Zoning Board of Appeals
September 22, 2021 Regular Meeting

STAFF REPORT

Subject: ZBA 21-034; 1300 South Maple Road

Summary:

Reagan Sims, representing property owner, is seeking a variance from Section 5.19.1 (A) Parking Standards Applicability. Grace Bible Church is proposing to construct a 34,000 square foot addition and a parking lot expansion of 107 spaces. The applicants request to reduce the requirement of 80 electric vehicle spaces to 10 electric vehicle spaces. The property is zoned R4B Multiple-Family Dwelling District.

EV-I Parking Spaces shall have an installed electrical panel capacity with a dedicated branch circuit(s) including conductor in a raceway or direct buried, and an Electric Vehicle Charging Station (EVCS) capable of providing charge energy to an EV Parking Space(s) (See Figure 3). EV-I Parking Spaces shall include signage indicating the space is to be exclusively used for EV's.

EV-R Parking Spaces shall have an installed electrical panel capacity with a dedicated branch circuit(s) including conductor in a raceway or direct buried, terminated in an approved method in a junction box, for an EV Parking Space(s).

EV-C Parking Spaces shall have an installed electrical panel capacity with a dedicated branch circuits(s) and cable/raceway that is capped for future EV Parking Space(s) (See Figure 1). The dedicated branch circuit panel space shall be stenciled or marked legibly with the following text: Future Electric Vehicle Charging Circuit.

EV Parking Ordinance

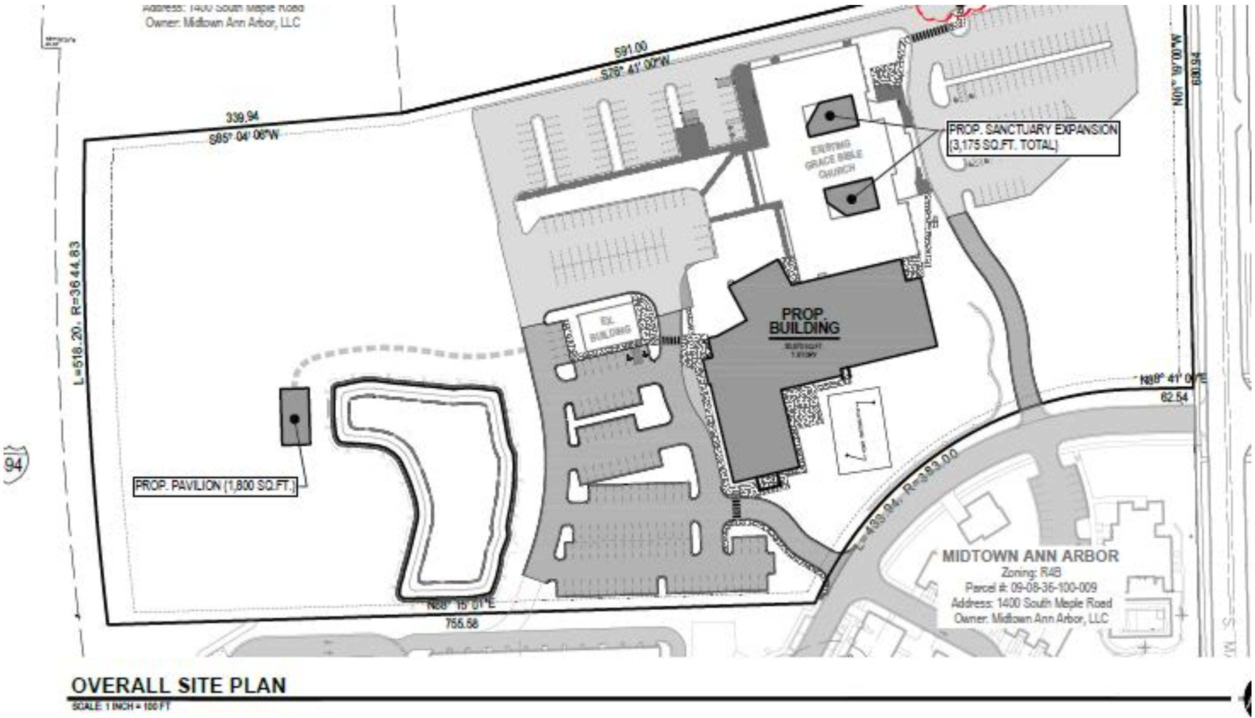
Background:

The subject property is located on the west side of South Maple Road, north of Pauline. The church was built in the early 1960's with subsequent additions since then. A site plan, special exception use and variance from planting street trees were approved in 2021.

Description:

The project involves two building additions totaling 34,045 in two separate areas. The first is the proposed expansion (3,175 sf) of the sanctuary into the courtyards within the existing church. This expansion allows for an additional ~300 ft of pew. The second, is a large expansion toward the south that will contain a gymnasium, youth ministry, child ministry, church offices and common space (~30,870 sf).

Zoning Board of Appeals
September 22, 2021



The project proposes an additional parking lot for 107 cars (New parking lot shown in darker shade), bringing the total number of parking spaces provided on the site to 339, 223 parking spaces are required. EV parking is calculated based on the number of required spaces, this would result in a total of 34 EV-Capable spaces, 23 EV-Ready and 23 EV-installed spaces (80 spaces total). The petitioner is seeking a variance of 70 EV spaces and is proposing to install a total of 10 EV spaces: Three EV-Installed; 3 EV Ready; 4 EV Capable

Site plans for City Council approval trigger the need for the entire site be brought into code compliance and the EV Parking was approved on January 19, 2021 and the site plan is scheduled for Planning Commission action on September 21, 2021.

Standards for Approval- Variance

The Zoning Board of Appeals has all the power granted by State law and by Section 5.29.12, Application of the Variance Power from the UDC. The following criteria shall apply:

In the case of an application for a variance from the parking requirements of Section 5.19 , a variance may be granted if the variance is in harmony with the general purpose and intent of the requirements.

- Applicant has submitted a response in the attached document.

Supplemental Application Information

Staff Response:

The total amount of parking provided on the site was discussed extensively by staff. The project is providing 114 more spaces than required by code. It is worth noting that parking requirements for churches were calculated allowing for parking on public streets and shared parking when provided on a public parking lot within 1,000 feet of the location. Both options are not available at the subject site. While the church currently has an arrangement with a business across Maple to provide extra parking on the weekends, there is no cross walk at this location and members are required to cross the street for access to the sidewalk leading to the church.

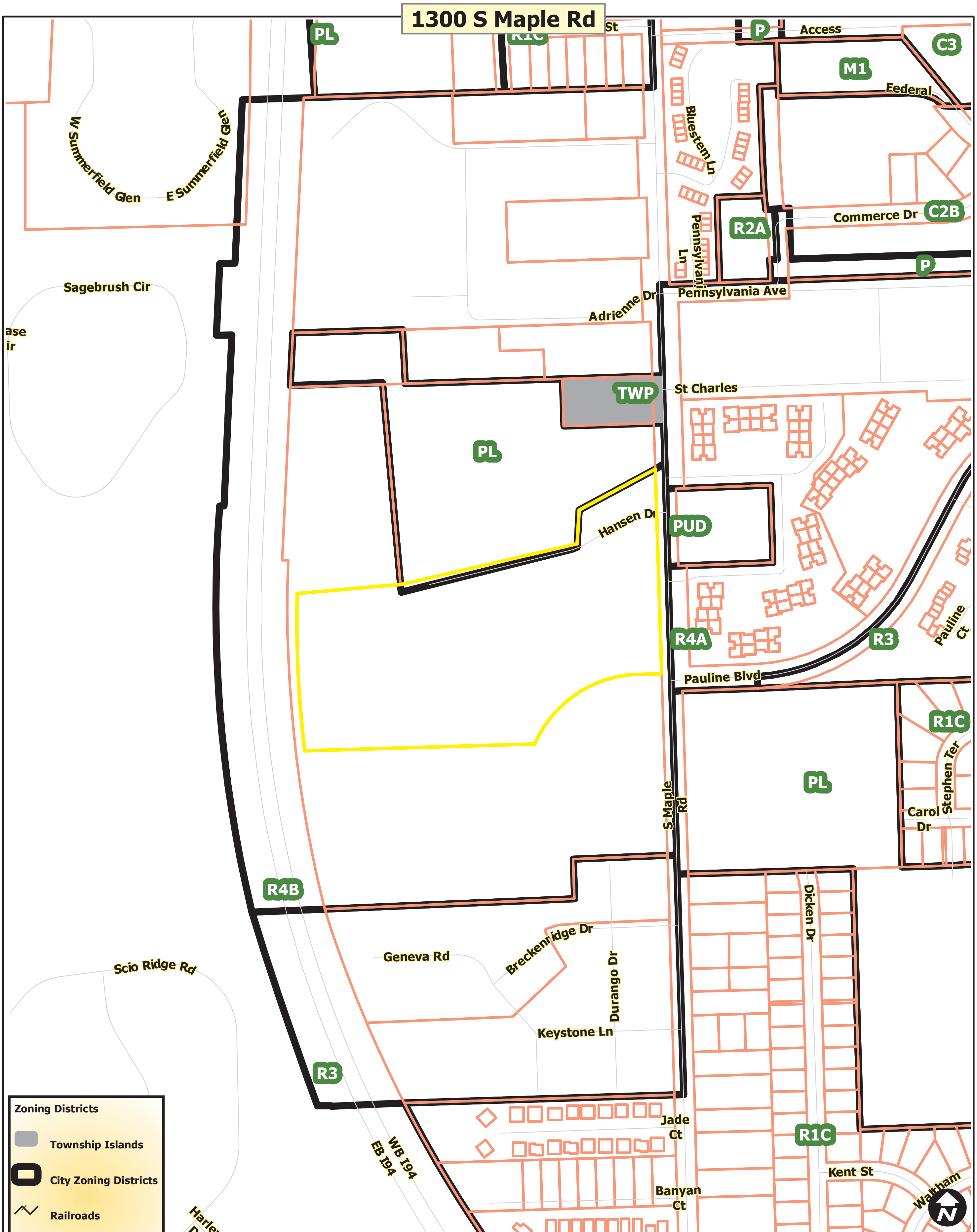
The petition is requesting a variance of 70 spaces from the EV parking requirements (80 spaces are required). Site plans for City Council approval trigger the need for the entire site be brought into code compliance, which means that all parking lots must comply with the EV parking requirements, not just the new parking lot. It is understood that much of the existing parking lots will not be altered, however more than the required amount of EV spaces are proposed to be newly constructed on site. The purpose and intent of the EV parking ordinance is to ensure parking lots are preparing for the future (EV Capable), while also providing for immediate support of electric vehicles (EV Installed and EV Ready). The best time to achieve this, as stipulated in the ordinance, is at the time of a significant development project on a site.

Staff concludes that maximizing the provision of EV Parking Spaces as part of the newly constructed parking area (making 80 of 107 new spaces EV compliant) would enable full compliance with the EV parking provisions of the UDC, solely in the area where new parking is being constructed.

Respectfully submitted,

Matt Kowalski
City Planner

1300 S Maple Rd



Map date: 2/12/2021

Any aerial imagery is circa 2020 unless otherwise noted

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1300 S Maple Rd

Railroads

Huron River

Tax Parcels

CITY OF ANN ARBOR MICHIGAN

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1300 S Maple Rd

Map date: 2/12/2021

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ZONING BOARD OF APPEALS APPLICATION

City of Ann Arbor Planning Services
City Hall: 301 E Huron Street Ann Arbor, MI 48107-8647
Phone: *734-794-6265* *Fax:* *734-794-8460* *Email:* planning@a2gov.org

PROPERTY INFORMATION

ADDRESS OF PROPERTY	ZIP CODE
1300 S. Maple Road	48103

ZONING CLASSIFICATION	NAME OF PROPERTY OWNER **If different than applicant, a letter of authorization from the property owner must be provided*
R4B	Grace Bible Church

PARCEL NUMBER	OWNER EMAIL ADDRESS
09-08-36-100-008	rsims@gracea2.org

APPLICANT INFORMATION

NAME
Reagan Sims

ADDRESS	CITY	STATE	ZIP CODE
1300 S. Maple Road	Ann Arbor	MI	48103

EMAIL	PHONE
rsims@gracea2.org	(734) 663-0589

APPLICANT'S RELATIONSHIP TO PROPERTY
Director of Next Steps and Operations: GBC

REQUEST INFORMATION

☑ VARIANCE REQUEST Complete Section 1 of this application	☐ REQUEST TO ALTER A NONCONFORMING STRUCTURE Complete Section 2 of this application

REQUIRED MATERIALS

One hard copy application complete will all required attachments must be submitted. Digital copies of supportive materials included in the submitted hard copy will only be accepted in PDF format by email or accompanying the hard copy application on a USB flash drive.

Required Attachments:

☑ Boundary Survey of the property including all existing and proposed structures, dimensions of property, and area of property.
☑ Building floor plans showing interior rooms, including dimensions.
☐ Photographs of the property and any existing buildings involved in the request.

OFFICE USE ONLY

Fee Paid: **ZBA:**

DATE STAMP

ACKNOWLEDGEMENT

All information and materials submitted with this application are true and correct.

Permission is granted to City of Ann Arbor Planning Services and members of the Zoning Board of Appeals to access the subject property for the purpose of reviewing the variance request.

Property Owner Signature : [signature] Date: 8/25/21

VARIANCE REQUEST

ARTICLE(S) AND SECTION(S) FROM WHICH A VARIANCE IS REQUESTED: (*Example: Article 3, Section 5.26*)

Chapter 55: Section 5.19.1; Table 5.19.1

REQUIRED DIMENSION: (*Example: 40' front setback*)	PROPOSED DIMENSION: (*Example: 32 foot 8 inch front setback*)
Feet: *Inches:*	*Feet:* *Inches:*

DESCRIPTION OF PROPOSED WORK AND REASON FOR VARIANCE:

The project involves a building addition of approximately 34,000 square feet and a parking lot expansion of 107 spaces. Requesting a variance for a total of 10 EV parking spaces, including: 3 EV-1 , 3 EV-R, and 4 EV-C spaces. See attached letter discussing our proposal.

The City of Ann Arbor Zoning Board of Appeals has the powers granted by State law and City Code Chapter 55, Section 5:29. A variance may be granted by the Zoning Board of Appeals only in cases involving practical difficulties or unnecessary hardships when all of the following statements are found to be true. Please provide a complete response to each of the statements below.

The alleged practical difficulties are exceptional and peculiar to the property of the Person requesting the variance, and result from conditions that do not exist generally throughout the City.

See attached detailed letter and supporting documentation explaining the practical difficulties unique to the church use.

The alleged practical difficulties that will result from a failure to grant the variance, include substantially more than mere inconvenience, inability to attain a higher financial return, or both.

See attached detailed letter and supporting documentation explaining the practical difficulties that are substantially more burdensome for a non-profit church.

Allowing the variance will result in substantial justice being done, considering the public benefits intended to be secured by this chapter, the practical difficulties that will be suffered by a failure of the Board to grant a variance, and the rights of others whose property would be affected by the allowance of the variance.

See attached detailed letter justifying a reduced number of EV parking spaces.

The conditions and circumstances on which the variance request is based shall not be a self-imposed practical difficulty.

See attached detailed letter explaining the conditions and circumstances that are unique to the church use.

A variance approved shall be the minimum variance that will make possible a reasonable use of the land or structure.

See attached detailed letter providing a reasonable proposal for the number of EV parking spaces that makes sense for the church use and its employees and members

Grace Bible Church

1300 S. Maple Rd.
Ann Arbor, MI 48103
734-663-0589

August 18, 2021

City of Ann Arbor
Zoning Board of Appeals
301 E. Huron Street
Ann Arbor, MI 48104

Subject: Variance Request on behalf of Grace Bible Church

Dear Board Members:

Grace Bible Church's Family Ministry Center building project is currently in progress for site plan approval, slated to go before the Planning Commission at the September 21 meeting. Our plan, as suggested by Planning Staff, is to submit the site plan with the complaint number of spaces. Planning Staff would then note in the plan that a variance is being requested and, if approved, the requested number of spaces would be updated to reflect the decision.

