background

For MHDVs in the United States, the transition to EVs is still nascent and mainly driven by buses, medium trucks, and vans (Buysse, 2022). As a result, little dedicated infrastructure has been built thus far for MHDVs, and most buildout plans are still under development. For example, Volvo Trucks North America announced in 2022 the installation of five charging stations to support electric MHDV charging between California's largest metropolitan areas, which are expected to be online by the end of 2023 (Volvo Trucks, 2022). In October 2022, TeraWatt Infrastructure announced its investment in a dedicated MHDV infrastructure network, with charging centers planned for every 150 miles between Port of Long Beach and El Paso, California (TeraWatt, 2022).

Several charging options are available for electric MHDVs. Vehicles can either charge overnight at lower power, or at higher power during breaks in their daily operations using fast and ultra-fast charging, which is referred to as opportunity charging. These opportunity chargers can either be installed at private locations, such as depots and logistics centers, or at publicly accessible charging stations. Overnight chargers can be installed at depots for vehicles that return daily to a single location, such as drayage, passenger buses, and last-mile delivery trucks, or at public dedicated truck resting areas for long-haul trucks that spend the night on the road. Different strategies are being considered by truck manufacturers and fleet operators for integrating different charger types into fleet operations.

Data and results

This section describes our methods for estimating the number of MHDV chargers needed at the national level. Similar to the LDV charger projection method, we first estimate the number of electric MHDVs that will be on the road based on federal policy goals and regulations. We then model the energy demand and estimate the total charger need for each year. Our methods are based on ICCT's Roadmap model (ICCT, 2022b), and a more detailed description of our methods can be found in Ragon et al. (2022).

EV adoption estimates

Projections of EV uptake are aligned with the EPA's proposal for the greenhouse gas emissions standards for heavy-duty vehicles – Phase 3. Under this proposal, EVs would make up 38% of bus sales, 44% of rigid truck sales, 34% of short-haul tractor trucks, and 25% of long-haul tractor trucks in 2032—an average of 36% for all MHDVs—growing from less than 1% in 2023 (U.S. EPA, 2023b; ICCT, 2023a). Those projections would result in a stock of 737,000 vehicles on the roads in 2032, up from 2,000 vehicles in 2023. As with LDVs, survival rates for HDVs by age, adopted from the EPA's MOVES3 model, are applied to determine the fleet turnover (U.S. EPA, 2021). We then utilize the ICCT's Roadmap model to estimate the energy needs for the electric MHDV.

Battery EVs are expected to dominate the MHDV EV market due to a better economic performance and a higher technology readiness level (Slowik et al. 2023). Hydrogen-powered vehicles offer higher energy storage than BEVs but are less cost-effective and will be needed in only a minority of use cases, such as for long-haul trucking in remote locations where access to infrastructure is limited. We assume that hydrogen trucks are used only when a vehicle has a daily mileage above 800 km (close to 500 miles), representing only 2% of all long-haul trucks and 0.3% of all HDVs.

Charger power output and utilization estimates

Overnight charging can deliver a significant portion of the energy needed to support a growing fleet of zero-emission MHDVs, especially for buses, urban trucks, and short-haul trucks, which have lower daily energy needs. These vehicles return to their depot daily, and overnight depot charging can allow fleets to take advantage of lower-cost electricity rates at night. We assume the stock of electric long-haul trucks will have access to public overnight chargers, although those trucks will rely on a higher share of opportunity fast and ultra-fast chargers, as they have larger energy needs. Projections of infrastructure utilization are based on a similar modeling method as EV CHARGE model and are adapted based on the MDHV market and discussions with MHDV charge point operators. Table 3 summarizes our assumptions of electric MHDV charging characteristics and utilization rates for a typical fleet.

Similar to the LDV infrastructure methodology described in the previous section, we assume that MHDV chargers will need to be replaced every 10 years on average. We assume that prior to 2022, there were no chargers that were explicitly serving MHDVs, thus, between 2023 and 2032, no chargers will need to be replaced.

Table 3. Overview of medium- and heavy-duty EV charger characteristics

Charger type	Nominal power output	Charging standard	Potential locations	Estimated electric range per charging hour	Estimated utilization (hours/day)
Overnight	100 kW DC	Combined Charging System (CCS)	Depot, public dedicated truck resting area	30–80 miles	8
Opportunity fast	350 kW DC	Combined Charging System (CCS)	Public charging station, depot, destination location	110–285 miles	0.5
Opportunity ultra-fast	1 MW DC	Megawatt Charging System (MCS)	Public charging station, depot, destination location	315–805 miles	0.5

Results

Figure 5 shows the resulting number of chargers needed by charger type to satisfy the national MHDV fleet's future energy needs. By 2025, we estimate a need of around 24,000 public opportunity chargers, consisting of 1,800 fast and 150 ultra-fast chargers, in addition to 22,000 overnight chargers at private locations. Should the availability of ultra-fast chargers still be limited in 2025 due to the longer timeline of grid upgrades, fleets would have to rely more heavily on fast chargers for opportunity charging. By 2030, the infrastructure need will be around 15,000 opportunity chargers, including 9,800 fast and 5,600 ultra-fast chargers, and around 270,000 overnight chargers. By 2032, 30,000 opportunity chargers, consisting of close to 12,800 ultrafast and 16,600 fast chargers, will be needed along with 500,000 overnight chargers.

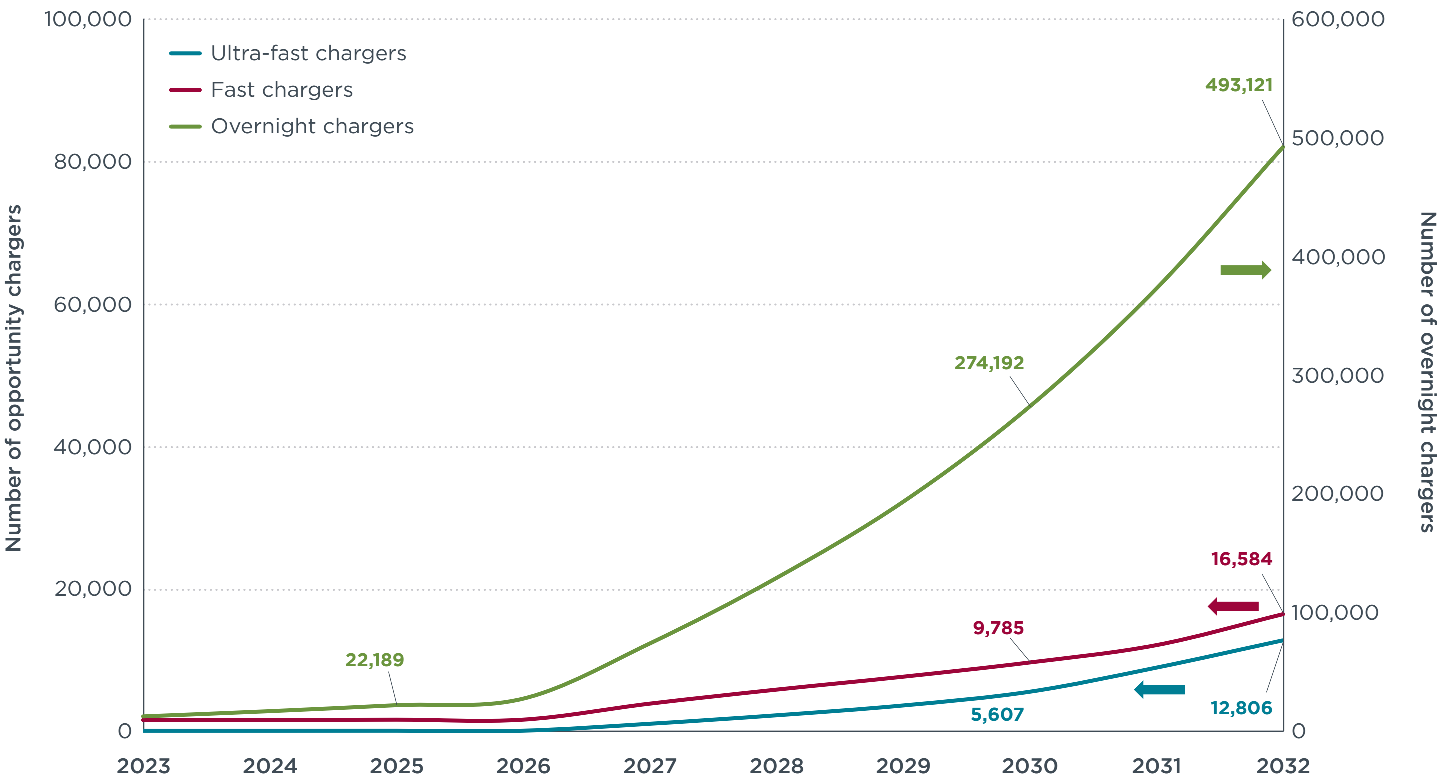

Figure 5. Cumulative U.S. EV medium- and heavy-duty charging needs, by charger type through 2032. Directional arrows indicate the corresponding axis.

