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Breakdown of Electric Vehicle Supply Equipment Installation Costs

August 2022

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LIST OF ACRONYMS

AC	Alternating current
ACL1	AC Level 1 (120volt)
ACL2	AC Level 2 (240volt)
AFDC	Alternative Fuels Data Center
BEA	Battelle Energy Alliance, LLC
BEV	battery electric vehicle
DC	direct current
DCFC	direct current fast charger
DOE	U.S. Department of Energy
EVSE	electric vehicle supply equipment
EVSP	electric vehicle service provider
ICCT	International Council on Clean Transportation
ICE	internal combustion engine
INL	Idaho National Laboratory
OEM	original equipment manufacturer – here referring to automobile suppliers
PEV	plug-in electric vehicle (includes BEVs and PHEVs, but not hybrid electric vehicles)
PHEV	plug-in hybrid electric vehicle
SAE	Society of Automotive Engineers
SCA	Smart Charge America
WSEV	WestSmart EV project
ZEV	zero emission vehicle (PEVs and fuel cell vehicles)

EXECUTIVE SUMMARY

The plug-in electric vehicles (PEVs) market is receiving help from the current political climate, incentives at the federal and state levels, excessive cost of petroleum fuel, growing focus on climate solutions, increasing investment and direction by automobile manufacturers and increased awareness through media reports and advertising. Increasingly, the transportation industry, in both the United States and many other countries, is aimed at electric motive energy where practical. Increased investment in research and development have led to increasing vehicle range and lower battery costs; both of which have been deterrents in the past.

The increasing demand for PEVs (consisting of the battery electric vehicle [BEV] and plug-in hybrid electric vehicle [PHEV], is challenged by the need for charging infrastructure to support these vehicles. The BEV relies totally on the on-board battery to supply the motive energy while the PHEV utilizes its battery and an installed internal combustion engine (ICE). The maximum benefit is achieved by using the battery power as much as possible. This arrangement requires the use of battery charging equipment, known as electric vehicle supply equipment (EVSE).

While the PEV is being effectively marketed, less is publicly reported on the EVSE needed to support it. It has been estimated that nearly 10 million charge ports will be needed by 2030 to accommodate the predicted growth of the EV market. Almost 80% of those ports will be home chargers and about 20% will be public or workplace chargers. However, the cost of the EVSE and its installation is not well known.

The installation of the EVSE requires on-site electrical work and typically requires area permitting and construction by a licensed electrical contractor. This cost is highly dependent upon the environment in which the EVSE is to be installed. While the cost of the PEV may be known and the cost of the charging equipment identified, the cost of the installation most often requires a site visit and estimate by the licensed electrical contractor. This unknown factor may be a significant hurdle for PEV enthusiasts or interested business owners.

Most of this detailed installation information is held as proprietary by EVSE network providers. However, some data has become available that allows for estimating these equipment and installation costs. The results of the data analyses are presented in this report.

This report supplies information on the cost of the equipment, from simple cordsets and individual pieces of charging equipment to the much more complex direct current fast chargers (DCFC). A substantial number of EVSE providers have entered the market and product for residential use is generally available for purchase online. Costs therefore are more easily obtained than in the past. Products vary from simple units to those having the ability for networking the equipment, data recording and reporting. Each is addressed with cost analysis.

This report also addressed the installation of these types of EVSE. Because these costs are highly dependent upon the physical conditions at the site, this analysis provides insight into the varying factors that affect the cost.

Prospective PEV buyers and commercial business operators can benefit from a more detailed and directed estimate of the cost for installation of EVSE. Through the choice of specific use cases that bracket most of the expected environmental aspects of installations, a closer estimate of the costs can be achieved to project the total cost of EVSE installation more accurately

With the significant increase in the number of EVSE needed in the coming years, a comprehensive understanding of the cost of EV charging infrastructure is needed to inform policy makers on the investment and incentives needs to support near- and long-term EV adoptions.

1 INTRODUCTION

1.1 Background

The global plug-in electric vehicles (PEVs) market is receiving help from the current political climate, incentives at the governmental levels, high cost of petroleum fuel, growing focus on climate solutions, increasing investment and direction by automobile manufacturers and increased awareness through media reports and advertising. PEVs, which include all-battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), can trace their modern-day design and market introduction to 2011 when Nissan delivered the Leaf (a BEV) and Chevrolet delivered the Volt (a PHEV). Increasingly, the transportation industry, in both the United States and many other countries, is aimed at electric motive energy where practical. Increased investment in research and development have led to increasing vehicle range and lower battery costs; both of which have been deterrents in the past. Figure 1 (Irle, 2021) illustrates this rapid growth.

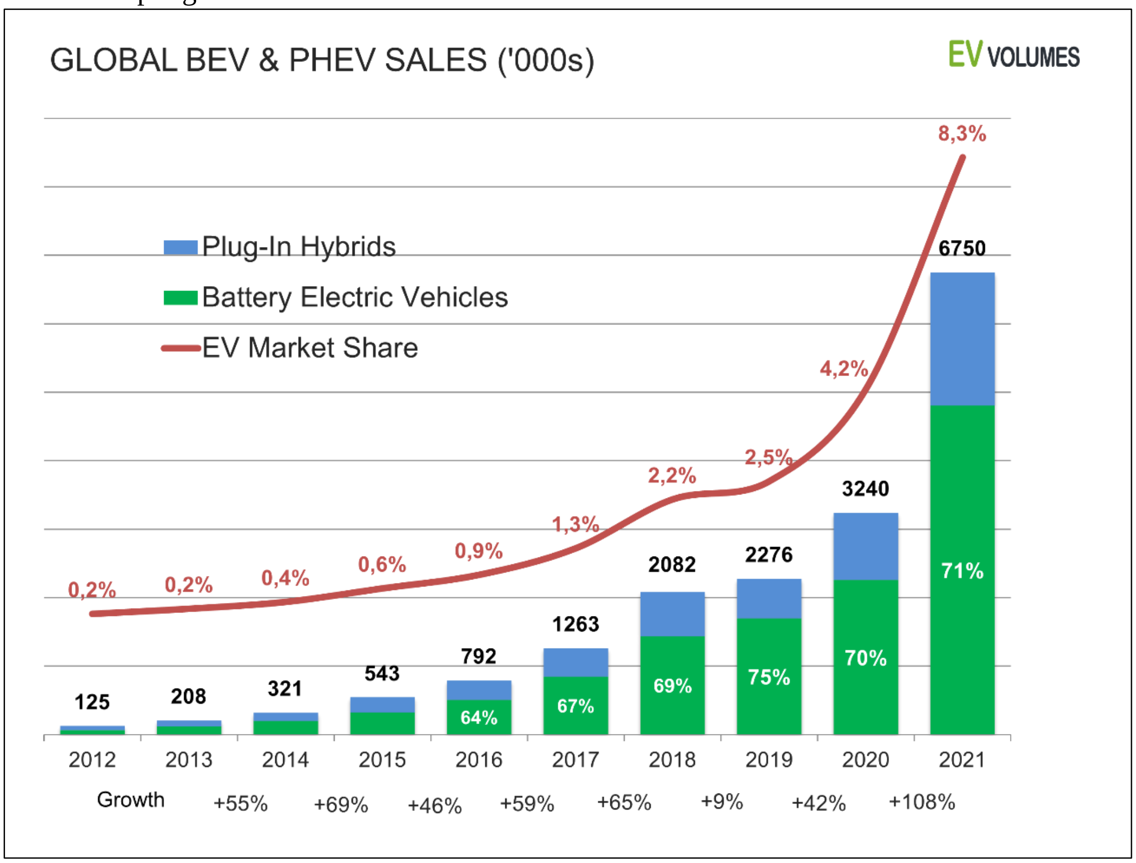


Figure 1. PEV Sales Worldwide (Irle, R., 2021)

In the United States (US), sales of new light-duty PEVs increased from 308,000 in 2020 to 608,000 in 2021. BEV sales accounted for 73% of all PEV sales in 2021. The overall market for light-duty vehicle sales increased by only 3% compared to the PEV sales increase of 85%. Figure 2 shows the US market sales since 2011.

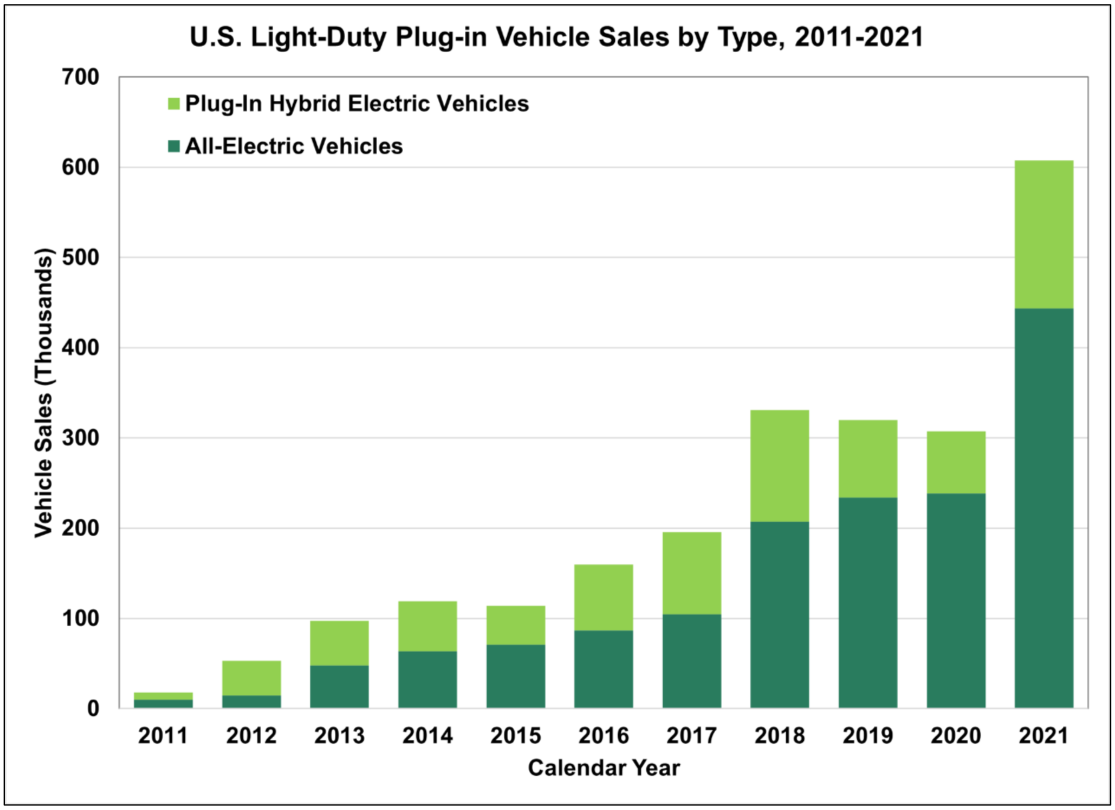


Figure 2. U.S. EV Sales per year (Minor, S, 2021)

The increasing demand for PEVs is challenged by the need for charging infrastructure to support these vehicles. The BEV relies totally on the on-board battery to supply the motive energy while the PHEV uses its battery and an internal combustion engine (ICE). The maximum benefit is achieved by using the battery power as much as possible. This arrangement requires the use of battery charging equipment, known as electric vehicle supply equipment (EVSE). Note that while hybrid electric vehicles (HEVs) also include a battery and ICE motive energy, they do not have a means for connection to an EVSE and are excluded from this discussion. In a comparable manner, fuel cell vehicles may be referred to as fuel cell electric vehicles (FCEV) because the fuel cell provides the electric motive power. However, these vehicles are also excluded from this discussion because their refueling requires hydrogen for the fuel cell and FCEV designs do not currently use an EVSE for recharging a battery.

Figure 2 also shows that while PHEV sales were a sizable portion of overall PEV sales in the US, that percentage of total PEV sales has been generally decreasing over the past seven years. Figure 1 shows the same consistency for global sales. This is important because BEVs need greater and more consistent access to charging stations than do PHEVs, that otherwise may utilize their ICE component.

Because recharging a PEV battery consumes more time than refueling an ICE vehicle and most PEVs can travel less distance than a comparable ICE vehicle between recharging/refueling, the EVSE is installed in convenient locations to allow PEV drivers to recharge when they may be otherwise occupied.

Home (or residential) charging supplies most of the charging needs for most PEV owners. Residential EVSE installations are a direct result of PEV sales.

Public charging is used for those looking to increase the potential electric mile range beyond that realized from home charging or for those who may not have access to residential EVSE. Business owners may install EVSE and restrict their use to employees only (workplace charging) or supply charging stations for their own fleet of PEVs (fleet charging). Some business owners may install publicly available EVSE for use by the public as an encouragement to patronize their business or may charge a fee for use (commercial charging). Other EVSE providers install public EVSE along traffic corridors to promote higher vehicle utilization while realizing income from usage fees.

Figure 3 (DOE, n.d.) shows the growth of US non-residential public and private EVSE infrastructure from 2011 through 2021.

