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Electric Vehicle Supply Equipment Installed Cost Analysis

2013 TECHNICAL REPORT

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Abstract

More than 140,000 plug-in electric vehicles (PEVs) have been sold since December 2010. Critical to maintaining this upward trend is achievement of a diverse and available charging infrastructure. The purpose of this study is to analyze one key element of the charging infrastructure—the cost of installation. While the fuel cost of electricity to charge a PEV is significantly lower than the cost of gasoline, the cost to hire an electrician to install electric vehicle supply equipment (EVSE) for charging ranges from a few hundred dollars to thousands of dollars per outlet or unit.

For this study, the EPRI research team analyzed a total of 637 site installation records with 1294 PEV charging units, covering the period 2009–2013. The residential locations were subdivided into single-family homes and multi-unit dwellings; the commercial locations were further subdivided into workplace, public/retail, and fleet charging.

This report specifically evaluates charging infrastructure installation costs, assesses trends, and suggests ways to reduce the cost of EVSE installation. The analysis focuses only on installation costs, excluding the costs of the charging equipment. The costs do not include design, overhead, administration, billing, networking, or other potential upstream costs. The goal is to analyze the available EVSE installation cost data in order to determine if there are differences according to geography or other factors that have affected installation costs. The report also examines the components of installation costs (labor, materials, taxes, and permits) in order to determine how these have varied by geography and over time. Finally, the report documents any trends in installation costs and evaluates how costs may change as the market matures.

Keywords
Plug-in electric vehicle (PEV)
Electric vehicle charging
Electric vehicle supply equipment (EVSE)
EVSE installation costs
Electric charging infrastructure

Executive Summary

Plug-in electric vehicles (PEVs) are off to a promising start, with more than 140,000 sold since December 2010. PEV drivers can now drive past gas stations to conveniently plug in and recharge their vehicle batteries at home. According to the J.D. Power and Associates Electric Vehicle Ownership Experience Study, nearly all drivers charge at home, two-thirds of them on a 240V Level 2 charger. While 43% also charge at work or other public locations, charging infrastructure availability remains one of the top concerns of consumers considering a PEV.[1] The J.D. Power study coupled with other comments from PEV drivers reveal that a diverse and available charging infrastructure is critical to the success of PEVs.[2]

The purpose of this study is to analyze one key element of the charging infrastructure—the cost of installation. While the fuel cost of electricity to charge a PEV is significantly lower than the cost of gasoline,[3] the cost to hire an electrician to install the electric vehicle supply equipment (EVSE) for charging ranges from a few hundred dollars to thousands of dollars per outlet or unit. In some cases, the upfront cost of infrastructure installation may lead a consumer to decide that a PEV is not a viable option. Similarly, the cost of installing PEV charging equipment in public parking venues, workplace settings, or fleet locales may in some circumstances discourage the provision of charging facilities.

For this study, the EPRI research team analyzed a total of 637 site installation records with 1294 PEV charging units. The residential locations were subdivided into single-family homes and multi-unit

[1] "2012 Electric Vehicle Ownership Experience Study: To Increase Electric Vehicle (EV) Sales, Automakers Must Address Economic Challenges, Not Just Tout Environmental Advantages," J.D. Power and Associates Press Release, November 8, 2012.

[2] Over 90% of surveyed Nissan LEAF drivers have a Level 2 station at home. Satisfaction with public charging remains very low among surveyed Nissan LEAF owners. Source: "California Plug-in Electric Vehicle Driver Survey Results," California Center for Sustainable Energy, May 2013.

[3] "Fuel Costs: PEVs vs. Gasoline Cars?" California Plug-in Electric Vehicle Collaborative, Communication Guide 4, May 2012.

dwellings; the commercial locations were further subdivided into workplace, public/retail[4], and fleet charging.

Figure 1 shows the breakdown of the database into residential and commercial sites.

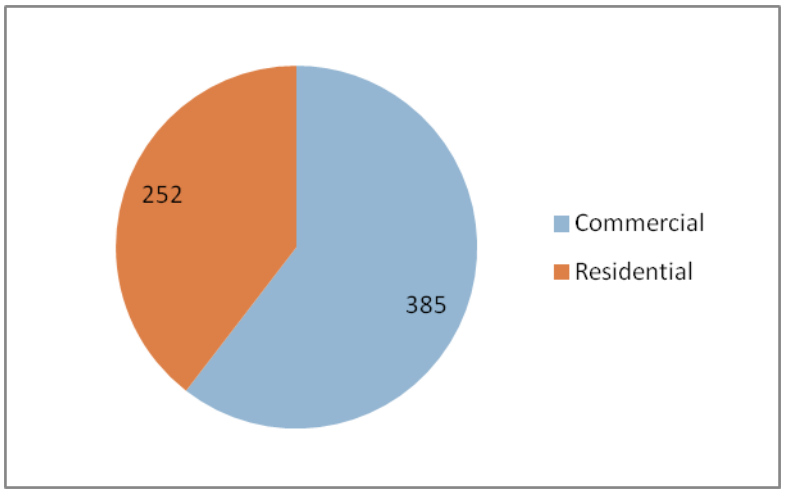


Figure 1
Number of residential and commercial sites analyzed

Figure 2 further divides residential and commercial installations into their component categories.

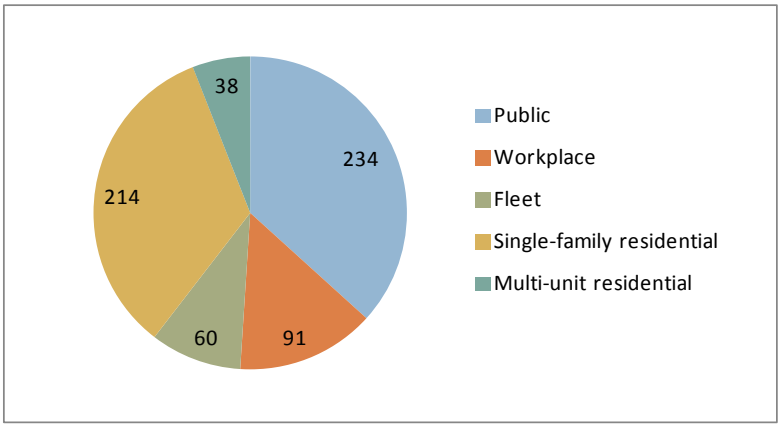


Figure 2
Number of sites by type of installation

[4] Limited data was available for retail sites, so this category was merged with the public category.

One key objective of the study was to obtain installation cost information from various parts of the United States and Canada. The study team contacted more than 56 individual parties, including utilities, EVSE manufacturers, EVSE installers, companies with PEV fleets and/or workplace charging sites, non-profits, and others to request participation in the study. Participants were asked to share any installation cost data they may have accumulated and provide qualitative insight into the installation process, obstacles encountered, and lessons learned. Since California has been installing EVSE units longer than any other state and is also the source of 40% of PEV sales, the majority of the responses are from the Golden State. However, the team was able to obtain residential and commercial data from 17 additional states and two Canadian provinces so that regional comparisons could be made. The study also compares the data collected for this effort with the few other studies that analyze installation costs, notably the *Plug-in Electric Vehicle (PEV) Roadmap for North Carolina*[5] and The EV Project.[6]

In order to gain a better perspective on what causes installation costs to increase or decrease, the team evaluated four cost categories: labor, materials, permits, and taxes. The costs do not include design, overhead, administration or other potential upstream costs. About two-thirds of respondents were able to provide some type of cost breakdown, which enabled the team to analyze the contribution of each component to total cost, as well as to assess trends over time.

Many of the installations included in this report were performed under government or utility-funded demonstration programs. Some of these programs established guidelines for installations and set the installation costs. For example, all federally funded programs, and some regional programs, required payment of prevailing wages (union rates), even for residential installations. This had the effect of increasing labor costs an estimated 15%–25% over non-prevailing wage rates, meaning that the dollar figures are probably higher than they would otherwise be in an unsubsidized market.[7]

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[5] *Plug-in Electric Vehicle (PEV) Roadmap for North Carolina.* North Carolina PEV (NCPEV) Task Force, February 2013.

[6] The EV Project is a large-scale, federally funded research effort that has been collecting data on approximately 8000 PEVs (LEAF, Volt, and Smart ED vehicles) and 12,000 residential, commercial, and DC fast charging installations. The project is beginning to release detailed analyses that include information about where and when charging takes place, how often, and for what length of time. The EV Project also collected data on installation costs.

[7] This is based on RSMeans prevailing wage, 2013 labor rates (union) vs. open shop labor rates (non-union); Table 2 provides additional information.

Another area of investigation was to determine what site conditions increase or decrease installation costs. Both quantitative and qualitative inputs were used to assess the factors that drive installation costs. There was consensus on most site-specific factors, with numerical data supporting the qualitative conclusions. A list of factors that increase costs is presented later in this summary.

Factors that help decrease per-EVSE costs include the installation of multiple EVSE units per site. Even though total costs increased as the number of EVSE units installed increased, the per-unit installation costs decreased. Similarly, there is potential for the installation of dual-voltage or dual-port EVSE units to reduce the cost per port of EVSE installations.

Some respondents cited factors that in their experience reduced costs, but which were contradicted by experience with other installations. For example, some participants recommended indoor garage installations believing they reduce costs, while others felt installations in garages, particularly multilevel structures, could increase costs.

The availability and variety of EVSE units have increased dramatically over the past few years, and the project team wanted to evaluate the impact of various charging configurations on installation costs. Three types of charging stations were compared:

- Single-port Level 2 units (208V or 240V, typically a 40-amp circuit[8])
- Dual-voltage units, Level 1 and Level 2, in a single EVSE unit (typically a 20-amp circuit for the Level 1 charging port plus a 40-amp circuit for the Level 2 charging port)
- Dual-port units, two Level 2 units in a single EVSE unit (typically 80 amps total, for two 40-amp circuits)

While the study team sought to evaluate the cost of installing stand-alone Level 1 EVSE units, the sample of Level 1 data collected was too small to analyze. Furthermore, drivers generally plug the Level 1 cord sets provided with PEVs into an existing 20-amp receptacle, and limited data is available on the cost to install new 120V outlets for PEV charging.

[8] This report refers to typical capacities of new circuits. Some Level 2 installations may use other circuit capacities. High-current (80- or 100-amp) Level 2 circuits (such as those needed for Tesla Motors PEVs) were not considered in this study.

Findings

This evaluation of EVSE installation costs covers the period 2009–2013. All of the quantitative analyses presented in this study exclude the actual cost of the EVSE unit itself and focus only on the cost of installing this equipment.

Figure 3 summarizes the number of EVSE units and charging ports installed and the type, by category, of installation. Residential locations typically had one installed EVSE unit per address, with the exception of multi-unit dwellings; commercial locations had anywhere from 1–10 EVSE units installed per site, or more.

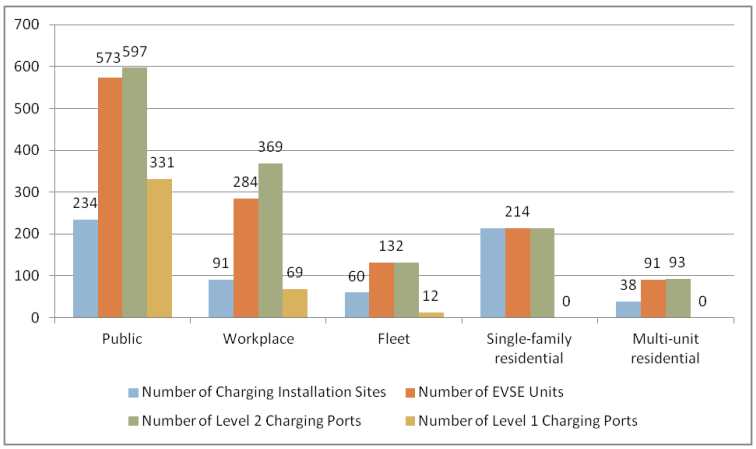


Figure 3
Number of charging sites by category

The key findings of the study are summarized below in the form of an overview along with two specific sections addressing the residential and commercial analyses. Subsequent chapters provide the supporting analyses for these key points.

Overview

The study found that recent installation costs averaged $1500–$1600 to install a Level 2 EVSE unit in a single-family home and around $4000 per EVSE unit at commercial sites, as shown on Table 1. The installation cost findings in this study are consistent with findings of other studies of installation costs, particularly the large-scale federally funded EV Project.

Table 1
Comparison of Average Installation Costs (per EVSE Unit)

	Residen-tial	Multi-Family	Commercial
EPRI Study			
Overall (2009–2013)	$1613	$3744	$3962
California (2012–13)[a]	$1512	$3744	$4412
Outside California (2011–2012)	$1499	n/a	$3118
The EV Project	$1375	n/a	$3500–$4500
North Carolina	$1098	n/a	$2638

[a]The study also collected California EVSE installation costs for 1996–2002 and 2009 projects. Only 2012–2013 costs are shown here to provide a more accurate comparison to findings outside of California.

The mainstream PEV market is less than three years old, and the majority of the installations studied were performed under federal, state, or utility demonstration programs. As a result, the industry does not yet have a true picture of what charging installations *should* cost in a true competitive marketplace. For example, administrative requirements of funded demonstrations—such as multi-year data collection, reporting, and prevailing wages—artificially increase the cost of installations by 15%–25%[9] and obscure the true cost of installations.

One important cost factor is the need for upstream capacity upgrades in locations with limited electrical supply.[10] This is likely to be more common in dense urban areas with older building stock, which is of concern since these areas are also considered to be important PEV markets.

[9] This assumption is based on anecdotal evidence from electrical contractors as well as data from RSMeans, which reports on labor rates nationally for numerous cities around the country. To determine the impact of prevailing wages on installation costs, investigators compared the 2013 national construction labor rate average for commercial prevailing wage labor (union) to non-prevailing wages (open shop). The prevailing wage rate was 25% higher than the open shop wage rate; Table 2 provides additional detail. A comparison of residential union and non-union wage rates was not possible.

[10] *Overcoming Barriers to Electric-Vehicle Deployment: Interim Report*. Committee on Overcoming Barriers to Electric-Vehicle Deployment, National Academies Press, May 2013.

Costs and Trends

The cost data supports the prevalence of single-family residential charging. In addition to the convenience of charging at home, single-family residential EVSE installations are the most economical in terms of capital costs. Multi-unit dwelling EVSE installation costs were found to be more than double single-family installations. Some commercial (workplace, public, but not fleet) costs are higher than either single-family or multi-unit dwelling costs. Fleet installation costs are typically less than public or workplace commercial installations. Additional findings include the following:

- Installation costs have been trending downward since 2009 and earlier. Since most of the residential installations studied in the report and in The EV Project were funded by federal or state grants, installers were required to pay Davis-Bacon Act prevailing wages, which are the equivalent of union wages. As these programs phase out, there should be a 15%–25% decrease in the labor component of installation costs. In addition, as the number of installations grows, competition for projects and larger scale purchases of materials may help lower costs. However, based on historical trends in labor rates for electricians and material costs, there is not likely to be a dramatic decrease in and breakthroughs in technologies, codes, or regulations.
- To date, approximately 10%–20% of residential installations required electrical upgrades.[11] Building code changes to require PEV charging circuits in new construction would reduce the number of upgrades required in the future.
- There is tremendous regional variation in installation costs due to differences in labor and material expenses as well as the relative age of the housing stock and commercial buildings. This is not as obvious in the EPRI data because the vast majority of installation records are from California. It is more evident in data from The EV Project, shown in Figure 4, which documented considerable variation in residential installation costs.[12]
- Permitting costs have increased substantially over the study period. While not a significant percentage of total costs for commercial installations, permit expenses represent a considerable portion of residential installation costs.

[11] This is based on qualitative input from participants and electricians.

[12] J. Francfort, "EV Project Charging Infrastructure Deployment Costs, Cost Drivers and Use," Idaho National Laboratory, presented at the Plug-in 2013 Conference, San Diego, CA (October 2013).

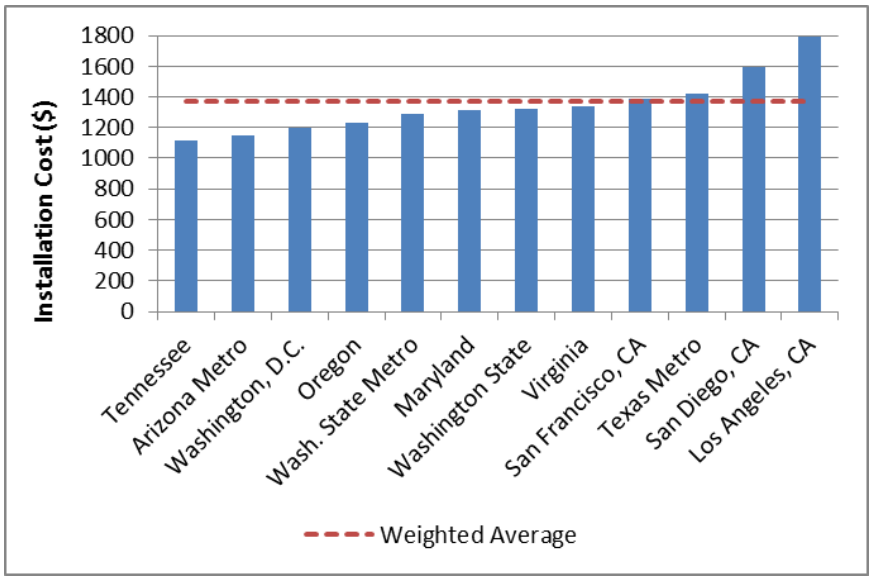


Figure 4
The EV Project data showing average residential installation costs

Residential Installation Cost Findings

The key findings of this study regarding residential installations include the following:

- Nearly all of the residential installations included in the dataset for this report were performed under a funded demonstration program. In some cases, the parameters of the program dictated the costs of the installation. The major demonstration programs required that prevailing wages be paid for most of the installations.
- The following site conditions increase the cost of residential installations:
  - Need for an upgrade due to lack of available capacity on the existing electrical panel
  - Need to rework the electrical panel or add a subpanel
  - Long distance from the electrical panel to the proposed charger location
  - Installation in a detached garage
  - Need for trenching through concrete or asphalt
- The average residential installation cost determined by this study ($1613) is somewhat higher than the cost reported by The EV Project ($1375). However, the average of California installations in The EV Project ($1519) is nearly identical to this study's findings for very recent California installations ($1512 in 2012–2013).

- The average installation cost appears to be consistent with the cost estimated by a 2012 J.D. Power study.[13]
- California is consistently the highest cost state in which to install EVSE. Many California installations are in major urban metropolitan centers, a factor mentioned anecdotally as potentially increasing labor and/or permit costs. Figure 4 illustrates the regional variation in residential data from The EV Project, which documented more than 4000 residential installations.[14]
- Despite the upward pressure caused by prevailing wage requirements, California installation costs have been trending downward compared to historical data. While labor costs have declined substantially over time, and material costs have declined slightly, residential permit costs have tripled compared to earlier installation data. Permitting is now a significant proportion of residential installation costs, ranging up to 22% of the installation cost. Figure 5 illustrates these trends.
- This study found that total installation costs are consistently lower outside of California. The EV Project data support the finding that residential installation costs outside of California are lower. While the study sample shows that the labor component of the installation cost was higher outside of California compared to within California, this result was clearly due to the high proportion of research projects in the outside-California sample. The labor component in such cases included additional fees to support non-installation functions such as data collection and analysis. The study found that material and permit costs are definitely lower outside of California.
- A separate North Carolina study found the residential installation cost in that state to be significantly lower.[15]
- According to J.D Power, approximately one-third of PEV drivers primarily use Level 1 charging with an existing outlet at

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[13] The average installation cost in the J.D. Power study is somewhat higher than the reported average cost of $1500, which included equipment costs for 60% of the participants. Source: "To Increase Electric Vehicle (EV) Sales, Automakers Must Address Economic Challenges, Not Just Tout Environmental Advantages." J.D. Power and Associates, Press Release, November 8, 2012.