Figure 6 illustrates the growth of additional new MHDV charger buildout from 4,000 in 2023 to 128,000 in 2032, a CAGR of 49%. Since the MHDV charging market is still nascent, we assume no chargers will need to be replaced between 2023 and 2032. By 2025, almost all (99%) of new chargers installed are overnight chargers out of the total 5,100 chargers. By 2030, we estimate new chargers will comprise around 4,000 opportunity chargers, including 2,000 fast and 1,900 ultra-fast chargers, and around 80,000 overnight chargers. By 2032, the new installed chargers will consist of 15,000 opportunity chargers, including 4,500 fast and 10,000 ultra-fast chargers, and 120,000 overnight chargers.

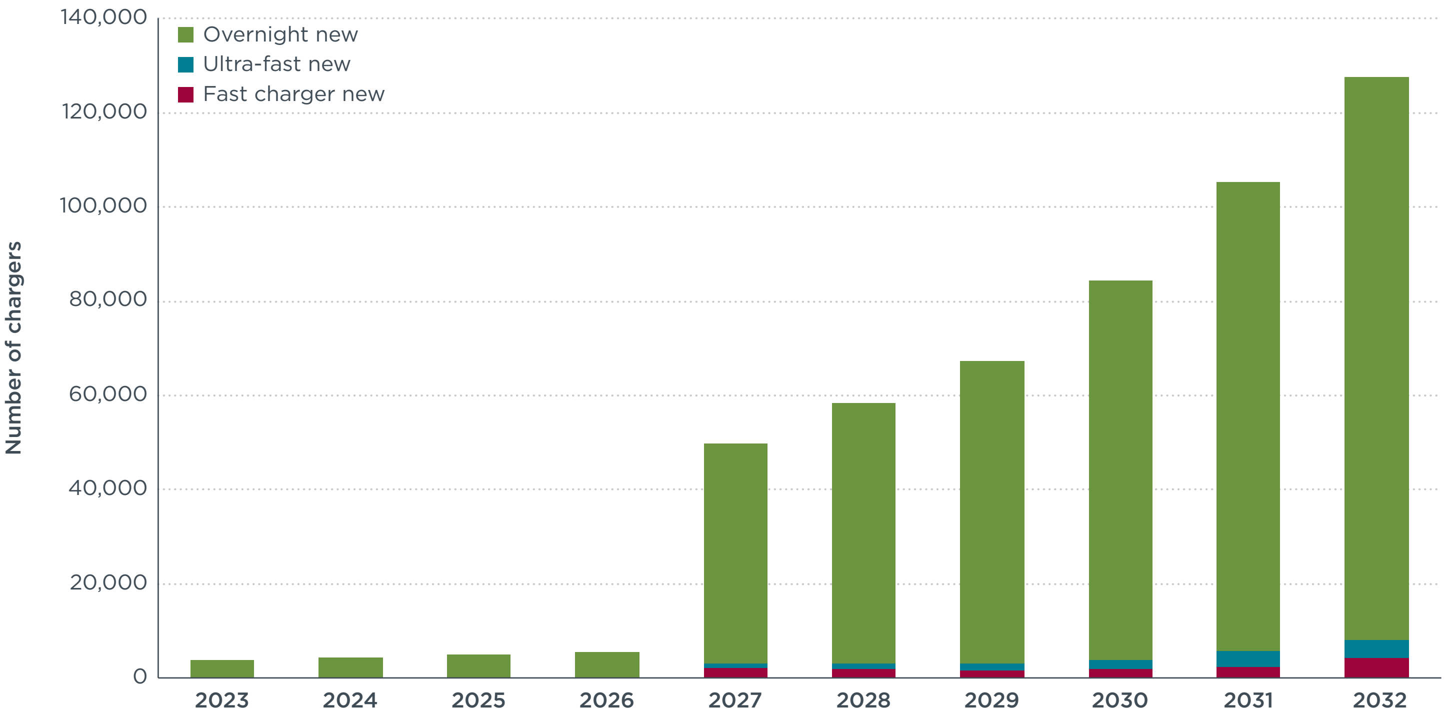

Figure 6. Estimated additional new medium- and heavy- duty chargers from 2023 to 2032

CHARGING INFRASTRUCTURE WORKFORCE OVERVIEW

Growing the U.S charging infrastructure will require a wide variety of workers to produce, install, and maintain the chargers. It is important to know what the net shift in jobs will be as a result of the EV transition. However, jobs projections to date have not presented a full picture. Barrett and Bivens (2021) produced job projection estimates but focused mainly on the production of EVs. Only one previous study has estimated the number jobs created by the development of EV charging infrastructure based on the Biden administration's goal of 500,000 public chargers, but that study did not reflect the recent federal proposal (Carr et al., 2021).

In this section, we identify the types of jobs involved in the LDV and MDHV charging infrastructure industry, as well as estimate the amount of each type of job that will be needed. To do this, we calculate the number of estimated person-days that will be needed for assembly and installation to add one additional charger, and for maintenance and repair of existing infrastructure. For example, four person-days means that adding an additional charger would require four days of work from one individual in one job type. Our estimates of the number of person-days required for electrical-related work is based primarily on interviews with Brian Morales from electrical contracting firm ProCal. For the remaining job types, we mainly apply formulas used in Carr et al. (2021) or primary research.

Below we list the types of jobs involved in charger installation, maintenance and repair, and assembly; describe the methodology used to find the associated person-days needed per charger; and present the total job projections in 2032 for combined LDV and MHDV charging infrastructure. We order each job description based on the blue-collar and white-collar job categories. Blue-collar jobs are traditionally associated with manual and construction labor which requires different types of training and job-quality strategies. White-collar jobs are typically performed in offices and often involve administrative and managerial roles. We also describe other types of charging infrastructure jobs that are not included in or jobs projection analysis.

To calculate the total workforce need, we make several assumptions. For each job type other than maintenance and repair, the annual full-time equivalent jobs are estimated by multiplying the number of person-days required by the annual additional new and replacement chargers needed, then dividing by 240 workdays per year, excluding vacation and sick time (assuming a full-time, full-year job requires 8 hours per workday and 2,080 hours per year or 260 days). For charger assembly, the domestically assembled chargers are assumed to be one-third of the additional new and replacement chargers needed. For software and electrical maintenance and repair, the annual full-time equivalent job estimates are based on the cumulative number of chargers that are operational each year.

BLUE-COLLAR JOBS

Electrical installation

The installation of EV chargers should be primarily carried out by skilled and appropriately trained electricians to ensure that units are correctly and safely installed. Electricians complete all required wiring work and connect the chargers to the utility line (SolarEdge, 2021; Tesla, 2020).

The charging infrastructure projects funded by the National Electric Vehicle Infrastructure (NEVI) program (87 Fed. Reg. 37262) require that all electrical installation, operations and maintenance work be carried out by electricians who meet certain skills training requirements to ensure safety and functionality. In addition, many states and municipalities have their own licensing and training requirements that may apply to NEVI-funded projects and other charging infrastructure projects.

We estimate the number of person-days of electrical installation work required for each MFH, workplace, and public Level 2 and DC fast charger using primary research estimation, in corroboration with discussions with ProCal and other field experts. For example, for residential SFH Level 2 charger installation, a crew consisting of one journey-level electrician and one electrical apprentice can install, conservatively, eight chargers per work week (each work week consists of five working days). This converts to roughly 1.2 person-days per charger. The amount of electrical installation work required for a Level 2 SFH charger will vary depending on the type of installation required. For example, a household with an existing 240-volt circuit available in the service panel would require less work than a job that requires installing new service panels, wiring, trenching, and running conduits. We estimate that the electrical installation work required for a Level 2 SFH charger would be about 1.2 person-days on average, based on the approximate $900 average labor cost to install (Nelder & Rogers, 2020; Nicholas, 2019) and an electrician rate of $100/hour (Cramer, 2023).

Electrical maintenance and repair

Chargers will require regular maintenance to address both hardware and software issues to maximize charger uptime and reliability. NEVI programs require funded chargers to have a 97% uptime reliability (The White House, 2023). Electrical maintenance and repair of EV charger hardware will primarily need to be performed by appropriately trained electricians to ensure that repairs to wiring and utility connections are completed safely and accurately. Most states and some local municipalities require that these types of tasks are performed by licensed electricians. Based on estimates from ProCal, our analysis assumes that maintenance of each MFH, workplace, and public EV charger will require 0.65 person-days of hardware maintenance annually (Brian Morales, interview with the author, July 7, 2023). We do not include estimates of the need for maintenance of single-family home chargers in our analysis.

Charger assembly

We focus on direct jobs in charger assembly plants and exclude charger component assembly. These occupations include electrical and electronic equipment assemblers, electromechanical equipment assemblers, team assemblers, computer-controlled machine tool operators, machinists, industrial production managers, and administrative jobs at the site, such as janitorial services and security, who do not directly work on the assembly lines (U.S. Bureau of Labor Statistics, n.d).

Many of the charger manufacturers have established or are building plants in the United States, demonstrating the feasibility for a domestically integrated market. In 2022, charging infrastructure manufacturer Tritium announced plans to build a U.S. facility which will produce 30,000 Buy America-compliant DC fast chargers per year and create 500 local jobs (The White House, 2022a). SK Signet, a South Korean-based EV charging company, opened its first American manufacturing facility in Plano, Texas, in June 2023 and expects to produce up to 10,000 DC chargers annually by 2026 and support 183 highly skilled jobs (SK Signet 2023). Blink Charging announced in October

2022 that it would build a new facility in the U.S. with an annual capacity of 10,000 DC fast and 20,000 to 40,000 Level 2 chargers, which will require 300 highly skilled manufacturing jobs (Blink Charging, 2022). Blink also has a charger assembly facility in Bowie, Maryland, that employs 50 workers and produces 10,000 Level 2 chargers at peak capacity (Blink Charging, n.d.).