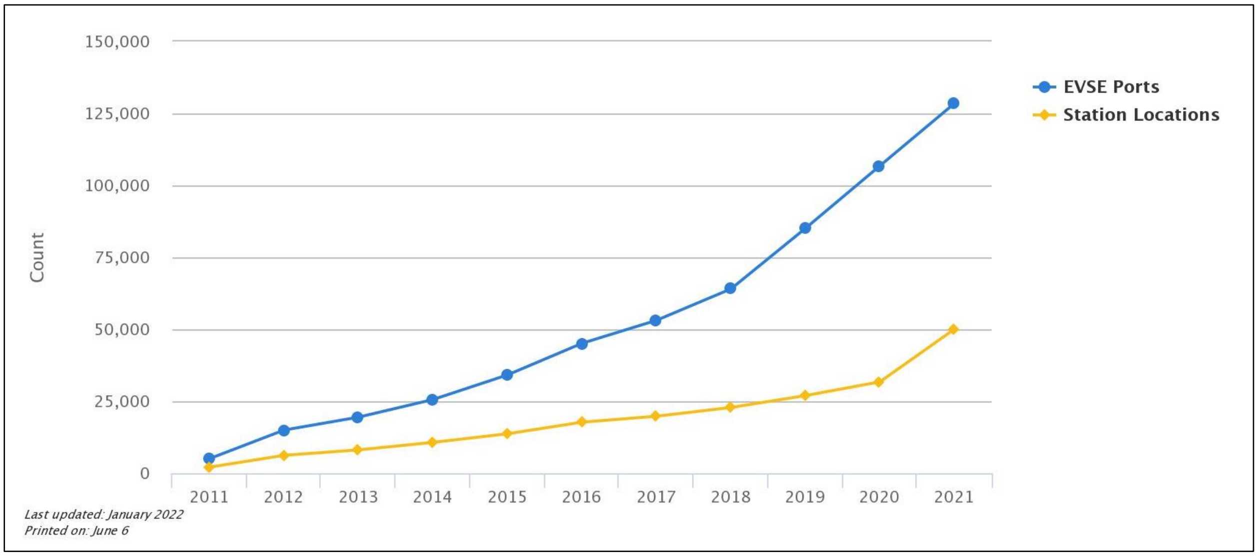


Figure 3. US Public and Private EVSE (DOE, n.d.)

While the upward trend of Figure 3 is significant, it is estimated that "9.6 million charge ports will be needed by 2030 to accommodate the predicted growth of the EV market. Almost 80% of those ports will be home chargers and about 20% will be public or workplace chargers." (ChargedEVs, 2022) This has been recognized as a priority in federal regulations as noted in the "2021 Infrastructure Investment and Jobs Act, which earmarked $7.5 billion for EV infrastructure at the federal level, $2.5 billion for EV charging and refueling infrastructure grants, and $5 billion towards the National Electric Vehicle Charging Program. The Biden Administration is also pursuing a goal of building and installing 500,000 DC charging stations across the country." (ChargedEVs, 2022)

There is a cost for the individual installation of the estimated 7.7 million residential EVSE and estimated 2 million public/private EVSE. This report supplies cost estimates for various categories (use-cases) of installation including the residential and public/private infrastructure. EVSE installation costs include both the cost of the equipment and the cost of its installation.

1.2 Electric Vehicle Supply Equipment Basics

The basic cost factors involved with EVSE designs are discussed in Appendix A. These include the method for power delivery, charging power levels, smart or basic units, the application for the EVSE and design specifics such as mounting method and number of connectors. Appendix A information related to EVSE costs are summarized here.

As discussed in Appendix A, while battery swapping and inductive (or wireless) charging systems are available for use for delivering power to the PEV, neither is mainstream in the U.S. and available data for this paper provides information on conductive systems only.

EVSE are rated by the electric utility power source. AC Level 1 units use 120 V AC circuits, AC Level 2 EVSE utilize 240 V AC circuits and DC Fast Chargers (DCFC) use 208/480 V AC circuits. In general, AC Level 1 would be the least costly (but slowest in delivery of energy to the PEV) and DCFC would be the costliest (but fastest in delivery of energy to the PEV).

EVSE are designed to be basic or smart units. Basic units fulfill the minimum design requirements to safely deliver electric power to the PEV while smart (also known as “networked”) EVSE provide other services. Such services may be access control, billing systems, networking capability, maintenance records and notifications, charging data, and so forth. Smart units need communication systems using the internet or cellular means and are more costly than basic units.

Wall mounted EVSE are generally cheaper than pedestal mounted units. While EVSE with more than one port may be convenient, they are more costly than single port units but typically less costly than two separate single port units.

This report will explore these cost factors based upon actual installation cost data. .

1.3 EVSE Installation

The installation of the EVSE requires on-site electrical work and typically requires area permitting and construction by a licensed electrical contractor. This cost is highly dependent upon the environment in which the EVSE is to be installed. Such cost factors include the distance the EVSE is to be installed from the power source, whether the utility input equipment needs upgrading, whether trenching is needed and if so, is it through concrete, landscape, or asphalt, and so forth. While the cost of the PEV may be known and the cost of the charging equipment identified, the cost of the installation most often requires a site visit and estimate by the licensed electrical contractor. This unknown factor may be a significant hurdle for PEV enthusiasts or interested business owners.

This report will explore the costs of buying and installing distinct types of EVSE with details of some of the cost drivers. This includes cost data for each of the most common EVSE types and their installation costs. Installation costs include labor (electrical and construction costs), raw materials (including wiring, conduit, construction materials, etc.), permit fees needed to perform the installation, travel costs incurred by the installer, and any added fees (such as design fees and overhead costs).

2 REPORT DATA

The data in this report was obtained from three main sources: Smart Charge America (SCA), the WestSmart EV project and The EV Project.

Since 2007, SCA (Smart Charge America, n.d.) has been working in the electric car charging business. It provides EVSE installation services for residential and commercial customers as well as supplying detailed information on the subject. Reporting over 11,000 installations overall, for this project SCA supplied more than 4,800 residential and 490 commercial installation records primarily from July 2018 to May 2022SCA works through their own network of in-house professionals, located in twenty major metropolitan areas in the U.S., and through outside contractors in other areas. Figure 4 shows the locations of the installations conducted supporting this analysis.

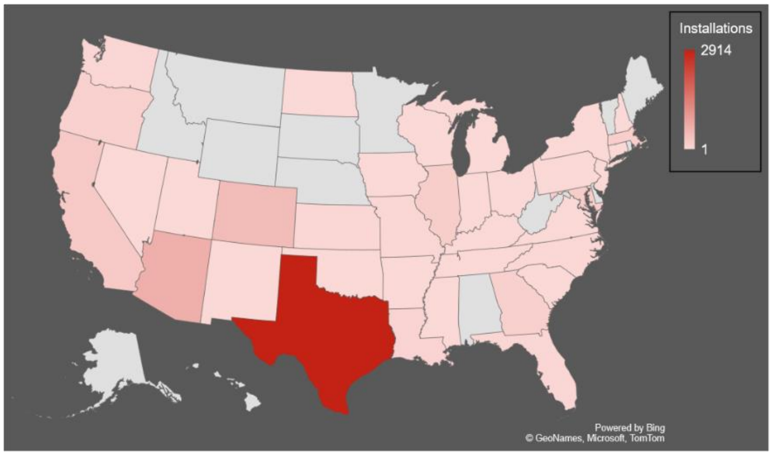


Figure 4. Map of installations completed by Smart Charge America

Table 1. SCA Installation Locations

State	Number of Sites Reported
Arizona	647
Arkansas	3
California	233
Colorado	463
Connecticut	1
District of Columbia	6
Florida	44
Georgia	146
Illinois	179
Indiana	3
Iowa	1
Kansas	40
Kentucky	2
Louisiana	79
Maryland	179
Massachusetts	157
Michigan	3
Mississippi	1
Missouri	43
Nevada	2
New Hampshire	1
New Jersey	1
New Mexico	1
New York	9
North Carolina	13
North Dakota	1
Ohio	2
Oklahoma	1
Oregon	122
Pennsylvania	4
South Carolina	2
Tennessee	2
Texas	2,914
Utah	1
Virginia	8
Washington	42
Wisconsin	1

INL also received data on fast charging installations from WestSmart EV (WSEV) Project. WSEV is Department of Energy (DOE) funded project to establish a 1,500-mile interstate PEV charging network across Utah, Idaho, and Wyoming through installation, operation, and data collection on DCFC, Level 2 commercial chargers, and Level 2 residential chargers. As part of this project, INL received data detailing the costs of 16 fast charging sites. Most of these installations were completed in 2019.

The EV Project was a deployment of over 12,000 AC Level 2 charging units and over 100 dual-port DC Fast chargers in 20 metropolitan areas across the United States. (INL, n.d.) The EV Project was conducted from 2010 to 2013. The EV Project costs were adjusted for inflation to 2019 dollars at a factor of 1.1 (Webster, 2022).

Figure 5. The EV Project Territory (INL, n.d.)

The EV Project initial scope included the areas noted in Figure 5 for both ACL2 and DCFC installations. Later, Georgia, New Jersey and Illinois were added. Eighty-eight of the DCFC units provided the data used in this report.

Table 2. The EV Project DCFC Installations

State	Number of DCFC Reported
Arizona	17
California	31
Oregon	14
Tennessee	14
Washington	12

3 COST ANALYSIS

3.1 EVSE Costs

To investigate the purchase price of distinct types of charging infrastructure, an internet search was completed on the EVSE available for purchase in July 2022. Amazon.com (Amazon, n.d.) identified more than 150 EVSE designed for residential applications from thirty-two different suppliers. Certainly, there are other suppliers not listed on Amazon.com but these supply significant pricing information.

EVSE prices are dependent upon the attributes of the equipment wanted by the consumer. These attributes are discussed in the following sections.

3.1.1 Cordsets

Most PEV OEMs provide a cordset with the vehicle. Tesla is one OEM that used to provide this cordset but no longer provides it free. A cordset typically uses a 120 V AC circuit to supply power to the PEV. It simply has the required safety and electrical design attributes to be a means to supply power and is generally considered to be an emergency use only device. That is, it may not be designed for use several times per day for the life of the vehicle, although the PEV user may choose to use it in this manner. Cordsets are typically portable in that they are not permanently attached to a circuit. Some cordsets are provided with a means to hang the cordset on a wall but the unit still is portable. Figure A-5 shows such a cordset.

Cordsets may display charging information for the current or most recent charge, but most are not smart per the definition in Appendix A. A few of the cordsets did supply a means to delay the start of a charge using an internal timer.

Cordsets may be AC Level 1 (ACL1) or Level 2 (ACL2) and several displayed on the Amazon site include adapters to allow selecting between the two. Cordsets configured as AC L1 deliver approximately 1.4 kW power when connected to a 15-amp circuit, supplying the slowest battery recharge rates. A 20-amp circuit could deliver approximately 1.9 kW power. This may suffice for PEV drivers with low daily travel requirements as it typically requires approximately 17 hours to charge a fully depleted average sized BEV battery.

The PEV owners for whom the ACL1 corset is sufficient may buy a second cordset to keep their original cordset for emergency use. There were 15 ACL1 cordsets listed on Amazon.com ranging in cost from $110 to $399. The median cost was $189.99. There were slight differences in features, such as cord lengths that varied from 20 to 25 feet. The Tesla cordset sells at $200.

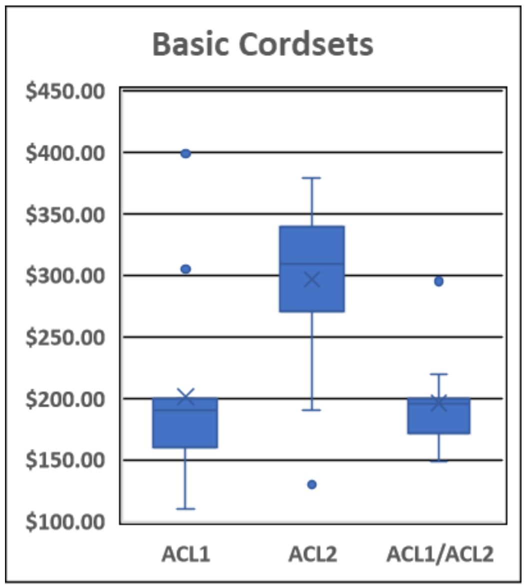


Figure 6. Basic Cordset Costs

Seventy cordsets were found that provided ACL2 (including those that could be used on ACL1 circuit) where costs varied from $129.99 to $549. The median cost was $299.99. Here again, there were slight differences between designs. These ACL2 cordsets provide between 3.3 kW to 7 kW power. They supply up to 7 hours and 3.5 hours to recharge a fully depleted BEV battery, respectively.

Two cordsets were smart in that they supplied wireless internet connections. The average price was $429.49. The value of a smart EVSE in residential applications is debatable. It may be of value in areas where the electric utility tariffs are higher during peak times and the EVSE is used to schedule the charge times although many PEV models provide that scheduling option in the PEV itself. A cheaper alternative to going smart may be the installation of a mechanical timer for about $65.

3.1.2 Residential Wallmount EVSE

The National Electric Code (NEC) Section 625 covers specific requirements for the installation of EVSE and includes that permanently installed EVSE must be supplied by an individual branch circuit. Many wallmount EVSE are designed with a plug to mate with the circuit receptacle, but it is expected that that circuit is also an individual branch circuit. A wallmount EVSE with a plug can be converted to be direct wired to the circuit.

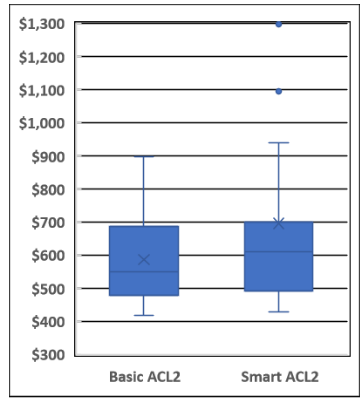


Figure 7. ACL2 Wallmount Costs

The Amazon.com search found 55 ACL2 wallmount units; 30 of which were basic units. These ranged in price from $335 to $899. Two units were identified with prices of $1,389 and $1,524 but these appeared to be directed for commercial operations. The median price for a basic ACL2 wallmount EVSE was $549.

The 25 smart ACL2 EVSE included three listed at over $1000; one of which was designed for an 80-amp circuit. These appeared to be more focused on commercial operations. The median price for the 22 units was $575.

Rocky Mountain Institute identified cost ranges for ACL2 residential EVSE at $380 - $689 depending upon the power delivery design (Neider, 2019). It also shows the equipment costs for EVSE have steadily decreased since 2010. The entry of many more EVSE providers into the market has a downward impact on prices.

The International Council on Clean Transportation (ICCT) issued a report in 2019 on infrastructure costs across U.S. metropolitan areas. In this report for residential charging, ICCT identifies the average costs associated with a single home for an ACL1 circuit upgrade at $400 and the average costs associated with a single home for an ACL1 charger upgrade at $700 or an average EVSE cost at $300. In addition, it identifies the average costs associated with a single home for an ACL2 circuit upgrade at $680 and the average costs associated with a single home for an ACL2 charger upgrade at $1,400 or an average EVSE cost at $720 (Nicholas, 2019).