[14] Detailed commercial data is not yet available from The EV Project. Residential data source: J. Francfort, "EV Project Charging Infrastructure Deployment Costs, Cost Drivers and Use," Idaho National Laboratory, presented at the Plug-in 2013 Conference, San Diego, CA (October 2013).

[15] Plug-in Electric Vehicle (PEV) Roadmap for North Carolina. NCPEV Task Force, February 2013.

home.[16] This means that about one-third of residences have zero installation cost, and the actual average EVSE installation cost across all residences is roughly two-thirds of the costs presented by this and other studies.

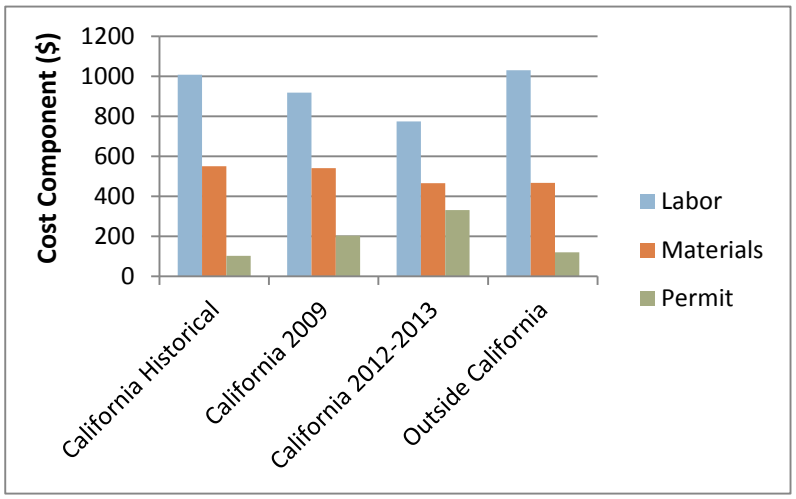


Figure 5
Labor, materials, and permit components of total residential installation costs

Commercial Installation Cost Findings

The project collected cost data and qualitative insights for 385 commercial charging sites with a total of 989 EVSE units installed. EVSE installation at commercial sites is not uniform in any way. Each site is unique, with many factors influencing costs. For commercial installations, factors that increased costs included the following:

- Need for an upgrade due to lack of available capacity on the existing electrical panel
- Long distance from the electrical panel to the proposed charging location
- Need for electrical panel rework or the addition of a subpanel
- Need for the installation of a transformer or other electrical infrastructure equipment
- Need for trenching through concrete or asphalt

[16] "To Increase Electric Vehicle (EV) Sales, Automakers Must Address Economic Challenges, Not Just Tout Environmental Advantages," J.D. Power and Associates Press Release, November 8, 2012.

- Siting decisions that increased the distance from the electrical panel (for example, to highlight the visibility of charging stations)

Other factors affecting commercial installation costs included:

- The cost of labor where the installation is sited[17]
- Whether a site has been previously wired for an EVSE installation
- The number and type of Level 2 EVSE units installed at each site
- Whether the installation is part of a research or demonstration project

Other major results regarding commercial installations include the following:

- Overall, the average cost is $3962 to install a Level 2 EVSE unit in a commercial setting.
- There are regional variations in commercial installation costs; in particular, California shows higher costs compared to projects outside of California. Based on the breakdown of the data into labor, materials, permits, and tax components, the greater expense of installation within California seems to be driven by higher labor costs. Detailed commercial data from The EV Project is not yet available for comparison.
- Workplace charging is less costly to install than charging at public sites. Fleet charging is the least expensive type of commercial installation.
- Installing more than one EVSE unit at a site drives down per-unit installation costs.
- Electrical panel replacements, the addition of subpanels, and the need for other electrical infrastructure equipment (such as new transformers) all increase costs substantially. However, it is important to right-size infrastructure in a way that avoids costly electrical work. Techniques to avoid expensive upgrades can include a mix of Level 1 and Level 2 charging, reworking panels to create more circuits, and reducing electrical demand through energy efficiency measures.
- On average, installing dual-port or dual-voltage units is less costly per charging port than installing two individual Level 2 EVSE units.

[17] Most of the funded demonstration programs focused on major metropolitan areas.

- Permit costs are not a significant factor influencing commercial installation costs. Permit fees in California are three times the cost of permits in other states, but permits still constitute a small portion (5%–8%) of total commercial installation costs.
- Poor siting choices can adversely affect costs, as can the presence of certain characteristics that lead to higher project costs.
- Outdoor locations are slightly less expensive than indoor locations, but anecdotal evidence provides contradictory insights.
- To date, Americans with Disabilities Act (ADA) compliance has not affected installations outside of California; however as the number of installations increases, the ADA is expected to have a cost impact. Within California, 1997 ADA guidelines have recently been updated and clarified. The guidelines allow an exemption if compliance with ADA increases project cost by more than 20%.

The Future of Installed EVSE Costs

Costs for installed EVSE units are categorized according to the following: EVSE, labor, permitting, and other costs. The expected near-term developments in each of these cost categories are described below.

Electric Vehicle Supply Equipment

There are now more than three dozen manufacturers of charging equipment with various capabilities, including Level 1, Level 2, DC fast charging, credit card and radio frequency identification (RFID) capable, networked and non-networked, plug-in, and hard-wired. As is often the case for new products, charging equipment costs have been steadily declining as additional manufacturers enter the market and as the range of options increases. In the 1990s, EVSE units cost between $3500 and $5000 and were non-networked devices. Today, Level 1 and Level 2 AC "chargers" are part of the vehicle, while the external EVSE device connects the car to electrical power and provides the communication signal necessary to initiate recharging the car's batteries.[18] Drivers can now choose to purchase charging equipment through a manufacturer's representative, through major Internet retailers, or at a home improvement "big box" retailer. Costs range from a few hundred dollars for a basic EVSE unit to more than $7000 for a network-connected, dual-headed EVSE unit.[19]

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[18] With AC charging, the majority of the power electronics equipment is located on board the vehicle. With DC charging, most of the charging equipment is located in the EVSE unit.

[19] "Accessory Tracker," Plug In America, http://www.pluginamerica.org/accessories, accessed August 2013.

Labor

While charging equipment seems to be following the typical new technology pattern of declining costs, it is not likely that labor costs will decline at as high of a rate. This project found that labor costs equal more than half the total cost of installation—ranging from 53%–68%. As noted above, installation costs have been declining overall and are likely to decline further from current levels. Since most of the residential installations reviewed by this project team and in The EV Project were funded by federal or state grants, installers were required to pay Davis-Bacon Act prevailing wages, which are the equivalent of union wages. As shown in Table 2, prevailing wages are estimated to add 20% or more to labor costs. In an unsubsidized market, prevailing wages would not be required for most residential or commercial installations, only for those that are classified as public works projects for government agencies.

Table 2
National Residential and Commercial Open Shop and Union Wage Rates[20]

Electrician Rates	Hourly Rate	Loaded Rate[a]
Residential	$35.10	$57.40
Commercial Open Shop	$41.90	$68.55
Commercial Union	$52.40	$ 78.40
Percent Increase Between Union and Open Shop	25%	

[a] taking into consideration overhead and profit

The transition to lower labor rates is promising; however, once this transition is complete, further reductions are unlikely. As shown in Table 3, construction labor rates have risen at a fairly steady pace over the past 20 years. Thus, while installation labor costs will probably continue to decline over the next few years as subsidized installations come to an end and the market becomes more competitive, it is unlikely that there will be major long-term declines in the cost of labor for charging installations.

Table 3
RSMeans Labor Cost Index[21]

Year	Index
1993	101.7
1994	104.4
1995	107.6
1996	110.2
1997	112.8
1998	115.1
1999	117.6
2000	120.9
2001	125.1
2002	128.7
2003	132.0
2004	143.7
2005	151.6
2006	162.0
2007	169.4
2008	180.4
2009	180.1
2010	183.5
2011	191.2
2012	194.6
2013	197.6

[21] January 1993=100. Source: "Building Construction Cost Data Book 2013," RSMeans, 2013.

Whether at home or in a commercial building, new 208V or 240V circuits must typically be installed by a licensed electrician. Even plug-in [22] EVSE units, permitted under the National Electric Code, must connect to properly wired 208V or 240V outlets. Local jurisdictions require permits and inspections of any electrical upgrades, and local permit fees and taxes are not within the control of EVSE installers. Fines can be levied for noncompliant installations, and cities can require removal of noncompliant work.

Permitting

In California, permitting costs have nearly tripled since the late 1990s as financially-strapped cities raise fees to cover the cost of services. In the case of residential installations, permit fees are becoming a substantial part (up to 22% in California) of the residential installation cost. Commercial permit fees have also risen but are not as noticeable as a percentage of cost since the total cost is higher. Figure 6 shows permit costs by state.

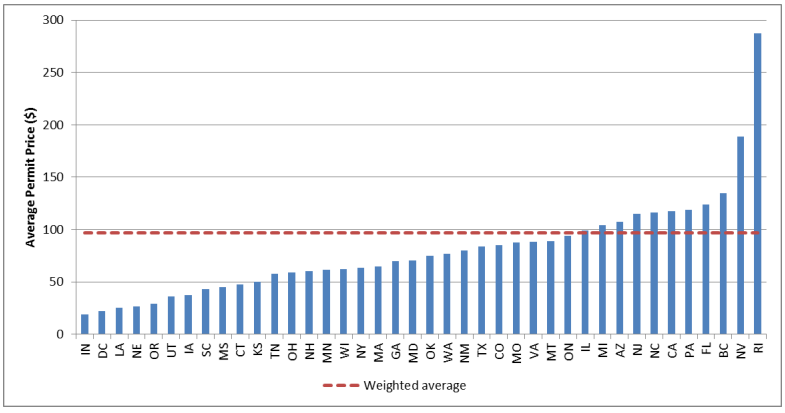


Figure 6
Permit costs by state/province: Bosch installations[23]

Other Costs and Overall Reductions

Materials, upstream capacity upgrades, and special work such as trenching and boring add significant costs to some installations, but may be reduced over time as experience in installations increases. Some economies of scale may occur as the volume of installation grows, and installers or integrators are incentivized to purchase materials in bulk, negotiate better labor rates, and invest in

[22] Most EVSE installations are connected directly to the wall circuit. Plug-in EVSE units have a cord and plug that can be connected to a wall receptacle that supplies 30 or 40 amps, similar to an electric clothes dryer.

[23] "Bosch Installation Data: What We've Learned So Far," Bosch Automotive Service Solutions, April 3, 2013.

technology such as web-based scheduling portals or on-site estimating and payment software. In addition, manufacturers may develop EVSE units that are easier to install or create load management technologies that minimize the need for costly electrical upgrades. A longer range strategy involves reexamining existing codes that require all electrical loads to be viewed as operating at 100% of their rated capacity at all times.

Another way that charging installation costs can be reduced is to include raceways, conduit, or full circuits in new residential and commercial construction.[24] California's Green Building Code has recommended the inclusion of charging circuits in new construction, but implementation is voluntary. Studies are underway to determine whether mandatory new-construction measures for charging should be adopted and by when.[25] Some cities such as Los Angeles have moved forward and adopted requirements for the installation of charging circuits in new construction.

A recent investigation completed by Clean Fuel Connection illustrates the potential for cost reductions. Three California contractors were asked to estimate the installation cost of a 40-amp, 240V residential charging circuit under various scenarios, ranging from minimally EV-ready to a situation where the site already has a fully capable EVSE-ready circuit. The requirements included 35 feet of conduit and wire, conduit mounted to building exterior, no trenching, and no panel upgrades. Installation costs ranged from $700 to $1100, well below the average found by this report for California ($1512).

This study evaluates infrastructure installation costs, assesses trends, and suggests ways to reduce the cost of EVSE installation. The analysis focuses only on s of the charging equipment. The goal is to analyze the available EVSE installation cost data in order to determine if there are differences according to geography or other factors that have influenced installation costs. The report also examines the components of installation costs (labor, materials, taxes, and permits) in order to determine how these have varied by geography and over time. Finally, the report documents any trends in installation costs and evaluates how costs may change as the market matures.

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[24] A raceway is designed as a space left inside the wall in new construction for a new circuit. A conduit is the pipe left for pulling wire. A circuit is the combination of raceway, conduit, and wire.

[25] 2010 California Green Building Code Standards, Supplement 57, Residential Voluntary Measures. California Building Standards Commission, July 1, 2012.

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Section 1: Introduction and Review of Existing Literature

Although electricity is available virtually everywhere in the United States, it has not been used as a transportation fuel since the early part of the 20th century. The shift from fueling with gasoline to fueling with electricity requires the development of a completely new fueling infrastructure, at home, at work and for longer distance travel. Installation of charging infrastructure can be more costly than expected, especially in older homes or commercial buildings. While the specific electrical work to install a 120 or 240 volt circuit is no more complicated than installing a new air conditioner or electric dryer circuit, the cost of installing a 240 volt charging circuit has received a great deal of attention in the media and blogs. This may be in part because drivers are not used to paying for their personal fueling infrastructure, or it may simply be that this unanticipated expense comes on top of the purchase of a plug-in car. Also because charging installations are a new phenomenon, building inspectors are paying closer attention to the installations and electricians may be charging more for the work.

Whether the high cost for installing charging infrastructure is perception or reality, it poses a significant barrier to the widespread adoption of PEVs. The purpose of this study is to evaluate infrastructure installation costs, assess trends, and suggest ways to reduce the cost of installation. The analysis includes installation costs only, excluding the costs of the charging equipment. The goal is to analyze the available installation cost data to determine if there are differences by geography or other factors that have affected installation costs. We also look at the components of installation costs (labor, materials, taxes and permits) to see how these have varied by geography and over time. Finally, we want to see if there are any trends in installation costs and evaluate how costs may change as the market matures.

Review of existing literature

Although a number of studies reference the difficulties of installing charging in homes and at commercial or public locations, there is very little detailed empirical data about installation costs. This section summarizes the information currently available in various studies.

J.D. Power and Associates

The J.D. Power and Associates "2012 Electric Vehicle Ownership Experience Study" was based on responses from more than 7,600 vehicle owners and respondents who either owned an EV, were considering an EV, or who had considered an EV but decided not to purchase one. The study found that nearly all drivers charged at home but 43% also charged at work or at public locations. One-third of drivers charged using a 120 volt wall outlet. Of the two-thirds that chose to install 240-volt charging station, the average cost for equipment, installation, and inspection was $1,500; however, 40% of these drivers received their charging equipment for free.[26]

American Council for an Energy-Efficient Economy

The American Council for an Energy-Efficient Economy (ACEEE)[27] study "Plug-in Electric Vehicle Challenges and Opportunities" provides estimated installation costs, as shown in Table 1-1.

Table 1-1
EVSE Installation Cost from ACEEE

Type of Charging	Installation Costs ($)
Level I	$100
Level II	$1,000 to $7,000
Level III (DC Fast Charging)	$20,000 to 50,000

Transitions to Alternative Vehicles and Fuels

The National Academy of Sciences study "Transitions to Alternative Vehicles and Fuels"[28] provides an analysis of various alternative fuel options and their ability to meet the 2050 greenhouse gas reduction goal of 80 percent reduction below 2005 levels. Table 1-2 shows the study's estimates for the installation cost of infrastructure for full battery electric vehicles and plug-in hybrid electric vehicles in 2011.

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[26] "To Increase Electric Vehicle (EV) Sales, Automakers Must Address Economic Challenges, Not Just Tout Environmental Advantages." J.D. Power and Associates, Press Release, November 8, 2012.

[27] Siddiq Khan and Martin Kushler, *Plug-in Electric Vehicles: Challenges and Opportunities,* June 2013, Report Number T133, American Council for an Energy Efficient Economy.

[28] National Academies Press, Transitions to Alternative Vehicles and Fuels, 2013, downloaded from www.nap.edu, Appendix G, p. 318

Table 1-2
Installation Costs from National Academy of Sciences

Charging Station	Installation Range of Costs	Average Installation Costs
Level I—residential	$0-$500	$200
Level II—residential	$300-$2,000	$1,300
Level II—commercial	$1,000-$10,000	$2,500
DC Fast Charge	$7,000-$50,000	$20,000

The authors provide useful information amortizing the costs of an expected 15 year vehicle life.

Transportation Energy Futures Series

The U.S. Department of Energy, Energy Efficiency and Renewable Energy Division has published a study on alternative fuel infrastructure expansion as part of the Transportation Energy Futures Series[29] that also discusses the ability of various low-carbon fuel technologies to contribute to the goal of 80% greenhouse gas reduction. Table 1-3 provides the report's projections of total capital costs (EVSE and installation) for Level 1 and Level 2 charging in residential and workplace locations in 2020 and 2050. Since these estimates include equipment costs, they cannot be directly compared to the results of the EPRI study. The cost estimates appear to be high, particularly for workplace locations.

Table 1-3
Electric Vehicle Equipment and Installation Costs from Transportation Energy Futures Study

EVSE Type	Level 1 Residence	Level 1 Apartment	Level II Residence	Level II Work
2020	$750	$750	$2,300	$7,000
2050	$500	$500	$1,800	$6,000

Plug-in Electric Vehicle Roadmap for North Carolina

The data in the Plug-in Electric Vehicle (PEV) Roadmap for North Carolina[30] is probably most similar to the data collected for this project. Some 143 residential installations and 102 commercial installations were evaluated. The residential

[29] Department of Energy, Transportation Energy Futures Series, "Alternative Fuel Infrastructure Expansion: Costs, Resources, Production Capacity and Retail Availability for Low-Carbon Scenarios" 2013. It is not clear from the report whether the term "apartment" includes all types of multi-unit dwellings such as condominiums, and cooperatives.

[30] "Plug-in Electric Vehicle (PEV) Roadmap for North Carolina," NCPEV Task Force, February 2013.

installations had an average cost of $1,098, which is notably lower than the average cost in the EPRI analysis.

The following are additional comments from the North Carolina study on residential installation costs (with report page numbers listed in parentheses):

- "Installation costs alone can vary greatly depending on the cable run length, trenching requirements, and power panel capacity but typically range from $300 to $2,000" (57).
- "There may be no additional costs [for an AC Level 1 installation] if a dedicated outlet is available within reach of the desired parking space" (63).
- For AC Level 1 charging that requires "a new outlet or upgrade [to] a 120 volt circuit, an electrician might charge $200 to $500 dollars depending on the specifics and assuming no abnormal construction is required" (63).
- "For those installing a residential AC Level 2 unit on a 240 volt circuit, the typical cost in NC ranges between $750 and $1,500 assuming no power panel upgrades are necessary" (63).
- "If sufficient supply infrastructure is not in place, costs could range upwards of $1,500 to $3,000" (63).

The commercial average installation costs in Table 1-4 are also significantly lower than the data collected for the present EPRI study. This may be the result of several factors including lower wage rates in North Carolina than other parts of the country.

Table 1-4
Commercial Installation Costs from North Carolina PEV Roadmap[31]

Installation Type	Station Count	Average Installation Cost (per unit)	Average Installation Cost (per charge port)
Wall Mount	21	$2,109	$2,109
Pedestal Mount	71	$2,875	$2,875
Dual Pedestal Mount	10	$4,129	$2,064

The following are additional comments from the study on commercial installation costs including the page number on which they can be found:

- "The cost of installing a commercial AC Level 2 charging unit for use by the public, employees, or fleet vehicles is typically between $1,500 and $5,000" (63).
- "Based on data collected by the working group for a number of commercial installs in the state of NC, the average cost is approximately $2,000 for a wall mount, ~$3,000 for a single pedestal unit, and ~$4,000 for a dual cord

[31] A weighted average was created for comparison purposes.

pedestal unit. Note that there is a large range in these costs and they are very specific to the power supply and location of a given site" (63).