Using the facility announcements, we approximate the person-day needed to assemble chargers. With Tritium and SK Signet factory's announcement as a reference point, we assume that it would take roughly four person-days to complete assembly of one DC fast charger (500 person times 240 workdays per year then divide by 30,000 chargers per year in the case of Tritium, 183 person times 240 workdays per year divide by 10,000 chargers in the case of SK Signet). A conversation with Tritium's representative in January 2023 showed that the factory is at half of its capacity with about 250 jobs filled. For Level 2 chargers, using the 300 jobs at the new Blink Charging facility, subtracting the person-days needed for DC fast charger, and corroborating with the information on their Bowie, Maryland, facility, we deduce that to produce a Level 2 charger at a facility, it would require on average 1 person-day.[4]

We then estimate the number of chargers that can be produced domestically that directly relates to the domestic assembly workforce based on existing and new facility announcements. Based on the Blink and Tritium charger facility production and capacity, and collected announcements from other charger companies, we find that the annual production for facilities with announced capacity is averaged at 33% of capacity in 2023 (Atlas Hub, n.d; White House, 2023; Blink Charging, 2022; Tritium Charging, 2023).[5] In the case that a facility that does not specify the amount of Level 2 and DC production and the company offers both types of chargers on the U.S. market, we assume DC production makes up one-fifth of total production based on the ratio of total Level 2 and DC deployed as of August 2023 (Atlas Hub, n.d) and Blink Charging's announcement of the new facility that will produce both Level 2 and DC chargers (Blink Charging, 2022). With the expectation that these facilities will ramp up production to meet demand, the ratio gradually increases to 75% by 2030 and stays constant onward to mirror the capacity of automotive plants in the United States (Bui & Slowik, 2022). For example, in 2028, most facilities will have a production-to-capacity ratio of 61%.

Based on these assumptions, we find that with the increase in capacity of existing facilities and the introduction of new facilities announced in 2023, 100% of DC fast charger needs based on our model could be produced in the United States between 2023 and 2032. For Level 2 chargers, 2023 has the highest ratio of production to new chargers compared to other years, at close to 33%, because future charger production announced by companies has not yet caught up with the charger needs in the future year. Therefore, we assume 33% of total new Level 2 chargers will be produced domestically between 2023 and 2032 to take into account future facilities or expansion announcements.

4 Total DC charger assembly jobs at the second Blink Charging facility would be 167 jobs, calculated from 10,000 chargers multiply by four person-day per chargers and divide by 240 workdays. This leaves 133 jobs for Level 2 charger assembly. The 0.8 workday per charger is calculated from 133 person times 240 workdays then divide by the 40,000 Level 2 chargers. At the first facility in Maryland, Blink has 50 workers produce 10,000 Level 2 chargers at peak capacity. This translates to 1.2 person-day per charger.

5 Based on Atlas Hub charger data, approximately 2,600 Blink chargers were deployed in 2022, which represents 26% of the Maryland facility capacity. Similarly, Tritium produced 3,200 chargers in the first four months of 2023. Assuming the same production pace, Tritium could produce up to 10,000 chargers in 2023.

General construction labor

The installation of EV charging infrastructure may involve general labor construction work depending on the site location, such as backfilling holes and repaving surfaces. In some jurisdictions, general construction labor may also complete trenching or underground work to lay conduits; in most cases this work is done by electrical workers. Analysis of survey data from Carr et al. (2021) shows that general labor construction work can range between 0.5 to 6 person-days for a Level 2 charger and 1 to 16 person-days for a DC fast charger. For this analysis, we assume that general construction labor would only be required for MFH, workplace, and public charger installations. The average person-days are 2.98 for a DC fast charger and 2.31 for a Level 2 charger, based on Carr et al. (2021).

WHITE-COLLAR JOBS

Software maintenance and repair

Some companies separately offer services to maintain software systems used by EV chargers to perform charging functions and collect payments from consumers. These jobs involve troubleshooting software and running computer diagnostics when EV chargers present technical problems. These jobs are generally entry-level positions that typically do not require a college degree and training is often provided by hiring companies. ChargerHelp estimates that each service technician would be able to handle software maintenance for 250 to 300 charging points (Levine, 2021). Based on this data and assuming 240 workdays per year,[6] we estimate that each MFH, workplace, and public charger will require roughly 1 person-day of software maintenance annually.

Planning and design

There are various planning and design stages that involve different skill sets in each stage of site construction and installation, from high-level federal, state, city, and municipal planning to direct site planning. For this paper, we only assess the jobs related to direct site planning.

The first step in the site planning process includes initial site evaluation to determine the current electrical capacity and identify the locations of other existing infrastructure such as gas, water, and sewer lines. After consultation with the site host or stakeholders, planners determine the optimal location for chargers and parking configurations. They then coordinate with all parties involved in the installation, such as electricians, general construction laborers, and administrators. Planners also obtain necessary permits from local government agencies. These site-planning steps are further detailed in several guidebooks (Eckerle & Vacin, 2019; New York State, n.d; Drive Electric Vermont, n.d).

We assume that planning and design work would only be required for MFH, workplace, and public EV chargers. Our estimates of the number of person-days of planning and design work required for each EV charger, based on Carr et. al (2021), are 3.7 for Level 2 and 3.98 for DC fast chargers.

Administration and legal

This work is necessary for each step of the EV charging infrastructure life cycle, including installations, operations, and maintenance. Administrative and legal work

6 Assuming 3 weeks of vacation and sick days

provides support, organization, and management of communications and payment between all companies, institutions, and public agencies involved. These jobs are available within both private industry and government. For example, some government employees will oversee the permitting process and provide referrals to other necessary governing functions for approval before the project breaks ground. Legal work refers to work performed by lawyers, paralegals, or legal assistants in each stage. We assume that administration and legal work would only be required for MFH, workplace, and public EV chargers and apply estimates of 1.08 person-days for Level 2 chargers and 1.54 person-days estimates for DC fast chargers from Carr et al. (2021).

OTHER JOBS NOT INCLUDED IN THE ANALYSIS

There are a variety of jobs related to the charging infrastructure ecosystem that are not captured in this analysis due to a lack of available data. These jobs include training and capacity building, charger recycling, operations, sales, marketing, finance, executive positions, and research and development. The fact that our projections do not include the full universe of charging infrastructure jobs suggests that the job potentials could be higher than what we quantify with available data.

PROJECTIONS OF EV CHARGING INFRASTRUCTURE JOBS

In the following section, we describe our methods for projecting the total number of EV charging infrastructure jobs that will be needed annually through 2032 and present the results of our analysis. The results of LDV and MHDV charging infrastructure jobs are presented separately. Our job projections for each of these types of EV chargers are based on our estimates of future charging needs and person-days of work required for each new and existing charger described in previous sections of this report.

LIGHT-DUTY VEHICLE CHARGING INFRASTRUCTURE WORKFORCE

Table 4 shows the person-day labor requirements for SFH and MFH chargers (Level 2), workplace chargers (Level 2), and public chargers (Level 2 and DC fast chargers) by job type. The underlying data and methods used to arrive at each of these labor estimates are described in the previous workforce overview section. We assume that Level 2 chargers in MFH, workplaces, and public locations will have the same labor needs. For single-family home chargers, we assume that the primary work required will be electrical installation and assembly work and do not include estimates for other types of jobs.

Table 4. Person-day jobs per charger for light-duty vehicle public, workplace, and home chargers for each type of jobs, ordered by the job projections in 2032

Job type	Public		Workplace	MFH	SFH
	DC fast	Level 2	Level 2	Level 2	Level 2
Blue-collar jobs					
Electrical installation	10.00	4.20	4.20	4.20	1.25
Electrical maintenance and repair	0.65	0.65	0.65	0.65	-
Charger assembly	4.00	1.00	1.00	1.00	1.00
General construction labor	2.98	2.31	2.31	2.31	-
White-collar jobs					
Software maintenance and repair	1.00	1.00	1.00	1.00	-
Planning and design	3.98	3.70	3.70	3.70	-
Administration and legal	1.54	1.08	1.08	1.08	-

Table 5 summarizes the jobs needed from U.S. light-duty vehicle public, workplace, and home chargers for each job type in 2032, ordered by the blue-collar or white-collar category and job types from the highest projection to the lowest and rounded to the nearest hundred. For each job type other than maintenance and repair, the annual full-time equivalent jobs are estimated by multiplying the number of person-days required (presented in Table 4) by the annual additional new and replacement chargers needed (presented in Figure 2 and Figure 4), then dividing by 240 workdays per year. For charger assembly, the workforce need is one-third of potential jobs due to the number of chargers that the United States is assumed to assemble domestically. For software and electrical maintenance and repair, the annual full-time equivalent job estimates are based on the cumulative number of chargers that are operational each year (presented in Figure 1 and Figure 3).