Tesla's ACL2 residential EVSE Gen 3 smart EVSE is listed at $400 (Tesla, n.d.) and the Gen 2 basic is listed at $500. The Gen 3 is rated at up to11.5 kW and the Gen 2 at up to 20 kW.

SCA provides installation services for all EVSE suppliers but has a special relationship with Tesla. In the residential installations, SCA provided 3,274 (95%) installations for Tesla EVSE and a total of 173 (5%) for other EVSE suppliers. They also provided 1,383 installations of the circuit only with the customer supplying the EVSE. Because EVSE cost information from SCA would be heavily influenced by the Tesla unit costs, it is not included in analyzing EVSE costs.

3.1.3 Residential Power Rating

The electrical rating of the ACL2 wallmount units found at Amazon.com generally ranged from 30 to 50 amps (5.8kW to 9.6kW). Typically, EVSE costs increased as the electrical rating increased for both smart and basic EVSE. This rate of change for smart EVSE in Figure 8 is approximately $7.50 per kW increase.

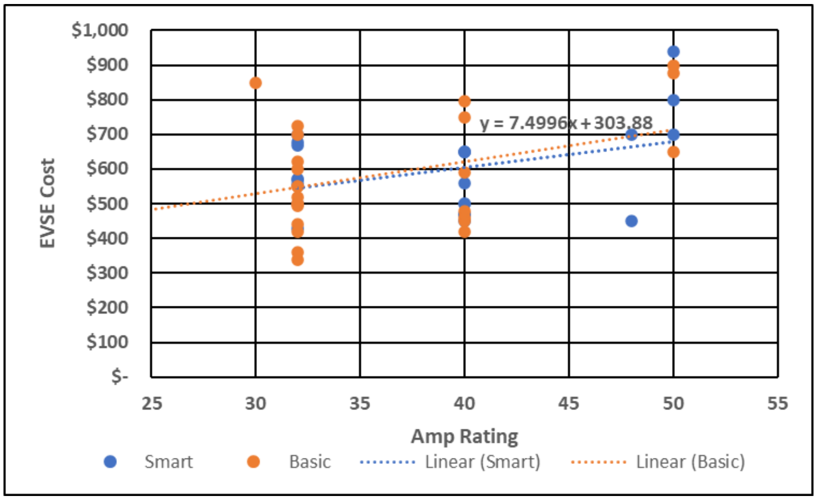


Figure 8. EVSE Cost vs kW Rating

3.1.4 Residential Dual port ACL2 EVSE

For residential users with two or more PEVs, a dual port EVSE may be desired. Four such EVSE were listed on Amazon.com at prices from 1.9 to 2.2 times the price of a single port unit.

3.1.5 Residential/Commercial Pedestal Modification

Pedestal EVSE are generally required when a wall or vertical structure is not available to which a wallmount EVSE may be attached or for EVSE especially designed to be free standing. Residential applications may include carports or other unenclosed areas. None of the Amazon.com EVSE were identified for pedestal applications. Clipper Creek offers a pedestal to which their ACL2 outdoor models may be attached for $800 (ClipperCreek1, n.d.) These pedestals may require an added bracket for a second wallmount EVSE. Clipper Creek offers this bracket for $215. Their quad mount kit is priced at $472.

EvoCharge (EvoCharge, n.d.) supplies pedestals at 4-, 6- and 8-foot heights starting at $886. The Tesla residential pedestal sells for $425.

3.1.6 Residential/Commercial Cable Management Systems

Cable management systems are desired to keep the charge cord off the parking surface. Some designs intend the cable to be wound around the EVSE unit. There is no cost for this, but the cord must be manually restored after each use.

Some systems supply an extension kit or retractor that is added to the top of the pedestal or attached to a wall. See Figure A-8 for one example. Clipper Creek offers a single extension kit for $1,132 and a dual extension kit for $1,605 (ClipperCreek2, n.d.). EvoCharge offers a similar system for $1,308. Dan Ultra EVSE cable management system was found on Amazon for $200.

Another system for cable managements includes a reel retractor. Clipper Creek offers one for use with the wall mount unit for $549. EvoCharge supplies the retractor for $1518.

3.1.7 Basic Commercial ACL1 EVSE

Figure 9.Plugzio Smart Outlet (Plugzio, n.d.)

Commercial ACL1 EVSE can be as simple as supplying a 120 VAC weatherproof outlet in a parking lot and allowing the PEV driver to plug in their own cordset. These may be found in fleet applications or workplace parking lots. In some cases, a locking cover may be provided to prevent theft of the cordset while charging.

There are some suppliers of adapters to the outlet to allow access control, billing and data collection. The Figure 9 Plugzio (Plugzio, n.d.)outlet costs between $297 to $597 depending on the communication type. Applications for these units include multi-unit dwellings, such as apartment building or condominiums, and workplace parking lots. The access control and communications allow authorized users only and provide billing capabilities.

3.1.8 Basic Pedestal ACL1 Commercial EVSE

Figure A-3 shows a commercial ACL1 pedestal EVSE from PowerPost. Their website provides a price of $1,495 for a basic single station unit. This unit includes a retractable cord reel. These units find applications in workplace charging, fleet charging, long term charging at airports, or any other application where a vehicle may be parked for several hours. As a basic unit, there is no access control or method for billing for usage. According to the website, “63% of ‘public access’ charging stations are currently free to use. Facilities are increasingly offering recovery charges as a perk.” (Powerpost, n.d.)

The ICCT working paper(Nicholas, 2019) identified the average hardware cost for a single port, basic, non-networked, pedestal mounted, 1.4 kW ACL1 commercial EVSE at $813 per EVSE.

3.1.9 Basic Pedestal ACL2 Commercial EVSE

The PowerPost website provides a price of $1,795 for a basic single station ACL2 unit. This unit is like their ACL1 pedestal unit including applications and features.

EvoCharge offers a pedestal mounted basic ACL2 without cable management for $1,365 and with the cable reel for $2,901 and cable retractor for $2,447.

The ICCT working paper (Nicholas, 2019) identified the average hardware cost for a single port, basic, non-networked, pedestal mounted, 6.6 kW ACL2 commercial charger at $1,182.

3.1.10 Smart (Networked) ACL2 Commercial Wallmount EVSE

Commercial wallmount EVSE typically supply many features not found in residential units including networking capability, access control, billing mechanisms, input to mapping and reservations systems, etc. Commercial applications for networked ACL2 wallmount units include locations where a wall or other mounting surface exists for multi-unit dwellings, public charging (destination charging or fuel stop charging), fleet charging where access control or allocation of charging costs are important.

3.1.11 Networked ACL2 Commercial Pedestal EVSE

As with residential charging, some electric vehicle service providers (EVSP) of commercial wallmount EVSE supply pedestals for attachment. Other providers design equipment as pedestal (also known as bollard) units. Figure A-5 shows a pedestal designed commercial ACL2 EVSE.

The Rocky Mountain Institute paper (Neider, 2019) identifies ACL2 commercial EVSE from $2,500 (7.7 kW power) to $4,900 (16.9 kW power).

The ICCT working paper (Nicholas, 2019) identified the average hardware cost for a single port, networked, pedestal mounted, 6.6 kW ACL2 commercial charger at $3,127.

3.1.12 DC Fast Charger

DC fast chargers (DCFC) enables the fastest recharging capabilities of all EVSE. The conversion from AC to DC power occurs in the unit so DC is delivered to the vehicle. As with AC EVSE, the vehicle's on-board battery management system controls the charge rate. Most currently installed DCFC deliver 50 – 60 kW but technology is increasingly adding to capabilities of 150kW and up. Companies like Tesla and Electrify America are now building most of their charging stations with DCFC that can supply 150kW to 350kW. Development of up to 3.75 MW power capability is planned especially for recharging heavy duty class 8 trucks (Morris, 2021). The cost of DCFC is highly dependent upon the output capability as the higher the output current, the greater design considerations need be over connector heating along with the higher cost of power conversion.

DCFC are typically found on traffic corridors where high utilization is expected. There are a few in workplace charging or fleet charging but the high cost of a unit typically means it is networked and owned by the EVSP. The Alternative Fuels Data Center (AFDC) supplies information, data, and tools to support decision makers in the use of alternative and renewable fuels. It currently lists 6,358 DCFC public stations with a total of 27,058 ports (AFDC, 2022) .

Rocky Mountain Institute (Nicholas, 2019) identifies the range of DCFC costs by power level: for 50 kW units as $20,000 to $35,800; for 150 kW units from $75,600 to $100,000 and for 350 kW units from $128,000 to $150,000.

In 2019, the ICCT working paper (Neider, 2019) reported average DCFC costs for 50 kW units as $28,401; for 150 kW unit as $75,000 and for the 350 kW unit units as $140,000. Costs are summarized in Table 3. In most cases, providers of DCFC do not publicly post prices.

Table 3. DCFC Cost by Power (Nicholas, 2019)

	Average Cost	$/kW
50 kW	$28,401	$568
150 kW	$75,000	$500
350 kW	$140,000	$400

3.1.13 Summary for EVSE Cost Estimations

- Basic ACL1 cordset - $190
- Basic ACL2 cordset - $300
- Basic residential ACL2 wallmount - $550
- Residential EVSE costs typically increase with increasing power rating at approximately $7.5/amp
- Smart (networked) residential ACL2 wallmount - $575
- Basic ACL1 commercial pedestal – $1,500
- Basic ACL2 commercial pedestal – $1,750
- Smart ACL2 commercial wallmount – price highly dependent on features and network with low end costs about $800, average at $1,500 and high end above $5,000
- Smart ACL2 commercial pedestal – price highly dependent on features and network with low end costs about $2,500, average at $3,127 and increasing with high end above $8,000

- EVSE accessories such as pedestals ($400 - $900), retraction mechanisms ($550 - $1,600), wheelstops ($35 - $50), signage ($10 - $26) add to equipment costs
- Smart DCFC – price highly dependent on power rating, features, and network

3.2 Installation Costs

For this paper, residential installations typically involve single family housing and commercial installations include workplace, public/retail, fleet and multi-family dwellings. While multi-family dwelling installations are primarily for the PEV driver and therefore at their "residence", the installation is more typically that of a commercial installation in likely requiring networked EVSE and parking garage type installations.

3.2.1 Residential Installation Costs

A residential driver of a PEV may choose to install just the electrical circuit in the home. The ICCT working paper (Nicholas, 2019) on installation costs show installation costs in a single home to upgrade for a new ACL1 circuit at an average cost of $400 and an upgrade for a new ACL2 circuit at an average cost of $680. In this ICCT working paper, for single family detached housing, it is noted the underlying studies reflect installed costs ranging from $650 to $2,423 with the higher costs associated with a greater number of wall penetrations, total circuit distance, or service upgrades.

Total cost of installations was available from each of the charging sites in the SCA dataset. Installation costs ranged from a low of about $150 for an easy installation to about $18,000 for a particularly challenging installation. The distribution of installation costs is shown in Figure 10.

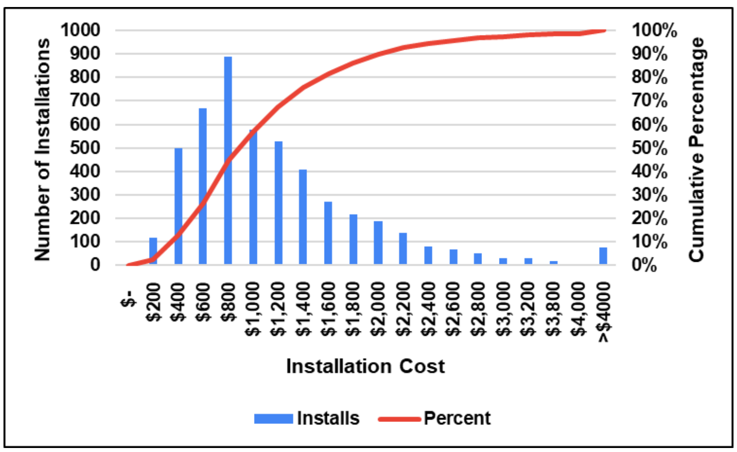


Figure 10. Distribution of Residential Installation Costs

While the average installation cost is $1,310 and the median cost is $1,098, 45% of installation costs are less than $800. Costs here may be higher than that found in the ICCT working paper because of the costs for many of the installations exceeding the high end of their study of $2,423 for factors related to installations discussed in Section 3.4.

3.2.2 Commercial Installation Costs

The ICCT working paper (Nicholas, 2019) on installation costs identifies installation costs for commercial ACL2 EVSE by the number of chargers per site. Installation costs per charger decrease as more units are installed at a particular site. Table 4 shows the breakdown of average costs associated with the installation of a single EVSE per site.

Table 4. ACL2 Commercial Installation Cost (Nicholas, 2019)

	In California	Not California
Labor	$2,471	$1,544
Materials*	$1,235	$1,112
Permit	$283	$82
Taxes	$156	$96
Total	$4,148	$2,836

*not including EVSE

3.2.2.1 Multi-Unit Dwellings

Muti-unit dwellings (including condominiums and apartments) are a special case of commercial installations. Typically installed for the PEV owner in the multi-unit dwelling, the EVSE would usually be installed in a specific location in the parking garage. There are exceptions where the condominium owner installs EVSE for the benefit of several potential owners. The difference is typically found in the data where one EVSE would indicate a single person and more than one EVSE or circuit would indicate the condominium owner's intent. Of the 490 circuits installed by SCA, 163 were installed in condominiums or apartments. Single units were installed in 133 of these sites. Installation costs ranged from $544 for hardwire an EVSE into a circuit to $61,389 to install 18 ACL2 Wallmount units.

For single unit EVSE, installation costs for ACL2 circuits ranged from $544 to $13,537 and are shown in Figure 11. Fifty-four percent of these installations were under $4,000. The average installation cost was $4,548 and the median installation cost was $3,983.