EV Project

Recently, there was a quantum leap in the amount of residential and commercial installation data available when Idaho National Laboratory (INL) published preliminary findings regarding costs of EVSE infrastructure installations from the EV Project databases.[32] The EV Project is a large scale, federally-funded research effort that has been collecting data on approximately 8,000 plug-in electric vehicles (Leafs, Volts and Smart EDs) and 12,000 residential, commercial and DC fast charging installations. The project is starting to release detailed analyses that include information about where and when charging takes place, how often, and for what length of time. The EV Project also collected data on installation costs. Table 1-5 presents a summary of the residential installation cost information presented at the Plug-in 2013 conference.[33]

Table 1-5
The EV Project Residential Installation Costs

Number of Installations	4,466
Minimum Cost	$250
Maximum Cost	$8,000
Average	$1,414
Median	$1,265

Commercial installation cost data is still preliminary, but in general the range of Level 2 commercial installations in The EV Project was between $3,500 and $4,500. Costs varied by region and the number of chargers installed at one location.

Review Summary

In the studies analyzed, a number of cost estimates were made but only two were based on actual installation cost data. One of those studies, the North Carolina Roadmap demonstrates average residential costs that are 37 percent lower than the average costs in the EPRI study and average commercial costs that are 53 percent lower. The EV Project residential data are also lower than the EPRI residential data (14 percent) when all states are included. The average cost for commercial installations in the EV Project database (given as $3,500 to $4,500) is in line with the EPRI average commercial cost of $3,962.

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[32] J. Francfort and T. Garretson, "EV Project and Charging Infrastructure Update," U.S. DRIVE Grid Interaction Tech Team, presented at USCAR, Southfield, MI (June 19, 2013).

[33] J. Francfort, Idaho National Laboratory, "EV Project Charging Infrastructure Deployment Costs, Cost Drivers and Use," presented at the Plug-in 2013 Conference, San Diego, CA (October 2013).

Section 2: Methodology

The data collection for this project focused on Level 2 charging only[34] since that is the primary type of charging installation that was covered by the early demonstration programs and tracked by study participants providing data. Although a third of PEV drivers primarily charge on Level 1 at home, the costs of these installations are harder to track since they typically use an existing outlet in a garage or exterior wall.[35] DC fast charging is also not included in our analysis since DC chargers are just beginning to be installed. Installation records were divided into residential, public, retail, workplace, and fleet.

Previous EPRI analyses have included data from California installations only. The goal of the current study was to collect similar data from all over the country. The team began in the summer of 2012 by reaching out to a broad range of parties who might have access to installation cost data. The project contacted 15 utilities (both municipal and investor owned), 10 EVSE manufacturers, eight EVSE distributors or installers, 20 fleets and 3 stakeholder organizations. Potential respondents received a detailed document that described the type of information the research team was seeking. Contacted parties were asked to provide whatever information they might have even if it was not in any great detail.

The team was hoping to collect detailed cost data about labor, materials, permits and taxes as well as details about factors that caused installation costs to increase or decrease. Some of this information was limited, so design, overhead, administration and other potential upstream costs are not included in these estimates. For residential installations, the team requested the following information:

- Type of residence: Single Family Home; Multi-Family Dwelling
- Electrical Service (original panel amps; re-worked panel, i.e., moving breakers around to make more space; panel upgrade; separate EV charging meter)
- Nature of Parking (attached garage; detached garage; other)

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[34] Some data was collected for dual 240 volt chargers (2 chargers in one unit) and dual voltage chargers (combination 120 volt and 240 volt).

[35] "To Increase Electric Vehicle (EV) Sales, Automakers Must Address Economic Challenges, Not Just Tout Environmental Advantages." J.D. Power and Associates, Press Release, November 8, 2012.

- Location of EVSE installation (inside or outside; floor or wall mount; at Multi-family Dwelling -- at assigned space, guest parking or common area)
- Need for Special Work (trenching, boring, concrete, stucco)

For public, retail, workplace or fleet installations, the data requested included:

- Project Type: Public (e.g. public parking garage); Retail (e.g. at Walgreen's); Workplace (at an employer's site); Fleet
- Number and type of EVSEs installed per project: Level 1, Level 2, DC Fast Charge
- Installation location: indoor, outdoor
- Level of Electrical Service: e.g., 208 or 480 volts; Single-phase or Three-phase
- Required Electrical Work: e.g., Re-work of existing panel, i.e., moving breakers around to make more space; New panel required; New transformer; Other
- Special work required: trenching, coring, boring, poured foundation

Respondents were also asked to provide qualitative information about charging installations including:

- Were costs affected by site selection or structural factors – how so?
- Was the site previously wired for charging equipment?
- Were Prevailing Wages paid for electrical contractor labor?
- Do permit costs include only the cost of the permit, or do they also include payment for electrical contractor labor?
- Were costs influenced by time constraints to expend incentive funds – how so?

The EPRI team conducted extensive follow-up, including multiple emails and phone calls. As is discussed below, many interested parties either did not have detailed installation cost information or were concerned about protecting customer information or intellectual property. Obtaining permission to use data required lengthy negotiations, Non-Disclosure Agreements and multiple discussions. After months of follow-up, we were ultimately successful in obtaining quantitative data from five sources for residential installation costs and quantitative data from 12 sources for commercial (public/fleet/workplace/retail) installations. In addition, 14 contacts provided qualitative information including reports and observations in phone interviews.

Data Obtained and Restrictions on Data

This study obtained quantitative information covering 18 states (Connecticut, California, Georgia, Alabama, Illinois, Texas, Arkansas, Louisiana, North Carolina, Nevada, Florida, Tennessee, New Jersey, New York, Wisconsin, Mississippi, Ohio, and Maine) and British Columbia and Ontario in Canada. In

addition, qualitative research with study participants addressed installation costs and factors influencing costs, in aggregate, for many states. A total of 252 individual single-family or multi-family residential installation records were collected with a total of 305 installed charging units. Some 385 commercial records were collected with a total of 989 EVSE installed. Commercial installations were divided between workplace, public, and fleet; the retail category of installations was folded into the public category, as too few retail installations were identified by study participants for meaningful analysis. Figure 2-1 shows the number of records collected for each category of installation site.

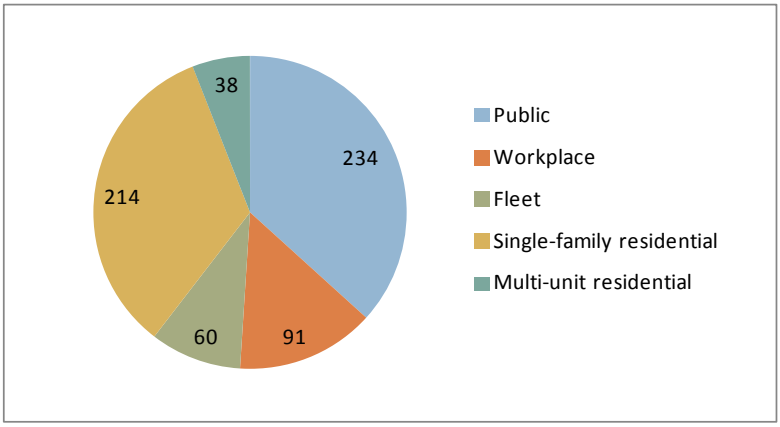


Figure 2-1
Number of Sites by Type of Installation

While this study captures only a fraction of the total installations over the past 3 years, it represents a cross-section of different types of Level 2 installations in different geographic areas. To preserve confidentiality, no end users are identified; all information was identified by city and state only. Figure 2-2 illustrates the sources of quantitative data in this study.

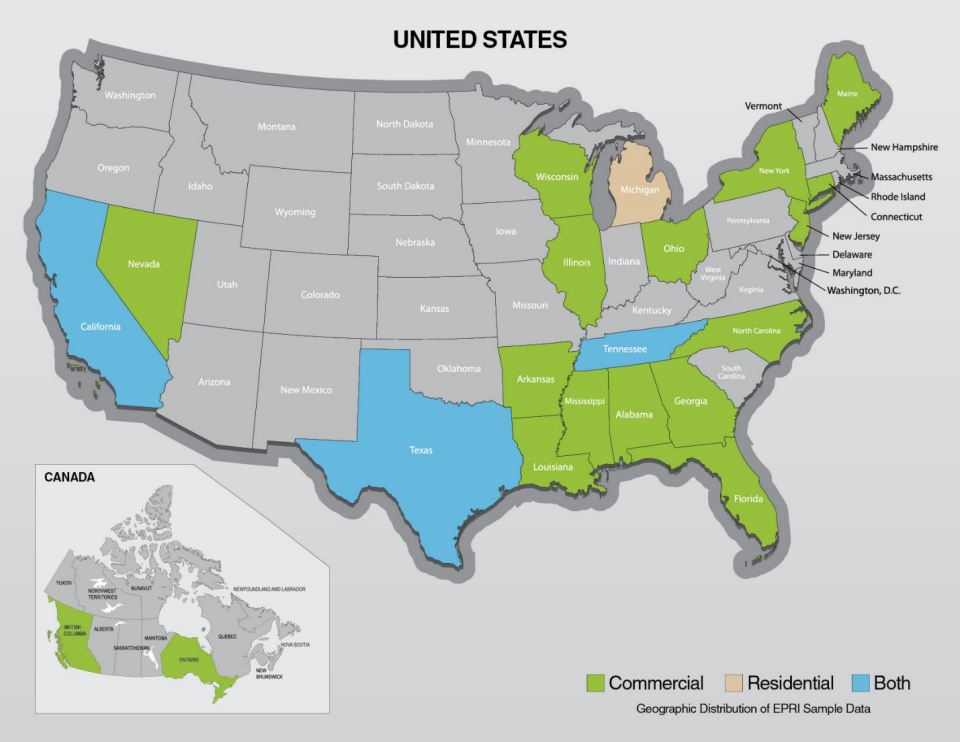


Figure 2-2
Geographic Distribution of Quantitative Sample Data

The following sections describe a number of obstacles that prevented our team from obtaining more data.

Conditions of Incentive Programs

Many Level 2 EVSE infrastructure installations in this study benefited from some kind of incentive funding—from the federal government, state public utilities commissions, local air quality agencies, electric utilities, or state government, among others. Many installations were part of research efforts to understand how, when and where PEV charging will occur; what effect pricing structures have on time-of-day of PEV charging; how PEV charging affects utility loads, or other objectives. As a result, installation costs do not reflect real world decisions by drivers making decisions to purchase and install charging. In some cases, a fixed price was negotiated for a demonstration project regardless of true cost. In other cases costs may be artificially high because of (i) extra metering equipment, (ii) deadlines from funding agencies to expend monies within a specified period, or (iii) requirements that Davis-Bacon prevailing wages be paid for all installation projects.

Government Funded Projects with Data Sharing Restrictions

Some of the largest potential sources of data such as The EV Project were not accessible until late in the project. Even then, only non-proprietary information can be made available. The EV Project was funded by approximately $120

million in grants from the U.S. Department of Transportation and the California Energy Commission. Part of the partnership agreement between Ecotality, the funding agencies and the automakers included strict data confidentiality and limitations on who could analyze the information. Where possible our analysis includes comparisons to The EV Project data.

Confidentiality Concerns/Proprietary Information

Several large manufacturers and installers felt that installation data was confidential and proprietary. They were willing, however, to share some aggregate data and many useful observations about the learning process they went through and obstacles encountered, which are included in our report. Utilities had confidentiality concerns as well and some were unable to share installation data.

Lack of Centralized Information

It was difficult to obtain large quantities of information from any single source. Utilities were often partners in demonstration projects with local governments and others, such as Clean Cities organizations, so it was difficult to access detailed installation data.

Other constraints included lack of detailed records with cost break-outs and use of third parties for installation (hence no access to cost records), among others. In addition, many installations were completed under a fixed price program, where all or most installations were performed for a pre-set price for a broad range of conditions. Several participants commented that the fixed installation prices dictated by the demonstration programs were too low and discouraged electrical contractors from participating. Other participants commented that, if given a template, they would be happy to collect data on future installations.

Section 3: Analysis of Level 2 Residential Installations

This project's analysis of the cost of residential Level 2 EVSE installations begins with an in-depth look at hundreds of California installations and a comparison to a small sample of installations in states outside of California. Given that California has the greatest number of PEVs sold and leased in the United States, as well as a long history of PEV experimentation and adoption, the majority of the available installation cost data is for California. To identify the costs, and cost drivers, for PEV residential installations, the project team collected a sample of 252 PEV residential installation records spanning from 2009 to September 2013. Of these, the vast majority (214) were single-family homes, but 38 were multi-unit dwellings.

The California data is split into three time frames, which reflect the time periods when residential EVSE installations were performed by the source providing data. The analysis includes a comparison to an additional sample of records from an earlier period, 1996 to 2002 (which this report designates as the "historical" period), when the first PEVs were introduced in small numbers.[36] The 2009 and 2012-2013 periods reflect time frames corresponding with more recent California roll-outs of electric vehicles for demonstration programs (2009) or current PEV market entry (2012-2013). These separate time periods in the California data enable us to analyze trends in the cost of installation over time.

Key Findings and Conclusions

Based on the sample of data collected for this study, the average cost to install a single-family residential EVSE is $1,613. If only the most recent installations are considered (2011 to 2013), the average is reduced to $1,512 in California and $1,499 outside California. Figure 3-1 provides the average and median costs for the historical period, 2009 and 2012-2013. The figure shows that installation costs have been declining over the 4 year period covered by the study.

[36] The California residential EVSE installation records come from the databases of Clean Fuel Connection.

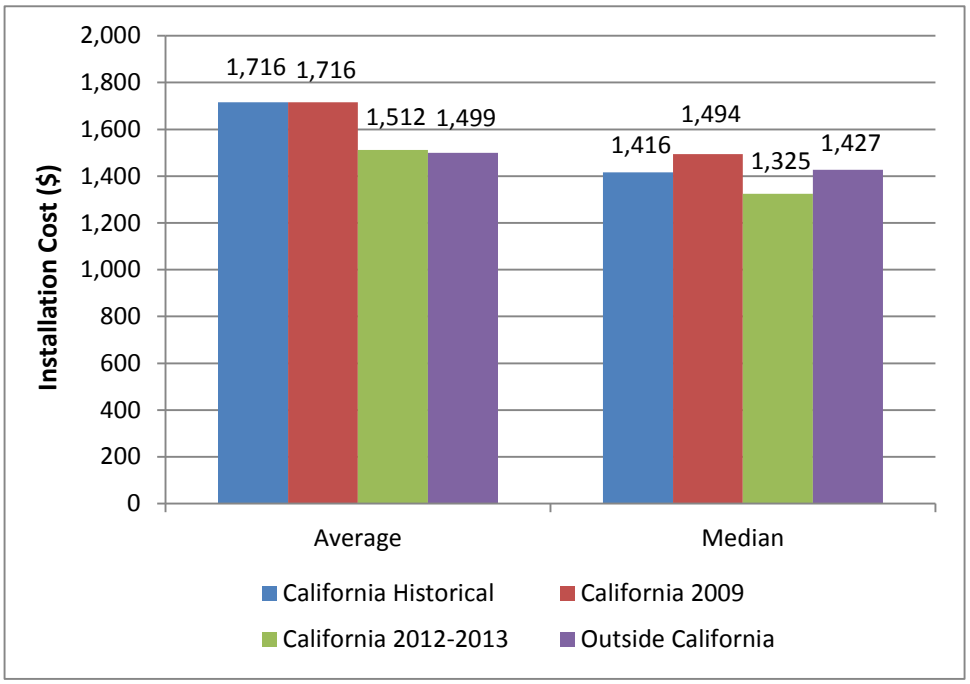


Figure 3-1
Average and Median Installation Costs for Historical and Recent Time Frames

Nearly all of the recent residential installations included in the dataset for this report were performed under funded demonstration programs. The major demonstration programs required that prevailing wages be paid for most of the installations, increasing labor costs by an estimated 15 to 25 percent.[37]

Within California, despite the upward pressure caused by prevailing wage requirements, labor and material costs have been trending downward. Permit costs, on the other hand, have risen dramatically, as shown by Figure 3-2. Residential permit costs have tripled between the 1996-2002 period and 2013. (Table A-2 in the Appendix provides more detail.) In California, permitting costs are now a significant proportion of total residential installation costs; in the 2012-2013 data, permits were 22 percent of the total installation cost.

While the study sample shows that the labor component of the installation cost was higher outside of California than within California, this result was clearly caused by a high proportion of research projects in the outside-California sample. The labor component in such cases included additional fees to support non-installation functions such as data collection and analysis. The study found that material and permit costs are lower outside California.

Site conditions have a significant effect on the cost of installations. Among the factors that increase cost of installation are:

[37] This assumption is based on anecdotal evidence from electrical contractors as well as data from R.S. Means.

- Longer distance from the panel to the EVSE location
- Lack of capacity on the panel
- Trenching asphalt or concrete
- Detached garage without electrical service
- Requirement for a subpanel
- Special metering

There are also factors that reduce installation costs including:

- Ability to attach conduit to home exterior
- Location of electrical panel close to charger location
- Attached garage
- Previous charging installation
- Pre-wiring during new construction

With respect to the future of installation costs, in the near term, costs should decline as the prevailing-wage demonstration programs are completed. Increasing volumes of vehicle sales and EVSE installations may also result in cost reductions. Over the longer term, however, without technology or policy improvements that allow EVSE to be installed at lower cost, residential installation expenses can be expected to face upward pressure as labor rates and material costs increase over time.

Analysis: Single-family Homes

Figure 3-1 provides an overview of the costs of EVSE installations in single-family homes, in California, during three time frames – Historical (1996 – 2002), 2009 and 2012-13. A sample of about 100 residential installations was obtained for each of these periods; data from the historical period was adjusted for inflation (labor and materials regional inflation rates) to reflect 2009 dollars. The 2009-2013 costs have not been adjusted for inflation. All of the residential installations in the 2012-13 sample reflect payment of Davis-Bacon prevailing wages, and hence incorporate differentially higher labor rates than earlier periods.

The total average cost of California installations did not decrease between the historical period and 2009; coincidentally, the total average cost is $1,716 for both time periods, in 2009 dollars. However, total average costs fall by 12% between 2009 and 2012, to $1,512. Median costs reflect a decrease of 11%, from $1,494 median cost in 2009 to $1,325 in 2012.

A much smaller sample of costs for single-family residential installations outside of California (Michigan, Tennessee, and Texas) during 2011 and 2012 shows a cost similar to California in 2012: $1,499 average cost, and $1,427 median cost. About 88% of the installations outside of California were performed using Davis-Bacon prevailing wage rates.

Figure 3-2 shows detailed breakdowns of average costs by component – labor, materials, and permit -- for California and non-California single-family home Level 2 EVSE installations. Detailed tabular data including taxes is included in Table A-2.

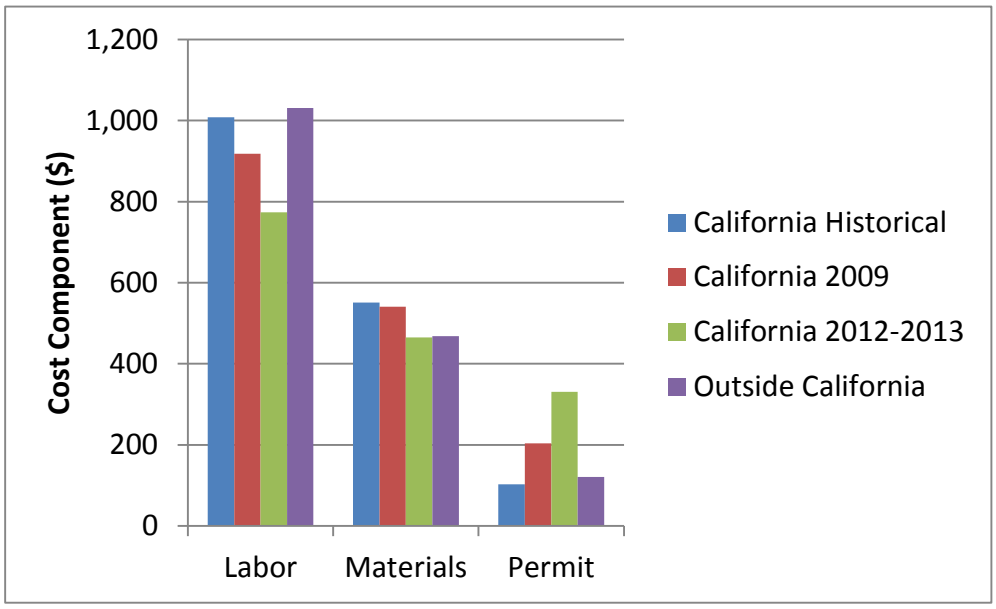


Figure 3-2
Average Residential Installation Costs by Component

Marked trends in the California data are apparent. Labor costs show steady declines of 9% and 16%, respectively, between Historical to 2009, and 2009 to 2012, despite the fact that the 2012 labor rates reflect prevailing wage costs. Materials costs show some decline as well (2% and 14% between each period). However, permit costs show steady increases of 98% between the Historical period and 2009, and another 62% increase between 2009 and 2012. Permit fees have reason dramatically as a percentage of total costs, rising from 6% in the Historical period, to 12% in 2009, to 22% in 2013.