The ordinance—City Code Chapter 55, Section 5.19.11—specifies that 35% of our 223 code-required parking spaces needed to be outfitted with EV charging capability as follows: 10% EV-I (or 23 spaces), 10% EV-R (or 23 spaces), and 15% EV-C (or 34 spaces). We are not in any way opposed to the growth of electric vehicles in general, as a response to climate change, or specifically in reference to this ordinance. However, we foresee several significant obstacles in complying with the requirement to equip our facility with a total of 80 EV charging stations. We believe that an ordinance such as this one is sensible for any parking facility that sees high usage and/or opportunity for long term parking, a parking facility of any size where the opportunity for increased profit outweighs the obligation, and any smaller parking facility where installation and maintenance of EV spaces would not cause a undue burden on the business or organization. However, none these situations apply to the church under the current ordinance. Therefore, we are making a request that the ZBA grant a variance to reduce the requirement of EV charging spots for our 1300 S. Maple property.

Specific challenges include:

1. Our parking lot is full on Sunday mornings for services but attendees park for an average of only 1.33 hours. With a level 2 charger, this would allow for less than 27 miles of potential charge at 6.6kW. Additionally, as our services are held in the morning beginning at 8AM, the

need for additional charge for our members after coming from homes where they are presumably charging overnight is negligible (the average attendee trip to the campus is 4.52 miles and the U.S. Department of Energy estimates that over 80% of EV charging occurs at home). Furthermore, our property does not allow for overnight or all-day parking for safety and liability reasons. Therefore, it is unlikely that this would be a practical or highly utilized option for our attendees, guests, or the general public.

2. Initial estimates of operating and installation costs show that it would be difficult for a non-profit such as ourselves to provide a service at this scale without committing ourselves to a continual loss. As a religious nonprofit and due to our location, we are unable to compete in the market to generate the revenue necessary to offset the costs of providing a system of that scale as a convenience to our attendees, staff, and short-stay visitors.
3. We have made and are making significant investments to enhance and modernize other aspects of our property to comply with other city ordinances. Specifically, these include upgraded water mains, additional storm water management, landscaping, trash enclosures, and fire suppression throughout both our existing and proposed buildings which have added more than $374,000 to the total cost of our property and facilities. We feel that with this level of investment, the addition of $172,000.000 in direct costs for installation and the cost of ongoing upkeep would make compliance with the new EV ordinance a factor our community would be unable to bear.

Thus, given the relative newness of the statute, we sincerely hope that the ZBA will greatly reduce the overall quantity of spaces required by the EV ordinance.

More detail on specific challenges.

1. A more detailed discussion of parking lot usage at Grace Bible Church.

Our lot of 223 code-required spaces is sized for the purposes of providing adequate parking and safe vehicular operation for our weekend services. Each service lasts approximately an hour and fifteen minutes. However, throughout the rest of the week, the lot has less than 25 spaces consistently utilized. During the week, the church has 25 employees who are the only group consistently on property for any amount of time longer than an hour, making 25 the highest number of long term occupied spaces on property during a seven day period.[1] Were we to install the required number of EV spaces according to the ordinance (a total of 80 spaces) and if our staff were to reflect 100% personal EV usage, almost 70% of those spaces would still remain empty outside of potentially the four-hour window from 8am to 12pm on Sunday morning. As regards the four-hour window, the window occurs on Sunday morning where families are traveling from homes throughout Ann Arbor, Dexter, Saline, and Ypsilanti to the church facility. Assuming the midpoint of those municipalities as an average, our attendees travel an average distance of 4.52 miles to reach the church. After an overnight charge, a trip of less than five miles does little to exhaust the reserves of today's EV

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[1] 25 as a number covers all full-time, part-time, intern, and seasonal employees utilized by the church annually.

batteries, setting aside any further innovations in battery capacity over the coming years. As a result, charging capability on our campus would provide little or no benefit to those who travel to the property for Sunday morning services.

Additionally, our church does not allow either all-day or overnight parking. The reasons for this are manifold including: safety issues pertaining to unknown persons onsite concurrent with an event where children or the vulnerable are present, liability issues for those utilizing church property unsupervised as we would now be inviting the public on to campus after-hours, and the potential of damage and other incidents to and on property inherit with overnight access. In order to make the change to overnight or all-day access (outside of insurance upgrades and the subsequent cost involved), the church would need constant monitoring solutions (both physical and technological) in order to ensure that both attenders and the public are protected. Such solutions come at a substantial additional cost.

2. A more detailed discussion of operation and installation costs prohibitive for a non-profit entity.

There are essentially two basic options for creating EV infrastructure: user-owned installation and ongoing service installation. For user-owned installation, we cite a 2015 Department of Energy report (provided along with this letter along with any updated report from 2019 in which the IN International Council on Clean Transportation comes to largely the same conclusions) which estimated the costs of installing various types of pedestal chargers in non-residential environments. From that report, we selected a basic AC Level 2 240v Charger capable of the median charging speed of 20mi/hour @ 6.6kW.[2] We felt this reflected a fair average system which reflected a lowered cost for installation compared to other units while maintaining a decent charging performance for the EV user. Whenever we refer to costs, units, or averages throughout this document, this is the end system to which we are referring.

For the install category, the cost per unit according to the DOE report for a single port, pedestal product with the aforementioned specifications is approximately $3,450.00.[3] This is a model which would include some but not all features such as POS capability, security measures, energy usage monitoring, cord retraction, diagnostic capabilities, and additional support for weather/damage protection. Outside of the unit itself, installation for each individual unit according to the DOE repost is $2,979.00.[4] This involves costs to upgrade electrical services and panels, meeting ADA accessibly requirements, pouring foundations, trenching, and traffic protection in addition to the costs of the actual materials and labor. In total, this leaves a conservative estimate of $6429.00 per spot installed. This does not include any cost associated with design or engineering. Additionally, this does not include any rising cost factors due to pandemic supply and material constraints, inflation over the succeeding

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[2] *Costs Associated With Non-Residential Electric Vehicle Supply Equipment*, U.S. Department of Energy, 2015, pg. 7, fig. 4.

[3] *Costs*, DOE, pg. 11, fig. 7.

[4] *Costs*, DOE, pg. 18.

years since this report was assembled, or any ongoing maintenance for the installed spaces.[5] According to the Department of Labor, inflation over that six year time period is roughly 17 percent.[6] For rough estimation purposes including inflation, cost installed is $7,500.00 per space. It is this cost, multiplied by the eventual install number of 80 EV spaces as required by the ordinance, that would provide a completely user-owned system for the church. The total cost would be $600,000.00 to the church for the total project with the initial cost for 23 EV-I spaces being $172,000.00 plus EV-C and EV-R. Again, this does not reflect any pandemic-era cost changes or maintenance costs.

For the ongoing expense category, we cite information already provided to the ZBA as a part of earlier granted variances on the subject of EV parking. Using the ChargePoint EV subscription system as a model, such an agreement would avoid the costs of purchasing the charger, saving as listed above of approximately $3450.00 per space. To use the system and for this cost reduction, the church would enter into an agreement that upon provision and installation of the chargers, the church would pay $2400.00 yearly per space for the ongoing software upgrades and scheduled maintenance of the chargers. For the initial required 23 spaces, that would be a cost of $55.200.00 annually. Eventually, at the full required amount of 80 chargers, that figure would rise to $192,000.00 annually. Though a partnership with a company like ChargePoint would save on the initial cost of the charger itself (approximately $79,350.00 in savings on 23 spaces), the church would still be required to provide the site preparation and infrastructure for each spot, a cost of $68,517.00 in addition.

The model provided by ChargePoint and other manufacturers is a business that profits off of the sale and maintenance of chargers to businesses that have other revenue streams which allow those business to provide a service or to profit from the charging in some other manner.[7] This is primarily because the profit generated by the actually charging is not enough to defray the cost of the chargers and installation (as we will discuss in more detail below). But as non-profit without any storefront or means of profit generation, the ChargePoint model is financially unfeasible for the church.The church does not sell products in the model of a store, restaurant, or financial institution for which EV charging could potentially facilitate business. It does not offer some sort of subscription or membership in the model of a golf course or workout facility into which the cost of charging could be absorbed. It does not charge tuition as a school into which the cost of charging could be added as potential benefit. The church would be forced to commit to what amounts to a $62,000.00 loss annually for the next ten years to provide this service.[8]

For a non-profit, the only hope remaining for an EV system would be that the cost of the system would be covered by profit from actual EV user charging. However, this is not the case for EV

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[5] Report assembled in 2015.

[6] Department of Labor, https://www.bls.gov/data/inflation_calculator.htm.

[7] A coffee shop installs because the act of charging brings customers into the shop, the gas station because it provides customers for the various products sold inside the store, the mall provides a service to its employees who in turn through their employment generate profit, etc.

[8] $62,000.00 annually over ten years is the total after adding the infrastructure cost to the annual subscription fees. After year ten, that number would drop to the subscription number alone.

charging in general as various studies have supported. First of all, the church does not sit in an area of high traffic or close to any major thoroughfares. The property is located an average of 4.5 miles away from either the Jackson Rd or Ann Arbor-Saline Rd entrances to 1-94 with other opportunities for public charging more accessible along the routes. We sit in a largely residential community without any large major businesses in the immediate vicinity, making work-hours charging unlikely. According to the Fleis and Vandenbrink traffic study the church has provided with its site plan submittal, South Maple is classified as a minor arterial roadway, a road with 50% of the vehicular traffic of a similar non-profit site granted a variance for similar practical difficulties.[9]

As for potentially covering the cost from our own attendees and their vehicles, we can take a family owning an EV with a 200 mile range as an example. The vehicle would take 10 hours to charge completely. Using $1.50 per hour as a normal charging rate, the vehicle would cost $11.50 to charge or, at 600 miles driven per month per year, a total of $414.00 annually. At $414.00, the church would need 134 families to charge full-time on the church's property to simply break even on the subscription costs without allowing for the actual cost of electricity. This mean approximately 61% of our attending families would need to purchase an EV and commit to charging solely on church property with zero at home charging, zero charging on the road, and zero charging in the workplace. Such a model is unrealistic even if the church had the ability to allow 24 hour access and offered programming which led to large periods of time on campus for attendees. As noted above, the church does not offer any such opportunities or access. The church would be left with no option but to function at a financial loss indefinitely.

Our Proposal

As an organization, we do recognize the benefit globally and locally, both short and long-term, to providing the necessary infrastructure for EV growth. The benefits to the environment, to heath in the form of cleaner air, and to a reduction in traffic/engine noise are significant positives.[10] We strongly support and join the city in the goal of the ordinance and the city's overall objective of carbon neutrality by 2030. Additionally, we recognize the long term benefits of EV charging specifically to our staff and employees here at the church. However, a non-profit organization must be able to provide that service, and all other community services it provides, at a number and at a level that is sustainable for the organization. Otherwise a non-profit organization such as the church cannot continue to function.

It is in the spirit of the overall usefulness of the ordinance that we propose the following revision as a variance. We request that the overall number of EV spaces required for our property by the ordinance be based off of our total staff and employee number rather than the code-required number of parking spots for our facility. We believe that this change better reflects the actual potential users of any installed EV infrastructure and therefore the actual benefit the EV ordinance can provide

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[9] Semcog Traffic Data, https://maps.semcog.org/TrafficVolume.

[10] As an organization, we—though we are not close from an access perspective—do border on an interstate where the noise is substantial, particularly to youth soccer programming in the rear of our property.

through our facility. This revision would change the base number from 223 spots (code-requirement) which are primarily used for Sunday morning short term parking to 25 spots (total employees) servicing individuals who spend 5 hours or more per day on campus. This would update our EV requirement (based on the respective 10% EV-I, 10% EV-R, 15% EV-C criteria) to 3 EV-I spaces, 3 EV-R spaces, and 4 EV-C spaces.

Thank you for understanding the position of the church and for considering this variance request. We thank the ZBA and city as a whole for the opportunity to further the more than eighty-year partnership the church has enjoyed with the city for the benefit of the community.

Estimating electric vehicle charging infrastructure costs across major U.S. metropolitan areas

Author: Michael Nicholas

Date: August 2019
Keywords: electric vehicles; charging infrastructure; United States

The rollout of electric vehicles is aided and enabled by a concurrent rollout of infrastructure at home and in public locations. Home charging provides most of the charging needed for most drivers, whereas public infrastructure improves the electric vehicle proposition for prospective buyers, increases the potential electric miles from electric vehicles, and provides charging for those without home charging. Exactly how much charging infrastructure will be needed and what it will cost are top questions for prospective electric vehicle owners, automakers, policymakers, and electric utilities alike.

The need for much more electric vehicle charging infrastructure across the United States through 2025 is well established by a recent charging gap analysis.[1] Based on that analysis, about 4 times more public charging infrastructure than was in place in 2017 is needed by 2025 to match expected electric vehicle market growth. The analysis finds that at least 100,000 public and workplace chargers will be needed across the 100 most populous U.S. metropolitan areas over 2019–2025. These chargers would help serve the 2.6 million new plug-in hybrid electric vehicle (PHEV) sales and battery electric vehicle (BEV) sales expected by 2025 in those 100 areas.

This paper analyzes the capital costs of the electric vehicle charging infrastructure needed for public, workplace, and home charging for the most populous 100 metropolitan areas in the United States from 2019 through 2025. We review charging equipment cost data, including installation and hardware, for chargers of various charging types and locations. These equipment costs are then applied to our recent estimation of public and workplace charging needs, along with home charging needs that are newly assessed here. Ultimately we quantify the infrastructure costs on a metropolitan-area basis. Excluded from this scope are charging costs outside the 100 largest markets, which is to say in smaller cities and fast-charging corridors linking the cities.

Charging cost by type and location

This section describes the types of electric vehicle charging infrastructure related to the charging location. Cost estimates and research studies were used to estimate installation and hardware-related costs for home and nonhome charging to obtain average hardware and installation costs. These installation and hardware costs are used to construct estimates by metropolitan area in the following section.

Three main categories of electric vehicle chargers are assessed in this paper: Level 1, Level 2, and direct current (DC) fast. Basic information regarding the different levels of chargers evaluated in this report is summarized Table 1. The voltage (V) column shows the voltage at which electricity is delivered to the electric vehicle, and the typical power in kilowatts (kW) is the rate of energy transfer. The associated electric vehicle miles of range per hour of charging and the typical charging locations are also shown. Generally, Level 1 is used in home charging, whereas Level 2 is used in a variety of charging conditions, and DC fast

1 Michael Nicholas, Dale Hall, and Nic Lutsey, *Quantifying the electric vehicle charging infrastructure gap across U.S. markets*, (ICCT: Washington DC, 2019), https://www.theicct.org/publications/charging-gap-US

Table 1. Electric vehicle charging infrastructure specifications in the United States.

Charging level	Voltage	Typical power	Electric vehicle miles of range per charging hour	Location
Level 1	120 V AC	1.2–1.4 kW AC	3–4 miles	Primarily home and some workplace
Level 2	208 V–240 V AC	3.3–6.6 kW AC	10–20 miles	Home, workplace, and public
DC fast	400 V–1,000 V DC	50 kW or more	150–1,000 miles	Public, frequently intercity

Note: AC = alternating current; DC = direct current; kW = kilowatt; V = volt

charging is most commonly used at public charging stations.

For this paper's estimation of charging equipment costs across U.S. metropolitan areas through 2025, several simplifying assumptions are made regarding charger power requirements. Chargers are assumed to be 1.4 kW for Level 1, 6.6 kW for Level 2, and DC fast chargers include a combination of 50 kW, 150 kW, and 350 kW. We define chargers by these listed power levels rather than the number of outlets. For example, two outlets on the same pedestal providing 3.3 kW per outlet when two vehicles are connected are counted as one Level 2 charger, and a 13.2-kW Level 2 charger pedestal with two outlets is counted as two chargers.

Table 2. Per charger public and workplace charger hardware cost.