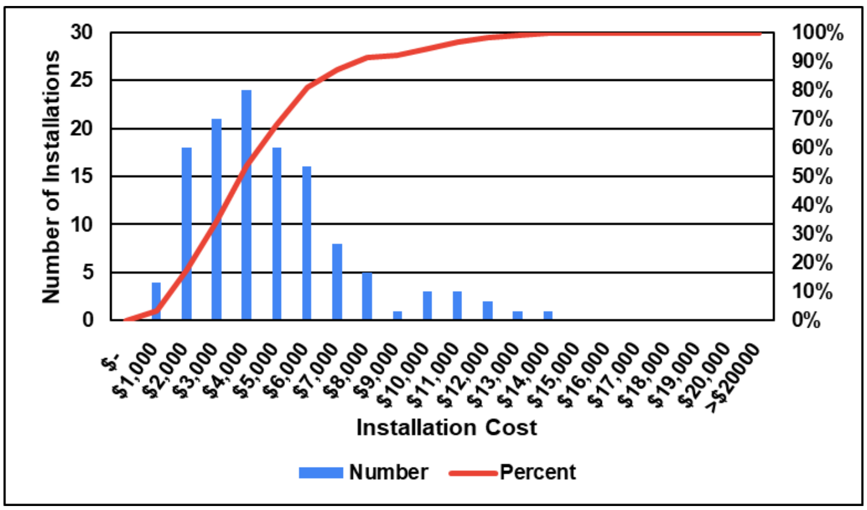


Figure 11. Condominium Installations (Single EVSE)

The ICCT working paper (Nicholas, 2019) also identified average apartment installation costs as $600 for an ACL1 circuit and $3,300 for ACL2 circuit. The average installation cost found in the SCA data is approximately $1,250 higher than that found by ICCT. This could be due to some of the cot factors explored in Section 3.5 such as circuit length or higher power circuits.

Twenty-five installations by SCA involved two or more EVSE. The cost per EVSE ranged from $1,475 to $5,220.

3.2.2.2 Commercial Installation Costs

Eighty-eight commercial installations involving a single EVSE were provided in the data from SCA, and Figure 12 show installations costs from those jobs

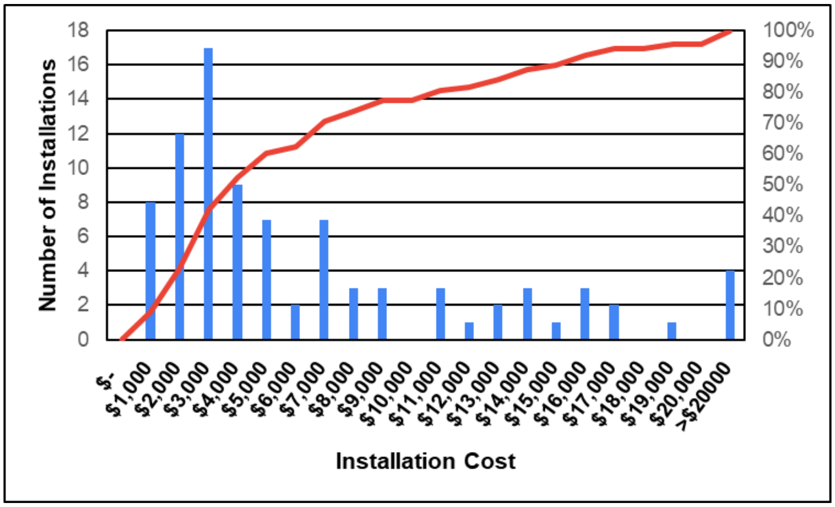


Figure 12. Commercial Installations (Single EVSE)

The average cost of installation was $6,628 which is highly influenced by the three high-cost installations. The median cost of installation is $3,959 which appears to be more representative. 52% of all installations cost less than $4000.

3.2.3 DCFC Installation Costs

As with the DCFC equipment costs, installation costs for DCFC as reported by the ICCT working paper (Nicholas, 2019) are identified by DCFC power requirements. For 1 DCFC per site, installation costs are identified in Table 5 below. The cost per unit decreases as more units per site are installed.

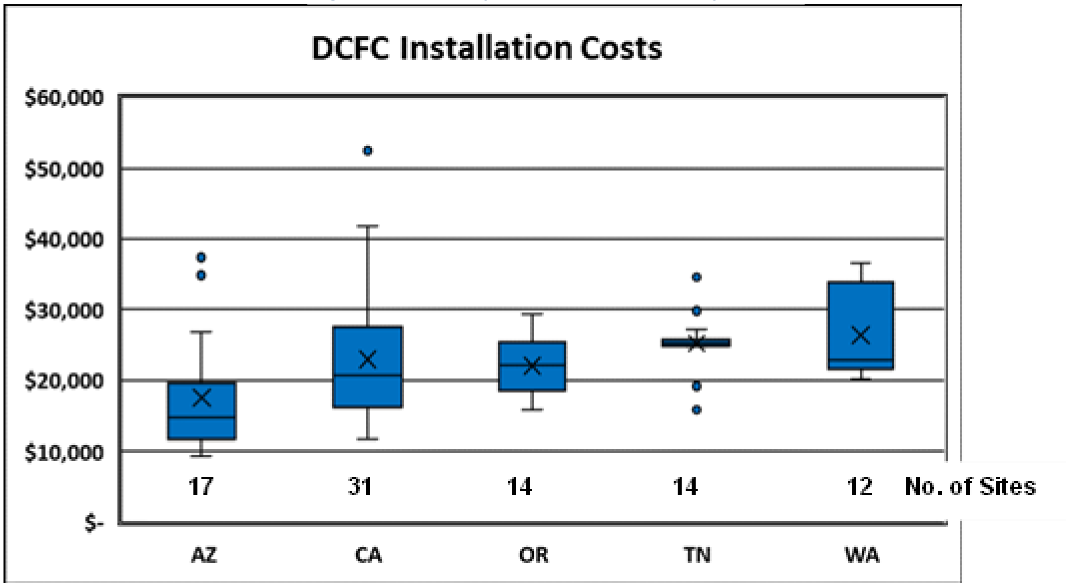
Table 5. DCFC Installation Cost (Nicholas, 2019)

	50 kW	150 kW	350 kW
Labor	$19,200	$20,160	$27,840
Materials*	$26,000	$27,300	$37,700
Permit	$200	$210	$290
Taxes	$106	$111	$154
Total	$45,506	$47,781	$65,984
$/kW	$910	$318	$189

*not including the fast charger

The EV Project installed 111 DCFC and supplied the detailed cost projections for more than 50 additional sites. One site was an extreme at $81,000 so it is eliminated. Also eliminated are states where the total number of installations was less than 10 DCFC. Tennessee was unique since all sites were with the same host and electric utility, thus making all sites nearly equal in cost. The examination of the installation costs after adjusting for inflation for these 60 kW units is shown in Figure 13.

Figure 13. EV Project Installation Costs by State



For each of the states, Figure 13 shows the average installation cost as the "X". The box outlines the 25thf percentile and 75th percentile while the mid-line shows the median value. The local minimums and maximums are displayed above and below the box with specific outliers noted by dots. The average installation cost for DCFC in the EV Project was $22,597 adjusted to 2019.

SCA supplied installation data for 17 DCFC. Five of these installations involved the installation of ACL2 EVSE or additional DCFC, and the data does not provide a breakdown between different power levels or DCFC types. Once installation included the installation of 18 Tesla superchargers at an installation cost of $301,135 or an average of $16,729 per DCFC. For the remaining 12 single unit DCFC sites, a summary of the installation work is shown in Table 6. Details of the installation costs, such as the circuit was already installed, are not available.

Table 6. SCA DCFC Installations

Description	State	EVSE Provider	Power Rating	Installation Cost
Install Proterra EVSE	Oregon	Proterra		$4,083
Install CPE250 + CT4021	Colorado	ChargePoint	62.5 kW	$4,700
Tie in Dual EFACEC	California	EFACEC	160 kW	$8,939
Install CPF25 – CPE100	Texas	ChargePoint	24 kW	$9,234
Install CPE250	Texas	ChargePoint	62.5 kW	$9,716
Install Tesla Superchargers	Texas	Tesla	~150 kW	$10,797
Install Tesla Superchargers	Texas	Tesla	~150 kW	$15,372
Proterra	California	Proterra		$16,835
Proterra	California	Proterra		$22,748
Install CPE250 + CT4021	Colorado	ChargePoint	62.5 kW	$35,653
Tesla Supercharger	Texas	Tesla	!150 kW	$35,820
Tie-in Proterra	Oregon	Proterra		$103,271

3.3 Factors Influencing Installation Cost

Several factors are common to the installation of EVSE regardless of type. The data was analyzed to determine the distinct factors that influence cost. These items are found below and detailed in the following sections.

3.3.1 Power Rating

The amount of power an EVSE can supply to a vehicle's battery is generally correlated with the cost of the EVSE. As power (or amperage) increases, the components in the EVSE are rated to a higher current, which means larger conductors and more expensive components. However, one should be aware that different vehicles can accept different levels of charging, so the power of an actual charge can be limited by the vehicle's battery management system or by the capabilities of the EVSE. (ChargeHub, n.d.)

3.3.2 EVSE Accessories

The way an EVSE is mounted influences the price. Figure 14 shows a Tesla wallmount charger (Tesla, n.d.) attached to a pedestal. Mounting an EVSE to a wall tends to be the lowest cost choice and is quite common for most residential charging. Since public EVSE are often placed in parking lots where employees or customers would want to use them, they often need to be pedestal mounted, which will increase the price.

Figure 14. Pedestal for Wallmount EVSE (Tesla, n.d.)

All DCFC are mounted as pedestal units, and this is not a factor in their installation.

The charge cable is approximately 20 feet in length. Figure 14 shows the cable is wrapped around the EVSE to keep it off the floor or ground. Systems are available to automatically retract or otherwise manage the charging cord.

Other accessories include wheelstops, to optimally position a vehicle near the EVSE for charging, and signage.

3.3.3 Labor

The EV Project, which installed 12,000+ Level 2 EVSE and 100+ DC fast chargers in 19 cities between 2011 and 2014 (INL, 2015) found one of the significant cost factors in the installation of residential EVSE was the labor cost. Labor costs reflected the prevailing market wages that varied from $55/hour near San Francisco and Seattle to as low as $11/hour in Texas.

3.3.4 Connection Type (hardwired vs plugged in)

Residential EVSE comes with distinct types of plugs (110v, 240v), depending on the level of EVSE or may be hard-wired directly to the electrical circuit by a certified electrician. The cost varies slightly between hard-wired and a plug. For example, ClipperCreek sells the LCS-20 (hardwired) for $379. The LCS-20P (same model but with a plug) sells for $395. Another example is the ChargePoint Home. The hardwired station is $519, while the plug-in station is $559. Siemens US2 hardwired sells for $442. The Plug-in station sells for $488. In general, the plug-in is preferred because the electrical circuit can be installed under a simple permit without having the EVSE on hand. Approximately 28% of the SCA installations were circuit installations with the customer supplying the EVSE. Some jurisdictions increase the permit fee if an EVSE is involved.

All commercial EVSE and DCFC are hard-wired, so this is not a factor for them.

3.3.5 Electric Utility Upgrades

Some electric utilities offer time of use (TOU) rates that encourage PEV charging during their off-peak demand times. Some of those electric utilities offer rates that require the PEV charging to be separately metered through a special utility meter. One example is San Diego Gas & Electric that has the EV-TOU or EV-TOU-5 rate using the normal house meter but the EV-TOU rate for a separately installed meter.

Some installations, residential or commercial require an electrical service upgrade. Electric utility costs associated with the upgrade can be significant. Some utilities provide this at little or no cost. Some installations, especially for DCFC require a significant upgrade or new service.

3.3.6 Physical distance from power source to EVSE

The physical distance from the service entry to the desired location of the EVSE affects the cost by the addition of conduit, conductor wiring and labor to install. Residential factors are typically less than commercial because commercial usually involves higher voltages and currents.

3.3.7 Hardscape Factors

The surfaces through which the cable run travels from the electrical service entry to the EVSE location also affects the cost. That surface may be landscaped that requires trenching or concrete/asphalt surfaces that require removal plus the trenching and restoration. Surface mounted conduit is the cheapest method of routing power to the EVSE, if available.

3.3.8 Permit Costs

The addition of an electrical circuit requires a permit in most jurisdictions. That cost varies considerably between geographic locations. The EV Project found that the permit fee as a percentage of the installation cost varied from around 4% in Dallas and Oregon up to 14.5% in San Diego. Some locations have reviewed and streamlined their permitting process and reduced fees in order to be favorable toward PEV adoption.

3.4 Factors Influencing Residential Installation Cost

3.4.1 Power Rating

The data provided by SCA identifies the power rating of the EVSE or installed circuit. Figure 15 shows the range of these circuit power ratings.

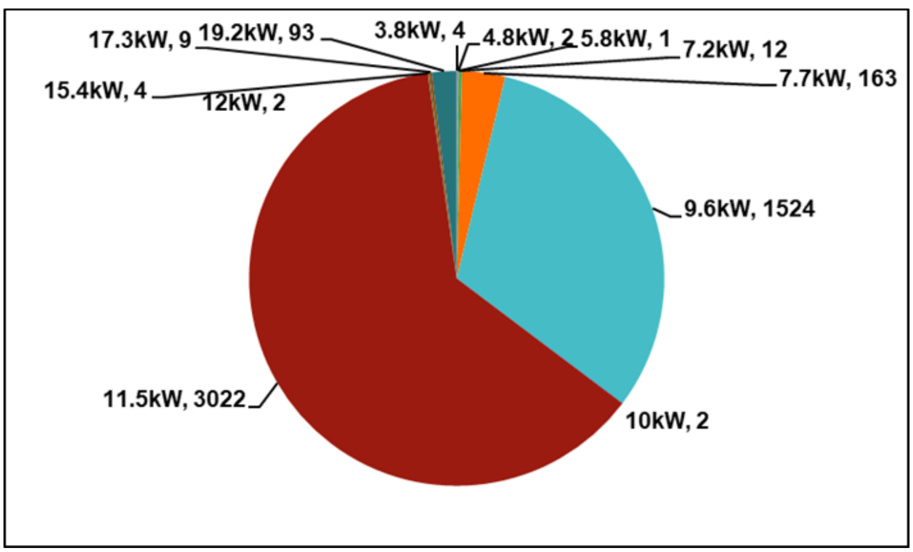


Figure 15. Residential Circuit Ratings

Figure 16 shows the residential installation cost vs the circuit power rating. On average, the circuit cost increased approximately $92 per increase in kW in circuit power rating. But there is a wide range of costs within the same power rating, which suggests that, while higher power rating EVSE would typically cost more to install, there are also other factors that may affect installation costs.