In contrast, Level 2 single-family home installations from states outside of California in 2011-2012 show that labor costs are significantly higher[38], and materials costs are on par. However, permit costs are quite a bit lower ($121 versus California average permit costs of $331), and permit costs represent only 8% of the total cost of installations.

Factors that Increase Single-family Residential Installation Costs

A number of the installation records collected by this study provided details regarding factors that might impact cost. These factors were isolated and

[38] As noted earlier, the outside-California sample contained a high proportion of higher-cost research projects.

compared to the average installation cost. As expected, longer conduit runs, limited panel capacity, and trenching work all were related to increased installation costs. The detailed data is shown in Table A-4, and the findings include:

- Installations with less than 36 feet of conduit consistently cost less than installations that require more than 36 feet of conduit. Even though there are fewer records outside of California with detailed breakdowns, the relationship between distance and cost holds true in areas outside of California as well as within California. The relationship is also consistent over time.
- EVSE installations that require special work (such as trenching, boring, or stucco) are more costly; this relationship also holds true across time and geography.
- Installations in homes with smaller electrical panels (less than 100 amps) are more expensive than homes with 101 – 200 amps or more than 200 amps.
- Residents who needed panel upgrades paid more for installation than did those who had site-specific placement or structural factors (for example, installations in a driveway versus inside the garage, or detached versus attached garages).

Analysis: Multi-Unit Dwellings

The expansion of charging installations to multi-unit dwellings is an important development for the growth of the PEV market since many potential buyers of PEVs live in rental apartments, cooperatives and condominiums. Residents of multi-unit complexes must also overcome hurdles related to dedicated parking, homeowner association requirements, the complexity of assigning costs to users of charging units, and (at times) incompatible electrical infrastructure.

Only a small number of multi-unit dwelling (MUD) EVSE installations have been performed. The study sample includes 38 installations undertaken in 2011 – 2012, all with labor rates at prevailing wages. Figure 3-3 illustrates that the average multi-unit installation cost is $3,744, more than double the single-family residential average ($1,512). In addition, the range between the lowest-cost installation and the highest is nearly $6,000, which is significantly wider than the range of single-family costs.

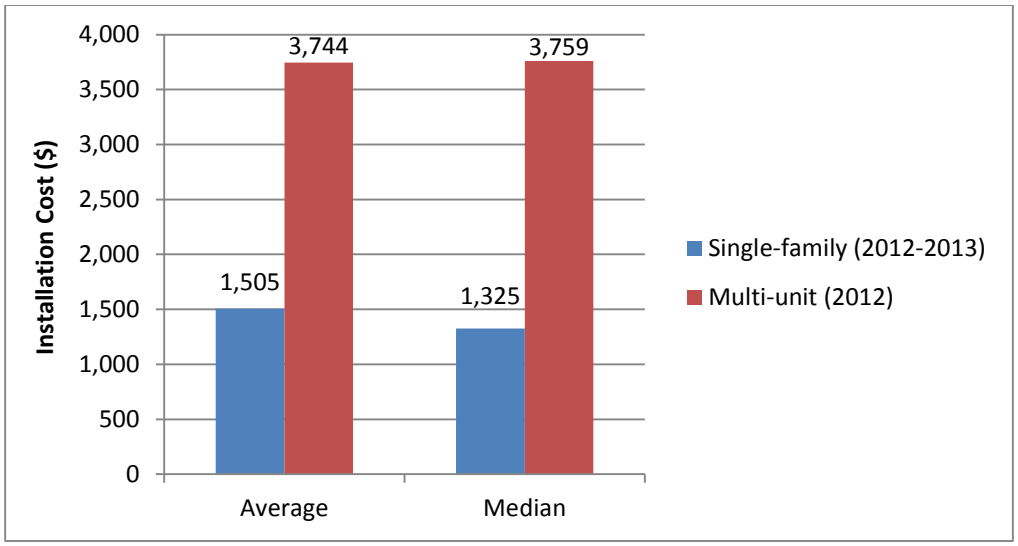


Figure 3-3
Comparison of Costs at Single-Family Residences and Multi-unit Dwellings

Comparing the components of MUD installations to single family installations, labor is about twice as costly for multi-unit installations, while materials are about three times as costly. The average permit cost ($343) is only slightly higher than the California single-family average ($331), but permit fees are a smaller percentage of the total average installation costs (9% for MUD vs. 22% for California single-family installations in 2012).

Comparison to the EV Project

Figure 3-4 represents a large subset of residential installation data from the EV Project, as reported in June 2013.[39] At $1,375, the national average EVSE installation cost is somewhat lower than the EPRI study average of $1,613. However, the California installations in the EV Project data cost more than the overall average and are closer to the California average in the EPRI study. The weighted average of the EV Project data for Los Angeles, San Diego and San Francisco is $1,519, nearly identical to the EPRI study sample ($1,512 in 2012-2013). The EV Project data in Figure 3-4 clearly illustrate regional variations in EVSE installation costs, with California installations being the most expensive, Tennessee and Arizona being the least expensive, and Pacific Northwest falling in the middle.

[39] J. Francfort and T. Garretson, "EV Project and Charging Infrastructure Update," U.S. DRIVE Grid Interaction Tech Team, presented at USCAR, Southfield, MI (June 19, 2013).

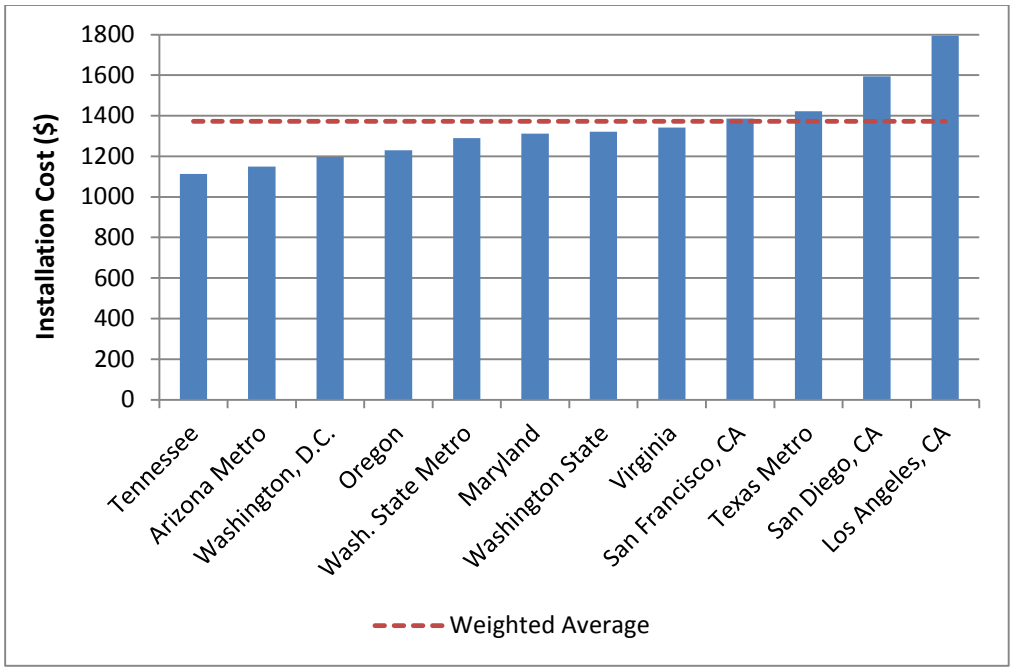


Figure 3-4
The EV Project Data: Average Residential Installation Costs

Permit Costs

Permit costs are available from several sources in addition to the EPRI data. The EV Project collected information on residential permit fees for each participating region.[40] Data is also available from Bosch Automotive Service Solutions (formerly SPX), an EVSE manufacturer and installer that has performed thousands of installations.[41] Figure 3-5 compares the average permit fees for states that are included in both datasets. There is also some anecdotal evidence that some cities are charging higher permit fees for EVSE installations than for other work of similar complexity or cost.

[40] J. Francfort and T. Garretson, "EV Project and Charging Infrastructure Update," U.S. DRIVE Grid Interaction Tech Team, presented at USCAR, Southfield, MI (June 19, 2013).

[41] "Bosch Installation Data: What We've Learned So Far…" Bosch Automotive Service Solutions, April 3, 2013.

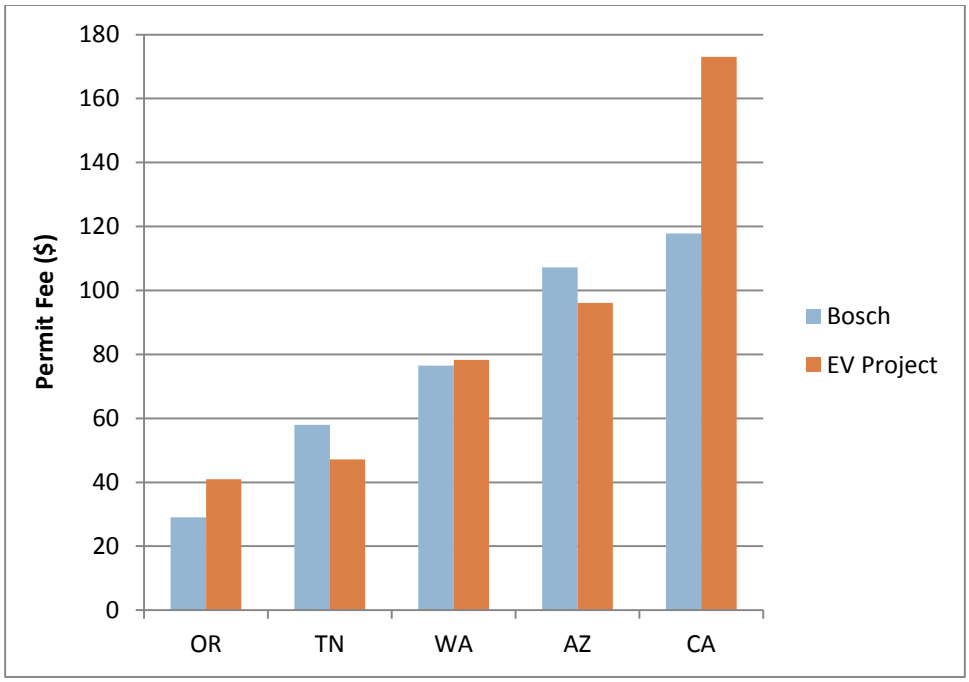


Figure 3-5
Permit Fees for States Covered by Both Bosch and EV Project installations.

The EPRI data is the only dataset that provides evidence of how permit fees have increased over time, as presented earlier in Figure 3-2.

Section 4: Analysis of Level 2 Commercial Installations

In this chapter we present analyses of baseline information regarding costs of commercial EVSE installations in the 2010 to 2013 time frame, derived from the sample of installation data collected for this study. Commercial installations encompass charging installations in three site categories: Public (public parking garage or lot, airport locations, retail locations such as hotels, stores, cultural destinations, and other public access locations); Workplace (at an employer's site); and Fleet.

Both qualitative insights and quantitative cost data are explored, to identify and better understand the factors that affect installation costs (e.g., regional differences, characteristics of commercial sites and their electrical requirements, influence of funded demonstration projects on costs, among others).

EPRI polled dozens of utilities, EVSE manufacturers, EVSE installers/contractors, fleets, private companies, and non-profit organizations to obtain data for use in this study. EPRI received quantitative data and/or qualitative insights on commercial installations from sources in a broad geographic area (18 states and two Canadian provinces: Alabama, Arkansas, California, Connecticut, Florida, Georgia, Illinois, Louisiana, New York, North Carolina, Ohio, Tennessee, Texas, New Jersey, Nevada, Wisconsin, Mississippi, Maine, and British Columbia and Ontario, Canada). The analysis also includes a comparison of EVSE installations at commercial sites within California to areas outside of California.

Table 4-1 illustrates the distribution of the Commercial sample over time, which reveals that the largest number of installations occurred in 2011 and 2012. Appendix B provides further detail on the distribution of the Commercial sample.

Table 4-1
Commercial Sample by Year and Location

	Year					
	2010	**2011**	**2012**	**2013**	**Total**	**Percent**
California	12	89	132	16	249	65%
Outside California	8	94	34	0	136	35%
Overall	20	183	166	16	385	100%

This study presents a current snapshot of recent experience, and many of the commercial installations during this period were part of publicly funded demonstration projects. Incentive funding requirements may have influenced costs (e.g., Davis-Bacon requirements to pay prevailing wages for labor, or union rates; site selection criteria; specific time deadlines for funds to be expended; among others). When evaluating study findings, it is important to keep in mind the research and demonstration context of many recent EVSE installation projects. Recently published data from The EV Project serves as a source of comparison and corroboration over the 2011 – 2013 time frame, and the EV Project data also reflect the influence of incentive funding requirements.

Key Findings and Conclusions

The installation of EVSE at commercial sites is not uniform in any way. Each site is unique, and many factors influence costs, both up and down, including:

- The distance from an electrical panel to the charging location
- Available electrical capacity
- Physical site attributes such as indoor or outdoor location or need for special work such as trenching
- The cost of labor where the installation is sited
- Whether a site has been previously wired for an EVSE installation
- The number and type of Level 2 EVSE installed at each site
- Whether the installation is part of a research or demonstration project.

The project collected cost data and qualitative insights for 385 commercial charging sites with a total of 989 EVSE installed. The analysis of this information leads to these summary findings:

- Overall, the average cost to install a Level 2 EVSE in a commercial setting is $3,962 per EVSE unit, or $3,005 per charge port. Commercial installation costs decreased somewhat over time, between the 2010-2011 period and the 2012-2013 period.
- Overall, the Level 2 commercial installation costs in this project's sample are consistent with the range of $3,500 to $4,500 per EVSE presented recently by the EV Project. Similarly, the major factors influencing installation costs are consistent between this study and The EV Project analyses.

- Installing more than one EVSE at a site drives down installations costs (per EVSE). Economies of scale, even for labor costs, are clearly visible with larger numbers of EVSE installed per site (5 or more EVSE).
- An opportunity to increase the base of charge ports at the least cost is afforded by installing Dual Voltage EVSE (with one Level 2 port and one Level 1 port in a single unit) or Dual Port Level 2 EVSE (with two Level 2 ports per unit). These are more expensive on a per-EVSE basis but are significantly less expensive on a per-port basis.
- Installations outside of California are substantially less expensive than in California. California has years of experience and much funding support for Commercial EVSE installations. However, California permit costs, higher labor rates, preponderance of installations requiring Davis-Bacon prevailing wages to be paid, and probably a large proportion of high-visibility siting locations, push costs in the state much higher than in most other states.
- Site characteristics play a key role in costs, and poor siting choices can adversely affect costs. When siting PEV charging in a commercial setting, a key decision to be made is the trade-off between the lower-cost installation that is near the electrical room, and the showcase installation that is at a highly visible location far from the electrical room. Some factors in this trade-off are:
    - Costs are reduced through proximity to a source of electricity, avoidance of special work (coring, boring, trenching, poured foundations), absence of a need for electrical panel work or new electrical infrastructure, flexibility in siting and/or minimal concern for the aesthetics at a site, and presence of prior wiring for EVSE charging.
    - A host of site challenges such as parking location constraints or long distances from electrical sources can push costs upward.
    - Fleet installations are typically much less costly than public or workplace charging installations, in large part because fleets typically are better able to influence siting choices in ways that minimize costs.

The commercial data revealed some unexpected findings:

- The need to re-work an electrical panel in order to make room for Level 2 EVSE charging often is associated with lower-than-average costs of installations.
- Permit costs are not a significant factor impacting commercial installation costs.
- The commercial data sample has an unusual distribution of costs: while half of the California installations cost $4,000 or less per EVSE, and over half the installations outside California cost $3,000 or less per EVSE, there is a significant portion of high-cost outliers in each sample. About 10% of the California sample has installations costing $10,000 or more per EVSE; about 10% of the Outside California sample has installations costing $6,000 per EVSE or more.

Overview of Quantitative Sample

EPRI's sample of quantitative commercial installation cost data reflects a total of 385 charging installation sites, with 989 EVSE installed. All of the quantitative data reflect installation costs for one of three configurations of Level 2 EVSE: Level 2 EVSE with a single charge port; Dual Port Level 2 EVSE (with two Level 2 charge ports)[42]; and Dual Voltage EVSE (with one Level 2 charge port and one Level 1 charge port in a single EVSE). The study excluded DC Fast Charge installations. While the study team sought to include data on the cost of installing stand-alone Level 1 EVSE, the sample of Level 1 data that we were able to collect was too small to analyze. The only discussion in this report of Level 1 installations stems from installations of Dual Voltage EVSEs.

Commercial installations are categorized according to installation site category as Public, Workplace, and Fleet. During the data collection stage of the project, the Public classification consisted of two separate categories: Public, defined to include public parking garages, airport parking, and other public access locations; and Retail, which consisted of shopping malls, storefronts, restaurants, and similar sites that provided parking for retail customers. However, the sample of quantitative data collected was not sufficiently large to adequately analyze Retail and Public as separate categories, which led the project team to combine these two groups into a single Public category for analysis.

Some charging locations were categorized by their principal use (for example, the principal use might be for Workplace charging, although the company fleet vehicles might use these EVSE on occasion; or the principal use might be for fleets, but public access is allowed).

Characteristics of the sample of installation cost data for this study include:

- Public charging accounts for about 60% of charging installation sites and number of EVSEs; Workplace accounts for about 25%; and Fleet accounts for about 15%. Figure 4-1 shows the number of EVSE within each site category.
- 54% of the total number of Level 2 charge ports are in Public locations, 34% are in Workplace venues, and 12% are in Fleet locations.
- 80% of Level 1 charge ports in this sample (via Dual Voltage EVSE) are in Public locations, with 17% in Workplace venues and only 3 % in Fleet sites.

[42] Some manufacturers offer multi-port (also called "multi-headed") EVSE with more than two ports. This study did not obtain any installation cost data for multi-port EVSE with more than two ports.