Level	Type	Chargers per pedestal	Per-charger cost
Level 1	Non-networked	One	$813
Level 1	Non-networked	Two	$596
Level 2	Non-networked	One	$1,182
Level 2	Non-networked	Two	$938
Level 2	Networked	One	$3,127
Level 2	Networked	Two	$2,793
DC fast	Networked 50 kW	One	$28,401
DC fast	Networked 150 kW	One	$75,000
DC fast	Networked 350 kW	One	$140,000

PUBLIC AND WORKPLACE CHARGER HARDWARE COSTS

Public and workplace charging infrastructure hardware costs include the charger and its pedestal. The main cost drivers are the power of the unit, in kW; whether it requires a pedestal; and whether it is networked with communication or payment gathering capability. Table 2 summarizes the costs applied in this analysis, based on the average hardware costs from several studies[2] and manufacturer price quotes.[3] For calculations, we determine an average cost per charger by level and type including mounting pedestal across all quotes and studies. As shown, Level 2 per-charger costs are lower when there are dual chargers, rather than one charger, per pedestal. Adding networking to a charger more than doubles the cost of hardware. For DC fast charging, we use the single charger cost for all calculations. Costs are reported in 2019 dollars, and future-year hardware costs are assumed to decline over time at the rate of 3% per year.

Based on existing trends from our charging gap analysis, future workplace charging is assumed to be 15% Level 1 and 85% Level 2. Networking enables chargers to communicate by WiFi or cellular signal to report usage, charge customers, and collect payment information. These cost estimates are based on workplace Level 1 not being networked and 62% of workplace Level 2 being networked, corresponding to the percentage of workplace charging that is paid.[4] Public charging is assumed to be 80%

2 Avista Utility, "Docket No. UE-160082 – Avista Utilities Semi-Annual Report on Electric Vehicle Supply Equipment Pilot Program" (2018), https://www.utc.wa.gov/_layouts/15/CasesPublicWebsite/CaseItem.aspx?item=document&id=00044&year=2016&docketNumber=160082&resultSource=&page=&query=&refiners=&isModal=&omItem=false&doItem=false; Department of Energy, "Transportation Energy Futures Series, Alternative Fuel Infrastructure Expansion: Costs, Resources, Production Capacity and Retail Availability for Low-Carbon Scenarios" (2013), https://www.osti.gov/biblio/1079728-transportation-energy-futures-series-alternative-fuel-infrastructure-expansion-costs-resources-production-capacity-retail-availability-low-carbon-scenarios ; Pierre Ducharme and Catherine Kargas. *Feasibility of a Pan-Canadian Network of DC Fast Charging Stations for EVs,* (Electric Vehicle Symposium 29: Montréal, Québec, Canada, June 19–22, 2016), https://www.mdpi.com/2032-6653/8/1/1/pdf; Josh Agenbroad, "Pulling back the veil on EV charging station costs," Rocky Mountain Institute, accessed Jan 5, 2019, https://rmi.org/pulling-back-veil-ev-charging-station-costs/

3 "Commercial EVSE: Public, Fleet, Workplace Charging," ClipperCreek, accessed February 1, 2019, https://store.clippercreek.com/commercial ; "Smart charging stations," Chargepoint, accessed February, 1 2019, https://www.chargepoint.com/products/commercial/

4 Gil Tal, Jae Hyun Lee, and Michael Nicholas, Observed charging rates in California, (Research Report – UCD-ITS-WP-18-02, Institute of Transportation Studies: University of California, Davis, 2018), https://itspubs.ucdavis.edu/index.php/research/publications/publication-detail/?pub_id=2993

networked, and all fast charging is assumed to be networked, as these are typical practices. For Level 1 workplace chargers we assume 80% will be simply a wall outlet, but average costs presented above are for the 20% of dedicated Level 1 chargers.

PUBLIC AND WORKPLACE CHARGING INSTALLATION COSTS

Installation costs are composed of labor, materials, permits, taxes, and utility upgrades, as shown in Table 3. These are based on the most recent and detailed cost estimates among the various investigations into costs for nonresidential infrastructure.[5] Notably, the Electric Power Research Institute (EPRI) studied 637 sites with 1,294 Level 2 charging units, including disaggregated costs for labor, materials, permits, and taxes. The EPRI study also shows how per-charger costs decline as more chargers are installed per site (i.e., sites with 3-5 chargers, and those with over 6 chargers). Costs are further disaggregated by sites within California versus those in the rest of the country and are applied as such in this analysis. For our analysis, based on the EPRI study, we assume workplace charging costs are 10% below, and public Level 2 are 11% higher, than the average numbers shown in Table 3. Utility upgrades are included in the materials cost, based on upgrades incurred in southern California.[6] In practice, part of these utility upgrade costs may be covered by the utility company. Typically, a utility provides the customer an upgrade allowance, above which the customer pays for the remainder of the upgrade cost.

Table 3. Installation costs for Level 2 public and workplace charger, by chargers per site.

		1 charger per site	2 chargers per site	3-5 chargers per site	6+ chargers per site
California	**Labor**	$2,471	$1,786	$1,491	$1,747
	Materials	$1,235	$958	$1,014	$908
	Permit	$283	$172	$110	$65
	Tax	$156	$121	$128	$115
	Total	**$4,148**	**$3,039**	**$2,745**	**$2,837**
Outside California	**Labor**	$1,544	$1,827	$1,647	$1,316
	Materials	$1,112	$1,039	$1,272	$874
	Permit	$82	$62	$59	$38
	Tax	$96	$89	$110	$75
	Total	**$2,836**	**$3,020**	**$3,090**	**$2,305**

Our DC fast charger installation costs, shown in Table 4, are based two sources.[7] Data from the Rocky Mountain Institute study are used to estimate costs for 50-kW chargers, and data from Ribberink et al. are used to project how costs scale for multiple chargers per site and for higher power stations. Similar to Level 2 charging, installation costs per charger fall as more chargers are installed per site. Also, costs do not rise proportionally with power so a charger with triple the power does not result in triple the cost. Hence, installation costs are mainly a function of the number of chargers per site.

Table 4 highlights the role power and multi-charger sites play in determining per-charger installation costs. For example, at a site with one 50-kW charger, installation costs are approximately $45,000. Increasing the power by 7 times to 350 kW results in an installation cost of approximately $65,000, reflecting higher material cost and the probability that switchgear and distribution lines may need to be upgraded. Although we show an approximately $20,000 increase, this is highly variable and certain sites with 350 kW require very expensive upgrades whereas other sites require modest upgrades depending on factors related to charging site

5 Idaho National Laboratory, U.S. Department of Energy, Plug-in electric vehicle and infrastructure analysis (INL/EXT-15-35708), 2015, https://inldigitallibrary.inl.gov/sites/sti/sti/6799570.pdf; NC PEV Taskforce, "Plug-in electric vehicle (PEV) roadmap for North Carolina" (2013), http://www.pluginnc.com/wp-content/uploads/2016/06/7-NCPEVRoadmap_April2014_v2.pdf; Ducharme and Kargas, "Feasibility of a Pan-Canadian Network"; Avista, Semi-Annual Report on Electric Vehicle Supply Equipment Pilot Program; Electric Power Research Institute, "Electric Vehicle Supply Equipment Installed Cost Analysis" (December 2013), http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002000577

6 Based on upgrades incurred in the Southern California Edison territory, $36.99 is added to each Level 2 charging installation. See J.R. DeShazo, Overcoming Barriers to Electric Vehicle Charging in Multi-unit Dwellings: A Westside Cities Case Study, (2017), http://innovation.luskin.ucla.edu/sites/default/files/Overcoming%20Barriers%20to%20EV%20Charging%20in%20Multi-unit%20Dwellings%20-%20A%20Westside%20Cities%20Case%20Study.pdf

7 Hajo Ribberink, Larry Wilkens, Raed Abdullah, Matthew McGrath, and Mark Wojdan, "Impact of Clusters of DC Fast Charging Stations on the Electricity Distribution Grid in Ottawa, Canada," (Electric Vehicle Symposium 30: Stuttgart, Germany, October 9–11, 2017); Agenbroad, "Pulling back the veil on EV charging station costs", Rocky Mountain Institute, accessed Jan 5, 2019, https://rmi.org/pulling-back-veil-ev-charging-station-costs/

Table 4. Installation costs per DC fast charger by power level and chargers per site.

	50 kW				150 kW				350 kW			
	1 charger per site	2 chargers per site	3-5 charger per site	6-50 chargers per site	1 charger per site	2 chargers per site	3-5 chargers per site	6-20 chargers per site	1 charger per site	2 chargers per site	3-5 chargers per site	6-10 chargers per site
Labor	$19,200	$15,200	$11,200	$7,200	$20,160	$15,960	$11,760	$7,560	$27,840	$22,040	$16,240	$10,440
Materials	$26,000	$20,800	$15,600	$10,400	$27,300	$21,840	$16,380	$10,920	$37,700	$30,160	$22,620	$15,080
Permit	$200	$150	$100	$50	$210	$158	$105	$53	$290	$218	$145	$73
Taxes	$106	$85	$64	$42	$111	$89	$67	$45	$154	$123	$92	$62
Total	$45,506	$36,235	$26,964	$17,692	$47,781	$38,047	$28,312	$18,577	$65,984	$52,541	$39,097	$25,654

readiness and electrical equipment. Location flexibility is paramount in reducing these costs. There is generally a site limit of 2.5 megawatts of power before a step change in costs. Therefore, the maximum number of chargers per site is 50, 20, and 10 for 50-, 150-, and 350-kW chargers, respectively. Finally, we note that there are some costs that may not be included in the installation costs above including signage, striping, lighting, and security cameras.

Trends in the number of chargers per site allow us to estimate overall future charging developments based on the preceding per-charger cost examples. Recent data on chargers per site from U.S. metropolitan areas with greater electric vehicle uptake serve as a guide for smaller markets. To determine the relationship between electric vehicle market development and chargers per site, markets are first categorized and binned by the status of the electric vehicle market development by metropolitan area at the end of each year from 2014 through 2018. The market development bins are defined by the electric vehicles per million population, ranging from 6,000 (in low electric uptake markets) up to 40,000 (high uptake). Then the associated charger locations and number of chargers per site were analyzed by metropolitan area.[8] These sites are grouped into four categories—one, two, three to five, and six or more chargers per site—to match the categories analyzed above. In areas with low numbers of electric vehicles per million population, sites with six outlets or more are rare but can still account for a large portion of a metropolitan area's chargers.

Figure 1 shows a trend toward more chargers per site in markets with greater electric vehicle uptake. The horizontal axis shows the relative electric vehicle market development in vehicles per million resident population in bins. The vertical axis shows the percentage of chargers per site size category, based on the charger data for all the metropolitan areas in each bin. For example, the lowest level of market development analyzed is 6,000 electric vehicles per million population, where approximately 30% of charging outlets are at sites with two chargers, 30% are with 3–5 chargers, 30% are with 6 or more chargers, and the remaining 10% are at sites with just one charger. Most metropolitan areas fall in the lower bins and the 40,000 electric vehicles-per-million bin is represented by just one metropolitan area, San Jose, in 2018.

The implication of the trend shown in Figure 1, based on Table 3, is that as electric vehicle markets grow, the number of outlets per site increases, and the per-outlet cost drops. Cumulative sales in San Jose by the end of 2018 are what define the highest market penetration category, where there are 40,000 electric vehicles per million population, and 60% of total outlets are located at sites with six or more chargers. The lines in Figure 1 represent the natural log fit of these points (e.g., $y = 0.21 * \ln(x) - 1.57$ for six or more chargers per site), and the equations shown are applied to the infrastructure buildout cost analysis that follows in the cost scenario section.

Compared to Level 2 chargers, DC fast chargers do not show such a clear trend for chargers per site versus electric vehicles per capita. However, overall site size for new installations is growing year by year. To reflect a general increase in the number of chargers per site, we extrapolate the trend from 2014–2018 into the future. In 2018, the percentages of chargers at one, two, three to five, and six or more chargers per site were 11%, 20%, 17%, and 52%, respectively. The corresponding percentages for 2025 are 5%, 13%, 15% and 67%. These percentages are

8 Downloaded from Alternative Fuel Data Center (Alternative fuel stations - electric, Accessed Sept. 1, 2014; Jan 1, 2016; Jan 1, 2017; Jan 1, 2018; and Jan 1, 2019), https://afdc.energy.gov/data_download/

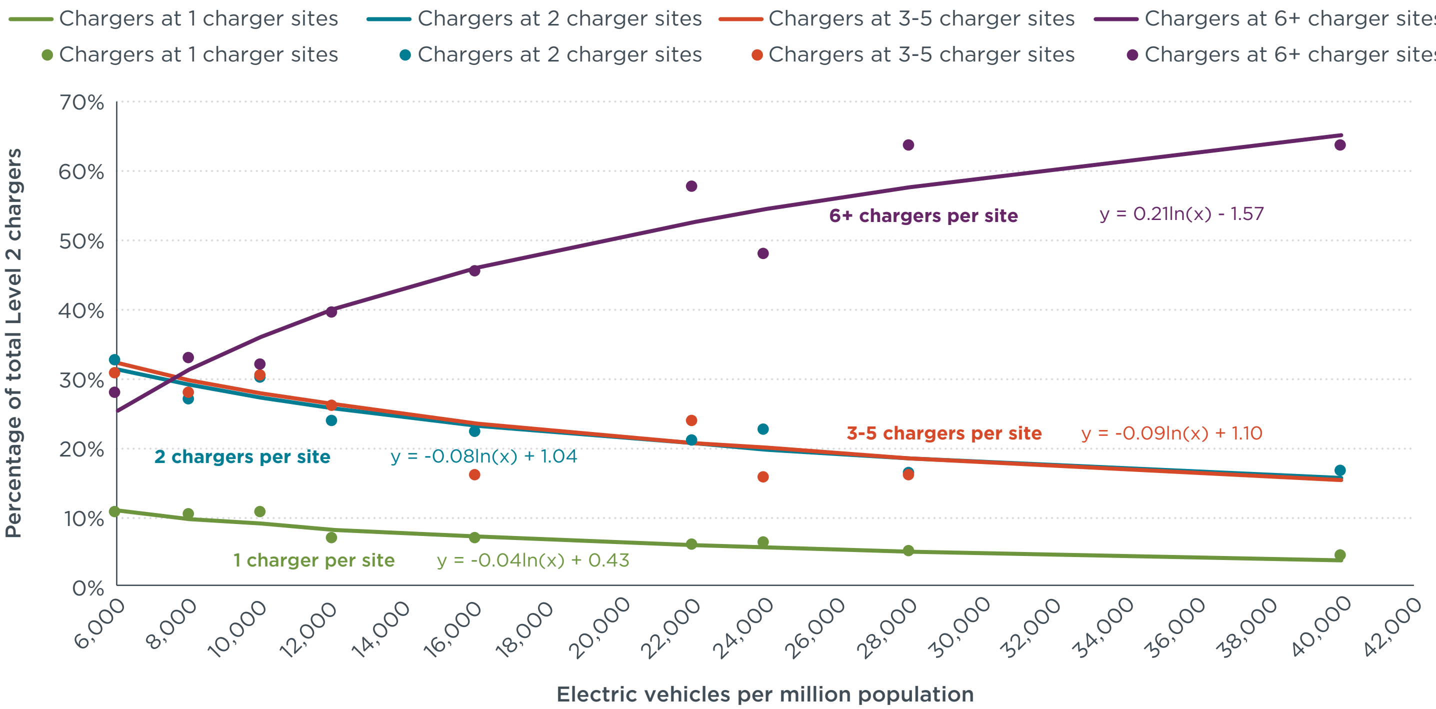

Figure 1. Percentage of public Level 2 chargers by site size as a function of electric vehicles per million population.

not applied as a function of market development, but rather by year across all metropolitan areas. We also assume the breakdown for the distribution of charger power is 44.4% for 50 kW, 44.4% for 150 kW, and 11.1% for 350 kW through our future year scenarios. This breakdown of DC fast chargers of varying power levels reflects our expectation of a continuing tradeoff between electric vehicle range and charger installation cost.[9]

HOME CHARGING HARDWARE AND INSTALLATION COSTS

Our charger cost analysis for home charging is similar to the previous discussion of public and home charging but accounts for varying cost by housing types. Home charging hardware and installation is typically less expensive than for public chargers. We separate the cost of home charging into charger level (Level 1 or Level 2) and housing type (detached house, attached house, and apartment). Hardware and installation costs are included, and installation is composed of labor, materials, taxes, utility upgrades, and permits. Some studies provide only installation cost, but not hardware costs, whereas others provide only hardware and installation costs combined.[10] We therefore represent the costs as combined costs for home charging estimates and average these across studies.