Table 5. Estimated full-time equivalent jobs for U.S. light-duty vehicle public, workplace, and home chargers in 2032

Job type	Public		Workplace	MFH	SFH	Total
	DC fast	Level 2	Level 2	Level 2	Level 2	
Blue-collar jobs						
Electrical installation	1,200	4,900	7,200	6,700	34,200	**54,200**
Electrical maintenance and repair	500	5,200	5,400	6,100		**17,200**
Charger assembly	400	400	600	500	9,000	**10,900**
General construction labor	300	2,700	4,000	3,700		**10,700**
White-collar jobs						
Software maintenance and repair	800	8,000	8,300	9,300		**26,400**
Planning and design	400	4,400	6,400	5,900		**17,100**
Administration and legal	200	1,300	1,900	1,700		**5,100**
Total	**3,800**	**26,900**	**33,800**	**33,900**	**43,200**	**141,600**

In 2032, the LDV charging infrastructure industry would generate close to 142,000 jobs. The majority of the jobs needed are the result of demand from Level 2 chargers in single-family homes (31%), multifamily homes (24%), and workplaces (24%), with the remaining from public Level 2 (19%), and public DC fast chargers (3%). By job type, electrical installation makes up 38% of the total jobs, followed by software maintenance and repair at 19%, electrical maintenance and repair at 12%, planning and design at 12%, general construction labor at 8%, and administration and legal at 4%. To put this into perspective, electrical installation and electrical maintenance and repair that require skilled and trained electrician totals at 71,400 jobs, excluding electricians that might be involved in other processes. This amounts to more than 10% of the estimated 690,000 people employed as electricians as of May 2022 (U.S. Bureau of Labor Statistics, 2022).

Figure 7 summarizes the LDV charging infrastructure workforce by job type from 2023 to 2032. The total number of jobs in 2025 and 2030 is 31,000 and 114,000, respectively. Details on the number of jobs each year by charger and job types are shown in the Appendix. The compound annual growth rate from 15,000 jobs in 2023 to 142,000 in 2032 is approximately 28%.

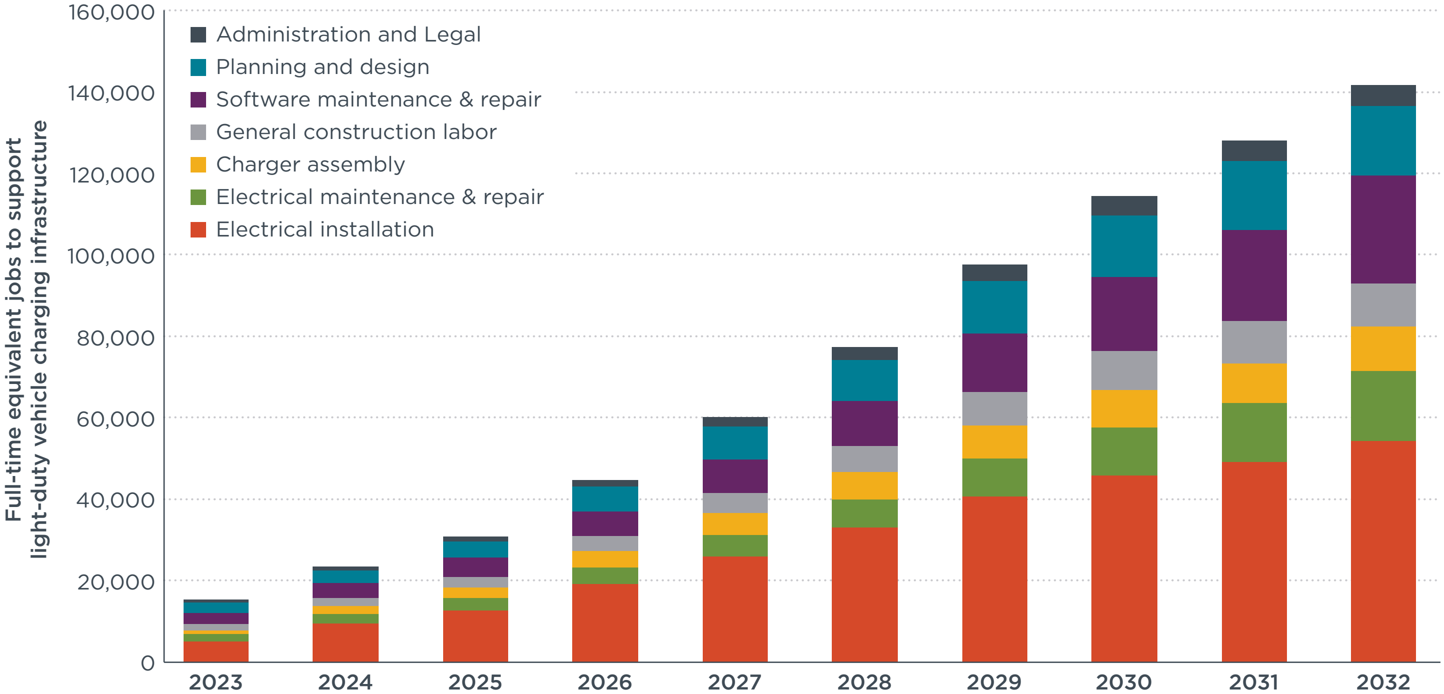

Figure 7. Estimated full-time equivalent jobs by job types to support U.S. light-duty vehicle charging infrastructure buildout from 2023 to 2032

MEDIUM- AND HEAVY-DUTY VEHICLE CHARGING INFRASTRUCTURE WORKFORCE

We apply the same job projection method described for LDV DC fast chargers in the previous section to project the number of jobs needed for MHDV charging infrastructure for two reasons. First, there is a lack of data and research on the labor requirements for MHDV chargers because MHDV charging infrastructure is still very new and is not as developed as LDV charging infrastructure. Secondly, the power capacity of MHDV overnight and opportunity fast chargers are within the range of LDV DC fast chargers (as demonstrated in Table 1 and Table 2), making it reasonable to assume that the labor requirements that we analyze in this report would be similar for other types of MHDV DC chargers.

For each job type other than software and electrical maintenance and repair, the annual full-time equivalent jobs are estimated by multiplying the number of person-days required (presented in Table 4) by the annual new and replacement chargers needed (presented in Figure 6), then dividing by 240 workdays per year. For software and electrical maintenance and repair, the annual full-time equivalent job estimates are based on the cumulative number of chargers that are operational each year (presented in Figure 5).

Table 6 shows the number of jobs for each job type and charger type in 2032, rounded to the nearest tenth. The MDHV EV infrastructure industry would generate around 16,000 jobs in 2032. These projections may reflect a conservative, lower-bound estimate of the MDHV charging infrastructure workforce needs because our estimates are based on the labor requirements of LDV DC fast chargers and may underestimate the work required for higher-capacity opportunity ultra-fast chargers.

Table 6. Estimated full-time equivalent jobs for U.S. medium- and heavy-duty vehicle public DC fast, ultra-fast, and overnight chargers in 2032

Job type	Fast chargers	Ultra-fast chargers	Overnight chargers	Total
Blue-collar jobs				
Electrical installation	180	140	4,980	5,300
Electrical maintenance and repair	50	40	1,340	1,400
Charger assembly	70	60	1,990	2,100
General construction labor	50	50	1,480	1,600
White-collar jobs				
Software maintenance and repair	70	50	2,050	2,200
Planning and design	70	60	1,980	2,100
Administration and legal	30	25	770	900
Total	**520**	**450**	**14,590**	**15,600**

Ninety-four percent of the jobs needed are the result of demand from overnight chargers, with the remaining 3% from ultra-fast chargers and 3% from fast chargers. By job type, electrical installation makes up 34% of the total jobs, followed by software maintenance and repair at 14%, charger assembly at 13%, planning and design at 13%, general construction labor at 9%, electrical maintenance and repair at 10%, and administration and legal at 6%.

Figure 8 illustrates the MHDV charging infrastructure workforce by job type from 2023 to 2032. The total number of jobs in 2025 and 2030 is 640 and 9,900, respectively. Details on the number of jobs each year by charger and job types are shown in the Appendix. The compounded annual growth rate from 460 jobs in 2023 to 16,000 in 2032 is approximately 50%.