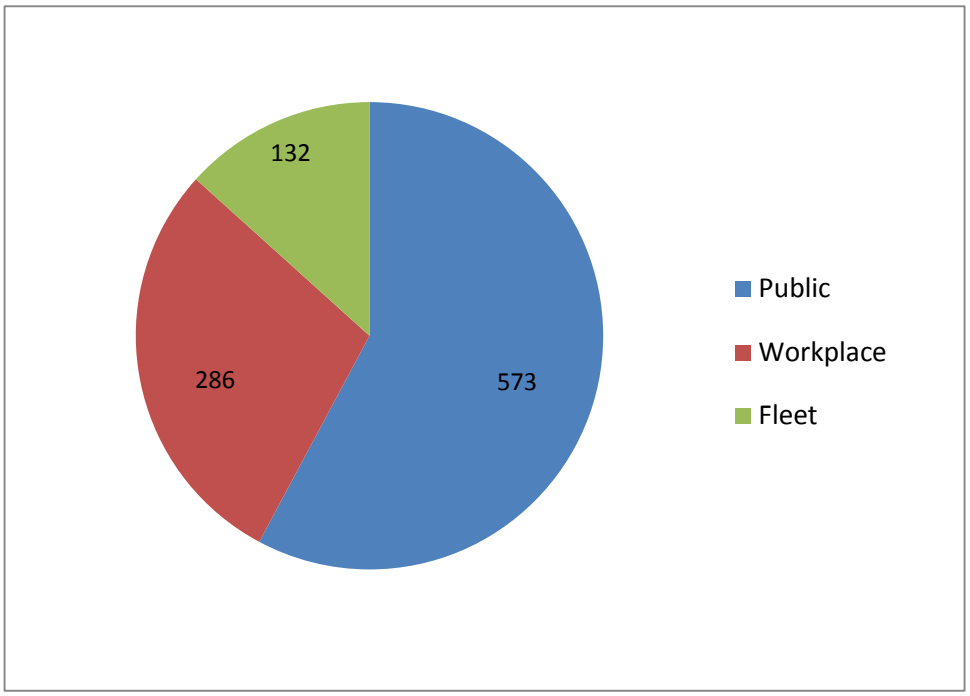


Figure 4-1
Number of EVSE by Site Category

Figure 4-2 illustrates the number of sites, EVSEs, and charge ports within each category. Appendix B provides additional data.

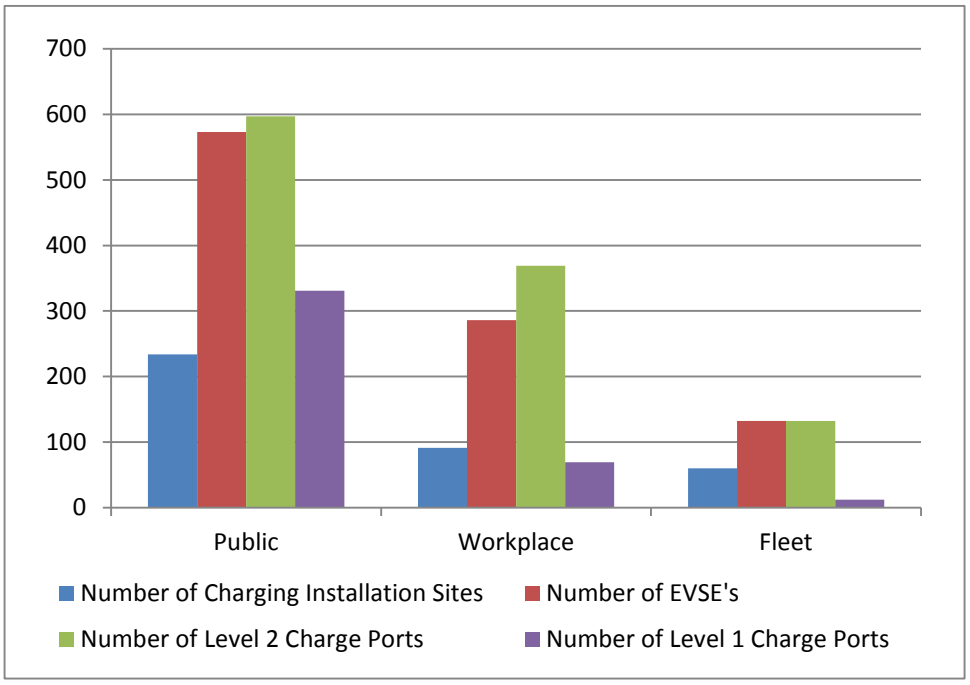


Figure 4-2
Commercial Installations by Site Category

Data Analysis

Using the confidential raw data from each respondent, the project team coded the data into a spreadsheet and used specially designed software to develop aggregated analyses along certain parameters. The software enables the data to be flexibly analyzed and viewed, in various configurations, while protecting the anonymity of data sources.

The quantitative data is segmented and analyzed in this study as follows:

- Commercial installations as a whole, and by category of Public, Workplace, and Fleet, in order to assess variations in cost by type of installation, trends, and the factors that drive total costs within each installation type.
- The total commercial sample alongside analyses of California versus Outside California. Due to the availability of a large number of commercial quantitative cost data from California sources, the project team was able to analyze California separately from the remainder of the cost data.
- Number of EVSEs installed at each site: one EVSE; two EVSEs; 3 to 5 EVSEs; and 6 or more EVSEs. This segmentation is undertaken to better determine whether economies of scale are possible with greater number of EVSE installed per site, and the factors influencing why, or why not. Figure 4-3 shows that:
  - 45% of Commercial installations are comprised of one EVSE per site
  - 26% of Commercial installations have two EVSEs per site
  - 20% consist of installations with 3 to 5 EVSEs per site
  - 9% of Commercial installations have 6 or more EVSEs per site.
- Public and Workplace breakdowns of installations (according to the number of EVSEs installed per site) are similar to the overall sample distribution; however, most of the Fleet installations in the sample (65%) installed a single Level 2 EVSE at each site. Table B-3 in Appendix B provides more detail.

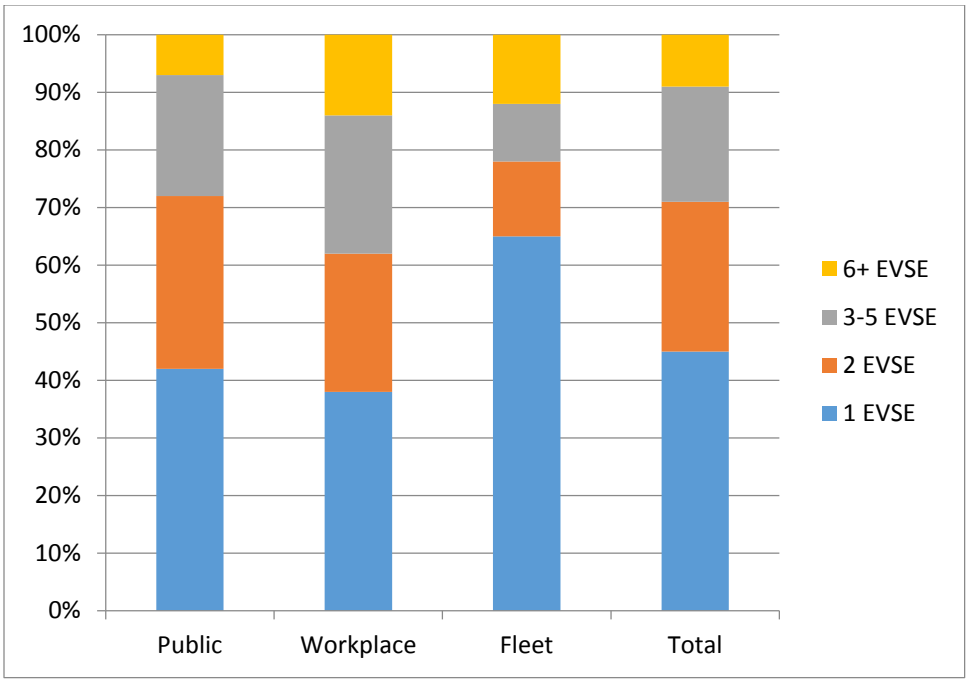


Figure 4-3
Commercial Installations by Per-Site EVSE Quantity

In addition, to determine the impact of certain site attributes on installation costs the team examined the presence, or lack thereof, of the following characteristics at each site:

- Indoor vs. outdoor location
- Need for the following types of electrical panel work:
  - Panel Upgrade (i.e., when the lack of electrical capacity necessitates that the panel is replaced with a new one that provides additional capacity);
  - Re-worked Panel (i.e., re-organizing the panel to create space for a 40 amp circuit for an EVSE); or
  - Addition of a Sub-Panel (splitting the current electrical panel capacity and adding additional circuit breakers by installing a sub-panel in a nearby location; the sub-panel embodies only a portion of the total panel amps);
- Need for new electrical infrastructure (such as a transformer or other equipment)
- Need for special work at the site, such as trenching, coring, boring, or a poured foundation
- Previously-installed wiring for EVSEs

In addition, the team analyzed qualitative information provided by study participants and other sources regarding factors that affect costs, which included:

- Site or structural factors that are challenging to overcome;
- Whether permit costs included time spent by contractors waiting in line to get permits.

Appendix B provides more information about the commercial site characteristics.

Assumptions for Multi-port EVSE

Due to the multiple configurations of Level 2 EVSE (single-port, dual-port, dual-voltage) at commercial locations, the costs must be examined on both a per-EVSE (or unit) and per charge port basis in order to obtain meaningful insights.

While it is clear that single-port and dual-port Level 2 EVSEs should be counted as having one and two ports, respectively, the project team decided that an intermediate assumption was required for the dual-voltage EVSEs. The dual-voltage EVSEs are capable of supplying two PEVs at the same time, but the power capability of the Level 1 port is less than the Level 2 port. Based on the typical circuit capacity of the various configurations, as shown in Table 4-2, the project team resolved to count the dual-voltage EVSEs as having 1.5 charge ports. This allowed the team to evaluate the installation cost differences by the number of EVSE units as well as by the port configuration to see if Dual Voltage or Dual Port EVSE are less expensive to install.

Table 4-2
Assumed Number of Charge Ports for Various EVSE Types

EVSE Type	Typical Circuit Capacity (Amps)	Assumed Number of Charge Ports
Single Level 2 EVSE	40	1
Dual-voltage (Level 1 and Level 2)	60	1.5
Dual-port Level 2	80	2

Total Sample

In the commercial sample overall, consisting of 385 installation sites, the average cost per EVSE is $3,962, and the average cost per charge port is $3,005. These results are in the range of findings from The EV Project presented recently by Idaho National Laboratory, which states "Nationally, commercially sited Level 2 EVSE average between $3,500 and $4,500 for the installation cost," excluding the cost EVSE hardware.[43]

The study data reveals significant variation in costs between California and other states, as illustrated in Figure 4-4. The average installation cost per EVSE is 29%

[43] J. Francfort, Idaho National Laboratory, "EV Project Charging Infrastructure Deployment Costs, Cost Drivers and Use," presented at the Plug-in 2013 Conference, San Diego, CA (October 2013).

lower outside of California than within California, and 8% lower per charge port. Median costs per EVSE in the Outside California sample are 30% lower than California, and 17% lower on a per charge port basis. Appendix B provides additional detail. Regional differences in costs are corroborated by results recently published on The EV Project, which noted "there is much variability by region and by installation. Tennessee and Arizona have average installation costs of $2,000 to $2,500" (compared to a national average between $3,500 and $4,500).[44]

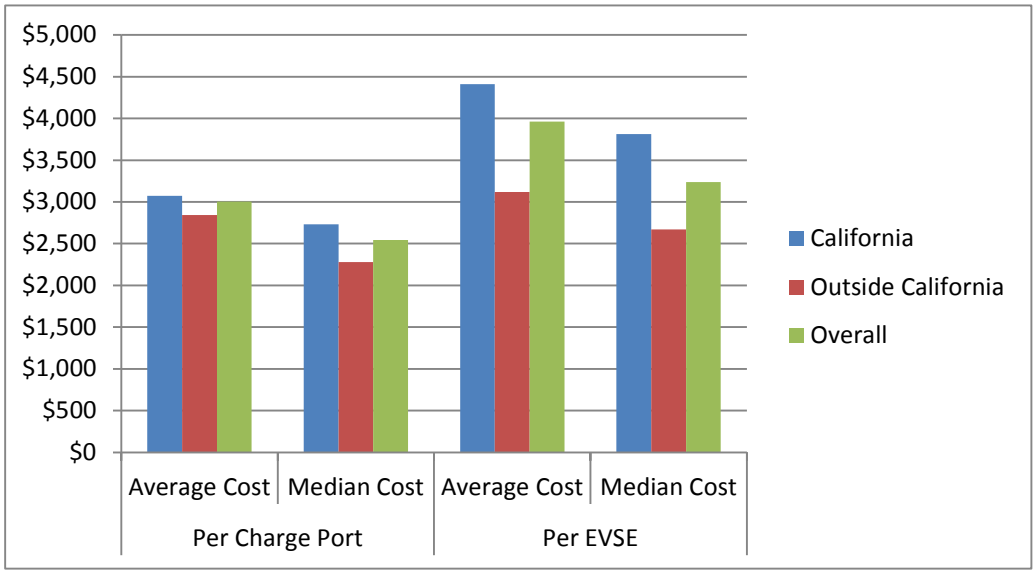


Figure 4-4
Commercial Installation Costs: Overall, California, and Outside California

Histograms of a data sample provide greater understanding of the average and median cost results. The histograms in Figure 4-5, Figure 4-6, and Figure 4-7 show installation cost per EVSE on the X axis, in buckets of $1,000; the Y axis denotes the number of installation sites within each bucket.[45] In the California commercial sample, half of the installations cost $4,000 or less per EVSE; while outside of California, more than half the installations cost less than $3,000 per EVSE. The overall commercial sample and the California sample each have a long "tail" at the high end, with 10% of charging installations among the most expensive: $10,000 or more per EVSE. The Outside California sample has a similar high-cost "tail", but the threshold for the top 10% of installations is significantly lower, at $6,000 per EVSE. The presence of a handful of high-cost projects raises the average cost results significantly, which is important to remember when interpreting the average and median cost results. Appendix B

[44] J. Francfort, Idaho National Laboratory, "EV Project Charging Infrastructure Deployment Costs, Cost Drivers and Use," presented at the Plug-in 2013 Conference, San Diego, CA (October 2013).

[45] For example, the bar marked as $5,000 indicates the number of sites with an installed cost per EVSE of $4,001 to $5,000.

presents hypothetical results for a modified sample of commercial data with the high-cost projects removed.

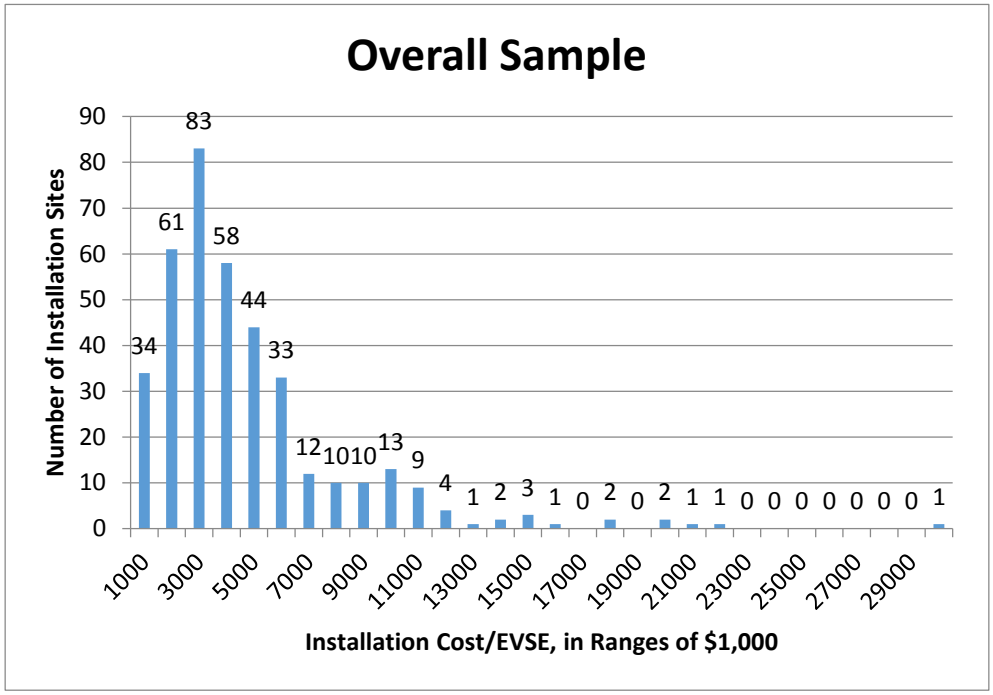


Figure 4-5
Installation Cost Distribution: Overall Sample

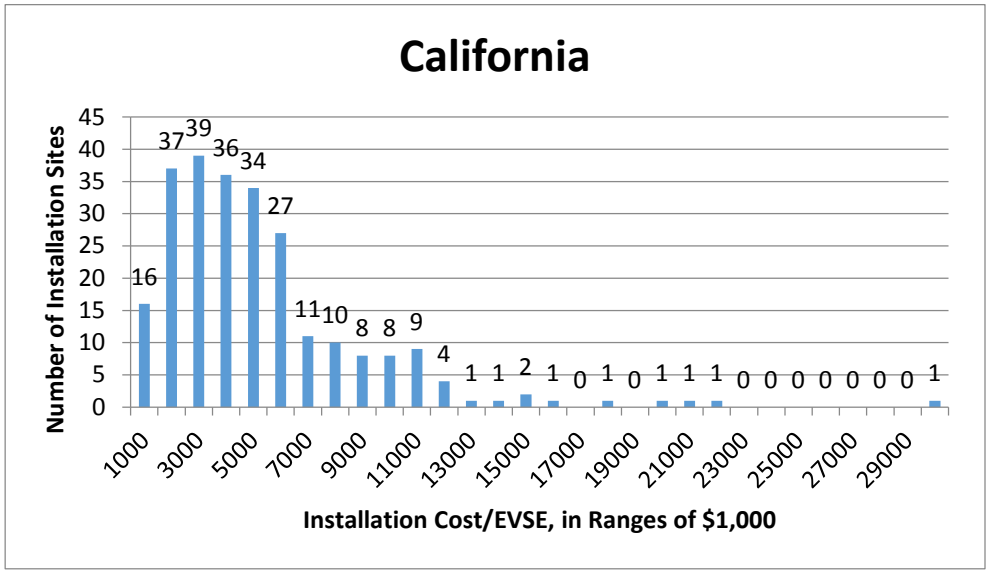


Figure 4-6
Installation Cost Distribution: California

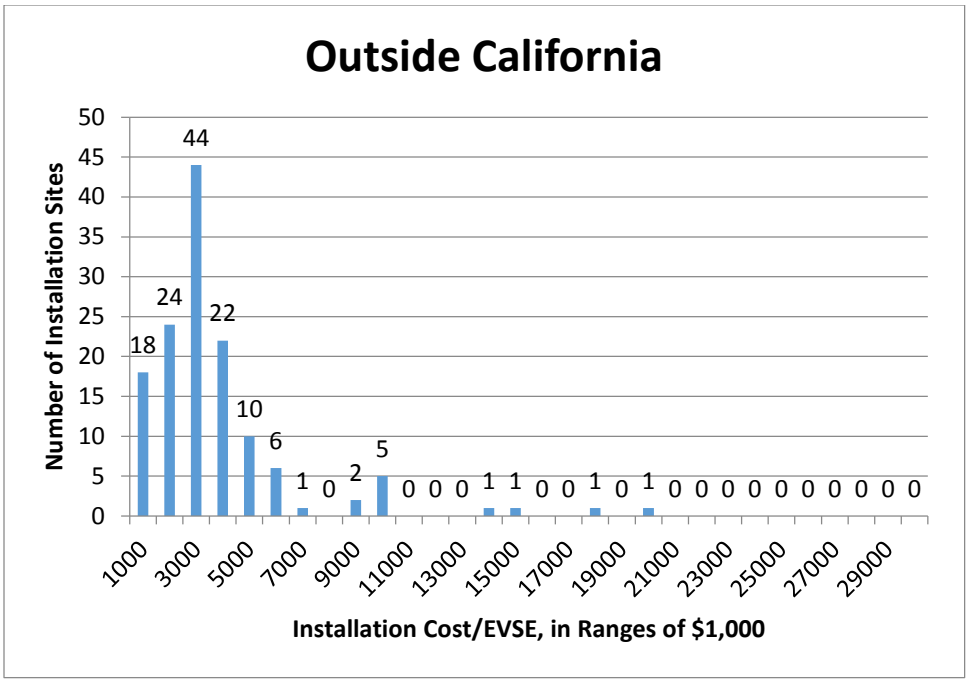


Figure 4-7
Installation Cost Distribution: Outside California

Comparison of Site Categories: Public vs. Workplace vs. Fleet

In general, one would expect Public and Workplace charging installations to be as likely to cost more than Fleet installations on a per EVSE basis or a per charge port basis. While Public and Workplace charging sites frequently involve the installation of 2 or more EVSE per site (which can lower costs per EVSE), other factors may outweigh this downward cost trend. Factors that contribute to potentially higher costs at Public and Workplace settings include: siting issues may be more complex and costly, due to aesthetic desire for high visibility parking locations or constraints on available parking spaces, leading to long distances from electrical panels; mall locations, airport settings or employer campus settings may result in long distances from electrical panels, as well; Americans with Disability Act requirements; availability of sufficient, incremental electrical capacity; installation locations requiring special work, such as trenching, coring, or boring, among others. As noted in a recent Idaho National Laboratory (INL) presentation on cost drivers in EVSE infrastructure deployment costs, "costs are significantly driven by poor siting requests. Example: mayor may want EVSE by front door of city hall, but electric service is located at back of building." [46]

In the data collected for this project, the Fleet sites are predominantly single-EVSE installations (which can increase costs), but this may be outweighed by a

[46] J. Francfort, Idaho National Laboratory, "EV Project Charging Infrastructure Deployment Costs, Cost Drivers and aUse," presented at the Plug-in 2013 Conference, San Diego, CA (October 2013).

typical fleet's less pronounced concern for aesthetics, greater flexibility in siting EVSE close to an electrical panel, and greater likelihood of an electrical panel with an additional 40 amps available.