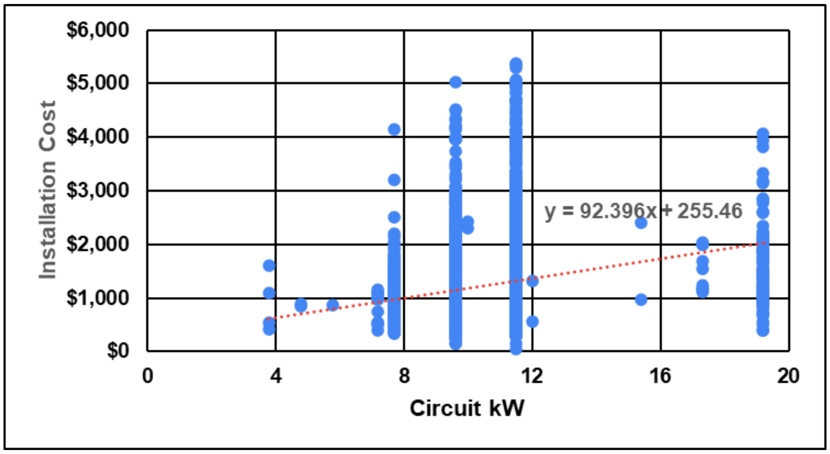


Figure 16. SCA Residential Circuit cost vs Power Rating

3.4.2 EVSE Accessories

For the residential installations provided by SCA, accessories were included in 224 installations, or about 5% of the installations. The cost of the accessories varied from $49 to $900.

3.4.3 Labor

The SCA average residential installation cost by state is compared to the electrician typical hourly wage as reported by Bureau of Labor Statistics (BLS, 2021). The result is shown in Figure 17.

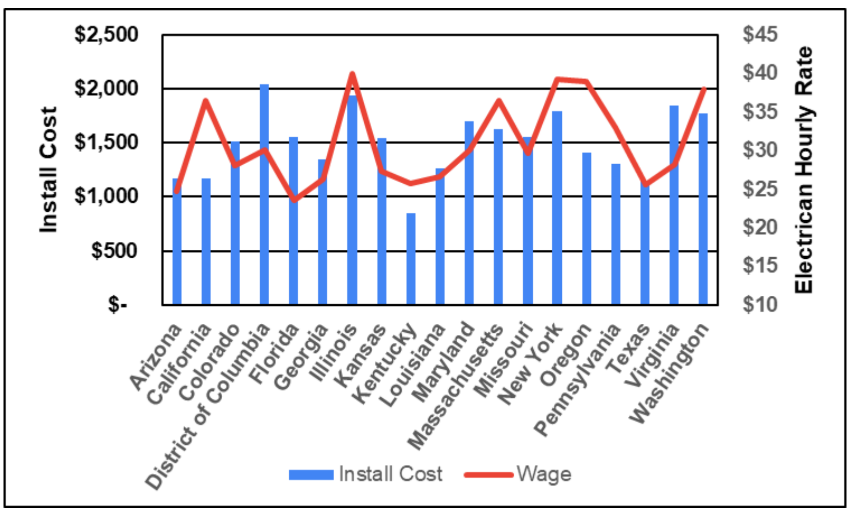


Figure 17. SCA Installations and Average Cost

While some of the states had just a few installations, in general, the cost for installation reflects the local electrician hourly labor rates.

3.4.4 Electric Service Upgrade

Six of the SCA installations required a service upgrade of the residential panel. The total installation costs for these varied from $2,558 to $5,341. With the average installation cost of $1310, the upgrade cost ranged from $1,248 to $4,031.

3.4.5 Physical distance from power source to EVSE

To evaluate the relationship between cost and distance to the power source, Figure 18 only considers circuits of 7.2 or 7.7 kW, Figure 19 only considers circuits of 9.6 kW and Figure 20 circuits of 11.5 kW.

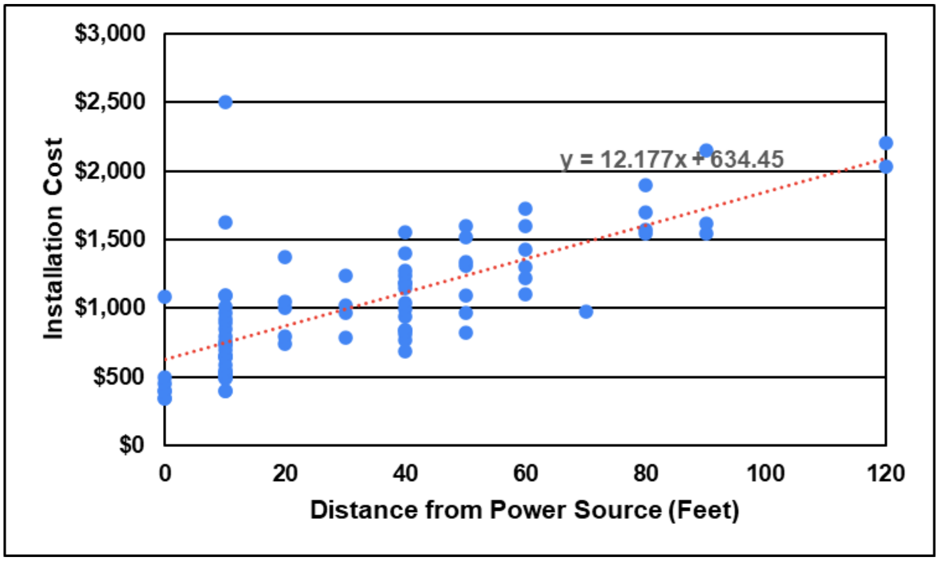


Figure 18. SCA Residential Installation Cost for 7 kW Circuit vs Distance

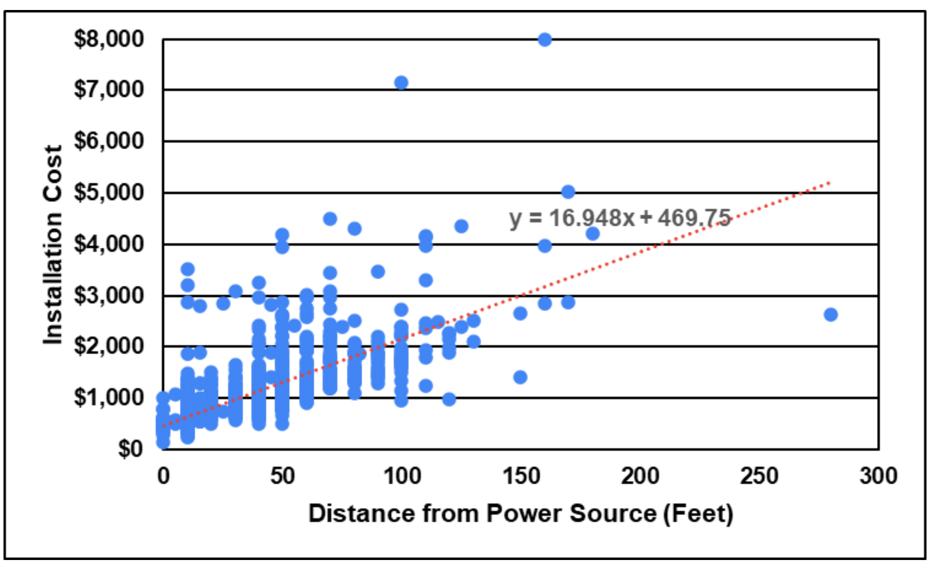


Figure 19. SCA Residential Installation Cost for 9.6 kW Circuit vs Distance

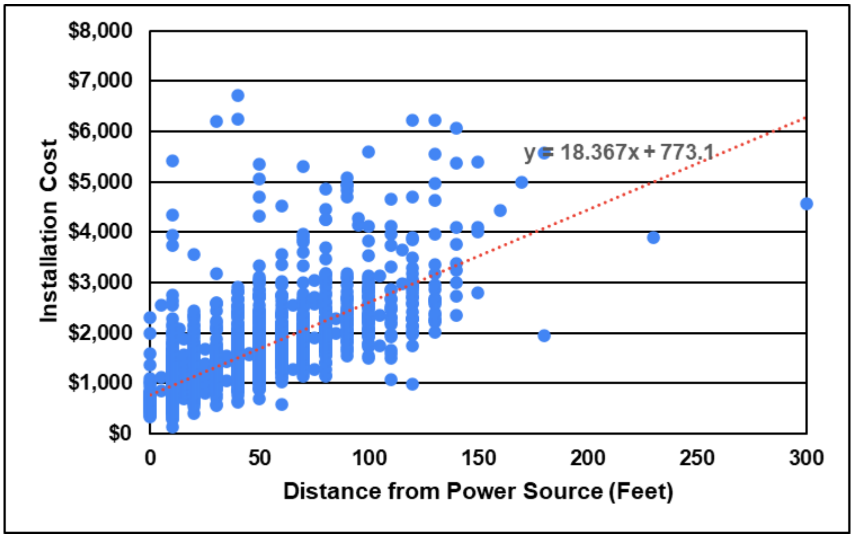


Figure 20. SCA Residential Installation Costs for 11.5 kW Circuit vs Distance

For the average installation, the installation cost increases between $12 - $18 per foot distant from the power source. The easiest installation would be an attached garage where the EVSE is installed directly on the opposite side of the wall from the power entry mains indicating the shortest distance possible.

3.4.6 Hardscape Factors

The SCA data provided no information relative to hardscape factors.

3.4.7 Permit Costs

Most residential installations for which permit costs are available took place in Texas. There the permit fees ranged from $15 in North Richmond to $100 in Dallas. As a percentage of the total installation costs, the permit fee ranged from 0.3% to 11.3% with the average of 3.5% of overall installation cost.

3.4.8 Time to Install

While the time it takes from customer decision to completion of installation is not a direct cost factor for residential installations, it can have an impact on the PEV buyer's decision to move forward with the purchase. Most owners would want to have the EVSE installed in their home by the time they take delivery of the vehicle. The easiest way to carry out this would be to have the circuit installed ahead of time for a plug-in EVSE. Figure 21 explores the average installation costs vs average installation days. The overall average time from contract to installation completion is 21 days.

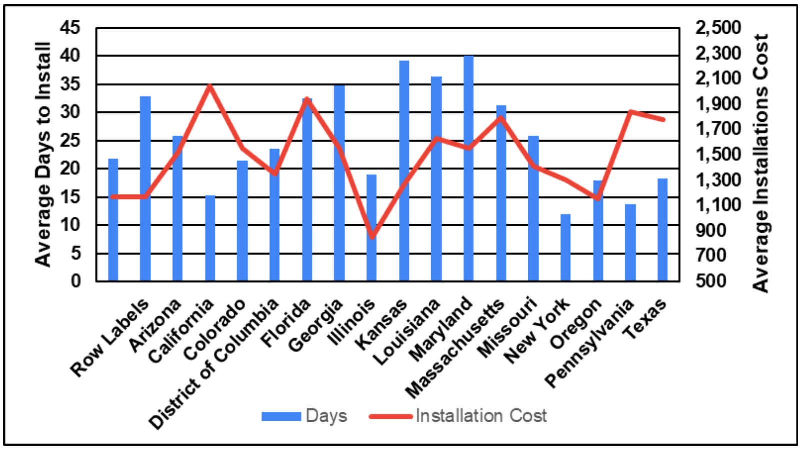


Figure 21. Average Times Contract to Install

3.4.9 Summary for Residential EVSE Installation Costs

Residential installation costs vary because of physical conditions at installation with median cost of $1,098.

- Circuit costs increased approximately $92 per increase in kW rating above 4 kW
- Approximately 5% of residential installations involve accessories that vary in cost from $49 to $900
- Installation costs are greatly dependent upon local electrician rates
- Service upgrades for residential installations are rare but added about $2,600 when needed.
- The physical distance the EVSE is installed from the power source adds about $12 per foot
- Permit fees typically make up 3.5% of overall project costs
- The average time from contract to installation completion is 21 days
- The average electrician's man-hours required for the installation was 5.4 hours

3.5 Factors Influencing Commercial Installation Cost

3.5.1 Power Rating

SCA supplied circuit power ratings for 112 condominium installations. Figure 22 shows the distribution of these installations.

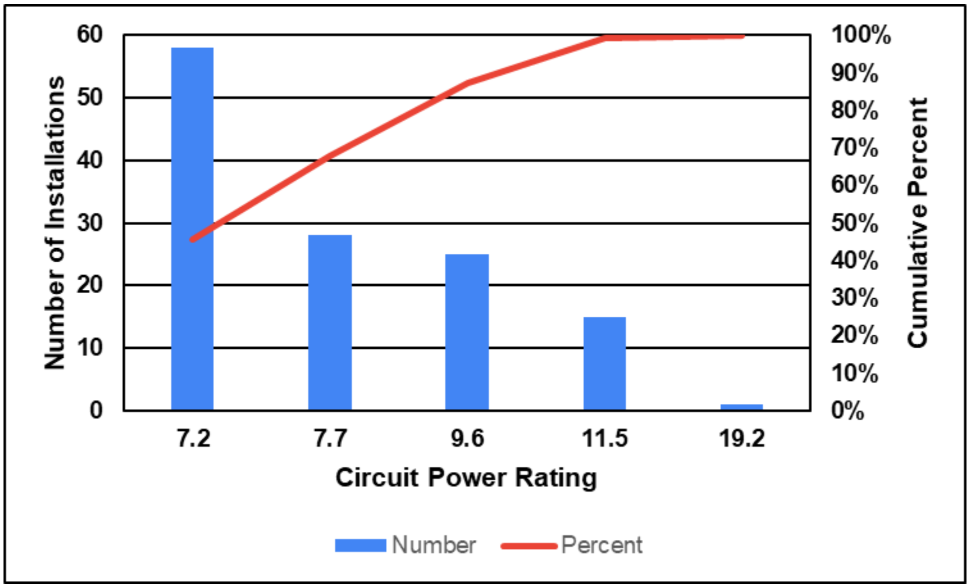


Figure 22. Distribution of Circuit Power Ratings

Installation costs for these ranged from $544 to $13.859. A comparison between the installation costs and the power rating yielded no significant observations; likely because the number of installations was insufficient.