Average charger hardware plus installation costs applied to our analysis for 2019 are shown in Table 5. As

9 Wei Ji, Michael Nicholas, and Gil Tal, "Electric Vehicle Fast Charger Planning for Metropolitan Planning Organizations: Adapting to Changing Markets and Vehicle Technology," Transportation Research Record, 2015, 2502 (1): 134–143, https://doi.org/10.3141/2502-16; Michael Nicholas and Dale Hall, Lessons learned on early electric vehicle fast-charging deployments, (ICCT: Washington DC, 2018), https://www.theicct.org/publications/fast-charging-lessons-learned

10 Idaho National Laboratory, U.S. Department of Energy, Plug-in electric vehicle and infrastructure analysis; Electric Power Research Institute, "Electric Vehicle Supply Equipment Installed Cost Analysis"; NC PEV Taskforce, "Plug-in electric vehicle (PEV) roadmap for North Carolina"; California Air Resources Board, "California's advanced clean cars midterm review: Appendix B: Zero emission vehicles and plug-in hybrid electric vehicles" (California Environmental Protection Agency, Air Resources Board, 2017), https://www.arb.ca.gov/msprog/acc/acc-mtr.htm; California Air Resources Board, "California's advanced clean cars midterm review: Appendix D: Zero emission vehicle infrastructure status in California and Section 177 ZEV states" (California Environmental Protection Agency, Air Resources Board, 2017), https://www.arb.ca.gov/msprog/acc/acc-mtr.htm; DeShazo, Overcoming Barriers; Agenbroad, "Pulling back the veil on EV charging station costs."

shown, the costs vary depending on the electric vehicle home charging situation and the housing type. For the housing types, detached house signifies a house not connected to any others; attached house signifies a house with a shared wall of up to three housing units; and apartments are structures with more than 3 units. We use an average cost across all studies and apply a 3% per year reduction in hardware cost. To give examples of some of the underlying studies, the total installed costs ranged from $650 in the Rocky Mountain Institute study to $2,423 for a networked charger as assessed by Avista Utility. Higher costs for home charging upgrades generally correspond to a greater number of wall and floor penetrations, total circuit distance, or service upgrades. As indicated, attached homes and apartments typically are associated with higher cost upgrades.

Two types of upgrades are shown in Table 5: charger upgrades and outlet upgrades. Charger upgrades refer to new wiring and a charger, whereas outlet upgrades refer to only new wiring and a 120-volt wall outlet (Level 1) or a 240-volt dryer-type outlet (Level 2) with no additional charger. Most vehicle purchases come with a convenience charger that can be plugged into one or both of these outlet types and the convenience charger is not considered an additional infrastructure cost for this analysis. Categories of electric vehicle-owning households that have no additional home cost are also shown for context, as these are discussed in our overall average cost calculations.

The 3% per year hardware reduction is not shown, but as an example, total installed costs for a hardwired Level 2 unit in a detached house drop from $1,445 in 2019 to $1,317 by 2025 and from $4,061 to $3,933 in an apartment over the same period. Outlet upgrades do not decrease in cost over the analysis period. Average outlet upgrade and Level 2 charger installation costs in attached houses are not detailed in any study and are therefore assumed to be the average of apartment costs and costs in detached houses. The Table 5 costs by home charging category and housing type are applied across the U.S. metropolitan area data in the cost assessment that follows.

Table 5. Installation and hardware costs for home chargers by housing type.

Home charging category	Detached house	Attached house	Apartment
Level 1 outlet upgrade	$400	$500	$600
Level 1 charger upgrade	$700	$800	$900
Level 2 outlet upgrade	$680	$2,000	$3,300
Level 2 charger upgrade	$1,400	$2,800	$4,100

Cost scenarios

Costs are estimated for home, public, and workplace charging for approximately 2.6 million new electric vehicle sales in the 100 most populous U.S. metropolitan areas over the 2019–2025 period. In modeling the overall vehicle fleet, which accounts for vehicle retirement, this amounts to a stock increase of 2.3 million vehicles, and a total stock of 3.2 million electric vehicles in 2025 in the top 100 metropolitan areas. This represents 88% of the estimated 3.6 million electric vehicles on the road in the United States in 2025. The cost scenarios presented below are shown in terms of the aggregated costs for all the metropolitan areas combined and on a per-electric-vehicle-sold per year basis.

HOME CHARGING

Home charging is an important part of the charging ecosystem. Its associated cost to support new electric vehicle sales in the top 100 most populous metropolitan areas for the years 2019–2025 is analyzed here. We apply electric vehicle charging dynamics and sales across the metropolitan areas and the areas' housing stock as in our previous analysis[11] to provide a breakdown of electric vehicles by home charging category and housing type.

Our overall U.S. estimates for the number of electric vehicle sales from 2019–2025 in each type of home charging situation, and across housing types, are summarized in Table 6. There are seven home charging categories, two vehicle types (BEV and PHEV), and three housing types. The first row shows drivers who do not use home charging, primarily relying on workplace and public charging. Level 1 users are divided into those who have an existing outlet with no upgrades needed, those who install a new upgraded 120-volt household outlet for their electric vehicle, and those who install a dedicated Level 1 charger (charger upgrade). Level 2 home charging has categories similar to Level 1, but includes those with existing 240-volt dryer-type outlets and upgrades for new outlets and new dedicated chargers (charger upgrade). Ratios for determining the outlets and upgrades by charging level were determined from the results of a California Air Resources Board survey.[12]

The categories in Table 6 have two broad classifications—those that

11 Nicholas, Hall, and Lutsey, Quantifying the electric vehicle charging infrastructure gap.

12 California Air Resources Board, "California's advanced clean cars midterm review: Appendix B."

Table 6. California electric vehicle drivers by home charging category and housing type for 2019–2025.

Home charging category	Detached house PHEV	Detached house BEV	Attached house PHEV	Attached house BEV	Apartment PHEV	Apartment BEV	Totals
No home charging	124,429	67,272	46,129	30,467	102,185	89,171	**459,653**
Level 1 no upgrade	484,233	234,054	121,330	60,841	66,920	37,426	**1,004,803**
Level 1 outlet upgrade	36,228	18,606	6,709	4,824	5,905	3,364	**75,636**
Level 1 charger upgrade	8,296	10,927	2,236	4,020	3,543	3,154	**32,177**
Level 2 no upgrade	38,195	89,917					**128,112**
Level 2 outlet upgrade	48,644	180,114	12,281	44,473	5,200	16,212	**306,925**
Level 2 charger upgrade	132,960	312,477	23,026	43,375	12,712	27,731	**552,282**
Total	**872,985**	**913,367**	**211,712**	**188,001**	**196,465**	**177,058**	**2,559,588**

Note: BEV = battery electric vehicle, PHEV= plug-in hybrid electric vehicle

require electrical work and those that do not. As indicated, approximately 967,000, or 38%, of the 2.6 million electric vehicle owners are estimated to either need to install a dedicated charger or do an outlet upgrade. These include the four categories of Level 1 outlet upgrades, Level 2 outlet upgrades, Level 1 charger upgrades, and Level 2 charger upgrades. This also highlights that more than 1.1 million electric vehicle owners (or 44%) will use existing 120-volt or 240-volt outlets, and the remaining 18% either do not plug in or exclusively use workplace and public charging infrastructure.

In Figure 2, the data from Table 6 are represented graphically to show the fraction of electric vehicle drivers in our 2019–2025 analysis by home charging investments needed. The figure shows the percentage of electric vehicle drivers in three housing types (detached, attached homes, apartments) and home charging categories (No home charging, Level 1 home charging, and Level 2 home charging). The hashed bars indicate that there is no additional cost incurred for home charging for these drivers. For example, in the leftmost column, 70% of electric vehicle drivers in the analysis are in detached homes, and this includes 29% that are estimated to be complete home charging upgrades (26% Level 2 and 3% Level 1) and 41% without any upgrades. Electric vehicle buyers in attached houses and apartments are less likely to use home charging than those in detached houses, likely reflecting challenging installations and lack of control over upgrades.

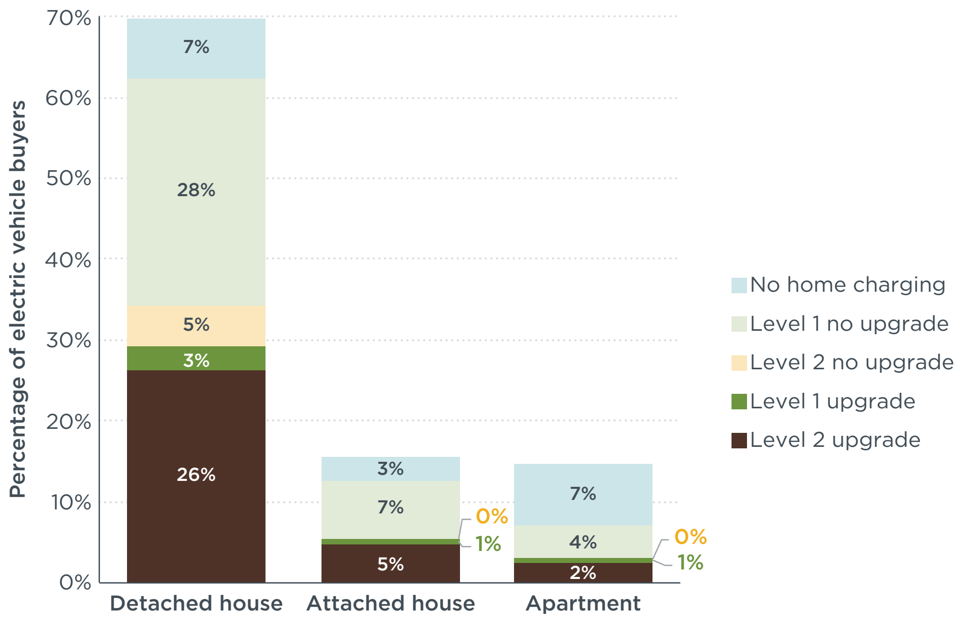

Figure 2. Percentage of new electric vehicle drivers by home charging access and upgrade.

Based on Figure 2 the majority of electric vehicle drivers will not be installing additional home infrastructure given current trends. Approximately 39% will simply use existing Level 1 (28% in detached houses, 7% in attached houses, and 4% in apartments), and 5% will use existing Level 2 charging (i.e., dryer outlet, largely in detached houses). The approximately 18% of all drivers not using home charging includes 5% of electric vehicle drivers rarely charging at all (primarily using PHEVs as hybrids) and the remainder relying on public and workplace charging.

Costs for the above electric vehicle driver, housing, and home charging calculations include the charging equipment costs from Table 5 and Table 6 for the 100 metropolitan areas.

The total cost for the 38% of customers assumed to undertake upgrades including upgraded outlets and installed chargers totals $1.3 billion. Averaged over all the new electric vehicle drivers, this represents $520 per new electric vehicle, decreasing from about $540 to $510 over the 2019–2025 period. A weighted average over only those electric vehicle drivers that had an upgrade at their residence results in $1,400 per vehicle. If costs are calculated separately for electric vehicles by housing type, and once again assigned only to those undergoing upgrades, we estimate $1,100 for those in detached houses, $2,100 for those in attached houses, and $3,100 for those in apartments.

PUBLIC AND WORKPLACE CHARGING

Total public and workplace charging infrastructure costs across the 100 metropolitan areas over the 2019–2025 period are estimated from the per-charger costs from Table 2, Table 3, and Table 4 and the distribution of outlets per site shown in Figure 1. Although overall costs are tallied based on the specific needs across the 100 areas, the results are presented here for all the areas combined to inform the overall charging infrastructure costs, the primary underlying cost components, and the costs on a per-electric-vehicle basis.

Figure 3 shows the overall 2019–2025 costs for workplace, public Level 2, and DC fast charging disaggregated by labor, materials, permits, taxes and hardware. The vertical axis shows the total costs for that charger category, which are approximately $190 million, $360 million, and $390 million for workplace, public Level 2, and DC fast, respectively. As indicated, hardware costs are the largest cost component in each case, representing 43%, 40%, and 68% of the total costs, respectively, for

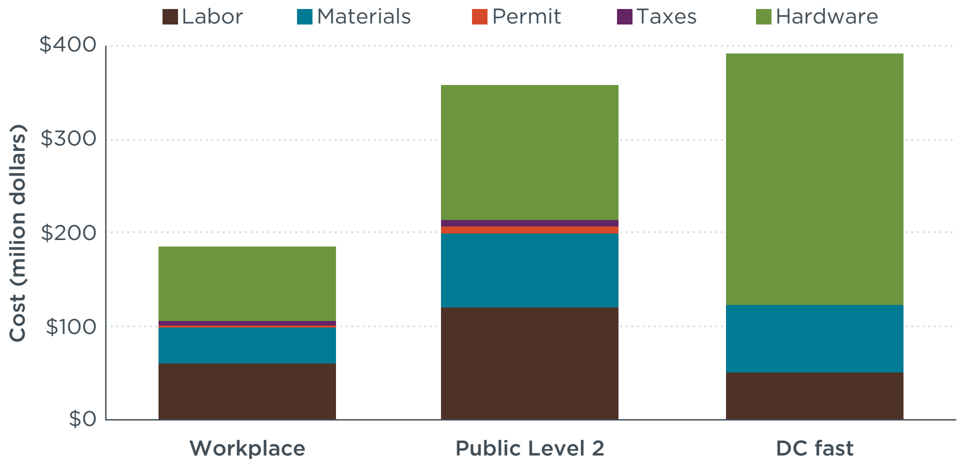

Figure 3. Workplace, public Level 2, and DC fast charger costs from 2019 through 2025.

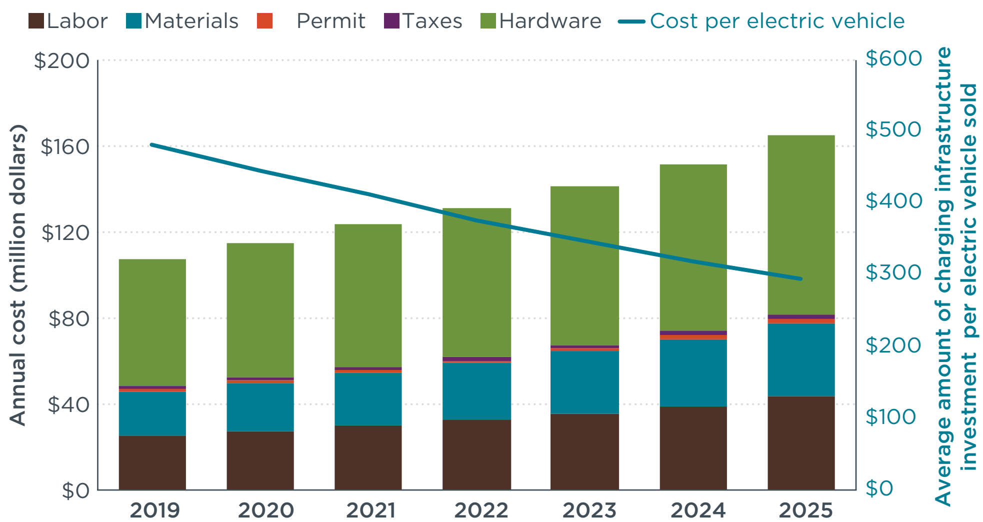

Figure 4. Total cost of public and workplace infrastructure and associated average aggregate charger cost per new electric vehicle sold for 2019 through 2025.

the three charging types. Workplace chargers and public Level 2 charger costs are similar in terms of the breakdown by cost component, but DC fast charging hardware is more expensive, especially for the highest power stations driving a relatively high hardware cost, as indicated on a per-charger basis in Table 2. Summing the costs by cost component, hardware costs are about $490 million, followed by labor at $230 million, materials at $190 million, taxes at $12 million, and permits at $9 million.