Figure 4-8 illustrates the average installation costs within the various site and location categories. The results show that Fleet installations are much less expensive than Public or Workplace charging installations, while Public sites have the highest installation cost. These relationships also hold true within California. The sample of Workplace sites outside of California reveals an exceptionally high cost, but the sample size is so small (only 14 sites) that results are inconclusive. Appendix B provides further insight into this data.

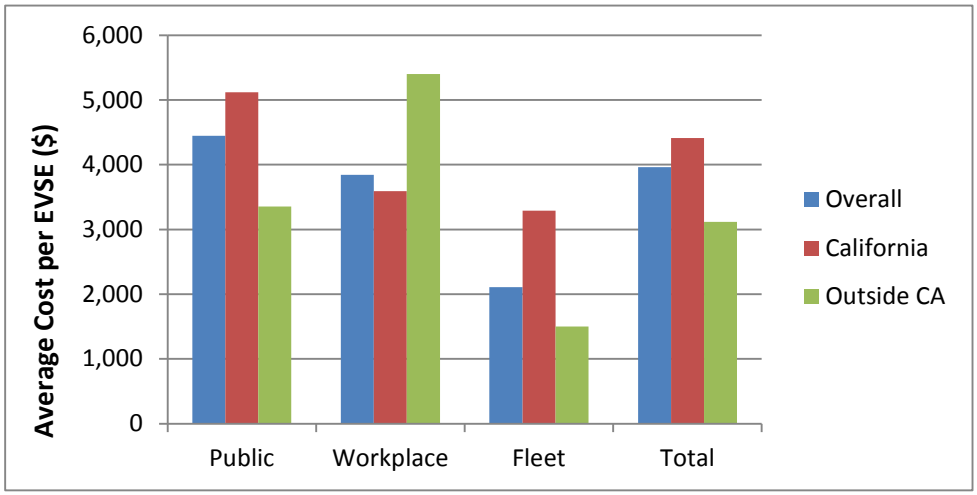


Figure 4-8
Commercial Installation Costs, by Type of Installation, Average Cost per EVSE

Cost Components (Labor, Materials, Tax, Permit) of Commercial Installations

To understand factors driving commercial installation costs, it is useful to examine the cost components (labor, materials, tax and permit). In this study's sample of commercial installations, labor consists of about 55 - 60% of the costs, while materials are about 30 - 35%; Permits account for about 5% and tax about 5%.

For all results presented in this section, the average costs for each category (labor, materials, permit, tax) reflect the average for all records in the sample that have a value specified for each category; some records are complete, but other records have only total cost data, while some have the total cost with partial cost component data. Hence, the averages for the cost categories do not always sum to the average for the total sample.

Figure 4-9 illustrates the average cost in each category, and compares the overall commercial dataset with projects inside California and outside of California. It is striking how much higher California labor costs are compared with labor costs

Outside California. On a per EVSE basis, average labor costs in California are more than double the average labor costs Outside California. (Since California installations have more multiport EVSEs, on a per charge port basis California labor costs are about 20% higher than Outside California).

Materials costs are much closer in California and Outside California; materials in California cost about 20% more than Outside California, on a per EVSE basis, and are 3% less than Outside California installations, on a per charge port basis.

Permit costs are not a significant proportion of the cost of commercial installations, ranging from 2% - 6% of total project costs (on a per charge port or a per EVSE basis). However, permit costs are 3 – 4 times higher in California than Outside California ($251 versus $65 on a per EVSE basis, or $180 versus $60 on a per charge port basis).

Permit data were analyzed on a per EVSE and per charge port basis, but many permitting authorities may issue permits on a per project basis. California permit costs are also significantly greater on a per project basis than Outside California: $533 average permit cost, per project vs. $152 per project Outside California, or more than three times higher.

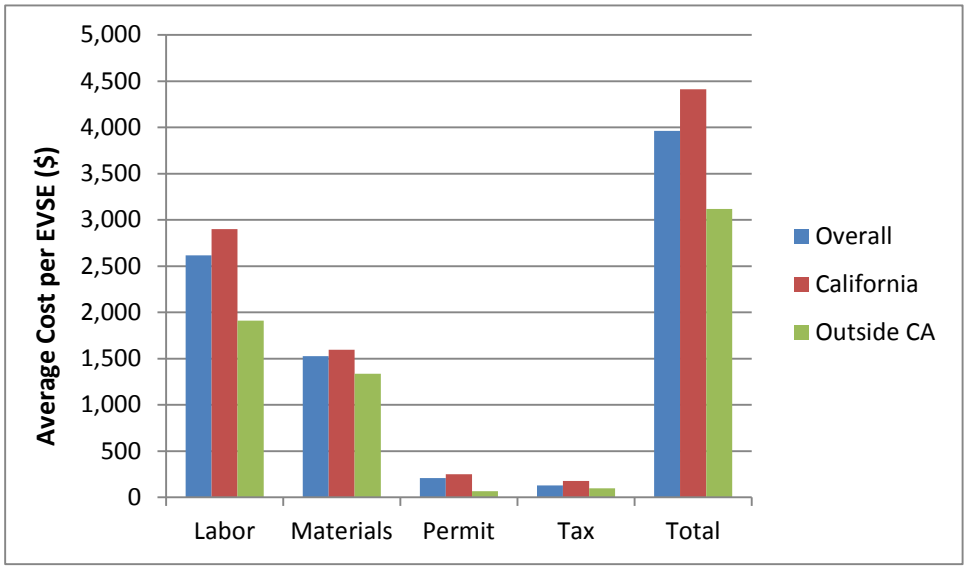


Figure 4-9
Commercial Installation Costs, by Cost Component

Cost Components, by Public vs. Workplace vs. Fleet Commercial Installations

To better understand cost differences among different installation site categories (Public, Commercial, Fleet), it is useful to examine the cost components of commercial installations. As noted earlier in this chapter, the Public charging installations are the most expensive (average per EVSE or per charge port), Fleet installations are the least expensive, with Workplace installations in between.

Labor costs (in both absolute values and in percentage terms) are highest in Public commercial installations (almost 70% of total costs, on a per EVSE basis), lowest in Fleet installations (about 60%) and in between in Workplace installations (about 65%). Materials costs show a similar pattern, where they are lowest in Fleet installations (close to 30% on a per EVSE basis, almost 40% in Public EVSE, and about 38% of total costs for Workplace stations. Permit costs per EVSE are highest for Workplace, lowest for Fleet, but all Permit costs are in the range of $150 - $250 per EVSE (about 4% - 8% of total costs).

Effect of Number of EVSE Installed per site on Installation Costs

Examining installation costs, segmented by the number of Level 2 EVSEs installed per site, is useful in determining whether economies of scale are possible in EVSE installations. As noted by Jim Francfort, INL, in a recent presentation on EV Project infrastructure installation data, "Multiple Level 2 units at one location drive down the per EVSE average installation cost."[47]

In the EPRI project sample, it is clear to see that economies of scale do apply in EVSE installations. When examining costs on a per charge port basis, costs decrease directly with an increase in the number of EVSE installed per site:

- $3,005 for all commercial sites (per charge port basis)
- $3,676 for 1 EVSE
- $3,036 for 2 EVSE
- $2,899 for 3 to 5 EVSE
- $2,733 for 6+ EVSE

On a per EVSE basis, findings are similar, but in this project's sample there is a slight increase in average cost per EVSE at sites with 6 or more EVSE:

- Overall average cost per EVSE is $3,962
- 1 EVSE is $4,845 per EVSE
- 2 EVSE are $4,078 per EVSE
- 3 to 5 EVSE are $3,541 per EVSE
- 6+ EVSE are $3,799 per EVSE.

Labor costs per EVSE decrease steadily as the number of installed EVSEs increases, falling 25% between installing 1 EVSE to installing 2 EVSEs (while materials fall 19%). The decrease is more pronounced when looking at labor costs to install 1 EVSE vs. 3 to 5 EVSEs: labor costs fall 32%, while material costs fall

[47] J. Francfort, Idaho National Laboratory, "EV Project Charging Infrastructure Deployment Costs, Cost Drivers and Use," presented at the Plug-in 2013 Conference, San Diego, CA (October 2013).

17%. On a per charge port basis, labor costs show a similar 31% drop between installing 1 EVSE vs. 3 to 5 EVSEs.

Material costs only show large decreases (of over 20%) when installations have 6 or more EVSEs – falling 32% between installing 1 EVSE and installing 6 or more EVSEs, on a per EVSE basis.

Examining installation costs segmented by number of EVSE installed per site, in California vs. Outside California, helps to illustrate the cost differences and the economies of scale possible in these two different regions. To begin with, California's installation costs are much more expensive than the Outside California sample. In fact, the lowest average cost per EVSE (from a high volume California installation) is still, on average, more costly than the most expensive, single EVSE installation Outside California.

California cost installation data shows the following patterns:

- Marked percentage decreases in labor costs from installing 1 EVSE, to 2 EVSE, through the 3 – 5 EVSE level, with a slight shift upward at the 6+ EVSE installation level. (However, the absolute value is still 26% below the per EVSE labor cost for installing 1 EVSE at a commercial site).
- A drop in Material costs of about 23% between installing 1 EVSE and installing 2 EVSEs per site. Adding further EVSEs per site (beyond the 2 EVSEs per site level) does not impact materials costs much.

In the Outside California sample, no clear economies of scale are apparent until the size of the commercial installation is 6 EVSEs or more, per site. However, this may be influenced by the fact that the cost of installations in the Outside California sample starts from a much lower base (compared to California), and hence it may be more difficult to achieve further cost reductions.

Permit costs, in general, are not a significant portion of the costs of commercial installations. In many cases, permit costs will be a small percentage of the overall cost of the project. Nevertheless, there are striking differences in California vs. Outside California permit costs. On a per EVSE basis, California permit costs average $251 overall, and go from a high of $453 for installing 1 EVSE per site, to a low of $104 for installing 6+ per site. However, Outside California, average permit costs start at an average of $64 per EVSE overall, and range from a high of $103 per EVSE for installing 1 EVSE at a site, to $24 per EVSE for installing 6+ EVSE at a site.

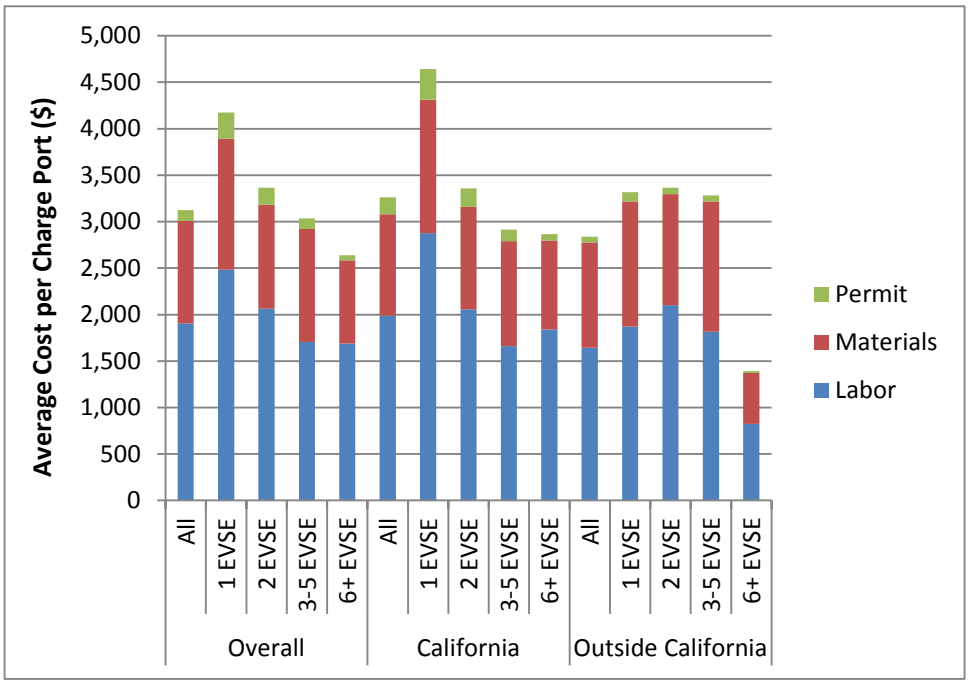


Figure 4-10
Commercial Installation Costs per Charge Port by Cost Category, by Number of EVSEs per Site

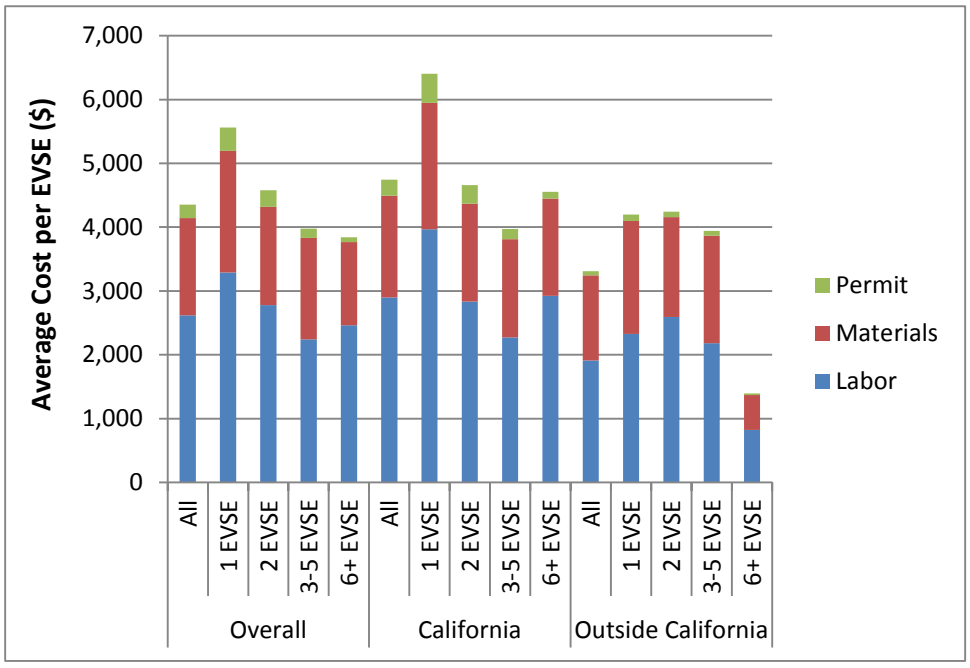


Figure 4-11
Commercial Installation Costs per EVSE by Cost Category, by Number of EVSEs per Site

Cost Impacts of Electrical Upgrades

At the present time, in order to charge a Plug-in Electric Vehicle using a Level 2 EVSE, it is necessary to have a dedicated 208 or 240-volt, 40-amp circuit available for the Level 2 unit.[48] The Level 2 unit may be a plug-in EVSE, which is now permitted under the National Electric Code, or it may be an EVSE that is hard-wired into the 240-volt circuit. Under either circumstance, it is usually the case that a new, 208 or 240-volt circuit must be installed by a licensed electrician, and the electrical upgrade will require a permit and inspection.

Should a commercial installation site have insufficient capacity on the electrical panel for 40 amp circuits for every Level 2 charging installation planned at the site, electricians explore various options to create additional capacity at the least expense. Three strategies for creating additional capacity include (i) panel upgrades, (ii) re-worked panels, or (iii) the use of a sub-panel. A panel upgrade is when the only way to add capacity is by replacing the existing electrical panel with a new panel. Re-worked panels occur when there is an opportunity to reorganize the breakers on the existing panel in creative ways to free up additional capacity. In general, a sub-panel is required when there is sufficient electrical capacity on the existing panel, but multiple additional circuits are needed in an area that may not have any (or sufficient) electrical service currently.

About 72% of all commercial installation sites in the project sample required some sort of work on the electrical panel (278 commercial sites out of a sample of 385 sites); of these, 71% required a Re-worked Panel, 21% required a new Panel Upgrade, and 8% required the addition of a Sub-Panel.

This additional electrical work needed to install 208 or 240-volt, 40-amp circuits for Level 2 EVSE often raises the cost of installations. However, in the case of re-working the panel, it can actually lower costs (or keep them close to the average for a type of installation).

- For example, for the entire project sample of commercial records, the average cost of a commercial installation is $3,962 per EVSE. However, installations with a re-worked panel have a lower per EVSE cost, by about 4%, vs. the overall sample.
- Among the various site categories, re-working the panel at Workplace installations seemed to have the most significant impact, lowering costs by 22% below the average per EVSE cost for the Workplace sub-set.
- Re-working the panel for Public installations seemed to help keep costs close to the average (only 2% above average).

This relationship did not hold true for Fleet costs. In the case of Fleets, all types of electrical panel work raised costs higher than the average (by 25% to 43%).

[48] Future technological improvements or building code changes may allow for options that could reduce cost, such as circuit sharing or charge sequencing.

However, installation costs at Fleet locations are substantially lower (47% lower) than the overall sample, or at Workplace or Public installations.

In the project sample, the sites that required the addition of a Sub-Panel had the highest costs, with average costs per EVSE between 41% and 47% higher, for the sample overall or each of the sub-sets of Workplace, Public, or Fleet installations. Both labor and materials are significantly greater for the addition of a Sub-Panel:

- Labor costs for installing a Sub-Panel are about 30% more than in the overall sample, and 33 - 36% greater than a Re-worked Panel (on either a per EVSE or per charge port basis).
- Material costs for installing a Sub-Panel are about 60% higher than the overall sample, but double the materials cost of a Re-worked Panel.

About 15% of the commercial installations in the EPRI sample required new Panel Upgrades, yet costs are close to that of the overall sample (5% higher on a per EVSE basis, 2% lower on a per charge port basis). However, new Panel Upgrades at Workplace installations cost about 26% higher (on a per EVSE basis) than the total EPRI sample overall, and about 20% higher than the sub-set of all New Panel Upgrades.

Fleet costs for EVSE installations are 47% lower, overall, than the total EPRI sample, on a per EVSE basis. However, because average Fleet costs are so low, the addition of electrical work has a strong upward push on costs.

- New Panel Upgrades exert the least upward pressure on costs, but still increase costs by 25% (per EVSE) above the overall Fleet average (per EVSE);
- Reworked Panels cost 36% more than the Fleet average (per EVSE); and
- Sub-Panels cost 43% more.
- Of note, however, is that even these higher Fleet costs are substantially lower than each cohort representing all New Panel Upgrades (36% less), all Re-worked Panels (25% less), and all Sub-Panels (48% less).