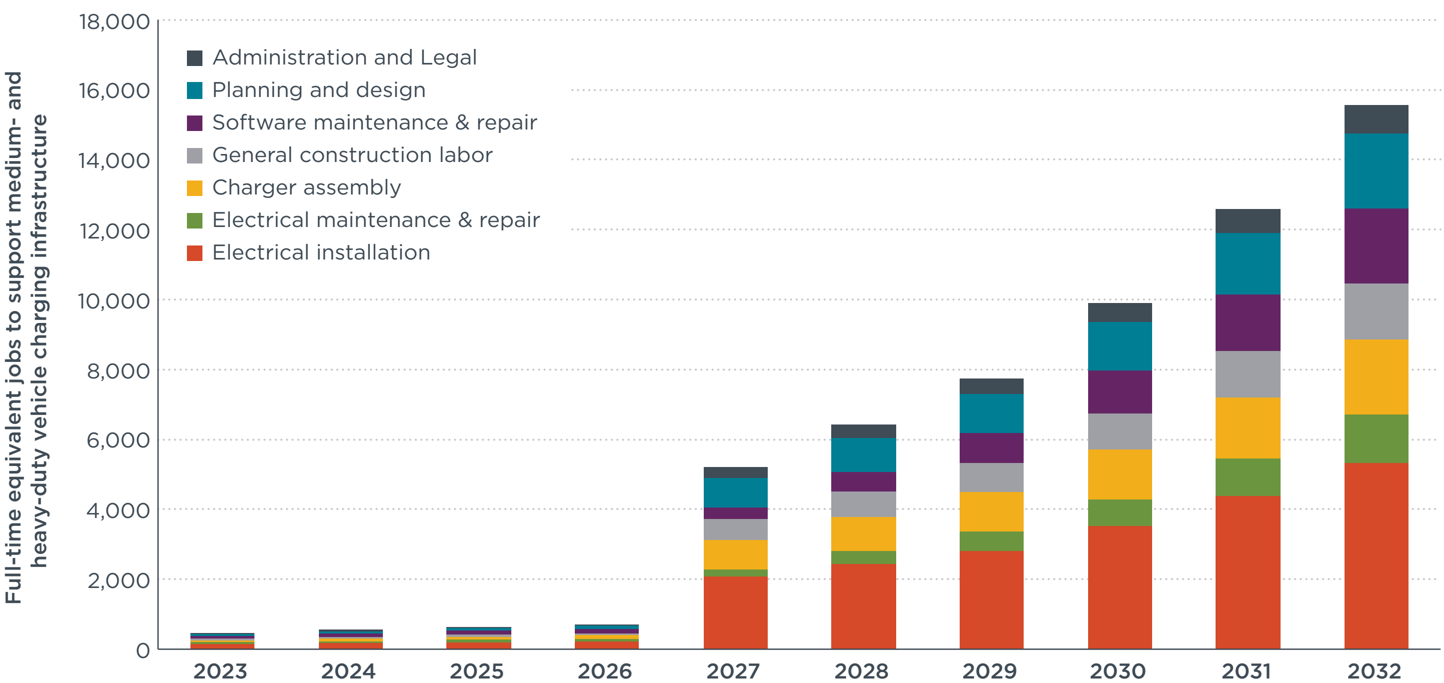

Figure 8. Estimated full-time equivalent jobs by job types to support U.S. medium- and heavy-duty vehicle charging infrastructure buildout from 2023 to 2032

Figure 9 illustrates the jobs associated with both LDV and MHDV charging infrastructure by job type from 2023 to 2032. Combining LDV and MHDV, the total number of charging infrastructure jobs will be more than 31,000 by 2025, 124,000 by 2030, and 157,000 by 2032. As a comparison, the EPI study estimated that the net job gain in the EV manufacturing sector (including vehicle assembly and related supply chain jobs) could be over 150,000 in 2030 under a best-case scenario in which 50% of total U.S. vehicle sales are BEVs, 75% of U.S. EV powertrains are produced domestically, and 60% of EVs sold in the U.S. are produced domestically (Barrett & Bivens, 2021).

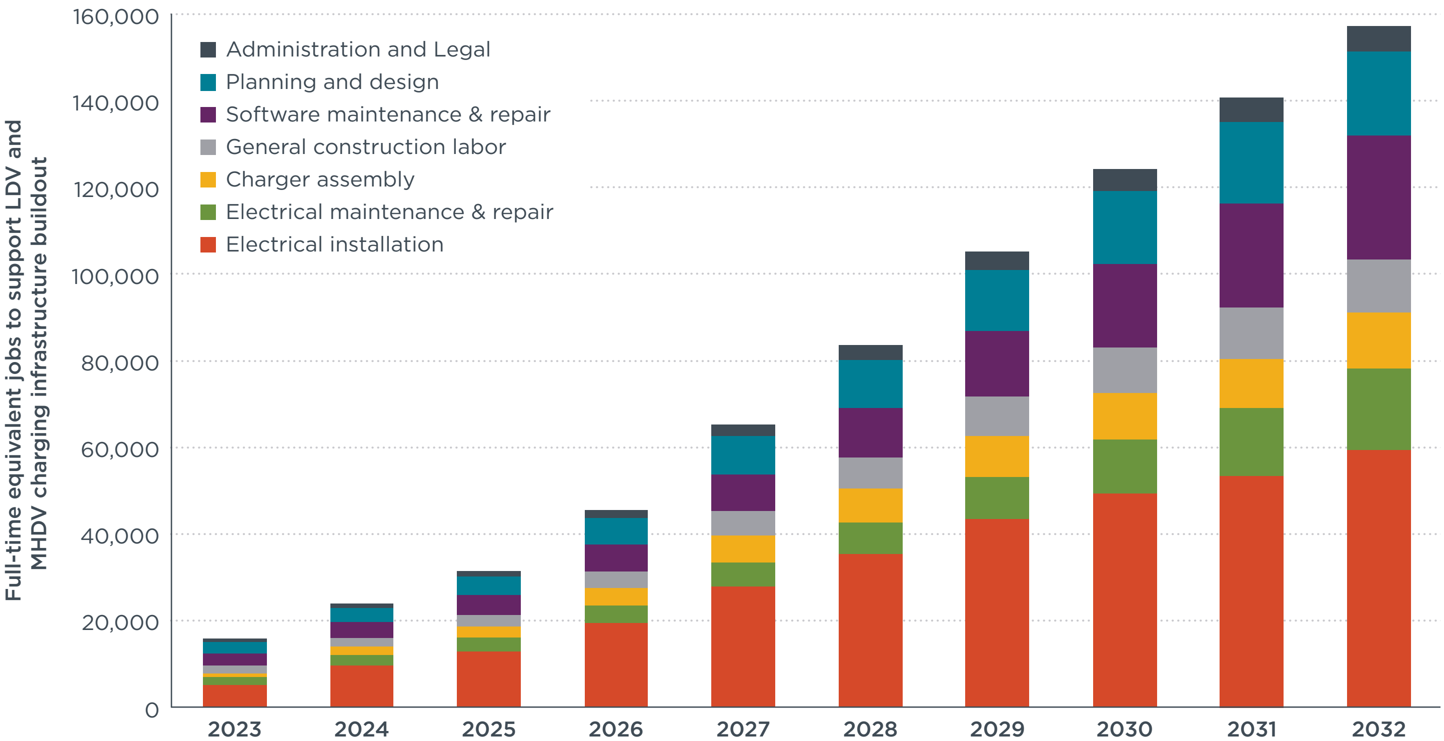

Figure 9. Estimated full-time equivalent jobs by job types from both light-duty and medium- and heavy- duty vehicle charging infrastructure buildout from 2023 to 2032

POTENTIAL FOR ADDITIONAL JOB CREATION

Components for EV chargers are currently manufactured both domestically and abroad. Government action could encourage companies to produce a larger share of EV chargers and components in the United States through regulatory and incentive pathways. Blue Green Alliance Foundation estimated in September 2023 that roughly 5,200 jobs will be created at EV charger manufacturing facilities over the course of several years (Blue Green Alliance Foundation, 2023). In this analysis, we estimate that approximately 33% of Level 2 chargers are produced domestically, leading to the creation of close to 10,900 Level 2 charger assembly jobs in 2032. The job potential from the assembly facilities could be 3 or more times higher than this projection. The analysis also assumes the MHDV charger-related work is similar to LDV DC fast charger work. As the MHDV charging infrastructure industry grows, the workforce needed to serve larger and higher-powered chargers might exceed our projections. Similarly, jobs that are not included in this analysis, such as training and capacity building, operations, sales, marketing, finance, executive positions, and research and development, can increase the total job needs above our estimates.

In addition, a domestically integrated EV infrastructure supply chain could provide further job opportunities than this study has estimated. There are already several dedicated government efforts to onshore the EV assembly industry and encourage automaker investments through the federal clean vehicle tax credits, domestic battery initiatives by the U.S. Department of Energy, and the Advanced Technology Assembly Loan (The White House, 2022b; Electrification Coalition & Securing America's Future Energy, 2022; Bui, 2022).

Broad efforts at the federal level to onshore the EV supply chain could be extended to the EV infrastructure supply chain at the state level. For example, provisions in the Build America, Buy America Act (U.S. Federal Highway Administration, 2023) that apply to the NEVI and the CFI discretionary grant program require that the cost of domestically manufactured components to be at least 55% of the total cost. Similar production requirements for state- and local government-funded projects could further incentivize investments in and the availability of domestic facilities to produce future EV charging infrastructure and create robust employment opportunities.

Financial policies to support higher recycling rates could also help secure a more integrated domestic mineral supply for all EV-related industries and create robust employment opportunities. For example, it is estimated that to achieve the Biden administration's goal of 500,000 new charging stations by 2030—assuming that all are 19 kW Level 2—the United States would need to meet approximately 500,000 kg of copper demand (S&P Global, 2022; International Copper Association, 2017). This projection likely underestimates the true copper need, given the anticipated demand for higher-power public chargers and 57 million home chargers that would require more than 57 million kg of copper, or more than 20% of U.S. copper production used for electrical and electronic products (U.S. Geological Survey, 2022). As copper is also a key mineral in the EV supply chain, it is expected to be in high demand in the coming years.

OPPORTUNITIES TO GROW A HIGH-ROAD CHARGING INFRASTRUCTURE INDUSTRY

This study demonstrates that there will be a growing demand for jobs in EV charging industry. Government strategies could help ensure an adequate and steady supply of workers for these jobs and that those workers are equipped with the proper skills and training. Meeting this demand will require building the high road economy in the EV charging industry. That means businesses will compete on quality, not cost, and invest in workers.