Figure 4 shows how annual charging infrastructure costs increase over time with higher electric vehicle sales volumes, and also how average charging costs for additional charging needed in each year decline on a per-electric-vehicle-sold basis. This decline is due to three factors. First, higher utilization of chargers, in terms of hours of active charging per day per charger, results in fewer chargers needed per electric vehicle. Second, installation costs decline as the number of chargers per site increases with growing market penetration. Third, we assume a 3% decline in per-charger hardware cost per year. The figure shows the installation and hardware costs increase from approximately $110 million to $165 million dollars in 2025. The blue line (right vertical axis) shows the average cost per electric vehicle, calculated by dividing public and workplace charging costs in each year by the number of electric vehicles sold in that year, and declines from $480 in 2019 to $300 in 2025.

To provide a more detailed understanding of how the charging infrastructure costs differ by electric vehicle type, Figure 5 shows the average cost of home and nonhome infrastructure separately for BEVs and PHEVs. The nonhome costs include workplace, public Level 2, and DC fast charging. The figure shows the average cost per new electric vehicle in the year sold and according to the year in which costs are incurred. Per BEV, the average home charger cost declines from $760 to $720 over 2019–2025, and the average nonhome charger cost declines from $690 to $420. Per PHEV, the average home charger cost declines from $320 to $300 over 2019–2025, and the average nonhome charger cost declines from $260 to $180. The BEV nonhome line includes DC fast charging cost whereas the PHEV nonhome line does not.

DC fast charging adds a significant cost to the average nonhome costs for BEVs. This is largely driven by the high cost of 150 kW and 350 kW hardware as shown in Table 2. Although a 3% cost reduction per year is applied to all nonhome charging hardware costs, the higher power DC fast charging hardware is relatively new and its cost may decrease faster as suppliers recoup development costs and move to higher production volume. Home costs are also greater for BEVs because more of the BEVs upgrade to Level 2 rather than use existing Level 1.

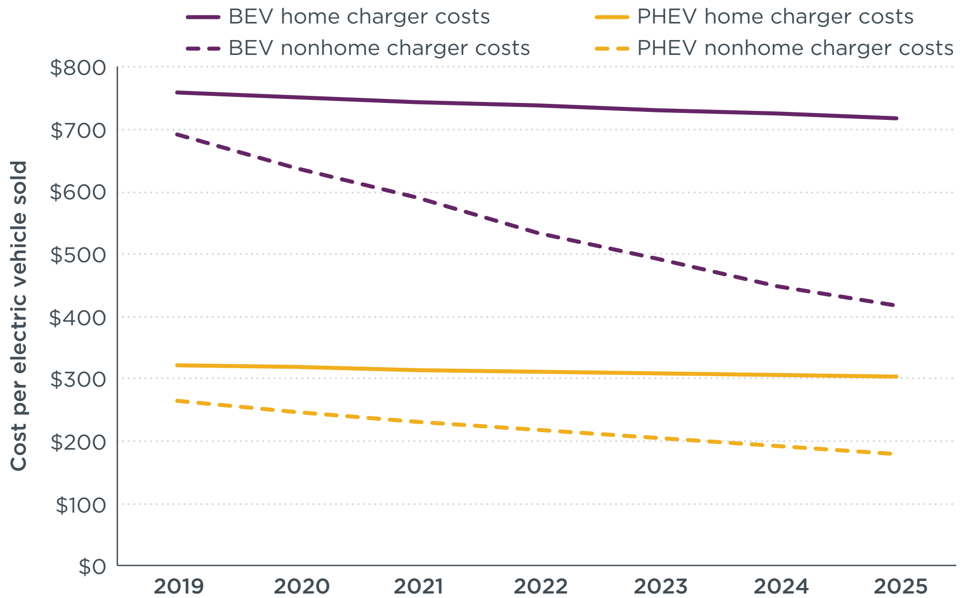

Figure 5. Average home and nonhome charger costs for BEVs and PHEVs.

Table 7. Summary of needed charging infrastructure and associated costs across 100 U.S. metropolitan areas over 2019–2025, by charging category.

Charging category	Chargers	Total 2019–2025 cost	Average 2019–2025 capital cost per charger
Home Level 1 no upgrade	1,005,000		
Home Level 1 outlet upgrade	76,000	$33 million	$440
Home Level 1 charger upgrade	32,000	$24 million	$735
Home Level 2 no upgrade	128,000		
Home Level 2 outlet upgrade	307,000	$339 million	$1,104
Home Level 2 charger upgrade	552,000	$948 million	$1,716
Workplace	48,000	$186 million	$3,880
Public Level 2	66,000	$359 million	$5,440
DC fast charging	5,000	$392 million	$81,818

Table 7 summarizes the total home, workplace, and public charging needed and the associated costs for the 2.6 million new electric vehicles in the 100 most populous U.S. metropolitan areas over 2019–2025. The home charging needs are shown by charging category (i.e., availability of Level 1 and Level 2) in the top six rows. Nonhome charging is shown in rows seven to nine. Counts refer to the number of new chargers in that category. As shown, the analysis finds that 5,000 DC fast, 66,000 public Level 2, 48,000 workplace, and 967,000 home charger upgrades will be needed from 2019–2025. In addition, within this analysis there are 1.1 million electric vehicle drivers who will use existing home charging outlets. Although not shown, there are another 460,000 electric vehicle drivers in this analysis who do not have home charging and will rely on public and workplace charging.

The costs in Table 7 show the relative contributions of the various charging types to the overall charging infrastructure costs for the major U.S. electric vehicle markets. The home charging costs ultimately result in more than half of the overall costs ($1.3 billion of $2.3 billion), followed by DC fast charging ($392 million), public Level 2 ($359 million), and workplace charging ($186 million). As indicated by the far right column, the average cost per charger is much higher for the DC fast charging ($81,818), followed by public Level 2 ($5,440), workplace ($3,880), and various home charging types. Home charging costs are a weighted average across housing types, and cost differences for those housing types are detailed in Table 5. Nonhome charging costs are similarly averaged across all years and metropolitan areas. This summary reinforces that there is a significant number of new electric vehicle buyers who will not need home upgrades.

In addition to the preceding summary analysis, similar results for two specific metropolitan areas are provided as examples of underlying analysis on charging infrastructure needs and the associated costs evaluated across the 100 metropolitan areas. Table 8 summarizes the home, workplace, public, and DC fast chargers needed over 2019–2025 and the associated estimated charger costs for the Portland and San Francisco metropolitan areas. These two examples are chosen because they represent large and growing electric vehicle markets and also are areas where there are many utility, state policy, and city activities to actively fill the charging needs.

In the Portland area, our scenario has the total electric vehicle stock increasing by 75,000 electric vehicles from 2019–2025. As shown in Table 8, the associated Portland area charging costs for home, DC fast, public Level 2, and workplace charging are $43 million, $13 million, $10 million, and $6 million, respectively. In the San Francisco area, our scenario has the total electric vehicles increasing by 220,000 vehicles from 2019 to the end of 2025. The respective San Francisco area home, DC fast, public Level 2, and workplace charging costs are $143 million, $36 million, $30 million, and $17 million, respectively. These two cases provide examples and local-level context for the level of investment this analysis implies for electric vehicle owners, electric utilities, governments, and private charging providers.

Table 8. Example results for amount of needed charging infrastructure and associated costs over 2019–2025 by charging category for two metropolitan areas.

Charging category	Portland area		San Francisco area	
	Charger outlets	Total 2019–2025 cost	Charger outlets	Total 2019–2025 cost
Home Level 1 no upgrade	29,000		90,000	
Home Level 1 outlet upgrade	2,000	$1 million	7,000	$3 million
Home Level 1 charger upgrade	1,000	$1 million	3,000	$2 million
Home Level 2 no upgrade	5,000		13,000	
Home Level 2 outlet upgrade	10,000	$10 million	32,000	$37 million
Home Level 2 charger upgrade	19,000	$32 million	57,000	$101 million
Workplace	1,600	$6 million	4,300	$17 million
Public Level 2	2,000	$10 million	5,400	$30 million
DC fast charging	160	$13 million	440	$36 million

Note: Metropolitan areas are the core-based statistical areas and represent populations of approximately 2.5 million residents in the Portland area and 4.7 million in the San Francisco area.

Conclusions

In this analysis, we evaluate the capital costs, including installation and hardware, for a scenario with 2.6 million new electric vehicle sales in the top 100 U.S. metropolitan areas over the 2019–2025 period. Our basic findings here are that home charging costs to support these electric vehicles total $1.3 billion, whereas new workplace, public Level 2, and DC fast charging costs total $940 million.

The home and public charging costs analyzed here exclude several major aspects of a comprehensive charging ecosystem. This analysis excludes the necessary charging infrastructure for fast-charging corridors to link cities, which has been the early focus of some auto industry efforts.[13] The 100 metropolitan areas analyzed here represent 88% of all new electric vehicles sold and 75% of the overall U.S. vehicle market, but smaller markets are outside the scope of this analysis. Also excluded from this analysis are the project management and land-related costs, which can be highly variable and location-specific. Finally, charging infrastructure for the potential increased electrification of ride-hailing services is not included in these cost estimates. Nonetheless, the estimates provided here are important to provide capital cost estimates to inform the scale of infrastructure investment needed in major markets.

We also note that investments are underway for substantial fractions of the necessary charging buildout. Electric utility charging infrastructure activities are proliferating and

13 For example see "Charge on the Road," Tesla, accessed June 11, 2019, https://www.tesla.com/supercharger; "About Ionity," Ionity, accessed June 11, 2019, https://ionity.eu/en/about.html; General Motors, "General Motors to collaborate with EVgo, ChargePoint and Greenlots to enhance the charging experience for customers," news release January 9, 2019, https://media.gm.com/media/us/en/gm/home.detail.html/content/Pages/news/us/en/2019/jan/0109-charging.html

increasingly including direct support for infrastructure to partially fill charging gaps.[14] For example, three California utilities received approvals in 2018 to invest $738 million in charging infrastructure although some of it is dedicated to heavy duty vehicle infrastructure and items outside the scope of this report.[15] Volkswagen dieselgate settlement funds are also substantial. Volkswagen's Electrify America funding has allocated $360 million for fast charging corridors, $330 million for public and workplace charging, and $14 million for home charging.[16] In addition, up to 15% of the settlement's $2.7 billion environmental mitigation funding can be spent by states on charging infrastructure.[17]

However, this analysis of charging indicates there remains a need for charging infrastructure funding to support electric vehicle growth trends in the United States through 2025. We make the following conclusions regarding our analysis of electric vehicle charging infrastructure costs in the 100 most populous U.S. metropolitan areas.

Substantial charging infrastructure investments are needed to fill the charging gap. Our findings indicate that, to serve the growing electric vehicle market, necessary investments in workplace, public Level 2, and DC fast charging infrastructure would increase from approximately $110 million in 2019 to $270 million in 2025, amounting to a total of about $940 million. In addition, home charging investments of $1.3 billion are needed, largely for the upgrades and installation of Level 2 charging in houses and apartment buildings. These charging infrastructure costs are approximately 25% for hardware, 50% for labor, 20% for materials, and 5% for permits.

Infrastructure costs are relatively modest—and steadily decrease—on a per-electric-vehicle basis. Costs for public charging infrastructure decrease substantially on a per-electric-vehicle basis. This is due to public chargers becoming more heavily utilized, the shift to more outlets per charging site, and decreased hardware costs as the market grows. The result is that the total public infrastructure costs per electric vehicle decline from $480 per electric vehicle in 2019 to $300 in 2025. Averaged over all electric vehicles, some of which need home charging upgrades, home infrastructure costs are around $510–$540 per electric vehicle sold.

Investing in home charging will remain important. More than half of electric vehicle owners are expected to continue using their existing home charging options without home upgrades. Around 38% of electric vehicle owners are expected to have upgrades to improve their home charging, with an average cost of $1,400 to install home outlets or chargers. However, this average includes charging costs that are typically much higher in apartments. Incentives such as off-peak electricity rates and smart charging could remain important as the market expands to ensure more charging at apartment complexes and ensure home charging is mutually beneficial to drivers and utilities. Although many will utilize Level 1 charging with existing 120-volt outlets, higher power Level 2 charging at home will become increasingly important as battery size and vehicle range increase.

Based on these findings, charging infrastructure buildout is a strong candidate for large-scale federal funding. Although state-level utility support is growing, city and state funding for charging is generally limited. Cost-sharing federal and local funding would help leverage limited funding to help fill the charging gap and allow local authorities to align the federal support with their own action plans. Federal grants, perhaps directed at cities that demonstrate high electric vehicle uptake, comprehensive electric vehicle action plans, and city policies (e.g., streamlined infrastructure permitting, aggressive electric vehicle-ready building codes) could also be effective.

Many related questions remain. These charging infrastructure costs, clearly substantial, are presented here in the absence of vehicle electrification benefits. Follow-on analysis of how electric vehicle costs decline and fuel-saving and emission benefits increase, would likely show a strongly positive case for charging infrastructure investments.[18] Determining the lowest-cost pathways for a sufficient charging ecosystem will require persistent tracking of developments with electric vehicle charging speeds, electric range, charging preferences, and charger utilization. Finally, if the electrification of ride-hailing fleets were to ramp up, this would greatly increase the need for charging infrastructure investments.

14 Smart Electric Power Alliance, "Utilities and electric vehicles: Evolving to unlock grid value," (March, 2018), https://sepapower.org/resource/utilities-electric-vehicles-evolving-unlock-grid-value/

15 Decision on the transportation electrification standard review projects, California Public Utility Commission May 31, 2018, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M215/K380/215380424.PDF

16 The Electrify America funds are referred to as "Appendix C" funds per the settlement. "Our Investment Plan," Electrify America, accessed April 25, 2019, https://www.electrifyamerica.com/our-plan

17 These are "Appendix D" environmental mitigation funds. See U.S. District Court, Northern District of California, San Francisco Division, Case No: MDL No. 2672 CRB (JSC), Third Partial and 3.0L Second Partial and 2.0L Partial and Amended Consent Decree, retrieved from https://www.epa.gov/enforcement/third-partial-and-30l-second-partial-and-20l-partial-and-amended-consent-decree

18 Previous analysis with much higher electric vehicle costs than today indicated as much, with benefits many times greater than the infrastructure costs. See National Research Council, Transitions to Alternative Vehicles and Fuels (Washington, DC: The National Academies Press, 2013), https://doi.org/10.17226/18264.

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Costs Associated With Non-Residential Electric Vehicle Supply Equipment

Factors to consider in the implementation of electric vehicle charging stations

November 2015

Prepared by New West Technologies, LLC for the U.S. Department of Energy Vehicle Technologies Office

EV Everywhere
U.S. DEPARTMENT OF ENERGY

Clean Cities
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Executive Summary

As more drivers purchase plug-in electric vehicles (PEVs), there is a growing need for a network of electric vehicle supply equipment (EVSE) to provide power to those vehicles. PEV drivers will primarily charge their vehicles using residential EVSE, but there is also a need for non-residential EVSE in workplace, public, and fleet settings. This report provides information about the costs associated with purchasing, installing, and owning non-residential EVSE. Cost information is compiled from various studies around the country, as well as input from EVSE owners, manufacturers, installers, and utilities. The cost of a single port EVSE unit ranges from $300-$1,500 for Level 1, $400-$6,500 for Level 2, and $10,000-$40,000 for DC fast charging. Installation costs vary greatly from site to site with a ballpark cost range of $0-$3,000 for Level 1, $600-$12,700 for Level 2, and $4,000-$51,000 for DC fast charging.

Many factors lead to highly variable costs associated with EVSE. The report includes example cost ranges for both different types and applications of EVSE as well as the cost factors that can influence whether a particular EVSE unit or installation will fall on the lower or higher end of the cost range. Employers, business owners, and fleet operators can find the best EVSE solution for a specific site by evaluating needs and opportunities, then strategically determining the optimal number of EVSE, types of features, and location.

In general, there is an industry consensus that the cost of EVSE units is trending downwards and will continue to decrease. However, installation costs are highly variable and there is no consensus among industry stakeholders about the direction of future installation costs. In addition, state and local incentives in many places encourage EVSE installation through funding and technical assistance.