Outside California costs for installations with Electric Panel Work are, on average, significantly lower than California installations (about 29% lower for the overall sample). Of note are:

- Re-working panels in California not only reduces the costs 14% below the average for the California sub-set, but it is also 4% lower than the Overall sample, and a few dollars below the overall Re-worked Panel sub-set.
- Interestingly, Re-worked panels cost about the same in California or Outside California. This is especially significant, since Outside California costs are typically so much lower than California installation costs.
- New Panel Upgrades (both in California or Outside California) cost more than the averages for each region overall (11% higher in California, and 7% higher Outside California)

- Sample sizes were too small to compare California vs. Outside California costs for the installation of Sub-Panels.

Figure 4-12 and Figure 4-13 illustrate the relationship of cost components (labor, materials, permit and tax) to the various types of electrical panel modifications. An examination of these results reveals:

- Permit and Taxes do not represent a significant portion of commercial installation costs (permits comprise about 5%)
- Overall, labor costs account for about 60% of the cost of an installation while materials are about 40%
- Installations requiring a Sub-Panel have greater material costs. In the total sample, installations requiring a Sub-Panel cost, on average, $5,829 per EVSE (versus the total sample cost of $3,962, or 47% higher)
- Installations requiring a Re-worked Panel typically had a greater proportion of expenditures in labor (closer to 70%), and a lower proportion of material cost. In general, the absolute dollar amounts expended for Re-worked Panels are lower than the costs for the overall sample ($3,799 per EVSE vs. $3,962 for the overall sample)

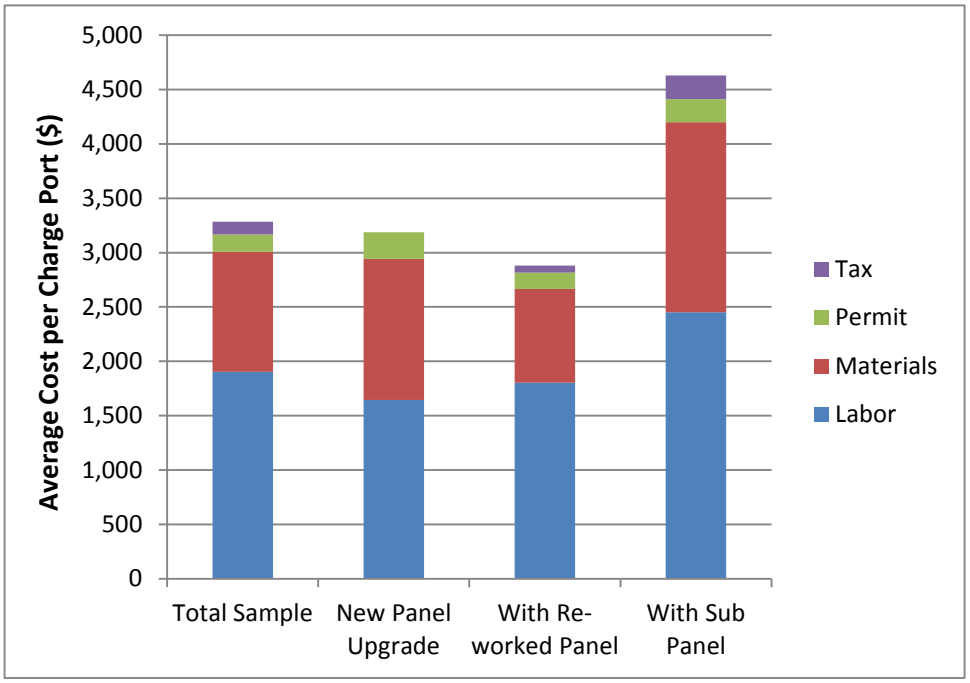


Figure 4-12
Commercial Installation Costs per Charge Port by Cost Category and by Type of Electrical Panel Work Needed

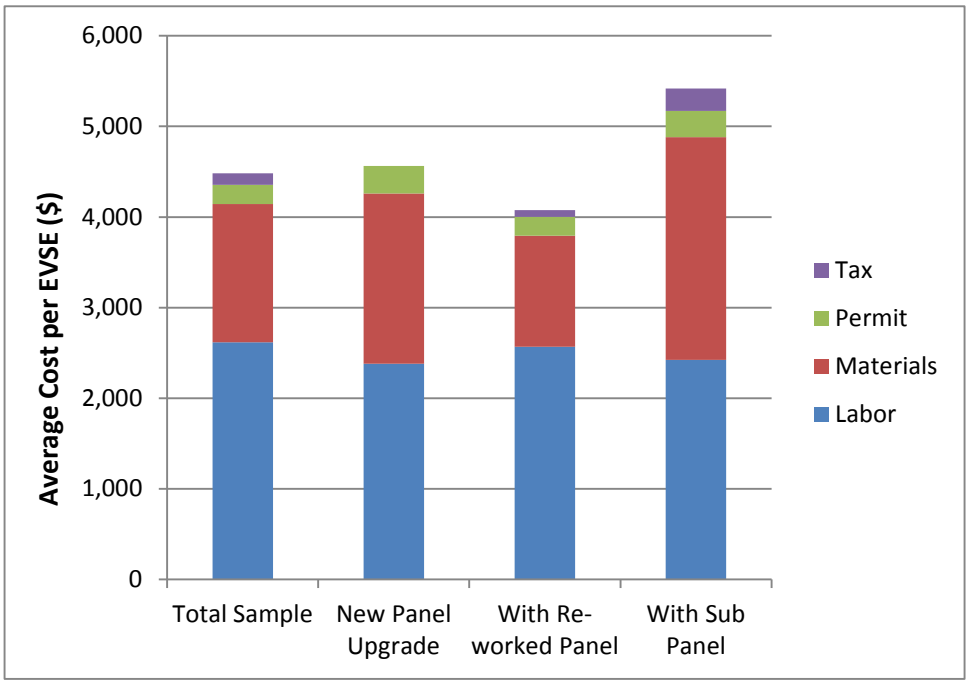


Figure 4-13
Commercial Installation Costs per EVSE by Cost Category and by Type of Electrical Panel Work Needed

Single Port vs. Dual Port vs. Dual Voltage EVSE

One of the opportunities to reduce installation costs may be to install a greater number of charge ports per EVSE. This opportunity is illustrated by the installation of EVSE with Dual Ports (two Level 2 charge ports per EVSE) and Dual Voltage (one Level 1 and one Level 2 charge port per EVSE). In order to capture the true costs of these installations, this analysis examines costs both on a "per EVSE" basis, but also on a weighted "per charge port" basis. (The weighting assumptions are described earlier in this chapter).

Table 4-3 illustrates the number of EVSE and number of charge ports for EVSE type, and shows the corresponding installation cost on both a "per chart port" and a "per EVSE" basis. Reviewing the data, it can be seen that Dual Port and Dual Voltage EVSE are more expensive to install than a single Level 2 EVSE, on a per EVSE basis. However, Dual Port and Dual Voltage EVSE installations are both less expensive on a per charge port basis.

Upon closer examination, it can be seen that installation of a Dual Port EVSE is less costly, on average, than the average cost of installing two single-port Level 2 EVSE. This analysis uses the overall average costs (per EVSE or per charge port), in order to reflect the best data from the largest sample size, and to avoid any bias from sub-sets of data with small sample sizes. A detailed comparison follows:

- One Dual Port EVSE, on average, costs $2,702 per charge port to install, compared to the $3,139 average cost per charge port of a single port EVSE.
- On average, the cost of a Dual Port EVSE installation ($5,405 per EVSE) is less than the cost of installing two, single port Level 2 EVSEs (2 x $3,139 per EVSE = $6,278).
- On average, the Dual Port EVSE installation is 16% less than the installation of two single Level 2 EVSEs.

When comparing "per charge port" installation costs among the three types of Level 2 EVSE, it is clear that Dual Port Level 2 equipment installations are the least expensive ($2,702 on average), then Dual Voltage ($3,010 on average), with the most expensive installation being a Single Level 2 EVSE ($3,139). If average cost data were only examined on a "per EVSE" basis, one would conclude the opposite: installing a Single Level 2 EVSE is least expensive ($3,139) vs. Dual Voltage ($4,515) vs. Dual Port L2 ($5,405).

One can look at "per EVSE" cost comparisons, and note that installing a single port Level 2 EVSE costs, on average, $3,139 per EVSE compared with the cost of $4,515 per EVSE to install a Dual Voltage EVSE. However, the average cost of installing a Dual Voltage EVSE is slightly less than 1.5 times the cost of installing a single Level 2 EVSE (about 6% less), and requires 1.5 times the amperage as compared to a single port Level 2 EVSE.

These findings illustrate a potentially promising strategy -- use of Dual Voltage and multi-port EVSE -- to lower costs to install EVSE charging units. As this analysis does not consider the price of the EVSE, this strategy may also provide additional savings on equipment at sites that require multiple charge ports.

Table 4-3
Comparison of Commercial Installation Costs: Single Port vs. Dual Port vs. Dual Voltage EVSE

	Quantity	Single Level 2 EVSE	Quantity	Dual Port L2 EVSE	Quantity	Dual Voltage L1 & L2 EVSE
Average Cost per Charge Port	468	$3,139	218	$2,702	618	$3,010
Average Cost per EVSE	468	$3,139	109	$5,405	412	$4,515

Impact of Certain Attributes on Installation Costs

The software developed to analyze the EPRI sample of commercial installation costs enables analyses of sites with, and without, key attributes, to gain insight into factors that might drive EVSE installation costs to be higher or lower. In this section, several "sorts" of the computer runs are examined, to gain insight

into the cost impact of certain installation characteristics. The factors examined in this section include:

- Installations at an Indoor vs. Outdoor commercial location
- Previously-installed 240-volt, 40-amp wiring at a site vs. Not
- Site or Structural Factors noted that might affect costs vs. Not
- Special Work (such as trenching, coring, boring, poured foundation) vs. Not
- Electrical Work to Panel (Reworked Panel, New Panel Upgrade, Sub-Panel) vs. Not
- Electrical Infrastructure Work (New Transformer, Other Equipment) vs. Not
- Permit costs include labor (e.g., time waiting in line at permit office, etc.) vs. Not
- Prevailing Wage paid vs. Not

Numerous participants of this study provided qualitative information regarding site characteristics and factors that might influence costs of commercial installations. This data is the basis for the analysis presented in this section.

The project team recognizes that it is probable that there are omissions in data regarding the presence or absence of certain characteristics (because the study participants either had no insight into these attributes, by site; or they had time constraints that precluded identification of these attributes, by site; or other factors). Nevertheless, this snapshot provides a general sense of the potential impact of each factor on commercial EVSE installation costs.

Major Impacts

- The greatest impact by far is apparent among the sites that self-identified as having "Site or Structural Factors that could have influenced costs". This sub-sample had an average installation cost per EVSE of $8,005, or more than twice the $3,552 average cost per EVSE of the entire sample of installations that did not have "site or structural factors." Additional insights include:
  - Labor and material costs both more than doubled in the sites with "site or structural factors"
  - This finding supports the conclusion that siting decisions play a significant role in determining the cost of EVSE installations
- The next largest impact stems from projects that had been previously wired with a 240 volt, 40 amp circuit. The average cost per EVSE among sites that had been previously wired was $2,169, or about half of the $4,160 average cost per EVSE among sites that had not. For the sites with existing available wiring:
  - Both labor and material costs were about 40% lower

- This finding supports the conclusion that establishing building codes that require electrical capacity for PEV charging in both residential and commercial new construction would enable lower EVSE installation costs going forward

- Sites that required special work (trenching, coring, boring, or poured foundations) cost significantly more than sites that did not ($4,664 per EVSE vs. $3,497 per EVSE). Special work sites were about 25% more costly than those that did not need special work. In addition:
  - Material costs were about 40% higher in sites requiring special work, and labor costs were about 16% higher
  - This finding further points to the impact of siting decisions on EVSE installation costs

Moderate Impacts

- The need for new electrical infrastructure (transformers, other equipment) had a marked impact on costs. Sites that needed new electrical infrastructure had average costs per EVSE that were 15% higher, $4,447 versus $3,873 for those sites that did require new electrical infrastructure. Furthermore,
  - Labor and material costs were 8% to 9% higher, and taxes (on materials) were higher.
  - This finding supports the conclusion that constraints on available electrical service, locally, could dampen future adoption of PEVs and installation of charging infrastructure, due to the need for higher cost installations.
- Installations in Outdoor locations were about 9% less costly than installations indoors ($4,027 average cost per EVSE outdoors vs. $4,439 average cost per EVSE indoors).
  - Labor costs were about $600 higher for indoor locations vs. outdoor locations
  - Anecdotes revealed some examples of circumstances where EVSE installations in indoor locations would prove much more costly than outdoor, especially when the electrical panel was on a different floor than the parking spaces where PEV charging would take place. However, there were similar cases of long distances from the electrical panel in outdoor locations.

Minor Impacts

- When examined as a whole, the need for work on the electrical panel (panel upgrade, re-worked panel, or sub-panel) proved to have only a minor impact: $4,029 average cost per EVSE for those sites needed electrical panel work vs. $3,838 for those that did not (about 5% more).
  - However, this is misleading because the preponderance of electrical panel work is for a re-worked panel, and that is shown to have a dampening

effect on costs, while panel upgrades and sub-panel work pose higher costs.

  - While the statistics generated in this analysis show minor impact, this obscures the fact that certain types of electrical panel work are strong cost drivers – either higher cost or lower cost.

- Sites that reported having Permit costs that included costs for labor (that is, costs for personnel to wait in lines to obtain permits) had significantly higher permit costs than sites that did not include labor in permit costs: $307 vs. $129 average cost per EVSE.
  - Sites with labor included in permit costs had permit costs that were more than twice as high as those that did not include labor in permit costs.
  - Nevertheless, the dollar amount is relatively small and does not affect overall costs significantly.
  - This finding supports the conclusion that commercial permit costs are not a significant driver in the overall cost of commercial EVSE installations.

Appendix B provides additional detailed discussion of the impact of each site characteristic.

Commercial Installation Costs Over Time

The project team examined the overall commercial sample, as well as California versus Outside California samples, to assess whether any trends in commercial installation costs are apparent over time. The sample was divided into two very narrow bands of time: installations in 2010 and 2011 are treated as a group and compared with installations performed in 2012 and 2013, as a group. For the overall sample, about half of the commercial installations fall within each time frame, as do half of the EVSE and charge ports. About 40% of the California projects and EVSE are in the 2010-2011 sample, and 60% in the 2012-2013 sample. The Outside California sample has 75% of projects and EVSE in the 2010-2011 sample, and only 25% in the 2012-2013 sample.

On a per charge port basis, average costs for the sample overall decline 13% from the earlier period to the latter period. California's average cost per charge port falls 18% over time, while Outside California's average cost per charge port falls 10% over time.

On a per EVSE basis, the California sample experiences a decline of 9% over time. However, the overall sample experiences a 6% increase in costs over time as do Outside California average costs per EVSE. The small Outside California sample in 2012-2013 appears to be heavily skewing the overall results, on a per EVSE basis, and it is not clear that the per-EVSE analysis can be meaningfully analyzed.

It does appear, however, from the California sample and the per port analysis, that there is a slight trend toward costs reductions in commercial EVSE installations over time.

Appendix A: Residential Installation Costs

Table A-1
Residential Level 2 EVSE Installation Costs at Single Family Homes

	Sample Size	Average	Median	Minimum	Maximum
California Historical: 1996-2002; (2009 $)	94	1,716	1,416		
California 2009 (2009 $)	93	1,716	1,494	792	5,178
California 2012 (2012 $)[a]	96	1,512	1,325	389	3,855
Outside California (2011 & 2012 $)[b]	25	1,499	1,427	384	4,077

[a] All prevailing wages
[b] Installations in MI, TN, TX; some prevailing wages

Table A-2
Historical and Recent Residential Installation Costs: California and Other States

	Sample Size	Labor	Materials	Permit	Tax	Total
California Historical: 1996-2002; (2009 $)	94					
Average		1,008	551	103	54	1,716
Median		866	456	50	44	1,416
California 2009 (2009 $)	93					
Average		918	541	204	53	1,716
Median		780	450	220	44	1,494
California 2012 (2012 $)[a]	96					
Average		774	465	331	40	1,512
Median		600	345	350	30	1,325
Outside California (2011 & 2012 $)[b]	25					
Average		1,031	468	121	–	1,499
Median		900	377	150	–	1,427

[a] All prevailing wages
[b] Installations in MI, TN, TX; some prevailing wages

Table A-3
Residential Multi Unit Dwelling Level 2 EVSE Installation Costs

	Sample Size	Average	Median	Minimum	Maximum
California (2012 $; Prevailing Wages)	38	3,744	3,759	1,260	7,246

Table A-4
Factors Impacting Single Family Residential Installation Costs

	Sample Size	California Historical 1996-2002; (2009 $)	Sample Size	California 2009 (2009 $)	Sample Size	California 2012-2013 (2012 $)[a]	Sample Size	Outside California (2011 & 2012 $)[b]
	94		93		96		25	
Average Cost		1,716		1,716		1,512		1,499
Conduit Length								
Conduit < 36'			53	1,447	47	1,377	1	1,215
Conduit > 36'			40	2,072	38	1,923	21	1,639
Special Work								
Trenching			3	2,293	3	1,657	2	2,954
Boring			2	1,844	1	1,935		
Stucco			14	1,805				
Original Panel Amps								
<100 Amps			32	1,995	8	2,270		
101 - 200			51	1,577	11	1,855		
200+			10	1,534				
Panel Upgrades			17	2,415	10	2,836		
Site Struct. Factors							2	3,360
Prevailing Wage Paid					All		22	1,620

[a] All prevailing wages
[b] Installations in MI, TN, TX; some prevailing wages

Table A-5
EV Project Data: Residential Installation Costs[49]

	Average	Number of Installations	Variation from Project Average
Tennessee	1,113.07	542	-18.9%
Arizona metro	1,148.88	357	-16.3%
Washington, DC	1,197.44	3	-12.8%
Oregon	1,229.06	465	-10.5%
Wash. state metro	1,289.56	730	-6.1%
Maryland	1,311.75	39	-4.5%
Washington state	1,321.36	80	-3.8%
Virginia	1,341.01	38	-2.3%
San Francisco, CA	1,386.13	1254	0.9%
Texas metro	1,422.77	128	3.6%
San Diego, CA	1,593.91	726	16.1%
Los Angeles, CA	1,794.64	415	30.7%

[49] J. Francfort and T. Garretson, "EV Project and Charging Infrastructure Update," U.S. DRIVE Grid Interaction Tech Team, presented at USCAR, Southfield, MI (June 19, 2013).

Appendix B: Commercial Installation Costs

Table B-1
Commercial Installations by Year

	Year				
	2010	**2011**	**2012**	**2013**	**Total**
California	12	89	132	16	249
Outside California	8	94	34	0	136
Overall	20	183	166	16	385

Table B-2
Commercial Installations by Site Category and Year

	Year					
	2010	**2011**	**2012**	**2013**	**Total**	**Percentage**
Public	5	109	108	12	234	61%
Workplace	6	39	42	4	91	24%
Fleet	9	35	16	0	60	16%
Overall	20	183	166	16	385	100%

Table B-3
Commercial Installations by Per-Site EVSE Percentage

	Public	**Workplace**	**Fleet**	**Total**
% 1 EVSE	42%	38%	65%	45%
% 2 EVSE	30%	24%	13%	26%
% 3-5 EVSE	21%	24%	10%	20%
% 6+ EVSE	7%	14%	12%	9%
	Public	**Workplace**	**Fleet**	**Total**
Total Number of Charging Installation Sites	234	91	60	385
1 EVSE	99	35	38	173
2 EVSE	70	21	8	99
3-5 EVSE	50	22	6	78
6+ EVSE	15	13	7	35

Table B-4
Commercial Installation Costs: California vs. Outside California

	California	Outside California	Overall
Cost per Charge Port			
Average Cost	$3,072	$2,841	$3,005
Median Cost	$2,732	$2,278	$2,543
Cost per EVSE			
Average Cost	$4,412	$3,118	$3,962
Median Cost	$3,814	$2,670	$3,236

Public vs. Workplace vs. Fleet

As is shown in Table B-5, Public charging installations are more costly than Workplace or Fleet. The average Public charging installation costs (per EVSE) are about 12% higher than the overall average, while Workplace is about 3% lower and Fleet is about 47% lower. Similarly, per charge port, Public charging installations are about 11% higher than the overall average, while Workplace are 10% lower and Fleet are 33% lower.