The policy strategies can include, but are not limited to, implementing wage and benefit standards, leveraging the existing labor-management training infrastructure, removing barriers to joining unions, and targeted hiring and investing in marginalized communities. This will attract more workers into the pool and ensure that the work is done at a high level of quality. Furthermore, these high-quality jobs will contribute to economic equity for historically marginalized and excluded workers and communities. More details on these high road strategies are found in Banerjee et al. (2021), Glass, Madland, and Walter (2022), Jacobs et al. (2022), McFadden, Santosh, and Shetty (2022), Walter et al. (2020), and Zabin et. al (2020).

Several opportunities embedded within federal and state funding could be continued or extended to support high-quality job creation in the charging infrastructure industry. For example, at the federal level, the Inflation Reduction Act provides bonus tax credits for investments that meet prevailing wage standards and apprenticeship-utilization requirements. Programs that provide pre-apprenticeships in low-income and disadvantaged communities or funding to employers to help upgrade construction workers' skills—leading to high-road jobs and long-term careers, including the EV infrastructure-related industry—are available in California and New York (California Department of Transportation & California Energy Commission, 2022, New York Department of Transportation, 2022).

Charger companies can also partner with other entities, such as local governments and union-affiliated contractors, to provide and improve training curriculums. For example, the EV charging infrastructure company ChargePoint recently partnered with the National Electrical Contractors Association to prepare its nearly 4,000-member companies, all of which are IBEW unionized, to install EV charging infrastructure in advance of the release of NEVI funding to States (The White House, 2022a).

CONCLUDING REFLECTIONS

The U.S. electric vehicle market is growing rapidly, and questions remain regarding on how much and how fast the charging infrastructure industry needs to grow to support this transition. This report helps answer some of these questions by quantifying the LDV and MHDV charging infrastructure need and estimating the number of jobs required by 2032 to support this growth. It also discusses some policy measures that federal and state governments could consider to ensure an equitable transition for workers in the EV infrastructure industry. Our analysis leads us to the following conclusions.

Growth in U.S. charging infrastructure can create about 160,000 jobs by 2032. Over 78,000 jobs, constituting nearly half of the total, will be in the fields of electrical installation and electrical maintenance and repair. These roles will demand skilled electricians who comply with local licensing standards and possess proper training to install and maintain EV chargers safely and accurately. When including charger assembly and general construction labor positions, the overall count of blue-collar jobs is expected to reach approximately 104,000. The additional white-collar workforce will collectively expect 54,000 jobs by 2032. Predominantly, the demand for jobs, totaling 142,000 or 90%, will stem from the LDV charging infrastructure sector. Around 16,000 jobs or 10%, will be necessary to support the growth of MHDV charging infrastructure.

Electric vehicle charging infrastructure buildout needs to accelerate in unison with EV uptake. Rapid deployment of public and home charging infrastructure is required to meet the goals set for EV adoption by the Biden administration. Similarly, rapid development of charging infrastructure for MHDV is essential to promote the electrification of the country's MHDV fleet. By 2032, LDV infrastructure requirement include 2 million workplace Level 2 chargers, 200,000 public DC fast chargers, nearly 1.9 million public Level 2 chargers, around 2.2 million Level 2 chargers for MFHs, and 35.2 million Level 2 chargers for SFHs. The MHDV fleet would require over 29,000 opportunity chargers, comprising 12,800 ultra-fast chargers and 16,600 fast chargers, along with close to 500,000 overnight chargers.

There is potential for even greater job growth if an increased share of charging infrastructure manufacturing occurs domestically. This analysis approximates that 33% of Level 2 chargers and 100% of DC chargers undergo final assembly domestically, resulting in a total of more than 13,000 jobs in 2032. This estimation excludes roles associated with charger component production and assembly. Elevating the proportion of domestically assembled EV chargers has the potential to amplify the number of jobs. Notably, provisions in the NEVI and CFI discretionary grant programs require that at least 55% of EV charger component costs must be domestically manufactured. Such requirements in state and local government-funded EV charger infrastructure initiatives, coupled with increased rates of charger recycling, could help increase the share of domestically conducted EV charger assembly and component production. This, in turn, has the potential to substantially increase the quantity of direct and induced jobs generated.

Government policies and industry partnerships can ensure that EV charging infrastructure jobs are high-road and that the work is carried out by appropriately trained workers. In high-road industries, firms compete on quality and innovation, rather than cost-cutting. Government policies that set wage and benefits standards, respect workers free and fair choice to join unions, build on existing training resources, and promote long-term career investment can incentivize the industry to create more high-road jobs. High-road jobs provide wages and benefits and remove barriers to unionizing, which will in turn attract and retain skilled workers. A growing charging infrastructure industry will require recruiting and training sufficient numbers of skilled workers. Policies that specify that work be done by appropriately licensed and trained workers will be important for ensuring that public dollars are used efficiently, and that infrastructure development and consumer experience are not at risk from inadequate installations and/or substantial maintenance needs.

The analysis presented here shows that the growing need for EV charging infrastructure can lead to close to 160,000 full-time equivalent jobs in the United States by 2032, with even greater potential for additional job creation if the share of charging infrastructure that is produced domestically increases. The analytical findings presented here are contingent on substantial continued electric vehicle market growth. This growth depends upon the adoption of the U.S. Environmental Protection Agency's proposed multi-pollutant emissions standards, in addition to the expansion of California's Advanced Clean Cars II, Advanced Clean Trucks, and Advanced Clean Fleet regulations to additional states. Our study indicates that such market developments and complementary support policies for charging infrastructure and supply chain domestic integration, job quality standards, and entry-level and skilled training can lead to the creation of a substantial number of high-road jobs in the charging infrastructure industry and support expanded economic benefits in local communities.

REFERENCES

Alternative Fuel Vehicle Refueling Property Credit. 26 U.S. Code §30C (2022). https://www.govinfo.gov/content/pkg/USCODE-2020-title26/pdf/USCODE-2020-title26-subtitleA-chap1-subchapA-partIV-subpartB-sec30C.pdf

Atlas Public Policy. (n.d). EV Hub [EV Charging Deployment]. https://www.atlasevhub.com/materials/ev-charging-deployment/

Banerjee, A., Poydock, M., McNicholas, C., Mangundatao, I., & Sai, A. (2021). *Unions are not only good for workers, they're good for communities and for democracy*. Economic Policy Institute https://www.epi.org/publication/unions-and-well-being/

Barrett, J., & Bivens, J. (2021). *The stakes for workers in how policymakers manage the coming shift to all-electric vehicles.* Economic Policy Institute https://www.epi.org/publication/ev-policy-workers/

Bauer,G., Hsu, C., Nicholas, M., & Lutsey, N. (2021). *Charging up America: Assessing the growing need for U.S. charging infrastructure through 2030*. International Council on Clean Transportation https://theicct.org/publication/charging-up-america-assessing-the-growing-need-for-u-s-charging-infrastructure-through-2030/

Blink Charging. (2022, October 18). *Following Secretary of Labor Marty Walsh's visit, Blink Charging announces plans to increase U.S. Assembly capabilities* [Press release]. https://blinkcharging.com/news/following-secretary-of-labor-marty-walshs-visit-blink-charging-announces-plans-to-increase-u-s-assembly-capabilities/?locale=en

Blink Charging (n.d.). *EV charger manufacturing in the U.S ... Why does it matter?* https://blinkcharging.com/ev-charger-manufacturing-in-the-u-s-why-does-it-matter/

Blue Green Alliance Foundation. (2023). *EV Jobs hub.* Retrieved from https://evjobs.bgafoundation.org/

Bui, A. (2022). *Money makes the world go electric: Why the U.S. government should invest in the EV industry.* International Council on Clean Transportation https://theicct.org/us-ev-investment-jul22/

California Air Resources Board. (2023a). *Advanced Clean Cars II.* https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/advanced-clean-cars-ii

California Air Resources Board. (2023b). *Advanced Clean Trucks.* https://ww2.arb.ca.gov/our-work/programs/advanced-clean-trucks

California Air Resources Board. (2023c). *Advanced Clean Fleet*. https://ww2.arb.ca.gov/our-work/programs/advanced-clean-fleets

California Department of Transportation and California Energy Commission (2022). *California's deployment plan for national EV infrastructure program.* http://rebuildingca.ca.gov/static/2022-ca-nevi-deployment-plan-a11y-8acc5dc59e4a797c873f28e1bfb74805.pdf

California Legislative Assembly. (2019). AB841. Reg. Sess. 2019-2020. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200AB841

CALSTART. (2022). *Summary of clean transportation provisions in the Inflation Reduction Act.* https://calstart.org/wp-content/uploads/2022/08/CALSTART-Summary-of-Key-IRA-Provisions.pdf

Carr, E., Winebrake, J., and Winebrake, S. (2021). *Workforce projections to support battery EV charging infrastructure installation*. Energy and Environmental Research Associates, LLC. https://etcommunity.org/assets/files/Workforce-ProjectionstoSupportBatteryElectricVehicleChargingInfrastructureInstallation-Final202106082.pdf

Climate Power. (2023). *Clean Energy Boom anniversary report.* https://climatepower.us/wp-content/uploads/sites/23/2023/07/Clean-Energy-Boom-Anniversary-Report-1.pdf

Cramer, K. (2023, September 5). *Electric car charging station installation cost.* HomeGuide. https://homeguide.com/costs/electric-car-charging-stations-cost