While the available cost information from past EVSE installations provides a wide ballpark range for future installations, the only way to determine a cost estimate for a specific site is to contact the utility, EVSE manufacturers, and EVSE installers for a site assessment. Clean Cities coalitions around the country bring together a network of contacts in the electric vehicle industry and are a good starting place for identifying local contacts. To find a local Clean Cities coalition, visit cleancities.energy.gov.

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Introduction

This document is designed to help employers, business owners, and fleet operators understand the costs associated with installing, operating, and maintaining electric vehicle supply equipment (EVSE), also known as electric vehicle "charging stations." It provides an overview of the equipment and processes needed to install EVSE and offers representative examples of cost ranges. The information presented is based on data collected from various studies around the country, as well as input from EVSE owners, manufacturers, installers, and utilities.

Many plug-in electric vehicle (PEV) drivers charge their vehicles at home using residential charging located at single family homes or multi-family complexes such as apartments and condominiums. This report however, focuses on the costs of non-residential stations such as public access, workplace, and fleet stations shown in the middle and top of the pyramid in Figure 1[1]. Increasing the number of EVSE available in these non-residential locations can help expand the electric driving range for PEVs, as well as enable PEV ownership for drivers without access to home charging. Public access charging stations are available for use by the general public or patrons/visitors to businesses, institutions, and municipalities. Workplace charging stations are intended for the use of employees or guests of a particular organization. Fleet stations are primarily used by business, government, or other fleet vehicles and are located at commercial, government, or other non-residential parking locations.

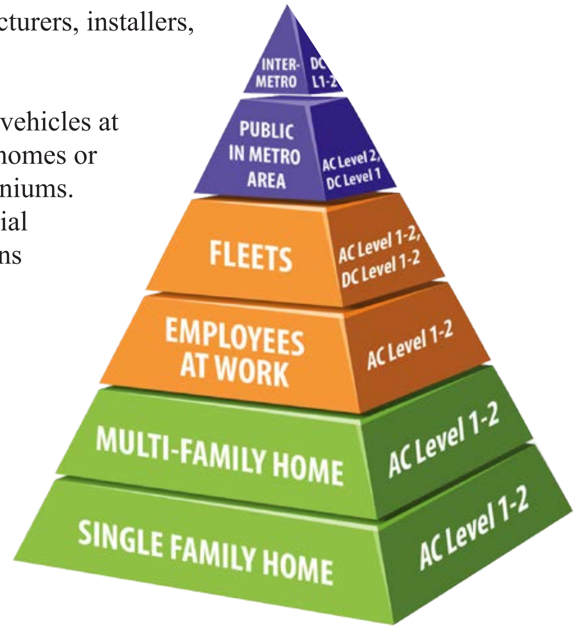

Figure 1. This pyramid illustrates how likely PEV drivers are to need and use each type of charging infrastructure. *Image from Argonne National Laboratory.*

EVSE Overview

EVSE consists of all the equipment needed to deliver electrical energy from an electricity source to a PEV battery. The EVSE communicates with the PEV to ensure that the plug is securely connected to the vehicle receptacle before supplying a safe flow of electricity. There are three primary types of EVSE. Two types—AC Level 1 and AC Level 2—provide alternating current (AC) to the vehicle, which the vehicle's onboard charging equipment

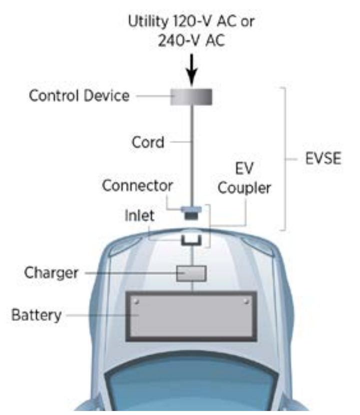

Figure 2. AC Level 1 and 2 charging schematic. *Image from Dean Armstrong, National Renewable Energy Laboratory (NREL).*

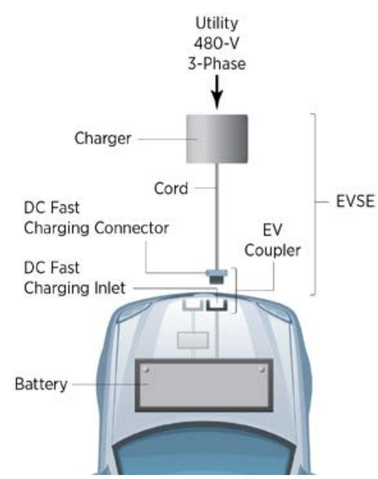

Figure 3. DC fast charging schematic. *Image from Dean Armstrong, NREL.*

1 This is a companion resource to the Clean Cities' Plug-In Electric Vehicle Handbook series available at www.cleancities.energy.gov/publications. These handbooks provide information about PEVs, benefits of owning EVSE, and the process for installing EVSE.

converts to the direct current (DC) needed to charge the batteries. Note that for AC Level 1 and 2 the *charger built directly into the car* is charging the battery. The third type—DC fast charging—provides DC electricity directly to the vehicle's battery. The charger is located off-board the vehicle, in the DC fast charger (DCFC). The charging schematics in Figures 2 and 3 depict the components involved with charging a PEV.

The differences in supply power and charging time for AC Level 1, AC Level 2, and DC fast charging are illustrated in Figure 4. The supply power is a product of the voltage in volts (V) and current in amperes (A). EVSE units are available in different amperage ratings which correlate to charging power. The vehicle charging time depends on the state of charge of the battery, the power coming from the EVSE, and the rate a vehicle can accept power, which may be lower than the supply power. The EVSE's dedicated circuit must be rated for a larger current than the EVSE continuous load rating (at least 125% larger) to conform to the National Electrical Code (NEC). For instance, a Level 2 EVSE rated for 30A continuous load will require a 40A circuit. Please refer to Appendix A for more information about EVSE charging types, PEV charging components, electrical hardware, and EVSE connector standards.

Charging Level	Vehicle Range Added per Charging Time and Power	Supply Power
AC Level 1	4 mi/hour @ 1.4kW 6 mi/hour @ 1.9kW	120VAC/20A *(12-16A continuous)*
AC Level 2	10 mi/hour @ 3.4kW 20 mi/hour @ 6.6kW 60 mi/hour @ 19.2 kW	208/240VAC/20-100A *(16-80A continuous)*
DC Fast Charging	24 mi/20minutes @24kW 50 mi/20minutes @50kW 90 mi/20minutes @90kW	208/480VAC 3-phase *(input current proportional to output power; ~20-400A AC)*

Figure 4. Description of charging level supply power and charging times. The power coming from the EVSE depends on the voltage from the electrical service and the EVSE amperage rating.

EVSE Costs Overview

The costs associated with installing and operating EVSE can vary widely, depending on the EVSE unit features, site location, available electrical capacity, and labor costs. It is difficult to compare or predict EVSE costs since actual costs of a given project will depend on the specific needs and constraints of the station and its users. The cost ranges shown in this document should only be used for the purposes of preliminary investigation of PEV charging infrastructure and not as a tool for estimating the cost of an individual project. To obtain estimates for a specific project, contact EVSE manufacturers and electricians[2]. The installation costs presented in this report are primarily from early installations of the technology that occurred between 2009

2 For more information, consult your local Clean Cities coalition. Contact information can be found at afdc.energy.gov/cleancities/coalitions/coalition_contacts.php

and 2013 because robust data sets of newer installations are not yet available. As the PEV market develops and matures in the future, installation costs may vary from those presented herein.

This report draws from published studies and interviews with industry experts to provide cost approximations across a range of EVSE types, geographic locations, and complexity. Two recent and robust sources of information are the EV Project and a study by the Electric Power Research Institute (EPRI).

Photo 1. This series of Level 2 EVSE were installed by the EV Project. *Photo from INL.*

The EV Project, funded by the U.S. Department of Energy (DOE) and private partners, deployed Level 2 and DCFC EVSE from 2011 to 2013. Idaho National Laboratory (INL) has cost data for about 2,500 single port Level 2 EVSE (pictured in Photo 1) and over 100 dual port DCFC installed for non-residential use.

EPRI conducted a study on installation costs for EVSE installed in the 2010 to 2013 timeframe. EPRI analyzed 385 commercial charging sites that installed 989 Level 2 EVSE including both single port and dual port EVSE (EPRI 2013).

The West Coast Electric Highway (WCEH) is another public-private partnership with cost information for DCFC installations. The WCEH installed 56 DCFC stations across Oregon and Washington between 2011 to 2015.

The costs associated with owning and operating EVSE include:

- EVSE unit hardware cost, which may include:
  - EVSE unit
  - optional EVSE equipment (e.g., RFID card reader);
- Installation cost, which may include:
  - contractor labor and materials for
    - connecting EVSE to the electrical service (e.g., panel work, trenching/boring, and repaving parking)
    - new electrical service or upgrades (e.g., transformers)
    - meeting Americans with Disabilities Act (ADA) requirements
    - traffic protection
    - signage
    - lighting
  - permitting and inspection
  - engineering review and drawings;
- Additional capital cost, which may include:
  - hardware extended warranty
  - repair labor warranty
  - land/parking space purchase or lease;
- Incentive credits (to reduce equipment or installation costs), which may include:
  - rebates
  - tax credits/exemptions
  - grants
  - loans

Photo 2. Pedestal-mounted EVSE installed by the City of Raleigh, N.C., for free public use. *Photo from Kathy Boyer, NREL 18520*

- Operation and maintenance cost
    - electricity consumption and demand charges
    - EVSE network subscription to enable additional features
    - management time
    - billing transaction costs
    - preventative and corrective maintenance on EVSE unit
    - repairs (scheduled and unscheduled).

A site owner may also want to consider the upfront costs that are incurred to identify viable locations for an EVSE station. This may include fees for consultants, site evaluations, or feasibility studies needed to assess the electrical capacity and location of utility service lines serving a given facility or site.

EVSE Unit Costs

EVSE units are available from many different manufacturers with a variety of designs and features. Features range from a simple unit that turns on and off to units that collect data, communicate to users, and provide a billing option for the owner of the charging station. The type and quantity of EVSE chosen for a site will depend on the intended users, site specific conditions, data management, and business case for the station. When purchasing an EVSE unit, an owner may choose to also purchase an extended warranty to cover potential repairs beyond the standard unit warranty period.

EVSE Unit Cost Drivers

EVSE unit costs are affected by the charging level, number of ports, communications system, data analysis, and other features.

Charging Level and Amperage Rating

All PEVs have a cordset that plugs into a Level 1 outlet (110-120V) and connects to the vehicle's charging port with a connector as shown in Photo 3. Providing Level 1 charging is the most inexpensive charging option. It can range from offering an outlet for a PEV driver to plug in a Level 1 cordset to offering an EVSE with a connector. Level 2 units are the midrange cost option and DCFC is the highest cost tier. The EVSE charging power depends on the voltage from the electrical service and the EVSE unit amperage rating. Level 1 EVSE are rated from 12-16A continuous, Level 2 EVSE are commonly rated from 16-48A continuous, and DCFC typically have a maximum of 60-200A. An increase in charging power also increases the cost of the unit due to the higher manufacturing cost to accommodate the higher amperage (e.g., a 48A Level 2 EVSE costs more than a 30A Level 2 EVSE).

Photo 3. This EVSE cordset can be stored in a vehicle and plugged into an available electrical outlet. It can be used for Level 1 or Level 2 charging. *Photo from AeroVironment.*

Charging Ports

Single port EVSE units provide access for only one vehicle to charge at a time. Multiple port EVSE units (commonly 2, 3, or 4 ports) are available to allow multiple vehicles to charge simultaneously or sequentially. DCFC connectors (the part of the EVSE that is inserted into the vehicle inlet) can meet either an SAE standard or CHAdeMO standard[3]. A dual port DCFC may offer multiple EVSE connector standards at one unit, but only allow one vehicle to charge at a time. Careful consideration should be given to these options so that the EVSE is compatible with the PEVs that will be using it as well as potential future estimated usage. Multiple port units are more expensive than single port units but both the unit cost and the installation cost are less expensive on a per-port basis for multiple port units.

Type of Mounting System

Units are typically available as either wall mounted (shown in Photo 4) or pedestal mounted (shown in Photo 5). Ceiling mounted units are also available but are more common for residential use. A pedestal mounted unit costs about $500-$700 more than a wall mounted one due to the material and manufacturing cost of the pedestal. There is also an additional construction cost for installing a pedestal mounted unit (e.g., pouring a concrete pad at the base). Typically, site owners choose a wall mounted unit if the parking spots to be used for charging are close to a wall, since the unit and installation cost less than a pedestal mount. However, pedestal mounted units provide more design flexibility, such as the ability to place the EVSE in the middle of a parking lot or in front of a sidewalk. They can also hold multiple EVSE units.

Photo 4. Wall mounted EVSE installed by the New York Power Authority for employee charging. *Photo from NY Power Authority, NREL 26468.*

In the EV Project, the average installation cost for a wall mounted Level 2 EVSE unit ($2,035) is 37% lower than the average installation cost for a pedestal unit ($3,209).

Photo 5. NREL employee plugging in his electric vehicle in one of the 36 EVSE in the NREL parking garage. *Photo from Dennis Schroder/NREL, NREL 26675.*

Additional Features

The most basic EVSE unit will be UL (Underwriters Laboratories) approved to safely supply electricity to the vehicle and provide lights to show when it has started and stopped charging. More sophisticated ("smarter") units are available with a variety of additional features described below, although these increase the cost of the EVSE unit.

- **Communications capabilities** enable different levels of data communication with the user, site host, utility grid, and the Internet. For instance, a user may be able to use a mobile application to remotely find an EVSE and check if it is available for use or out of service. Also, site hosts may be able to remotely update pricing, push messages out to users, and control other charging parameters.
- **Access control** restricts the use of EVSE to specific users. Systems range from a simple keypad or padlock to more complex, (e.g., granting access through radio-frequency identification (RFID) cards or mobile phone applications.)
- **Point of sale (POS)** functionally allows units to recover costs/fees associated with charging events. They could include a credit card reader, RFID reader, or mobile phone application.

3 See Appendix A: Acronyms, Definitions, and Equipment Overview for more information about EVSE connectors and standards.

- **Energy monitoring** tracks the EVSE's energy consumption and provides reports on greenhouse gas emissions reductions. This can help site hosts show how the EVSE is contributing to their sustainability goals.
- **Energy management and demand response** optimizes load management to maximize charging during low rate periods and minimize charging during high-rate periods. For instance, an EVSE can be programmed to only charge a vehicle during predetermined times.
- **Advanced display screen** provides user communication, advertising, and brand promotion.
- **Retractable cord** protects the cord and connector from damage and freezing, as well as reduces the risk of tripping on the cord.
- **Automated diagnostics** are used to troubleshoot issues or malfunctions that occur with the EVSE.

Networked or Non-Networked

EVSE units can be networked or non-networked. Networked units are connected to the Internet via a cable or wireless technology and send data to a network host's computer server, also known as the "back office." They provide the ability to remotely access availability of EVSE in real-time. Non-networked units are not connected to the Internet. They provide basic charging functionality without advanced communications or monitoring capabilities, so the equipment is priced lower than networked EVSE. Secondary systems can be purchased to incorporate additional features such as access control, payment systems, and data collection into a non-networked unit. These secondary systems can be useful if a grant or incentive requires data collection but the site host wants to purchase a non-networked EVSE.

Networked EVSE are typically part of a charging network, which is a group of EVSE units with access control and payment systems that are managed by a single organization. A sampling of the major networks includes AeroVironment, Blink, ChargePoint, GE WattStation Connect, Greenlots SKY, NRG eVgo, SemaConnect, and Tesla. Each charging network has its own PEV driver payment model, the most common being monthly subscriptions, pay-as-you-go (pay per charge), and free (free to charge; no subscription fee required). Benefits of a site host paying for a charging network can include charging station visibility and availability for drivers, energy monitoring, station usage analysis, automated payments, automated diagnostics, access control, and customer support. A site host may set pricing policies using a networked EVSE (e.g., employees consume electricity for free and visitors pay a fee).