These relationships hold true for California: Public charging installations are more costly than Workplace (16% above the state average), while Workplace is about 20% less than the state average, and Fleet is about 25% less.

Outside California, Public charging installations are 8% higher than the total Outside California sample, while Fleet installations are 52% lower on average. The sample for Workplace installations Outside California illustrates exceptionally high costs, but the sample size is so small (only 14 sites) that results are inconclusive.

Table B-5
Commercial Installation Costs, by Type of Installation

Average Cost per Charge Port	Public	Workplace	Fleet	Total
Overall	$3,343	$2,704	$2,018	$3,005
California	$3,553	$2,419	$2,902	$3,072
Outside California	$2,914	$5,330	$1,499	$2,841
Average Cost per EVSE	**Public**	**Workplace**	**Fleet**	**Total**
Overall	$4,448	$3,842	$2,109	$3,962
California	$5,119	$3,594	$3,289	$4,412
Outside CA	$3,355	$5,399	$1,499	$3,118

Table B-6
Range of Commercial Installation Costs, by Cost Category, California vs. Outside California

Average Cost per Charge Port	**Labor**	**Materials**	**Permit**	**Tax**	**Total**
Overall	$1,904	$1,103	$158	$117	$3,005
California	$1,987	$1,094	$180	$139	$3,072
Outside California	$1,644	$1,133	$60	$98	$2,841
Average Cost per EVSE	**Labor**	**Materials**	**Permit**	**Tax**	**Total**
Overall	$2,618	$1,527	$209	$130	$3,962
California	$2,899	$1,597	$251	$177	$4,412
Outside CA	$1,911	$1,335	$65	$98	$3,118

Table B-7
Labor, Materials and Permit by Cost Category, California vs. Outside California

	Average Cost per Charge Port				
	Number	**Total**	**Labor**	**Materials**	**Permit**
Overall	1304	$3,005	$1,909	$1,103	$117
1 EVSE	228	$3,676	$2,484	$1,407	$282
2 EVSE	266	$3,036	$2,065	$1,119	$183
3-5 EVSE	356	$2,899	$1,707	$1,214	$115
6+ EVSE	455	$2,733	$1,688	$894	$56
California	927	$3,072	$1,987	$1,094	$180
1 EVSE	146	$4,148	$2,875	$1,437	$330
2 EVSE	218	$3,039	$2,056	$1,103	$199
3-5 EVSE	197	$2,745	$1,661	$1,130	$123
6+ EVSE	366	$2,837	$1,841	$957	$69
Outside California	378	$2,841	$1,644	$1,133	$60
1 EVSE	82	$2,836	$1,870	$1,347	$100
2 EVSE	48	$3,020	$2,100	$1,195	$72
3-5 EVSE	159	$3,090	$1,815	$1,402	$66
6+ EVSE	89	$2,305	$823	$547	$24
	Average Cost per EVSE				
	Number	**Total**	**Labor**	**Materials**	**Permit**
Overall	989	$3,962	$2,618	$1,527	$209
1 EVSE	173	$4,845	$3,289	$1,908	$363
2 EVSE	198	$4,078	$2,781	$1,537	$259
3-5 EVSE	291	$3,541	$2,242	$1,589	$145
6+ EVSE	327	$3,799	$2,463	$1,304	$73
California	645	$4,412	$2,898	$1,597	$251
1 EVSE	104	$5,824	$3,967	$1,983	$453
2 EVSE	158	$4,193	$2,836	$1,531	$290
3-5 EVSE	145	$3,729	$2,271	$1,541	$158
6+ EVSE	238	$4,357	$2,926	$1,524	$104
Outside California	344	$3,118	$1,912	$1,335	$64
1 EVSE	69	$3,370	$2,329	$1,768	$103
2 EVSE	40	$3,624	$2,595	$1,563	$84
3-5 EVSE	146	$3,354	$2,181	$1,685	$75
6+ EVSE	89	$2,305	$823	$547	$24

Commercial Installations by Site Characteristics

The commercial sample site characteristics are outlined below. This provides baseline information, with explanations of how each characteristic is portrayed in the sample of commercial installation sites:

- Location – Inside (24%) vs. Outside (65%); note: 11% did not identify a location.
- Electrical Panel Changes (Panel Upgrades, Re-worked Panel, Sub-Panel).
  - 72% of all sites had some kind of work to the Electrical Panel;
  - Of the cohort with some kind of work to the Electrical Panel, about 21% of those required Panel Upgrades (lack of electrical capacity necessitates that the old panel is replaced with a new one, with more electrical capacity); 71% of those required a Re-worked Panel (re-organization of the panel to create space for a 40 amp circuit for an EVSE); and 8% of those required a Sub-Panel (splitting the current electrical panel capacity by creating a sub-panel in an nearby location, with only a portion of the total panel amps).
- New Electrical Infrastructure Needed (New Transformer or Other Equipment needed). Note that the project team did not specifically ask whether the addition of new electrical infrastructure was provided by the utility or provided by the customer; however, given the context of data collection, it is assumed that these are non-utility provided.
  - Only 9% of sites overall required new electrical infrastructure; about half needed a new transformer and half needed other equipment
- Number of EVSEs, by type:
  - 45% of total sites have installed single port Level 2 EVSE;
  - 8% of sites have installed Dual Port Level 2 units (those units with two Level 2 charge ports);
  - 47% of sites have installed Dual Voltage EVSE (with both a Level 1 and Level 2 charge port in a single unit).
- Special Work such as trenching, coring, boring, or poured foundation:
  - Trenching (38% of total sites);
  - Boring (5%);
  - Coring (5%);
  - Poured Foundation (26%)
- Qualitative Factors (obtained as part of quantitative surveys):
  - Presence of Site or Structural factors that might have influenced costs (12% of total sites);
  - Sites Previously wired for EVSEs or simply as a 240 volt, 40 amp circuit (9% of total sites) ;

- Whether Prevailing Wages were paid (73% of total sites);
- Whether Permit costs included time spent by contractors waiting in line to get permits (20%), or only reflect the actual cost of the permit itself.

Table B-8 provides a breakdown of the commercial data based on characteristics that the team believes are determinants of installation cost. Not all information was provided for all sites so the data probably under-report the number of actual occurrences.

Table B-8
Commercial Installation Site Characteristics

	Public	**Workplace**	**Fleet**	**Total**
Total Sites	234	91	60	385
Site Locations	**Public**	**Workplace**	**Fleet**	**Total**
Inside	58	25	9	92
Outside	148	59	45	252
Unknown	28	7	6	41
Panel Changes	**Public**	**Workplace**	**Fleet**	**Total**
Panel Upgrades - New	44	9	6	59
Sub Panel	14	4	3	21
Reworked Panel	126	58	14	198
Total	184	71	23	278
New Electrical Infrastructure	**Public**	**Workplace**	**Fleet**	**Total**
New Transformer	6	8	1	15
Other Equipment	1	15	2	18
Total	7	23	3	33
Number of sites with EVSE by Type	**Public**	**Workplace**	**Fleet**	**Total**
Level 2 Single Port	75	44	54	173
Dual Port Level 2	19	11	0	30
Dual Voltage	140	36	6	182
Special Work	**Public**	**Workplace**	**Fleet**	**Total**
Trenching	111	33	3	147
Boring	16	3	0	19
Coring	9	8	2	19
Poured Foundations	77	21	4	102
Other Factors	**Public**	**Workplace**	**Fleet**	**Total**
Site/Structural	39	5	2	46
Previously Wired	11	19	3	33
Prevailing Wages	191	47	44	282
Permit Included in Labor	43	22	11	76

Table B-9
Installation Costs by Type of Electrical Work Needed and Cost Component

	Number	Average Cost per Charge Port	Number	Average Cost per EVSE
Total Sample	1304	$3,004	989	$3,962
New Panel Upgrade	234	$2,943	165	$4,165
Reworked Panel	612	$2,688	433	$3,799
Sub Panel	59	$4,284	43	$5,829
Public	763	$3,343	573	$4,448
New Panel Upgrade	111	$2,587	74	$3,864
Reworked Panel	326	$3,182	229	$4,529
Sub Panel	41	$4,360	28	$6,385
Workplace	404	$2,704	284	$3,842
New Panel Upgrade	99	$3,458	68	$5,008
Reworked Panel	248	$2,051	169	$3,003
Sub Panel	13	$4,783	11	$5,435
Fleet	138	$2,018	132	$2,109
New Panel Upgrade	25	$2,479	23	$2,641
Reworked Panel	39	$2,603	35	$2,863
Sub Panel	5	$2,414	4	$3,018
California	927	$3,072	645	$4,412
New Panel Upgrade	123	$3,500	88	$4,892
Reworked Panel	576	$2,614	397	$3,792
Sub Panel	56	$4,400	40	$6,105
Outside California	378	$2,840	344	$3,118
New Panel Upgrade	111	$2,323	77	$3,334
Reworked Panel	36	$3,875	36	$3,875
Sub Panel	3	$2,141	3	$2,141
Total Sample		$3,005	989	$3,962
Labor		$1,905		$2,618
Materials		$1,103		$1,527
Permit		$158		$209
Tax		$117		$130

Table B-9 (continued)
Installation Costs by Type of Electrical Work Needed and Cost Component

	Number	Average Cost per Charge Port	Number	Average Cost per EVSE
Total with Sub Panel		$4,284	43	$5,829
Labor		$2,450		$3,423
Materials		$1,748		$2,460
Permit		$214		$289
Tax		$216		$247
Total with Re-worked Panel		$2,688	433	$3,799
Labor		$1,804		$2,568
Materials		$861		$1,226
Permit		$152		$208
Tax		$65		$74
New Panel Upgrade		$3,187		$4,563
Labor		$1,644		$2,380
Materials		$1,299		$1,180
Permit		$244		$303
Tax				

Comparison of Commercial Installation Costs: With and Without Specific Characteristics

Installations at Indoor vs. Outdoor locations

About 35% of all commercial installations are in indoor locations, compared with 65% that are in outdoor locations. (This is the opposite of what we find in residential installations at single-family homes – the vast majority of those installations are indoors). Analysis of installations of 813 EVSEs reveals that it is about 9% less expensive to install EVSE at commercial sites in outdoor locations ($4,027 per EVSE, on average) than indoor locations ($4,439 per EVSE). Factors that prominently affect costs include siting choices and proximity to the electrical panel, and need for conduit in circumstances requiring special work indoors. Higher labor costs (about $600 per EVSE) for indoor locations appears to be a key element of increased costs. Some project managers noted the complexity of indoor installations in parking garages, where the available parking space is on a different floor than the electrical supply, as an example of how indoor installations can be more costly.

Previously wired with 208 or 240 volt, 40 amp circuit vs. Not

About 13% of total EVSEs installed in the EPRI sample indicated that these locations had been previously wired with a 208 or 240-volt, 40-amp circuits. It could well be the case that many of these sites are legacy charging locations (sites where charging equipment was installed in the 1990's, when electric vehicles were entering the market). Sites that had been previously wired cost $2,619 per EVSE on average, vs. $4,160 per EVSE for those that had not been previously wired (about 48% less). Both labor and materials costs are dramatically lower in the installations that had been previously wired for a 40-amp, 240-volt service (40% lower for labor, and 39% lower for materials).

Site or Structural Factors Noted vs. Not

Commercial sites with 9% of the total sample's EVSEs noted that certain site or structural factors (such as aesthetics or desire for prominent location in siting; unique structural features such as needing to install an EVSE on one floor of a parking garage while the electrical panel is on a different floor) may have influenced costs. In those installations, it was significantly more expensive to install Level 2 EVSE -- more than double the cost of the sample who did not note "site or structural factors." Average cost per EVSE for installations citing "site or structural factors" was $8,005 per EVSE compared to a $3,552 average cost per EVSE for those who did not note this. Labor costs more than doubled ($5,141 vs. $2,309) and material costs doubled ($ 2,703 vs. $1,376) in sites noting "site or structural factors." These sites most likely account for many of the high-cost projects that are found in the database, which cause substantive increases in average costs.

Special Work (coring, boring, trenching, poured foundation) vs. Not

When commercial installations require Special Work such as coring, boring, trenching, or poured foundations to complete the installation of Level 2 EVSE, it can increase the cost of the installation. This is shown in the study sample, where sites accounting for about 40% of the total sample's EVSEs require some kind of Special Work. These installations have higher average costs per EVSE ($4,664 per EVSE) vs. installations in the sample that did not specify a need for Special Work ($3,497 per EVSE). Material costs are about 40% higher in the sites with Special work than without, while labor costs are about $16% higher.

Electrical Panel Work (New Panel Upgrade, Re-worked Panel, Sub-Panel) vs. Not

Installations representing about 65% of EVSE installed in commercial settings indicated that some type of Electrical Panel Work was required. While re-working panels can lower costs, the addition of a new panel upgrade or a sub-panel typically raises installation costs. About 70% of the sites requiring Electrical Panel Work had a re-worked panel, so there is a possibility that costs could

decrease. The study results indicate that the average cost per EVSE among those with Electrical Panel Work is only slightly higher ($4,029 per EVSE, or 5% higher) than installations that do not require Electrical Panel Work ($3,838 per EVSE). It appears that the lower cost influence of re-worked panels balances out the higher cost influence of sub-panels and new panel upgrades, in this sample.

New Electrical Infrastructure Needed (Transformers or Other Equipment) vs. Not

In the study sample, about 16% of EVSEs installed are at commercial sites where New Electrical Infrastructure is needed. Note that the project team did not specifically ask whether the addition of new electrical infrastructure was provided by the utility or the customer, but based on the context of data collection, it is assumed that these were provided by the customer. Higher costs on average, per EVSE ($4,447 per EVSE, or about 15% higher), are seen in the sample of installations requiring New Electrical Infrastructure, versus those installations that did not require this ($3,873 per EVSE). Both labor and materials costs are higher for installations requiring New Electrical Infrastructure (which is what one would expect, since these circumstances require additional equipment and additional labor to install the equipment).

Permit Costs include Labor (e.g., time waiting in line for permits)

In reviewing Permit Cost data with respect to all EVSE installations, there is always a question about whether the permit cost is strictly the cost paid to the permitting authority, or whether it is a cost noted on an invoice (and which may include time spent by an electrician waiting in line, or driving in traffic, to obtain permits for an installation). Surprisingly, installations making up 16% of EVSEs in the sample report that permit costs include labor payments (for time spent waiting in line at permit offices). Analysis of the data does clearly show that the average permit cost associated with these installations ($307 per EVSE) is more than twice the average permit cost for installations that do not report including time for labor in the cost of installations ($129).

Table B-10
Comparison of Commercial Installation Costs: Sites With and Without Specific Characteristics

	Number	Average Cost per EVSE	Labor	Materials	Permit	Tax
Costs for Overall Sample, with						
Electrical Work	641	$4,029	$2,577	$1,504	$228	$132
No Electrical Work	348	$3,838	$2,727	$1,600	$150	$126
Special Work	394	$4,664	$2,815	$1,792	$246	$224
No Special Work	595	$3,497	$2,435	$1,263	$198	$104
Prevailing Wage Paid	615	$3,927	$2,593	$1,448	$206	$152
No Prevailing Wage Paid	374	$4,019	$2,682	$1,740	$219	$124
Site or Structural Factors Noted	91	$8,005	$5,141	$2,703	$260	$281
No Site or Structural Factors Noted	898	$3,552	$2,309	$1,376	$196	$118
Permit Costs Included Labor	156	$4,592	$2,935	$1,813	$307	$190
No Labor in Permit Costs	833	$3,844	$2,551	$1,464	$129	$95
	Number	**Average Cost per Port**	**Labor**	**Materials**	**Permit**	**Tax**
Electrical Work	924	$2,857	$1,803	$1,052	$167	$115
No Electrical Work	400	$3,339	$2,217	$1,287	$127	$126
Special Work	585	$3,141	$1,904	$1,210	$184	$224
No Special Work	719	$2,894	$1,906	$981	$150	$91
Prevailing Wage Paid	867	$2,787	$1,796	$995	$151	$152
No Prevailing Wage Paid	438	$3,436	$2,244	$1,457	$184	$109
Site or Structural Factors Noted	134	$5,457	$3,517	$1,850	$181	$187
No Site or Structural Factors Noted	1171	$2,725	$1,693	$1,001	$152	$110
Permit Costs Included Labor	203	$3,538	$2,163	$1,336	$227	$147
No Labor in Permit Costs	1102	$2,907	$1,851	$1,053	$99	$95

Effect of Excluding High-Cost Projects

The study team undertook a limited examination of the effect of outliers on costs, evaluating one large source of California commercial installation data when outliers (defined in this examination as installations that cost $10,000 per EVSE or more) were removed, versus when the outliers remained in the sample.

When evaluating the cost of installations in the sample, it became apparent that there were numerous outliers, especially high-cost outliers, that appear to raise the average costs of commercial EVSE installations. (Refer to the histograms of the Overall Sample, California Sample, and Outside California Sample, presented in the body of the report).

While these data are important to retain in the overall analysis (to reflect the fact that there will be always be extraordinary circumstances on occasion that increase costs), the study team decided to undertake a "test case," that analyzed commercial installations when high-cost outliers are removed from the sample. In order to protect the confidentiality of the data, results of this test are reported in percentage change only (not in absolute $ values).

The key results of this test are outlined below.

Nature of the Sample

- The overall number of charging installation projects in the sample decreased by about 10%, while the number of EVSEs decreased by about 7%.
- About 39% of the sites that indicated that "Site or Structural Factors" influenced costs were excluded.
- None of the sites that indicated they had been "Previously Wired" for 240 volt, 40 amp charging were excluded.
- A number of projects requiring Special Work were excluded, notably 50% of those requiring boring; 21% of those requiring coring; 14% of those requiring trenching; and 12% of those requiring a poured foundation
- There were 9% fewer installations that required Electrical Panel Work, and 8% fewer installations that required new Electrical Infrastructure.
- A greater percentage of projects were excluded that had only 1 EVSE installed per site (12% less) or 2 EVSE installed per site (10% less) vs. 3-5 EVSE installations or installations with 6 or more EVSE.
- About 40% of Dual Port installations were excluded as a result of excluding high-cost outliers of $10,000 per EVSE or more; about 8% of Dual Voltage installations were excluded and 3% of single port Level 2 installations were excluded.

These findings are interesting because they mirror, in large part, the analysis presented in the section regarding installations with, and without, certain attributes and their impact on cost.

Average Cost Impacts

As a result of the exclusion of high-cost outliers from this sample, the average cost per EVSE fell by 15%. Average costs for installations with 1 EVSE fell by 21% while 2 EVSE installations fell by 19%. Among the sites with Electrical Panel Work, average costs at sites with a New Panel Upgrade fell by 11%, those with Re-worked Panels fell by 14%, and those with a Sub-Panel fell by 18%.

Sites with just single port Level 2 EVSE installations saw only a 5% decrease in average costs per EVSE, while sites with Dual Port EVSE installations saw a 40% decrease in average costs per EVSE, and sites with Dual Voltage installations saw a decrease in average costs per EVSE of 13%.

Conclusion of Examination of Excluding Outliers

It is clear from this test that there are significant impacts on the overall results posed by high-cost projects. This analysis supports the findings of EVSE installations with, and without, certain characteristics, in that factors that drive up cost were well represented among the sites that were excluded when high-cost outlier sites were excluded. Similarly, sites that drove costs lower, such as sites being previously wired for 240 volt, 40 amp charging were not excluded as part of the group of sites costing $10,000 or more, on average, per EVSE installed.

This analysis supports the conclusions that factors such as site selection, ample electrical capacity and electrical service, and the number of EVSE installed per site are key drivers in commercial installation costs.

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