For other commercial installations, the relationship between installation costs and circuit rating was investigated. For installations involving a single EVSE unit, the change in installation cost for power rating is shown in Figure 23. Only circuits of less than 150 feet were considered to reduce the distance cost influence. As before, a clear relationship between the circuit rating and cost is not present.

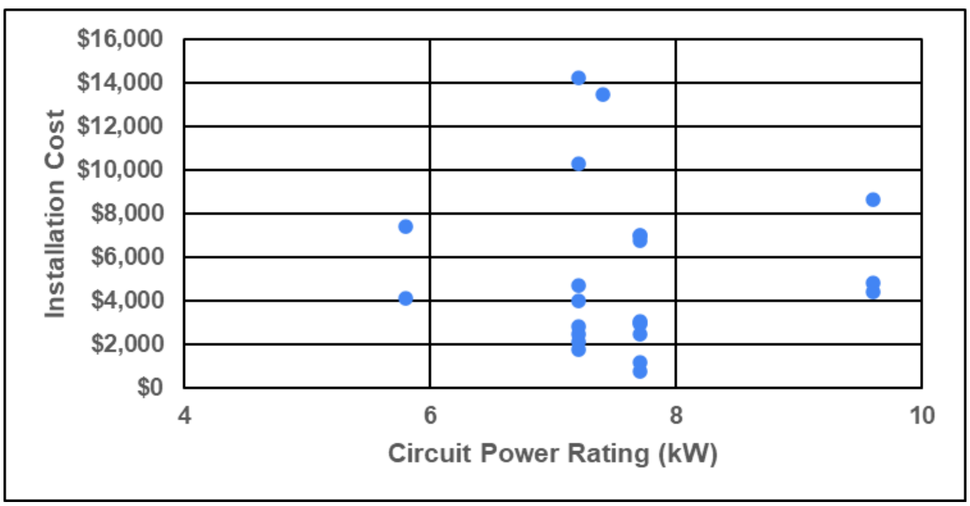


Figure 23. Commercial Installation Cost vs Circuit Power

3.5.2 Accessories

The installations for multi-family units included accessories for 125 of the 153 installations. Amount spent on accessories varied between locations with California spending an average of $6632 per site. Overall, the average cost of accessories was $975.

Forty-six of the 83 commercial installations involving a single EVSE included accessories. The cost ranged from $38 to $6,304 per site with an average of $979. The type of accessory was not named.

3.5.3 Labor

Although SCA provided data for installations in ten states, 79% of the installations were in Texas. With just a few data points in the other states, a comparison by labor costs per state is not possible.

It does seem reasonable that the installation costs are related to the time required by the electricians to conduct the installation. Figure 24 shows this comparison for condominium installations. Only two installations occurred in the District of Columbia so no conclusion for this difference can be made.

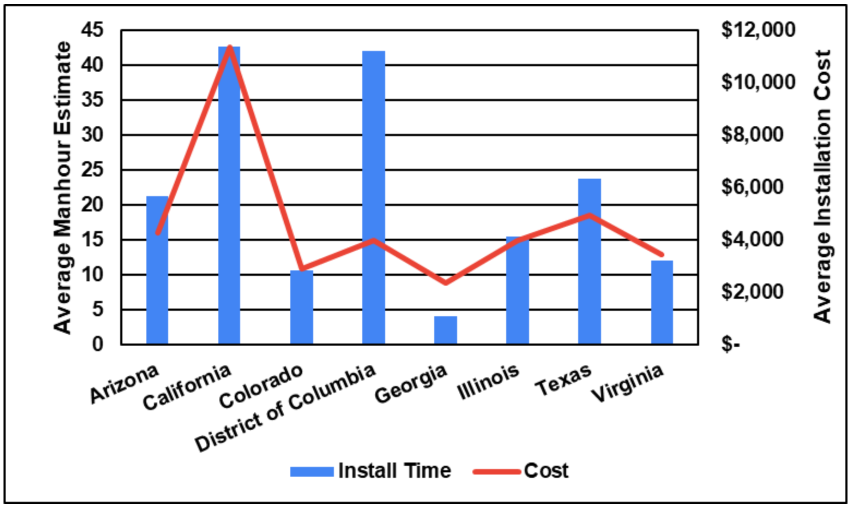


Figure 24. Condominium installation manhours vs installation cost

3.5.4 Electric Service Upgrades

Only one service upgrade was shown in the SCA data for a commercial site involving a 240v circuit. The cost for the upgrade was $2,656.

3.5.5 EVSE Installed per Site

In general, the more units that can be installed at the same time in the circuit, the lower the average cost per unit. This is most often seen in commercial installations. The SCA data supplied information on 57 commercial installations where multiple EVSE were installed. Figure 25 shows the comparison.

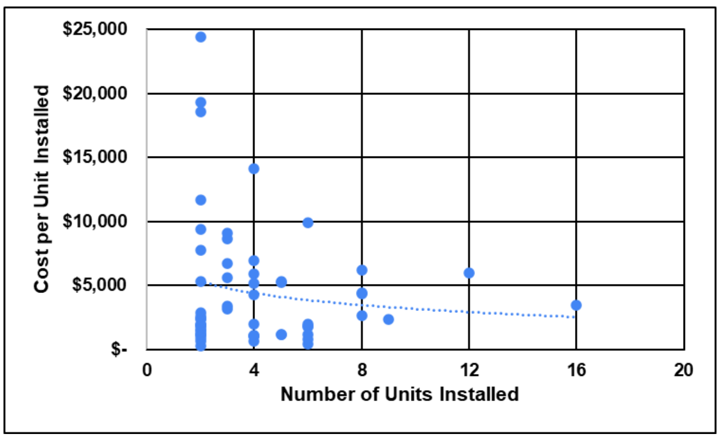


Figure 25. Cost per Unit vs Number of Units

3.5.6 Physical distance from power source to EVSE

The physical distance from the power source to the EVSE was supplied for 78 of the condominium installations. Figure 26 shows the relationship between the installation costs and the distance of circuit run. Only 30 to 40-amp circuit installations were considered here. The average cost for the circuit installation increased approximately $16 for each foot of circuit added.

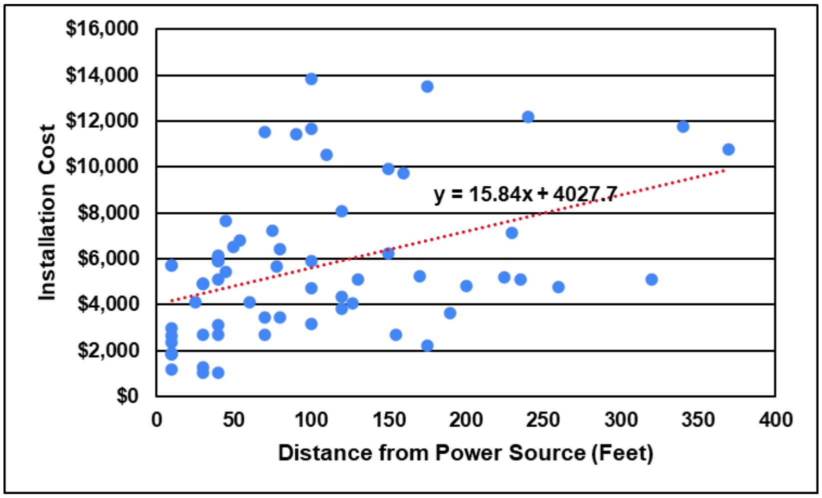


Figure 26. Condominium Circuit Lengths

SCA supplied 32 installations containing circuit run lengths for commercial installations involving a single EVSE. The installation cost vs the circuit run is shown in Figure 27. On average, the installation cost increases approximately $20 per foot distant from the power source.

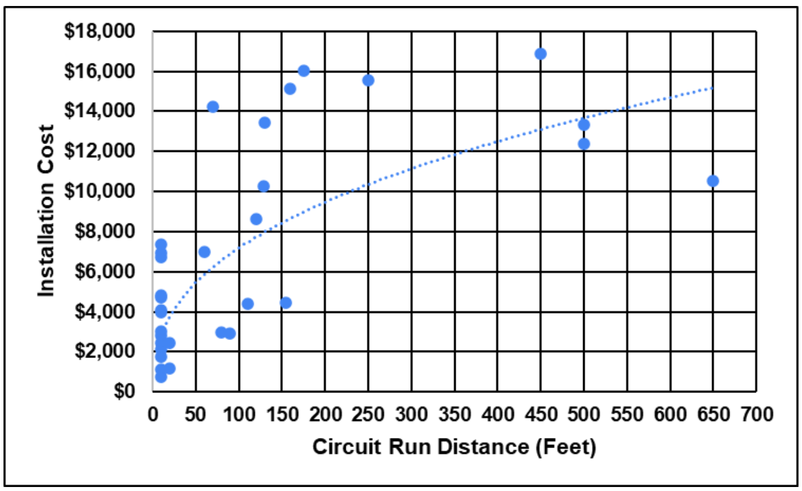


Figure 27. Commercial Installation Cost vs Distance

3.5.7 Hardscape factors

Commercial installations are significantly affected by the hardscape factors for routing power to the EVSE. Many ACL2 EVSE are installed in parking lots and require concrete and asphalt work. A cost not necessarily found in the installation cost data is the impact on the customer's parking lot where the Americans with Disabilities Act (ADA) sets requirements for accessibility to the EVSE. Restriping of parking spaces, addition of ramps, etc. add to installation costs.

No hardscape factors were named in any of the commercial installations. Surface mounted conduits are typically used inside parking garages.

3.5.8 Permit Costs

SCA data provided permit costs for two cities in Texas so insufficient data was available to adequately analyze commercial permitting costs.

3.5.9 Days to Install

A potential cost factor for commercial installation is the time it takes to install the circuit. This can also be of significance to the customer. For condominiums, the average days to install the EVSE and circuit vs the average installation cost by geographic area is shown in Figure 28.

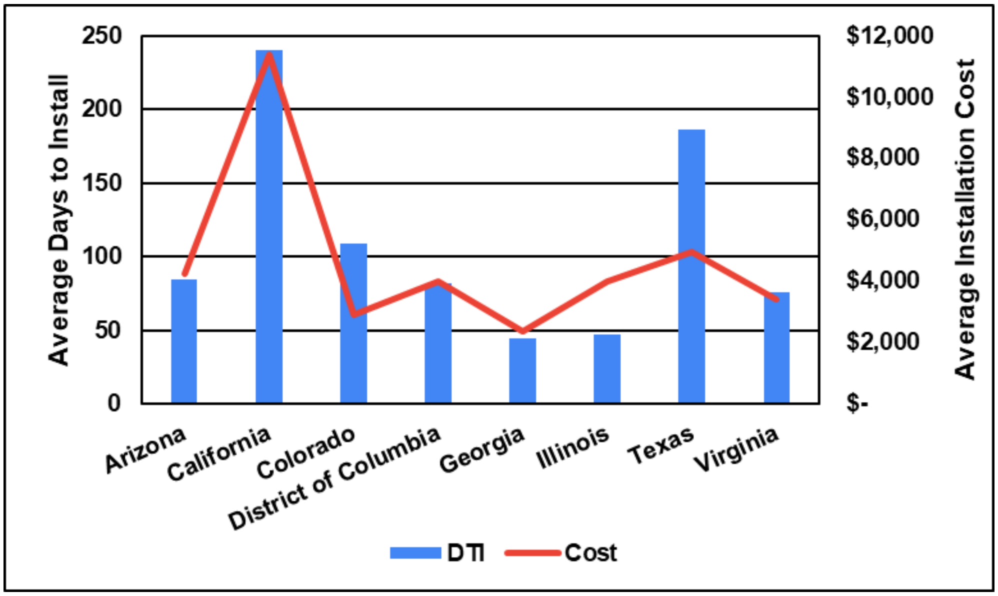


Figure 28. Average Days to Install EVSE for Condominiums

Some of the installations experienced exceptionally prolonged delays including ten of more than one year. Reasons for the delays were not provided. Excluding these specific installations, the average number of days from contract to completion of installation for the 81 commercial installations of single unit EVSE was 102 days. As shown in Figure 24, installation costs are related to the electricians' man-hour estimates. While the average installation days was 102, the average electricians' man-hour estimates were 22.3 hours. Most of the time from contract to completion of installation is well beyond actual circuit installation time.

The average electrician's time for residential installations reported in Section 3.4.9 was 5.4 hours. It would be expected that installation time for commercial installations would be longer.

3.5.10 Summary for Commercial EVSE Installation Costs

Commercial installations include both multi-family dwellings and other commercial settings.

- The median installation cost for multi-family dwellings was $3,983.
- The median installation cost for other commercial installations was $3,959.
- The installation cost for commercial installations increased approximately $380 per increase in circuit power rating
- Approximately half of the commercial installations required EVSE accessories such as wheelstops, signs, etc. at an average cost of $979 per site.