EVSE Unit Costs Ranges and Examples

EVSE unit costs have decreased over the past five years as the PEV industry has matured and manufacturers have improved EVSE technology. The EVSE unit costs presented in Table 1 are based on single port products available in 2014 and 2015. EVSE with multiple ports may have a price higher than these ranges.

EVSE Unit Costs

EVSE Type (single port)	EVSE Unit Cost Range
Level 1	$300-$1,500
Level 2	$400-$6,500
DCFC	$10,000-$40,000

Table 1. EVSE unit cost ranges based on units available in 2015

The lowest price Level 1 unit is a simple plug-in cordset costing about $300. A wall mounted cordset with a keypad for access control is at the middle of the cost range. A hardwired Level 1 pedestal unit with access control and cable management could cost closer to $1,500. A pedestal Level 1 EVSE is shown in Photo 6.

Photo 6. Portland International Airport installed 42 Level 1 EVSE for employees and airport customers. *Photo from Telefonix.*

Single port Level 2 units are available spanning a $400-$6,500 cost range depending on the included features. While there is no standard EVSE unit for the fleet, workplace, or public sites, the graphic in Figure 5 illustrates example costs for sample Level 2 EVSE units with different tiers of additional features. The pictured examples are meant only to show how the cost of an EVSE unit may change based on the mounting system and selected features.

Ballpark Cost Ranges for Level 2 EVSE

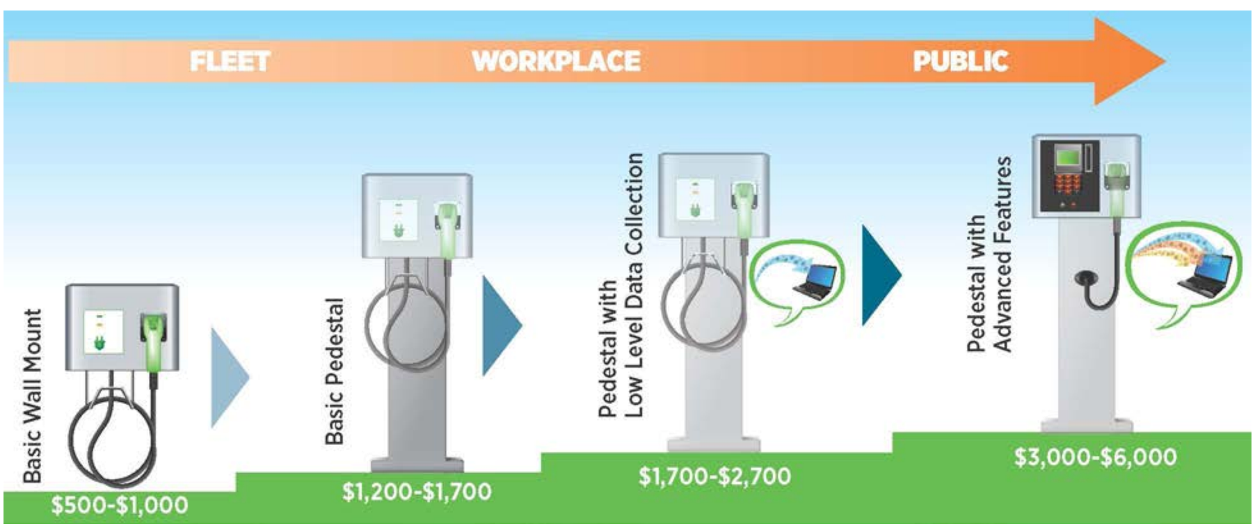

Figure 5. Ballpark cost ranges for different tiers of Level 2 EVSE units. *Image from Kristina Rivenbark, New West Technologies.*

A low price DCFC costing approximately $10,000 would typically have low power (25-50kW) with low charging amperage, a single port, and no display or networking components. The lower cost for a low power output is a tradeoff for a slower charging speed but it may be a good fit for the vehicles that are expected to use the DCFC. A mid-price DCFC will have higher power (50kW+), single or multiple ports, a keypad or some other simple form of access control, and a simple display. It might also be networked and have POS. The highest price DCFC will have higher power (50kW+) with high charging amperage enabling multiple vehicles to charge at once, RFID or some other advanced access control method, an advanced display, and software enabling energy consumption monitoring and data analysis, in addition to being networked and having POS. A high end single port DCFC could cost up to $40,000.

Installation Costs

Potential EVSE hosts are encouraged to have an electrical contractor complete a site evaluation when budgeting for a specific EVSE installation. An initial site evaluation should include determining the electrical capacity of the site, the location of distribution or service lines, the required electrical capacity for the type and quantity of EVSE units, and the best location for the EVSE unit(s). The best location for the units will take into consideration minimizing the installation costs and ADA accessibility requirements.

For Level 2 commercial EVSE in the EPRI study, the installation cost break down is approximately:

- Labor: 55 - 60%
- Materials: 30 - 35%
- Permits: 5%
- Tax: 5%.

During the installation process, a contractor will procure the EVSE unit(s), install a new or upgraded electrical service or connect the EVSE to an existing electrical service that will accommodate the EVSE load, install the EVSE equipment, and re-stripe parking spaces as necessary to fulfill the ADA parking requirements. The local electric utility may need to be involved if the necessary electrical supply upgrades to the facility are considerable (e.g., higher capacity supply wires, transformers, etc.).

Installation Cost Drivers

A simple installation will be at the lower end of the cost range while a more complex installation will move toward the middle or higher end. An installation becomes more complex when it requires one or more of the following:

- Trenching or boring a long distance to lay electrical supply conduit from the transformer to the electrical panel or from the electrical panel to the charging location;
- Modifying or upgrading the electrical panel to create dedicated circuits for each EVSE unit if none are already available;
- Upgrading the electrical service to provide sufficient electrical capacity for the site;
- Locating EVSE on parking levels above or below the level with electrical service; and/or
- Meeting ADA accessibility requirements such as ensuring the parking spaces are level.

Level 2 commercial sites that required special work such as trenching or boring were about 25% more costly than those that did not need special work (EPRI 2013).

"Electric service" refers to the utility infrastructure that provides power to customers.

This infrastructure consists of many components such as power generating stations, substations, transmission lines, and distribution facilities, including transformers.

Connecting the EVSE to the Electrical Service

The EVSE unit is connected to the electrical service by wiring enclosed in an electrical conduit. A surface-mounted conduit can be placed along a wall or ceiling. If the conduit needs to run underground, such as in a parking lot, contractors will trench or bore a path for the conduit.

Assuming $100 per foot to trench through concrete, lay the conduit, and refill, it would cost:

- $5,000 to trench 50 feet
- $10,000 to trench 100 feet

When trenching is needed, contractors will dig the trench, lay the conduit, and then back-fill the trenched area. An open trench is shown in Photo 7 and replaced trench is shown in Photo 8. Before digging, a contractor will need to have any existing buried utilities marked by contacting a state's utility marking service (Miss Utility or 811). In some areas of the country, it costs from $10-$20 per foot to trench through soil, and $100-$150 per foot to trench through asphalt or concrete. The total cost of trenching is affected by:

Photo 7. Trenching through a parking lot to install a public dual-port Level 2 EVSE in Haverstraw, N.Y. *Photo from New York State Research and Development Authority (NYSERDA).*

- Type of material being dug (asphalt, concrete, or soil);
- Labor costs;
- Distance to be traversed (wire pull boxes may be needed for long distances);
- Asphalt or concrete replacement (if needed);
- Re-landscaping (if needed);
- Re-striping parking areas (if needed); and/or
- Temporarily closing roads or parking lots (if needed).

Photo 8. Trenching through soil and sidewalk was needed to install EVSE at the University of Buffalo. *Photo from NYSERDA.*

For some sites, directional boring may be a more cost effective method for installing the conduit in longer runs. Whereas trenching opens the ground from above to dig a path, the boring process consists of drilling a tunnel underneath the surface. Since boring is less invasive, there are fewer costs for disposing of removed concrete and restoring the surface to its original appearance. It also has the added benefit of not disrupting traffic flows. However, enough room must be available to locate boring pits at the starting and ending points of the bore path.

Electrical Upgrades

It is important to consult with a licensed electrician when installing EVSE. In most cases, each EVSE unit must have an available dedicated circuit. There are some cases where multiple EVSE can be connected to a dedicated circuit, such as when the circuit is controlled by an energy management system. Be aware that this option is available and have your licensed electrician provide additional guidance.

The site must also have sufficient electrical capacity at the appropriate voltage flowing from the utility to the site's electrical panel to meet the EVSE power needs. If the site does not meet these requirements, then it will need electrical service upgrades. Contact the utility to make sure that the system can handle the load.

Electrical work can vary from a simple electrical panel modification to more costly transformer upgrades or installations. Site hosts are encouraged to choose an EVSE design that meets their projected requirements. However, to minimize costs, consideration should be given to a design that doesn't require more power than the available electrical capacity. If electrical upgrades are necessary, the costs can be minimized by placing the EVSE unit close to the electrical service. A long distance from the EVSE to the electrical service can lead to higher trenching costs. It can also lead to higher material costs in order to meet electrical requirements (e.g., larger wire to account for voltage drops).

3 Fundamental EVSE Electrical Needs

1. A dedicated circuit for each EVSE unit on the electrical panel (in most cases).
2. Sufficient electrical capacity from the utility connection to the electrical panel.
3. Sufficient electrical capacity at the panel.

Electrical Panels

If there is insufficient capacity on the electrical panel for the dedicated circuit(s), an electrician will need to create additional capacity by replacing or upgrading the panel, re-working the panel to provide more breaker positions, or adding a sub-panel for the EVSE units. If there is sufficient capacity on the panel, then additional breakers can be simply added to the panel to create the necessary dedicated circuits.

About 72% of Level 2 commercial installations in the EPRI study required work on the electrical panel.

New or Upgraded Electrical Service

When a customer requests new or upgraded electrical service to power EVSE, the utility will make sure that the existing or new electrical service will safely deliver the proper voltage and power requested for the equipment being installed. Some installations require upgrades to the electrical service, such as upgrading the utility distribution line and/or transformer, or installing a new transformer. DCFC sites or sites with many Level 2 units are more likely to require a service upgrade than a single Level 1 or Level 2 EVSE. For the DCFC stations along the WCEH, it cost $10,000-$25,000 for service upgrades such as installing a new transformer (Botsford 2014). Some installations may need to bring in new electrical service from the grid to the host site. In the EV Project, the costs of extending new electrical service for DCFC installations varied from $3,500-$9,500 per site (INL 2015a).

It is important to work with the utility early in the process to minimize costs, optimize the electrical design, and eliminate scheduling bottlenecks.

In Seattle, one large commercial building was able to bundle energy efficiency upgrades with their EVSE installations as a way to avoid upgrading the electrical service for the building. They were able to free up electrical capacity with a large lighting retrofit for the facility.

Photo 9. Electrical meter and switch servicing Level 2 EVSE. *Photo from Don Karner.*

Metering Systems

Some utilities may have special commercial rates for PEV charging, which requires a separate electrical service and meter. The electricity consumed at the EVSE can be measured by the EVSE unit software, which is typically a feature available through a network subscription. However, for separate utility billing, the meter accuracy must meet the utility's billing standard. An external meter can also be installed for networked or non-networked EVSE. Photo 9 shows a typical electrical meter. The cost for installing a new service with a separate meter depends on the distance to the power source, trenching requirements, local codes, and the amount of labor required for connecting the meter to the electrical service. Some utilities offer incentives to reduce the cost associated with installing a separate meter.

Planning for Growth

It is a good practice to consider long term EVSE needs when installing an EVSE unit. If a site host anticipates installing more EVSE in the future, it is cost effective to install conduit from the electrical panel to future EVSE locations while the ground is already trenched for the

Upgrading the electrical service for future EVSE loads and installing conduit to future EVSE locations during the initial EVSE installation can result in significant future cost savings.

initial EVSE installation. Future EVSE installations would simply require running wire through the existing conduit and putting the EVSE unit in place. Upgrading the electrical service for the anticipated long term EVSE electrical load is also recommended. These steps may result in an increased initial installation cost but will result in significant cost savings if additional EVSE are installed in the future.

Labor Costs

Labor costs for EVSE installation will vary based on the contractor's hourly rate and the time it takes to perform the work. These costs are affected by the contractor's experience and the geographic location. Complying with prevailing wage laws or using union labor may cost 20% more than similar work done for private sector entities (EPRI 2013).

Photo 10. Facebook supplies free PEV charging to its Menlo Park, Calif., employees. *Photo from Lauren Bonar Swezey, NREL 26457.*

Visibility and Aesthetic Factors

Aesthetic requirements such as making conduit less visible, replacing disturbed landscaping, or placing the unit in a location that requires extensive trenching can add cost to a basic installation. Some site hosts may choose to place the EVSE in a high visibility location to bring attention to the EVSE and make it easy for drivers to find. However, choosing a high visibility location can add significant installation costs if it is far from the electrical panel.

In the EPRI study, 9% of commercial Level 2 sites had site factors including visibility and aesthetics that more than doubled the average installation cost from $3,552 to $8,005.

Poured Foundation and Traffic Protection

Some pedestal mounted EVSE are directly installed on an existing hard surface such as a sidewalk. Others will require a concrete foundation as part of the installation process. Foundations range in complexity from placing a precast base on the surface for about $100 to digging a hole and pouring concrete. Hole depth, and therefore the amount of concrete needed, depends on the depth to which the ground water in soil can freeze. In some locations, a site owner may install bollards or wheel stops to protect the EVSE from being damaged by vehicles. A ballpark bollard cost is $200-$800 and wheel stops are generally $100-$200.

Geographic Region

Some states have notably lower or higher EVSE installation costs than average. The EV Project installed public Level 2 EVSE in 13 markets around the country. The average installation cost for those markets ranged from $2,100-$4,600, as shown in Figure 6. The primary reason for the geographic difference in cost is the labor cost in each region. Additionally, each region's local authority having jurisdiction (AHJ) had varying interpretations of ADA requirements. The Washington D.C. installations had the least expensive average

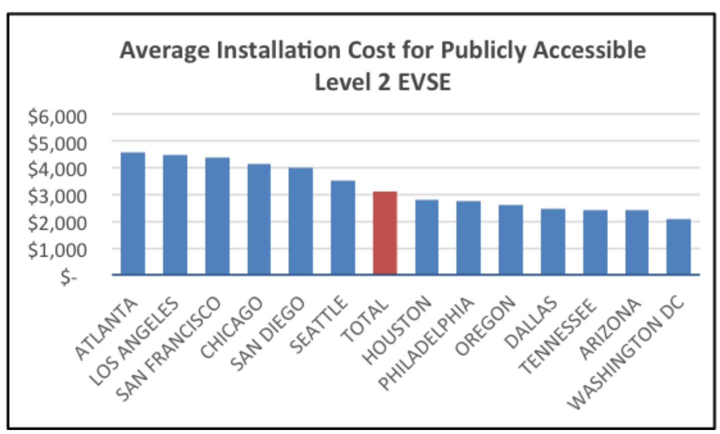

Figure 6. Average installation cost for publicly accessible Level 2 EVSE by EV Project market. *Graph from INL (INL 2015b).*

cost because nearly 80% of them were wall mounted. The Atlanta installation costs had a high average since many of them were installed in a high visibility parking space requiring long electrical runs from the electric service panel. Costs for labor and permitting at California sites made them among the most expensive sites (INL 2015b).

Installation Cost Ranges and Examples

Installation costs are highly variable and are difficult to compare from one site to another. The installation cost ranges and averages described in Table 2 are based on past installations and provide a ballpark idea of how much future installations may cost. These installation costs do not include the cost of the EVSE unit.

Ballpark EVSE Installation Costs

EVSE Type	Average Installation Cost (per unit)	Installation Cost Range (per unit)
Level 1	not available	\$0-\$3,000* *Source: Industry Interviews*
Level 2	~\$3,000 *EV Project (INL 2015b)*	\$600-\$12,700 *EV Project (INL 2015b)*
DCFC	~\$21,000 *EV Project (INL 2015d)*	\$4,000-\$51,000 *EV Project (INL 2015d) and (OUC 2014)*

Table 2. Ballpark costs for installation of Level 1, Level 2, and DCFC EVSE (not including the EVSE unit.)