Doll, S. (2021, October 22). *Electric vehicle (EV) charging standards and how they differ. Electrek*. https://electrek.co/2021/10/22/electric-vehicle-ev-charging-standards-and-how-they-differ/

Dow, J. (2023, July 12). *SAE wants to certify NACS by end of year, and fix plug & charge too. Electrek*. https://electrek.co/2023/07/12/sae-wants-to-certify-nacs-by-end-of-year-and-fix-plug-charge-too/

Drive Electric Vermont. (n.d). *Charging installation guide.* https://www.driveelectricvt.com/charging-installation-guide

Eckerle, T., & Vacin, G. B. (2019). *EV Charging Station Permitting Guidebook.* California Governor's Office of Business and Economic Development https://businessportal.ca.gov/wp-content/uploads/2019/07/GoBIZ-EVCharging-Guidebook.pdf

Electrification Coalition and Securing America's Future Energy. (2022). *Fact sheet: IRA EV tax credits.* https://www.electrificationcoalition.org/wp-content/uploads/2022/08/SAFE_1-sheet_Webinar.pdf

Enphase O&M Marketplace. (2022). *EV charger maintenance basics.* https://www.365pronto.com/blog/electric-vehicle-charger-maintenance

Environmental Defense Fund & WSP. (2023). *U.S. Electric Vehicle Manufacturing investments and jobs.* https://www.edf.org/sites/default/files/2023-08/EDF%20WSP%20EV%20report%208-16-23%20FINAL%20FINAL.pdf

EV-Volumes. (2023). *EV Data Center.* http://www.ev-volumes.com/datacenter/

Glass, A., Madland, D., & Walter, K. (2022). *Prevailing wages can build good jobs into America's EV industry.* Center for American Progress. https://www.americanprogress.org/article/prevailing-wages-can-build-good-jobs-into-americas-electric-vehicle-industry/

GNY Insurance. (n.d). *What are EV charging stations and how do they work?* https://www.gny.com/products/electric-vehicle-charging-stations

Hackmann, M. (2022). *P3 Charging Index Report 07/22 – Comparison of the fast charging capability of various EVs.* P3. https://www.p3-group.com/en/p3-charging-index-comparison-of-the-fast-charging-capability-of-various-electric-vehicles-from-a-users-perspective_07-22/

International Copper Association. (2017). *Copper intensity in the electrification of transport and the integration of energy storage.* https://copperalliance.org/wp-content/uploads/2017/05/2017.04-E-Mobility-Factsheet-4.pdf

International Council on Clean Transportation. (2022a*). ICCT comments on EPA proposed HDV rule.* https://theicct.org/comments-epa-proposed-hdv-rule-may22/

International Council on Clean Transportation. (2022b). *Roadmap Model Documentation*. https://theicct.github.io/roadmap-doc/

International Council on Clean Transportation. (2023a). ICCT comments on EPA proposed rule, titled "Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles – Phase 3". https://www.scribd.com/document/654782588/ICCT-comments-on-EPA-proposed-rule-titled-Greenhouse-Gas-Emissions-Standards-for-Heavy-Duty-Vehicles-Phase-3#

International Council on Clean Transportation. (2023b). EVCHARGE Model Documentation. https://theicct.github.io/EVCHARGE-doc/versions/v1.0/

Jacobs, K., MacGillvary, J., Lopezlira, E., Huang, K. (2022). *The public cost of low-wage jobs in the US construction industry*. University of California Berkeley Labor Center https://www.ipaglobal.com/wp-content/uploads/2023/02/Value-Union-Labor-Construction-Projects-IPA-Study.pdf

Joint Office of Energy and Transportation. (2023, May). *Private sector continues to play key part in accelerating buildout of EV charging networks*. https://driveelectric.gov/news/private-innvestment

Joint Office of Energy and Transportation (n.d). *Technical Assistance and Resources for States and Communities*. https://driveelectric.gov/states-communities

Department of Transportation. https://driveelectric.gov/news/private-innvestment

LeVine, S. (2021, January 25). *An $80,000 per year job of the future: EV charging station technician*. Medium. https://themobilist.medium.com/an-80-000-a-year-job-of-the-future-ev-charging-station-technician-64999c93220d

McFadden, M., Santosh, S., & Shetty, R. (2022). *Quantifying the value of union labor in construction projects*. Independent Project Analysis, Inc. https://www.ipaglobal.com/wp-content/uploads/2023/02/Value-Union-Labor-Construction-Projects-IPA-Study.pdf

National Electric Vehicle Infrastructure Standards and Requirements. 87 Fed. Reg. 37262 (February 28, 2023). https://www.federalregister.gov/documents/2023/02/28/2023-03500/national-electric-vehicle-infrastructure-standards-and-requirements

Nelder, C., and Rogers, E. (2020). *Reducing EV charging infrastructure costs.* Rocky Mountain Institute. https://rmi.org/wp-content/uploads/2020/01/RMI-EV-Charging-Infrastructure-Costs.pdf

New York Department of Transportation. (2022). *New York State National EV Infrastructure Formula Program Plan*. https://www.fhwa.dot.gov/environment/nevi/ev_deployment_plans/ny_nevi_plan.pdf

New York State. (n.d). Charge NY best practice guides and cases. https://www.nyserda.ny.gov/All-Programs/chargeny/charge-electric/best-practices

Nicholas, M. (2019). *Estimating EV charging infrastructure costs across major U.S. metropolitan areas.* International Council on Clean Transportation. https://theicct.org/sites/default/files/publications/ICCT_EV_Charging_Cost_20190813.pdf

Pierce, L., & Slowik, P. (2023). *Home charging access and implications for charging infrastructure costs in the United States.* International Council on Clean Transportation. https://theicct.org/publication/home-charging-infrastructure-costs-mar23/

Ragon, P., Mulholland, E., Basma, H., & Rodríguez, F. (2022). *A review of the AFIR proposal: public infrastructure needs to support the transition to a zero-emission truck fleet in the European Union.* International Council on Clean Transportation. https://theicct.org/publication/afir-eu-hdv-infrastructure-mar22/

Qualifying advanced energy project credit. 26 U.S. Code §48C (2009). https://www.govinfo.gov/content/pkg/USCODE-2021-title26/pdf/USCODE-2021-title26-subtitleA-chap1-subchapA-partIV-subpartE-sec48C.pdf

SK Signet. (2023, June 7). *SK Signet celebrates grand opening of new Plano-based EV charger manufacturing facility* [Press release]. https://eng.sk.com/news/sk-signet-celebrates-grand-opening-of-new-plano-based-ev-charger-manufacturing-facility

SolarEdge. (2021). SolarEdge home EV charger installation manual version 1.00. https://www.solaredge.com/sites/default/files/se-home-ev-charger-installation-manual-eng.pdf

S&P Global. (2022). *The Future of Copper: Will the looming supply gap short-circuit the energy transition?* https://cdn.ihsmarkit.com/www/pdf/1022/The-Future-of-Copper_Full-Report_SPGlobal.pdf

Tamborrino, K., & Olander, O. (2023, August 29). *Biden administration offers rules for labor standards and wages under climate law.* Politico. https://subscriber.politicopro.com/article/2023/08/biden-administration-offers-new-details-on-prevailing-wage-apprentices-00113193?source=email

TeraWatt. (2022, October 20). *TeraWatt developing I-10 electric corridor, the first network of electric heavy-duty charging centers.* https://terawattinfrastructure.com/ideas/terawatt-developing-i-10-electric-corridor-the-first-network-of-electric-heavy-duty-charging-centers/

Tesla. (2020). Gen 3 Wall Connector Manual. https://www.tesla.com/sites/default/files/support/charging/Gen3_WallConnector_Installation_Manual.pdf

Tritium Charging. (2023, May 11). *Tritium announces record preliminary year-to-date results and increases CY2023 guidance* [Press release]. https://www.tritiumcharging.com/tritium-announces-record-preliminary-year-to-date-results-and-increases-cy2023-guidance/

U.S. Bureau of Labor Statistics. (n.d). *Careers in EVs.* https://www.bls.gov/green/electric_vehicles/

U.S. Bureau of Labor Statistics. (2022, May). *Occupational Employment and Wage s, May 2022: 47-2111 Electricians.* Statistics. https://www.bls.gov/oes/current/oes472111.htm

U.S. Census Bureau. (2021). *American Community Survey 1-year estimates – B25033* [Total population in occupied housing units by tenure by units in structure]. https://data.census.gov/table?q=b25033

U.S. Department of Energy. (n.d). *Alternative Fuels Data Center: Electric vehicle charging station locations.* https://afdc.energy.gov/fuels/electricity_locations.html#/find/nearest?fuel=ELEC

U.S. Department of Energy. (2023). *Building America's clean energy future*. https://www.energy.gov/invest

U.S. Department of Labor (2022). *Dollar threshold amount for contract coverage under State prevailing wage law.* https://www.dol.gov/agencies/whd/state/prevailing-wages

U.S. Department of Labor (n.d). *Government contracts.* https://www.dol.gov/general/topic/wages/govtcontracts

U.S. Department of Transportation. (2021). *Fact sheets: National Electric Vehicle Infrastructure Formula Program*. https://www.fhwa.dot.gov/bipartisan-infrastructure-law/nevi_formula_program.cfm

U.S. Department of Transportation. (2023). *View grant opportunity: Electric Vehicle Charger Reliability and Accessibility Accelerator Grant opportunity.* Grants.gov. https://www.grants.gov/web/grants/view-opportunity.html?oppId=350190

U.S. Environmental Protection Agency. (2021). *Population and activity of onroad vehicles in MOVES3.* https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1011TF8.pdf

U.S. Environmental Protection Agency. (2023a). *Multi-Pollutant Emissions Standards for Model years 2027 and Later Light-Duty and Medium-Duty Vehicles.* https://www.govinfo.gov/content/pkg/FR-2023-05-05/pdf/2023-07974.pdf

U.S. Environmental Protection Agency (2023b). *Greenhouse gas emissions standards for heavy-duty vehicles – Phase 3.* https://www.govinfo.gov/content/pkg/FR-2023-04-27/pdf/2023-07955.pdf

U.S. Federal Highway Administration. (2023). *Q&As for Build America, Buy America (BABA) implementation plan to enhance Buy America for Electric Vehicle (EV) chargers.* https://www.fhwa.dot.gov/construction/contracts/buyam_qaev/#:~:text=For%20EV%20chargers%20manufactured%20on%20or%20after%20July%201%2C%202024,occur%20in%20the%20United%20States.