- SCA data confirms that the installation costs per EVSE are reduced as multiple EVSE are installed at the same site.
- The physical distance from the electrical service entrance increases cost approximately $16-$20 per foot.
- On average, the time to complete the installation in commercial settings is 102 days.
- On average, the electrician's time to install a commercial condominium circuit was 22.3 hours,

3.6 Factors Influencing DCFC Installation Cost

3.6.1 Power Rating

The EV Project 60 kW DCFC and the WestSmart 50 kW DCFC installation costs provide the distribution of installation costs per kW as shown in Figure 29.

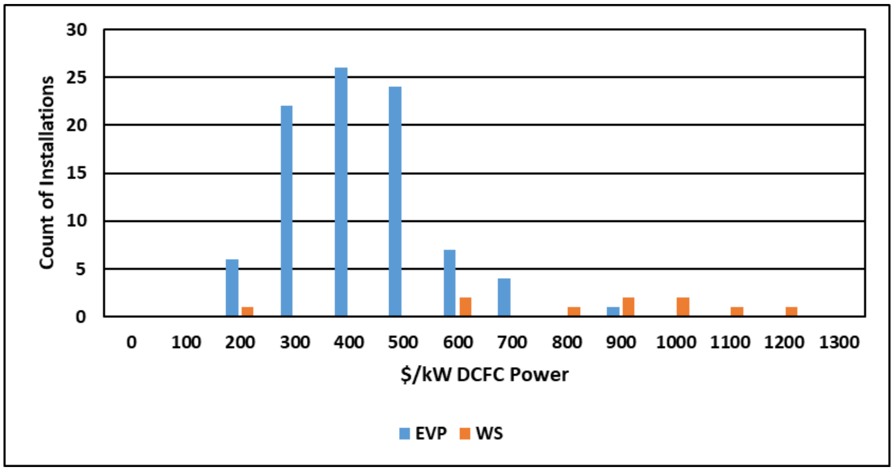


Figure 29. DCFC Installation Cost per kW

The average installation cost for the EV Project after adjustment for inflation was $377/kW and the average installation cost for the WestSmart DCFC was $786/kW. The $/kW for the EV Project DCFC may be a bit lower because The EV Project rejected sites where costs were considered excessive.

Installations provided by SCA often included ACL2 equipment or added DCFC and installation costs per kW information was not helpful.

3.6.2 Labor

The EV Project selected installation contractors based upon their ability to meet DOE-mandated Davis-Bacon Act requirements. For states with ten or more DCFC installations, the installation costs for DCFC sites not requiring a service upgrade versus labor rates are shown in Figure 30. Note this figure uses installation costs adjusted for inflation and U. S. Bureau of Labor Statistics average hourly wage rates for electrical contractors in the geographic areas.

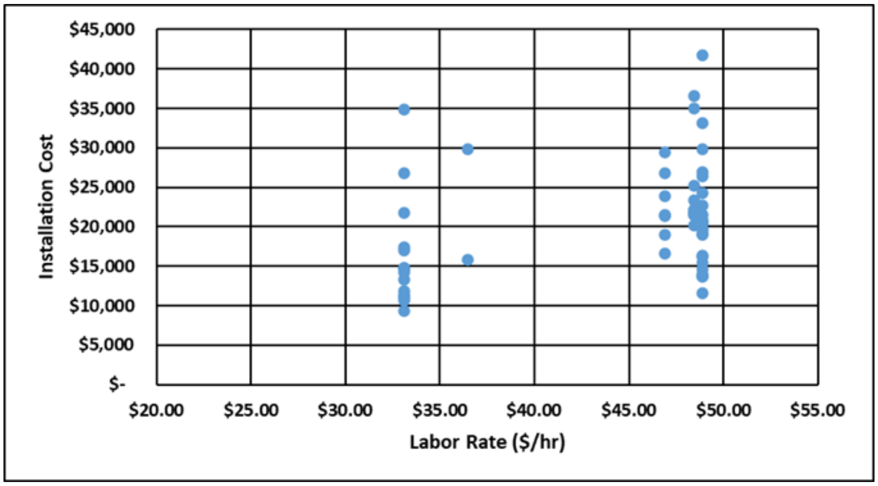


Figure 30. DCFC Installation Cost vs Labor Rate

On average, the cost of installation of DCFC increases $350 per dollar increase in the labor rate.

3.6.3 Electric Utility Upgrades

The EV Project found that the addition of new electrical service at the site was the single largest differentiator of installation costs for DCFC.

The cost for the service upgrade was not identified separately. Rather, the notes included whether or not a service upgrade was required. For states with ten or more DCFC installations, the average DCFC installation costs by service upgrade factors are shown in Figure 31.

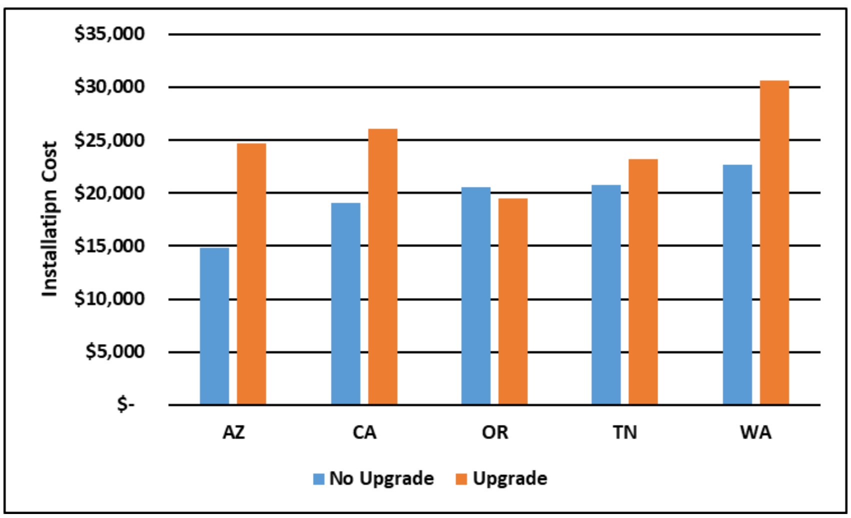


Figure 31. DCFC Installation Costs with or without Utility Upgrade

Some utilities participated in service upgrade costs to a greater extent in some states. In general, adding new service added between $2,500 and $10,000 to the cost of the installation with the average of about $5,000. The average increase across all projects was 29 percent.

3.6.4 Physical distance from power source to EVSE

As with residential and commercial ACL2 installations, the greater the physical distance from the power source to the DCFC, the higher the cost for materials, labor and hardscape factors. For the EV Project, installation costs versus distance from the power source for DCFC not requiring a service upgrade are shown in Figure 32. Using 2019 installation costs for the EV Project, costs increase an average of $200 per foot. The shortest distance recorded in The EV Project was 15 feet.

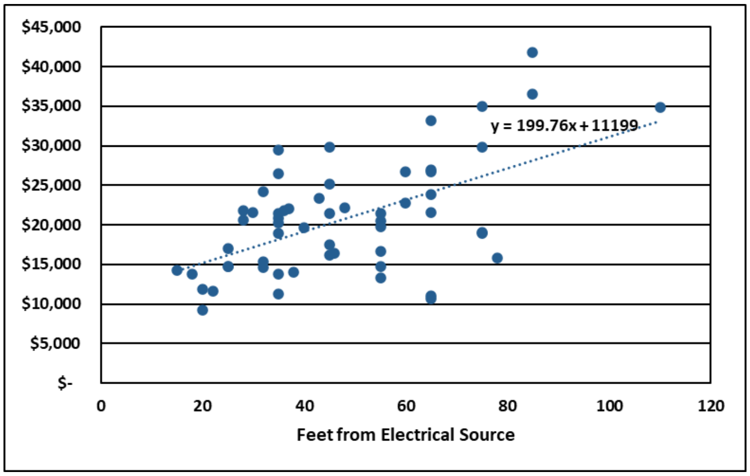


Figure 32. Distance Effects on DCFC Installation Costs

3.6.5 Hardscape factors

DCFC installations may be affected by hardscape factors. The EV Project found that the surface on or under which the wiring and conduit were installed was the second largest cost driver for DCFC installations.

Several factors affected the installation costs so in the attempt to isolate the hardscape factors, only DCFC installations where a service upgrade was not needed and whose distances from the electrical source to the DCFC of less than 75 feet are considered. A total of 53 installations met these criteria. Installations were rated as installed through gravel or non-gravel, which included concrete, asphalt, and other surfaces. For the states with both conditions, the results are shown in Figure 33. The average increase in costs for the non-gravel conditions was 21 percent.

3.6.6 Permit Costs

As noted above, permit costs varied widely across the EV Project sites. Many jurisdictions required engineered drawings for the DCFC that were not necessarily needed for other permits. These costs varied from about $1,000 to $3,000 and accounted for about 5 to 10% of the installation cost. The time to prepare the drawings had an impact on project schedules.

3.6.7 Summary for DCFC Installation Costs

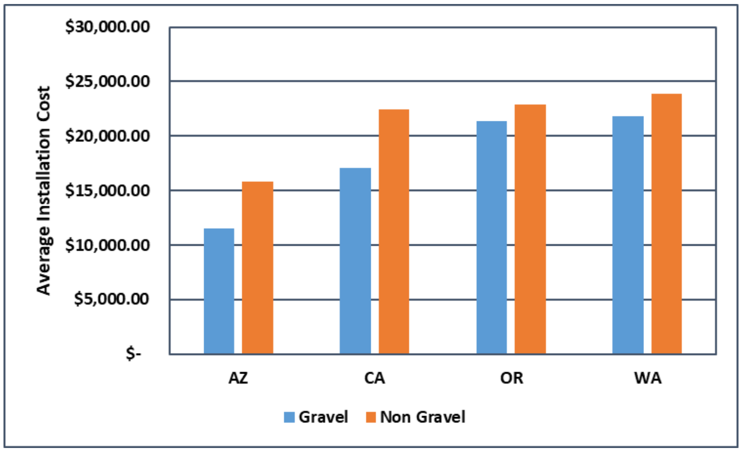


Figure 33. Hardscape Factor on DCFC Installation Cost

Estimating the cost for installation of DCFC is difficult because it depends so much on the physical conditions and electrical service to the area for planned installation. In addition, the number of units and whether additional ACL2 EVSE are to be installed are factors. However, the average installation cost for DCFC in the EV Project was $22,597 and the average installation cost for the SCA data was $19,500.

- Average installation cost for DCFC without service upgrades is approximately $20,000
- The installation cost as a function of the DCFC output power decreases significantly as the output power increases
- DCFC installation costs are significantly affected by the local labor rate increasing as much as $350 per dollar increase in the labor rate.
- Adding a service upgrade to the DCFC installation may increase costs by $5,000
- Increasing the physical distance from the electrical power source to the DCFC can cost approximately $200 per foot
- Hardscape factors can add approximately 21 percent to expected installation costs
- Permits add approximately 5 – 10% to project costs.

4 COST SUMMARY

EVSE installation costs consist of equipment costs and installation costs. Tables 7 and 8 summarize these costs.

Table 7. Summary of EVSE Costs

	ACL1		ACL2		DCFC
	residential	commercial	residential	commercial	price highly dependent on power rating, features, and network
Basic cordset	$190	NA	$300	NA	
Basic wallmount EVSE	NA	NA	$500[1]	NA	
Smart (networked) wallmount EVSE	NA	NA	$575[1]	$1,500	
Basic pedestal EVSE	NA	$1,500	NA	$1,750	

Smart networked pedestal EVSE	NA	NA	NA	price highly dependent on features and network with low end costs about $2,500, average at $3,127 and increasing with high end above $8,000	
1. EVSE costs typically increase with increasing power rating at approximately $7.5/amp 2. EVSE accessories such as pedestals ($400 - $900), retraction mechanisms ($550 - $1,600), wheelstops ($35 - $50), signage ($10 - $26) add to equipment costs					

Table 8. Installation Cost Summary

	Residential	Commercial	DCFC
Median Installation Cost	$1,100	$4,000	$20,000
Power Rating	+ $92/kw above 4 kW	+$380 per/kW above 4 kW	Indeterminate
Accessories	5% added $49 - $900	50% added $980	Indeterminate
Labor	Dependent on local rates	Indeterminate	+$350/$ increase in rate
Circuit Upgrade	Rare but $2,600 when needed	Rare but $2,660 when needed	Adds 29% to project
Circuit Length	Adds $12 per foot	Adds $16 - $20 per foot	Adds $200 per foot
Hardscape Factors	Indeterminate	Indeterminate	Adds 21% to project
Permit fees	3.5% of project cost	Indeterminate	Add 5 – 10% to project
DTI	21 days	102 days	NA
Electrician’s Man-hours	5.4 hours	22.3 hours	NA

REFERENCES

Amazon. (n.d.). *Amazon.com*. https;//www.amazon.com [Accessed July 12, 2022].

BLS. (2021). *Annual mean wage of electricians, by state, May 2021.* https://www.bls.gov/oes/current/oes472111.htm#st [Accessed July 27, 2022].

ChargedEVs. (2022). *Trends in EV charging capabiities.* https://chargedevs.com/sponsored/trends-in-ev-charging-capabilities/ [Accessed June 6, 2022].

ChargeHub. (n.d.). *Find Out the most Optimal Charging Solution for your Home According to the Electric Vehicle you Drive.* https://chargehub.com/en/find-the-right-charging-station-power.html [accessed July 5, 2022].

ClipperCreek1. (n.d.). https://store.clippercreek.com/ev-charging-station-mounting-cs-pedestal?search=cs%20pedestal [Accessed June 20, 2022].

ClipperCreek2. (n.d.). https://store.clippercreek.com/mounting-solutions [Accessed June 20, 2022].

DOE. (n.d.). *U.S. Public and Private Electric Vehicle Charging Infrastructure.* Alternative Fuels Data Center https://afdc.energy.gov [Accessed June 6, 2022].

EvoCharge. (n.d.). https://evocharge.com/ [Accessed June 20, 2022].

INL. (2015). *How do Residential Level 2 Charging Installation Costs Vary by Geographic Location?* https://avt.inl.gov/sites/default/files/pdf/EVProj/HowDoResidentialChargingInstallationCostsVaryByGeographicLocations.pdf

INL. (n.d.). *The EV Project - Plug-in Electric Vehicle Charging Infrastructure Demonstration.* https://avt.inl/gov/project-type/ev-project.html [Accessed July 26, 2022].