U.S. Geological Survey. (2023). *Copper.* https://pubs.usgs.gov/periodicals/mcs2023/mcs2023-copper.pdf

Volvo Trucks North America. (2022, July 14). Volvo trucks constructing California electrified charging corridor for medium- and heavy-duty EVs [Press release]. https://www.volvotrucks.us/news-and-stories/press-releases/2022/july/constructing-california-electrified-charging-corridor-for-medium-and-heavy-duty-electric-vehicles/

Wallbox. (2022, April 11). *Wallbox enters first phase of buildout for its U.S. EV charger assembly facility* [Press release]. https://wallbox.com/en_us/newsroom/wallbox-enters-first-phase-of-build-out-for-its-us-ev-charger-assembly-facility.html

Wall, M., Madland, D., & Walter, K. (2020). *Prevailing Wages: Frequently Asked Questions*. Center for American Progress. https://www.americanprogress.org/article/prevailing-wages-frequently-asked-questions/

Walter, K., Higgins, T., Bhattacharyya, B., Wall, M., & Cliffton, R. *EVs should be a win for American workers.* Center for American Progress. https://www.americanprogress.org/article/electric-vehicles-win-american-workers/#:~:text=Lawmakers%20in%20large%20EV%20markets,people%20across%20climate%2Drelated%20spending.&text=These%20proposals%20are%20an%20encouraging%20start.

The White House. (2023, February 15). *Fact sheet: Biden-Harris administration announces new standards and major progress for a Made-in-America national network of EV chargers.* https://www.whitehouse.gov/briefing-room/statements-releases/2023/02/15/fact-sheet-biden-harris-administration-announces-new-standards-and-major-progress-for-a-made-in-america-national-network-of-electric-vehicle-chargers/

The White House. (2022a, February 8). *Fact sheet: Biden-Harris administration ensuring future is Made in America.* https://www.whitehouse.gov/briefing-room/statements-releases/2022/02/08/fact-sheet-biden-harris-administration-ensuring-future-is-made-in-america/

The White House. (2022b, June 28). *Fact sheet: Biden-Harris administration catalyzes more than $700 million in private sector commitments to make EV charging more affordable and accessible.* https://www.whitehouse.gov/briefing-room/statements-releases/2022/06/28/fact-sheet-biden-harris-administration-catalyzes-more-than-700-million-in-private-sector-commitments-to-make-ev-charging-more-affordable-and-accessible/

The White House. (n.d.) Justice40. https://www.whitehouse.gov/environmentaljustice/justice40/

Xu, B., Davis, A. W., & Tal, G. (2021). Estimating the Total Number of Workplace and Public EV Chargers in California. *Transportation Research Record.* 2675(12), 759-770. https://doi.org/10.1177/03611981211031214

Zabin, C., Auer, R., Cha J. M., Collier, R., Richard F., MacGillvary, J., Myers, H., Strecker, J., & Viscelli, S. (2020). *Putting California on the high road: A jobs and climate action plan for 2030*. University of California Berkeley: Center for Labor Research and Education. https://laborcenter.berkeley.edu/wp-content/uploads/2020/09/Putting-California-on-the-High-Road.pdf

APPENDIX

Table A1. Number of chargers by charger type needed to support the U.S. light-duty EV market growth through 2032

Year	Public		Workplace	Multi-family home	Single-family home	EV stock
	DC fast	Level 2	Level 2	Level 2	Level 2	
2023	42,776	333,729	210,283	86,706	2,080,917	4,361,814
2024	56,652	400,931	275,861	130,452	3,130,837	6,281,026
2025	66,869	487,760	359,378	198,884	4,615,213	8,920,897
2026	81,490	605,948	479,407	312,426	6,903,748	12,897,078
2027	98,362	753,099	637,008	484,116	9,997,330	18,179,643
2028	117,580	933,505	832,063	721,564	13,895,276	24,797,559
2029	138,870	1,159,591	1,073,266	1,040,405	18,601,138	32,843,084
2030	160,414	1,411,360	1,342,782	1,434,552	23,750,206	41,695,318
2031	181,086	1,675,834	1,629,767	1,877,521	29,068,011	50,815,968
2032	200,484	1,910,726	1,995,535	2,242,543	35,178,426	60,485,692

Table A2. Estimated jobs for U.S. light-duty vehicle public, workplace, and home chargers by charger type by 2032

Year	Public DC	Public L2	Workplace L2	MFH L2	SFH L2	Total
2023	1,419	5,977	3,844	1,888	2,258	**15,385**
2024	1,778	6,321	5,170	3,043	7,037	**23,349**
2025	1,520	7,925	6,660	4,724	9,958	**30,788**
2026	2,045	10,299	9,322	7,714	15,343	**44,724**
2027	2,400	12,860	12,327	11,748	20,779	**60,114**
2028	2,957	15,794	15,633	16,624	26,276	**77,285**
2029	3,351	19,716	19,750	22,850	31,895	**97,563**
2030	3,535	22,865	23,305	29,349	35,261	**114,315**
2031	3,784	25,611	26,613	34,982	37,038	**128,028**
2032	3,823	26,799	33,667	34,065	43,248	**141,602**

Table A3. Estimated jobs for U.S. light-duty vehicle public, workplace, and home chargers by job type by 2032

Year	Electrical installation	Electrical maintenance and repair	Charger assembly	General construction labor	Software maintenance and repair	Planning and design	Administration and legal	Total
2023	4,950	1,824	881	1,614	2,806	2,548	762	**15,385**
2024	9,431	2,340	1,972	1,969	3,600	3,109	930	**23,349**
2025	12,728	3,014	2,612	2,549	4,637	4,049	1,198	**30,788**
2026	19,203	4,006	3,972	3,719	6,164	5,911	1,748	**44,724**
2027	25,895	5,342	5,329	5,008	8,219	7,969	2,352	**60,114**
2028	32,927	7,054	6,749	6,435	10,853	10,244	3,023	**77,285**
2029	40,683	9,241	8,218	8,229	14,217	13,111	3,863	**97,563**
2030	45,858	11,779	9,123	9,607	18,121	15,319	4,507	**114,315**
2031	49,064	14,528	9,651	10,585	22,351	16,884	4,965	**128,028**
2032	54,183	17,196	10,951	10,708	26,455	17,085	5,022	**141,602**

Table A4. Number of chargers by charger type needed to support the U.S. medium- and heavy-duty EV market growth through 2032

Year	Fast chargers (350 kW)	Ultrafast chargers (1 MW)	Overnight depot chargers (100 kW)	Total
2023	1,686	147	12,725	**14,558**
2024	1,694	148	17,133	**18,975**
2025	1,734	152	22,189	**24,075**
2026	1,734	153	27,667	**29,554**
2027	3,988	1,123	74,239	**79,350**
2028	5,961	2,307	129,479	**137,747**
2029	7,780	3,684	193,742	**205,206**
2030	9,785	5,607	274,192	**289,584**
2031	12,225	8,980	373,671	**394,876**
2032	16,584	12,806	493,121	**522,511**

Table A5. Estimated jobs for U.S. medium- and heavy-duty vehicle chargers by job type by 2032

Year	Electrical installation	Electrical maintenance and repair	Charger assembly	General construction labor	Software maintenance and repair	Planning and design	Administration and legal	Total
2023	158	39	63	47	61	63	24	**455**
2024	184	51	74	55	79	73	28	**545**
2025	213	65	85	63	100	85	33	**644**
2026	228	80	91	68	123	91	35	**717**
2027	2,075	215	830	618	331	826	320	**5,214**
2028	2,433	373	973	725	574	968	375	**6,421**
2029	2,811	556	1,124	838	855	1,118	433	**7,735**
2030	3,516	784	1,406	1,048	1,207	1,399	541	**9,901**
2031	4,387	1,069	1,755	1,307	1,645	1,746	676	**12,585**
2032	5,318	1,415	2,127	1,585	2,177	2,116	819	**15,557**

www.theicct.org

communications@theicct.org

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

BEIJING | BERLIN | NEW DELHI | SAN FRANCISCO | SÃO PAULO | WASHINGTON