Irle, R. (2021). *Global EV Sales for 2021*. https://www.ev-volumes.com/ [Accessed June 6, 2022].

Minor, S. (2021). *New Plug-in Electric Vehicle Sales in the United States Nearly Doubled from 2020 to 2021*. Department of Energy.

Morris, C. (2021). *NREL researchers, industry partners test Megawatt Charging System with up to 3.75 MW of power.* https://chargedevs.com/newswire/nrel-researchers-industry-partners-test-megawatt-charging-system-with-up-to-3-75-mw-of-power/ [Accessed July 5, 2022].

Neider, C. &. (2019). *Reducing EV Charging Infrastructure Costs.* Rocky Mountain Institute.

Nicholas, M. (2019). *Estimating electric vehicle charging infrastructure costs across major U.S. metropolitan areas.* The International Council on Clean Transportation.

Plugzio. (n.d.). https://www.plugzio.com/plugzio-integrated-in-wall-outlet [Accessed July 5, 2022].

Powerpost. (n.d.). https://www.powerpostevse.com/assets/about_powerpostevse.pdf [Accessed July 5, 2022].

Smart Charge America. (n.d.). https://smartchargeamerica.com [Accessed June 6, 2022].

Tesla. (n.d.). https://shop.tesla.com/product/wall-connector?tesref=true [Accessed July 6, 2022].

Tesla. (n.d.). https://shop.tesla.com/product/wall-connector-pedestal [Accessed July 19, 2022].

Webster, I. (2022). *$1 in 2013 - 2022/Inflation Calculator*. https://www officialdata.org/us/inflation/2013?amount=1. [Accessed July 11, 2022].

APPENDIX A: ELECTRIC VEHICLE SUPPLY EQUIPMENT COST FACTORS

At its very basics, the EVSE receives electrical energy from the electric utility and delivers it to the PEV. Because a PEV battery operates on DC current, a battery charger is a device that converts the incoming utility AC into the DC needed for charging. That conversion from AC to DC may occur on-board or off-board the PEV.

While the EVSE delivers the power, the charge is totally controlled by the PEV's on-board battery management system. That system considers several factors including battery status, state of charge, temperature, etc. in allowing the delivery of power to the battery.

The methods for power delivery, energy levels and other design factors are discussed here.

A.1. Power Delivery

At present, three major categories of technology related to delivery of power for recharging PEVs exist: conductive charging, inductive charging and battery swapping.

Battery swapping involves the complete change-out of the depleted PEV battery and installation of the same size and configuration of a fully recharged battery. This technology is in limited use in the world and has its own benefits and drawbacks. It requires vehicles that have the exact same size and configuration batteries, vehicles designed for this rapid replacement and garaging facilities in which the battery swapping occurs. Standardized PEV batteries do not currently exist in the United States and this method is not considered in this report.

Inductive or wireless charging is a method of power transfer that does not rely on direct contact between the supply current and the vehicle. Power transfer occurs between coils in the supply equipment and coils installed on the vehicle. Figure 4 shows an example of such a system. The charging coil may be in other locations, such as a post to which a vehicle approaches with its receiving coil in the bumper. Inductive charging has certain advantages including the elimination of physically handling the connectors. A disadvantage is that the two coils need to be in proximity for the transfer to occur efficiently and results in a high-energy field between vehicle and wireless source. This design is not as common as others are and requires PEVs designed with this feature. Currently, the public infrastructure in the United States has not adopted this as typically available and few PEVs provide this method as a choice. Data on installation costs for wireless charging were not available for this report.

Figure A- 1 Inductive Charging Design[1]

Conductive charging uses the physical connection between the charging station and the PEV and is the most common method for power delivery.

[1] https://www.pluglesspower.com/learn-about-plugless-2/ [accessed June 6, 2022]

A.2. Charging Power Levels

EVSE are designed to charge at specific power levels including:

- AC Level 1 EVSE: Most PEV suppliers provide an AC Level 1 EVSE with the purchase of a PEV. While these EVSE (cordset) use standard 120V household outlets to supply up to 1.9 kW of power to the PEV, most OEMs consider these to be for emergency use only. That is, they are used to recharge the battery in case the vehicle is stranded away from a normally installed EVSE. For residential applications, this involves the installation of a dedicated electrical circuit specifically for this device. Level 1 EVSE may also be designed for private use in workplace, fleet or public charging where a vehicle may be idle for a significant time. This EVSE design receives the electric utility AC input and delivers the AC to the PEV where the on-board charger converts it to DC for charging. This level of power delivery may be sufficient for drivers of PEVs with smaller batteries and short electric range, but a full charge for a long-range EV at this rate may take more than 20 hours. This will likely not be satisfactory for many drivers for their residential application.

Figure A- 2. AC Level 1 cordset.

Figure A- 3. AC Level 1 Public EVSE[2]

- AC Level 2 EVSE: These EVSE are installed in a 240V AC circuit and can deliver up to 19.2 kW to the PEV depending upon the PEV's charger design. Residential AC Level 2 EVSE

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[2] https://www.powerpostevse.com/portland-international-airport-boasts-largest-number-of-ev-chargers-at-us-airport.html [Accessed June 6, 2022]

typically deliver 3.3 kW for a 15-amp circuit or 7.7 kW for a 40-amp circuit. Charge time to fully charge a depleted battery is typically 3.5 to 7 hours. EVSE may be designed to "hardwire" into the electrical circuit or plug-into a receptacle. The higher charge delivery requires an 80-amp circuit and are more typically found in commercial applications.

Figure A-4. Residential AC Level 2 EVSE[3]

Figure A- 5. Commercial AC Level 2 EVSE[4]

- DC Fast Chargers (DCFC): DC fast chargers are typically found in public locations and can typically recharge PEVs to 80% of battery capacity in approximately 30 minutes, depending upon the battery management system. Note that the AC to DC conversion occurs in this EVSE so that DC is delivered to the PEV. Most DCFC currently installed can supply 50 kW, but more recent installations can supply up to 150 kW, 350 kW or higher depending upon applications. BEVs are typically provided with DCFC inlets but most PHEVs do not provide this inlet. The faster recharge time does not help the PHEV's smaller battery.

[3] https://www.amazon.com/dp/B08CXZ9MX3/ref=as_li_tl?ie=UTF8&tag=Tyche-6245-20 (LEFANEV brand) [Accessed June 6, 2022]

[4] https://www.chargepoint.com/products/commercial [Accessed June 6, 2022]

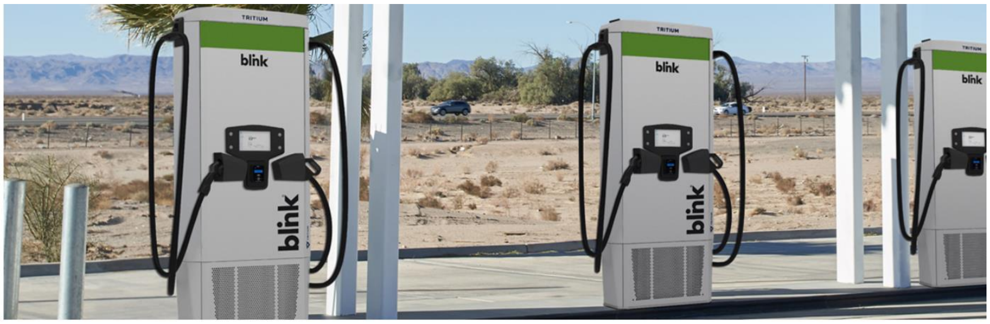

Figure A- 6. DC Fast Charger[5]

A.3. Standard vs Smart EVSE

The basic function of the EVSE is to supply the method for recharging a PEV. An EVSE that supplies no other functionality is a standard EVSE. It is required to meet all the design and safety requirements but simply supplies power to the vehicle. Some basic EVSE provide information related to the current charge in progress, such as elapsed time or charge energy delivered. Most PEVs designs include features the operator can select to control charging as well and for many functionalities, the standard EVSE is sufficient.

Smart EVSE provide functionality beyond the simple providing of power. The level of sophistication varies between suppliers of the EVSE, but most will typically include a wireless or wired connection to the internet or cellular communications to a network operator to provide access control, data collection, scheduling of charging, payment for services settings, notification of required servicing, mapping services for nearby chargers and so forth.

A.4. Charging Applications

Along with the EVSE design for electrical delivery noted above, specific applications also factor into the EVSE design. Typical applications include residential, commercial private and commercial public.

Residential EVSE include those installed at a private residence. The installation may be in a garage or car port. The residential EVSE may be AC Level 1 or 2. They may be basic or smart units as described above and are selected by the PEV owner if data or other charging features are a consideration. These are typically wall mounted units that may be hard-wired into the electrical circuit or plugged into the dedicated circuit receptacle.

Commercial/private applications include all situations where the public does not have access to the equipment. This includes workplace charging, private fleet operations, business visitor parking, single building condominiums and apartments, multi-building apartments and other such situations.

Workplace EVSE benefit the employees who drive PEVs. Installed in the private parking areas for employees, the employee may charge during normal work hours. These EVSE are typically AC Level 1 or 2, although a few companies use DC Fast Chargers, and may be basic or smart units, depending upon the employer's needs such as access control or billing for use. Utilization of the workplace EVSE may be a cost for the employee or may be provided as a benefit. Federal facilities require fees for employee use in workplace charging. Most often, pedestal mounted EVSE are used as the stations are generally required to be free-standing.

Fleet charging is like workplace charging except that the company owns all the vehicles. As with workplace charging, access is typically controlled to prevent public charging and the needs of the fleet

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[5] https://blinkcharging.com/products/commercial-products/ [Accessed June 6, 2022]

determine the design requirements for the EVSE. Depending upon the available locations for the EVSE, they may be wall-mounted or pedestal mounted units.

For condominium or apartment applications that include a parking garage, the EVSE may be installed by and owned by the PEV owner. In other situations, the management company may install the EVSE and charge a user's fee. Where multiple buildings are in use, the EVSE units, typically wall-mounted, may be in one or more public areas and thus, an access control method is desirable.

Public charging stations are located to allow widespread use of the EVSE. For destination charging, a host site allows the installation of the EVSE on the property as it enhances the business opportunities for the host. That is, while charging the PEV, the owners may be shopping or visiting the host site. In general, the host site absorbs the cost of the installation, equipment and service and recoups that cost through incentives or access fees. The host also sets its own policies such as user groups, pricing and availability. Public access units may also be installed in fuel islands or along transportation corridors. Thus, access control features and other data features, such as billing systems, access control, notification that maintenance is needed, etc. become important. Networked EVSE are typical and use wireless or cellular communications with a networking service. Service providers and the network operators may work with several different EVSE suppliers. Public charging may employ AC Level 1, 2 or DC Fast Chargers. The AC Level 1 and 2 units are typically pedestal mounted units.

A.5. EVSE Physical Design

A.5.1 EVSE Mounting

The wall mount unit shown in Figure 7 is the most basic design for an EVSE. It can be found in residential, workplace, fleet, or commercial applications where a wall may be found at the parking site. Lacking a wall for mounting, a pedestal will be needed as seen in Figure 6 and 8. Some EVSE designs use the same wall mounted unit and attach it to a pedestal. All DCFC designs are configured in a stand-alone pedestal type mounting. The pedestal mounted unit is typically more expensive than the wall mount because of the added hardware but also because a suitable mounting pad may be an added cost.

A.5.2 EVSE Connectors

The Society of Automotive Engineers (SAE) standardizes the requirements, configurations, and equipment followed by most PEV suppliers in the United States. The J1772^{TM} Standard, Figure 10, is used in all but Tesla supplied PEVs for AC Level 1 and Level 2 charging.

Figure A- 7. J1772 Connector and Inlet[6]

Not all PEVs are equipped for DC fast charging. As noted above, this capability is not as important for PHEVs. However, for BEVs, DC fast charging is important. Many PEVs were delivered in the US before the SAE developed the fast-charging standard so there are unique designs for the DCFC connector and port.

Figure A- 8. J1772 CCS and Inlet[7]

Note that this connector inlet allows the use of either the DCFC or AC Level 1 or 2 connector.

The CHAdeMO standard (designed in Japan) is another standard employed in DCFC. Figure 12 shows this standard design.

[6] https://www.rema-ev.com/type-1-connector [Accessed June 8, 2022]

[7] https://www.rema-ev.com/ccs-1-connector/ [accessed June 8, 2022]

Figure A- 9. CHAdeMO-Compliant Connector[8]

Finally, Tesla provides unique connectors for their vehicles that are not compatible with the J1772 design. However, Tesla offers adapters for their vehicles that allow for charging at J1772 AC Level 2 and CHAdeMO EVSE. Currently, Tesla does not supply adapters that allow non-Tesla vehicles to charge at Tesla EVSE.

A.5.3 EVSE Ports

The EVSE may be designed for one or more connectors (or ports) to supply up to four vehicles at a time. Some residential users may choose to install a dual port EVSE if they have or plan to have more than one PEV. Figure 6 shows the commercial application with a single port for each EVSE. That is, only one vehicle may be charged from that EVSE. Figure 7 shows a dual-port EVSE in the commercial application so that two PEVs may charge at the same time. Note that is the EVSE is designed to charge more than one vehicle at a time, the input power requirements are increased as well. Some DCFC are designed with two connectors: one of the J1772 standard and one of the CHAdeMO standard (Figure 9). Although two connectors are available, the unit will charge only one PEV at a time and for this report, this unit is considered to have just one port.

Some parking lot designs may place a single port EVSE between two parking stalls to allow the PEVs to share the EVSE. Some may place a dual port EVSE at the intersection of four parking stalls to share charging with four vehicles. Nevertheless, this report considers these to be single and dual port EVSE respectively based upon the number of vehicles that may charge at any time.

[8] https://www.chademo.com/portfolios/jae-connector-10/ [accessed June 8, 2022]