**The \$0 installation cost assumes the site host is offering an outlet for PEV users to plug in their Level 1 EVSE cordsets and that the outlet already has a dedicated circuit.*

Level 1 Installation

Offering Level 1 charging at a site can range from providing an electrical outlet for PEV drivers to plug in a portable Level 1 cordset (shown in Photo 11) to installing a wall mounted or pedestal mounted EVSE unit.

When offering an electrical outlet for Level 1 charging, the installation process may be as simple as confirming the outlet is a commercial grade National Electrical Manufacturers Association (NEMA) outlet and it is connected to a dedicated circuit breaker. Ground-fault circuit interrupter (GFCI) outlets, which protect against electrical shock, are required for outdoor use. It is a good practice to ask an electrician to inspect an outlet and ensure it is in good condition before using it for Level 1 charging. If a dedicated outlet is available within reach of the parking space, there may be no additional installation costs.

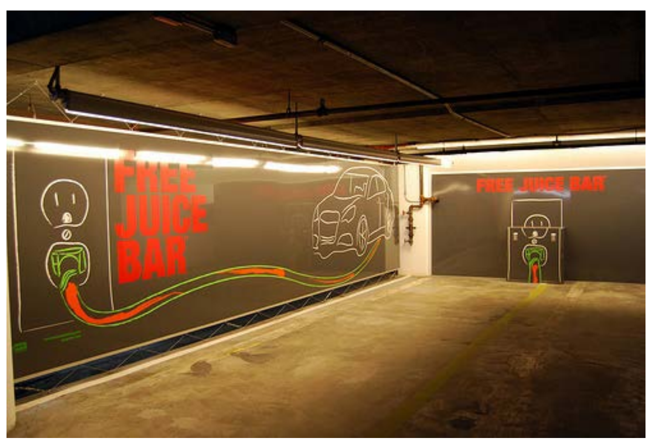

Photo 11. The Juice Bar at Charles Hotel in Cambridge, Mass., offers a wall outlet for PEV drivers to plug in their Level 1 cordset. *Photo from Steve Russell.*

According to the North Carolina PEV Task Force, if a new outlet or upgrade to a 120V circuit is needed, there may be a cost of $200-$500, assuming no unusual construction is needed (NCPEV 2013). A site host may choose to install outlets along a parking lot. A reasonable cost range for installing an outlet and dedicated circuit in a parking lot or garage is $300-$1,000 per outlet. Installing multiple outlets on a site can result in the costs being closer to the lower end of that cost range. Installing a wall mounted Level 1 EVSE hardwired to the electrical service would also cost around $300-$1,000 assuming the unit is located within 50 feet of the electrical service and no trenching or complex electrical work is needed.

The installation cost for offering pedestal mounted Level 1 EVSE (shown in Photo 12) will greatly depend on the selected location. Trenching or boring to connect the EVSE to the electrical service can add a significant cost to the installation process. A ballpark cost range for a pedestal mounted Level 1 EVSE installation, assuming no major electrical upgrades are needed, is $1,000-$3,000.

Additionally, there are products available that allow site hosts to install multiple electrical outlets mounted to a wall or a pedestal. This enables site hosts to place outlets in a convenient location for PEV drivers to plug in their portable Level 1 EVSE cordsets.

Photo 12. Level 1 pedestal EVSE at Rosalind Franklin University in Illinois. *Photo from Telefonix.*

Level 2 Installation

There is significant variation in costs for installing Level 2 EVSE. The EV Project has cost data from 2,809 non-residential, workplace and public, Level 2 EVSE installed between 2011 and 2013 with an average installation cost of $2,979. The average installation cost for workplace charging ($2,223) was lower than for public charging ($3,108). This cost information is on par with the EPRI study's non-residential Level 2 installations, which cost on average $3,005 per port. The graphs in Figure 7 and Figure 8 show the distribution of Level 2 EV Project installation costs, one for public charging (Figure 7) and the other for workplace charging (Figure 8).

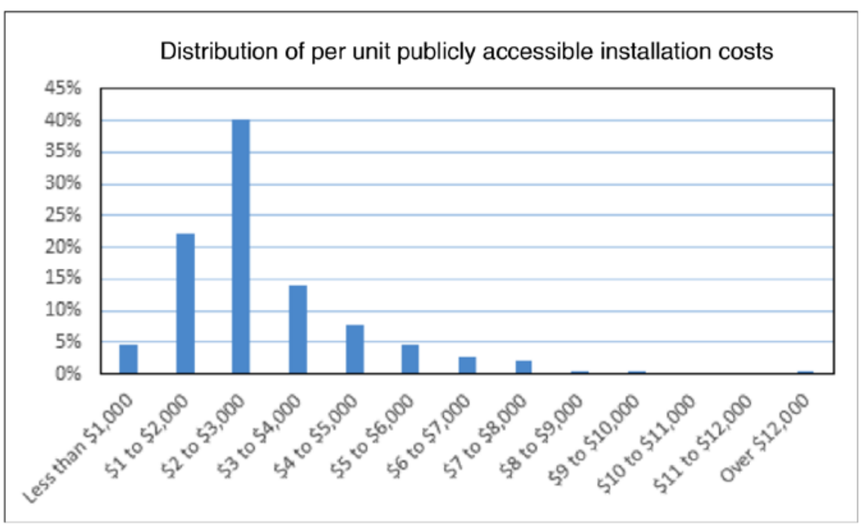

Figure 7. Distribution of EV Project per unit Level 2 public installation costs for about 2,500 installations. *Graph from INL.*

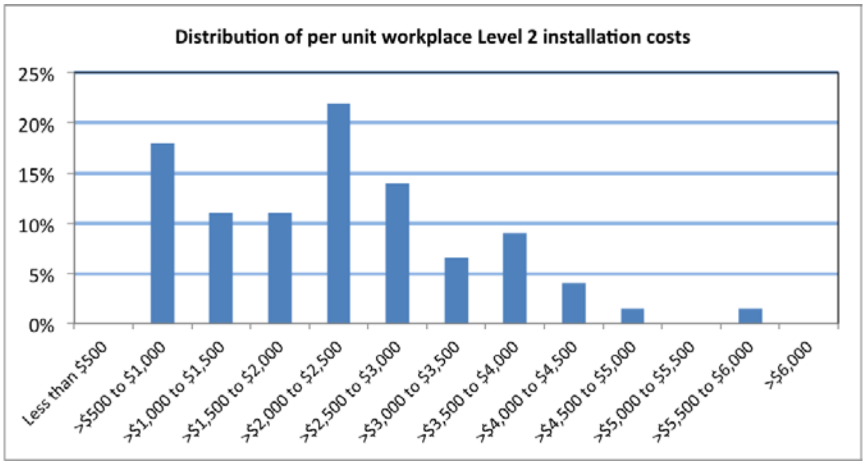

Figure 8. Distribution of EV Project per unit Level 2 workplace installation costs for 208 installations. *Graph from INL.*

DCFC Installation

There is also a wide variation in cost for installing DCFC. In the EV Project, the cost to install over 100 dual port DCFC units ranged from $8,500 to $50,820 with an average installation cost of $23,662. The lower installation costs ($8,500-$20,000) were generally for sites that were able to use existing electrical service. Figure 9 shows the distribution of EV Project DCFC installation costs, by cost tier. The WCEH had an average installation cost of $40,000 for the DCFC. The higher DCFC installation costs for the WCEH compared to the EV Project is partially due to many WCEH installations taking place in rural locations that required electrical service upgrades. The WCEH project had rigorous design and construction standards that required a deep concrete foundation. The EV Project focused on taking advantage of existing electrical service infrastructure to drive down costs.

The Orlando Utilities Commission (OUC) installed five DCFC units in Orlando with installation costs ranging from $4,000-$9,000 each (OUC 2014). They were able to minimize costs through careful selection of site locations such that minimal trenching or boring was needed to connect the DCFC to the electrical service. OUC also conducted a competitive bidding process that included training electricians on how to install EVSE.

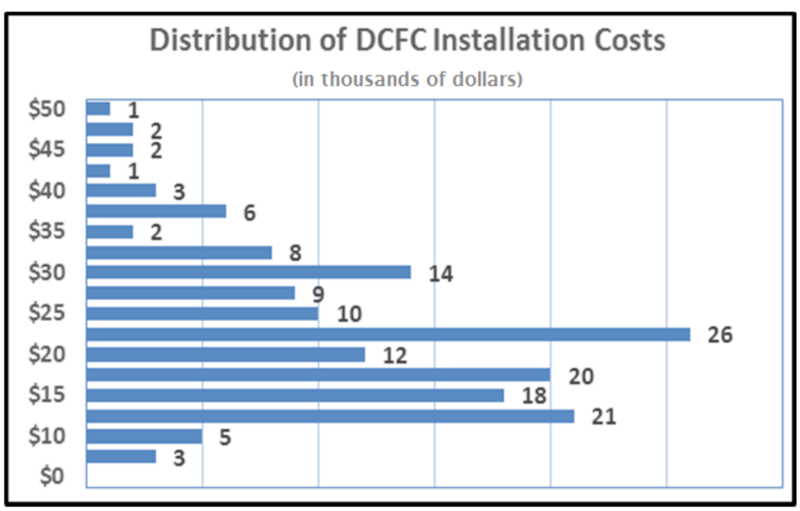

Figure 9. Distribution of EV Project per unit DCFC installation cost, shown in thousands of dollars. *Graph from INL.*

Operation and Maintenance (O&M) Costs

Operation and maintenance (O&M) costs for EVSE include charges for electricity, software subscriptions, station management, billing, site rental or lease, preventative maintenance, and corrective maintenance.

Ask your local utility if they offer special PEV charging rates or time-of-use (TOU) rates.

Electricity Consumption Charges

EVSE operating costs include the cost of electricity to charge the vehicles. Charging hosts are encouraged to contact the electric utility to review the options for rate structure and any implications of using PEV charging rates or time-of-use (TOU) rates on the facility as a whole. In general, the annual electricity consumption cost for an EVSE owner is determined based on the electricity rate measured in dollars per kilowatt-hour ($/kWh) and the amount of electricity consumed. Commercial electricity rates typically range from $0.08-$0.15 per kWh, while industrial fleets could have lower rates[4]. The consumption of electricity will vary based on the number of vehicles using the EVSE, power output of the EVSE, vehicle power acceptance rate, climate, and amount of time the vehicles charge. See Appendix C for electricity consumption examples for Level 1, Level 2, and DCFC EVSE.

Electricity Demand Charges

In addition to electricity costs based on energy consumption, many commercial and industrial facilities may be subject to power demand charges from the utility. The use of Level 2 and DCFC stations located at these facilities may result in higher electricity costs by increasing the facility's peak electricity demand[5]. Some locations that have not previously been subject to demand charges may find that the additional power consumption from EVSE will now result in demand charges.

Demand charges can cause a business' monthly utility bill to increase by as much as four times (INL 2015d). An EVSE site can experience demand charges from $0 to over $2,000/month. At many sites, demand charges can be avoided by strategically managing the EVSE energy consumption such as charging at off peak times or staggering vehicle charging during high consumption periods. Some EVSE models come with energy management features. Separate load management systems that automatically sequence multiple EVSE to avoid demand charges can also be purchased. It is recommended that the utility be contacted prior to installation of the EVSE to obtain information regarding demand charges and how they may be minimized or eliminated.

Photo 13. One of many side by side DCFC and Level 2 EVSE installed along the West Coast Electric Highway in Oregon and Washington. *Photo from Washington State Department of Transportation (WSDOT).*

4 Retail electricity rates for each state by sector can be found at http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a.

5 Each utility has its own rate structure that may or may not include demand charges. Once a customer uses power in excess of the utility's threshold, typically 20-50kW, the utility transitions the customer to a rate structure that includes demand charges. The demand charge is determined by looking at the consumer's average energy consumption in 15 minute intervals for the whole month, identifying the highest average value (kW), and charging a fee ranging from $3-$40/kW. The utility may also have different fees based on the time of day and season. Any use of electricity that causes peak demand to exceed this highest average value will result in increased demand charges for the entire month.

Network Fees

If an EVSE unit is networked, the owner will pay a fee that covers the cost for cellular/Wi-Fi network communications and back office support. Network fees will vary from $100-$900 annually, depending on the type of EVSE unit (Level 1, Level 2, DCFC), the EVSE unit features, and the EVSE manufacturer or provider.

Ask suppliers or manufacturers about network fees before purchasing your equipment.

Maintenance and Repair

Since the PEV market is relatively new, there is not much information available about the maintenance costs or lifespan of EVSE. The information below addresses the potential maintenance costs according to best assumptions from industry experts. The type of EVSE and its features will affect the maintenance and repair costs. Regular maintenance is generally not required for Level 1 and Level 2 basic EVSE units. If the EVSE is damaged due to vandalism or driving over a cord, it is more common to replace the damaged component than to try to repair it. For budgeting purposes, some industry stakeholders assume EVSE has at least a 10 year lifespan.

EVSE units with advanced features or communications systems may require more periodic maintenance than a basic unit simply because there are more components that have the potential to malfunction. In many cases a local electrician has the skills to trouble shoot problems with units. Extended warranties and other options made available by the EVSE manufacturers can reduce the long term maintenance and repair costs. In addition to warranties that cover replacement EVSE hardware, there may be warranties available to cover the labor to perform a repair.

Photo 14. The Hartford's workplace charging installations at various locations across Connecticut will help the company meet its greenhouse gas reduction goals. *Photo from the Hartford, NREL 26470.*

Level 1 EVSE

Over time, there may be a need to replace the commercial grade NEMA electrical outlet used with portable Level 1 EVSE cordsets. Depending on the outlet age, type, and use, the outlet should function appropriately for many years. The cost of an outlet can range from $1-$40 depending on whether it is for an indoor or outdoor application, the quality level, and if it protects against electrical shock (GFCI rated). An electrician's fee for replacing outlets is in the $50-$75 range, depending on how many outlets need to be changed.

Maintenance Budget (sample case):

- Replacement or upgrade of electrical outlet to maintain safe operation;
- Replacement of cordset due to vandalism or misuse; and
- Replacement of EVSE unit or cordset at the end of its useful life.

Level 2 EVSE

Basic Level 2 EVSE require minimal maintenance. They are often modular in design, so that malfunctioning components can be replaced, avoiding the cost of replacing the whole unit.
Maintenance Budget (sample case):

- Repair or replacement of EVSE components due to malfunction or vandalism (if not covered under warranty);

- Replacement of EVSE unit at the end of its useful life;
- For networked units, add:
  - Cost of technician troubleshooting (if not covered in network subscription fees), and
  - Cost of manual resets for software malfunctions.

DCFC EVSE

DCFC units require ongoing maintenance because they have cooling systems, filters, and other components that do not exist in Level 1 or Level 2 units.

Maintenance Budget (sample case):

- Replacement of charge cord due to vandalism or misuse;
- Repair or replacement of EVSE components (if not covered under warranty);
- Technician troubleshooting (if not covered in network subscription fees);
- Manual resets for software malfunction (if not covered in network subscription fees); and
- Preventative and corrective maintenance.

Station Management

Management activities for a station or cluster of stations might include managing driver access, billing, providing driver support, and monitoring the station. Renting or leasing a location, such as parking spots, can be an added operational cost if the EVSE owner does not own the property. The value of a parking space will vary widely depending on geographical location.

Additional Cost Factors

Incentives

Many incentives are available to reduce the cost of installing EVSE. Electric vehicles are of greater interest in certain parts of the country due to policies enacted for zero emissions vehicles and low carbon fuels. EVSE incentives offered by state agencies or by local utilities take a variety of forms such as tax credits/exemptions, rebates, grants, or loans. Figure 10 illustrates the type of electric vehicle incentives in each state, as of July 2015. Details about these incentives can be found in Appendix D. Because available incentives frequently change, visit the AFDC Laws and Incentives website at afdc.energy.gov/laws for current incentive information. In addition to financial assistance, many states provide technical assistance to incentivize EVSE installations. While the Federal Alternative Fuel Infrastructure Tax Credit has expired, equipment installed before December 31, 2014 may still be eligible.

State EVSE Incentives

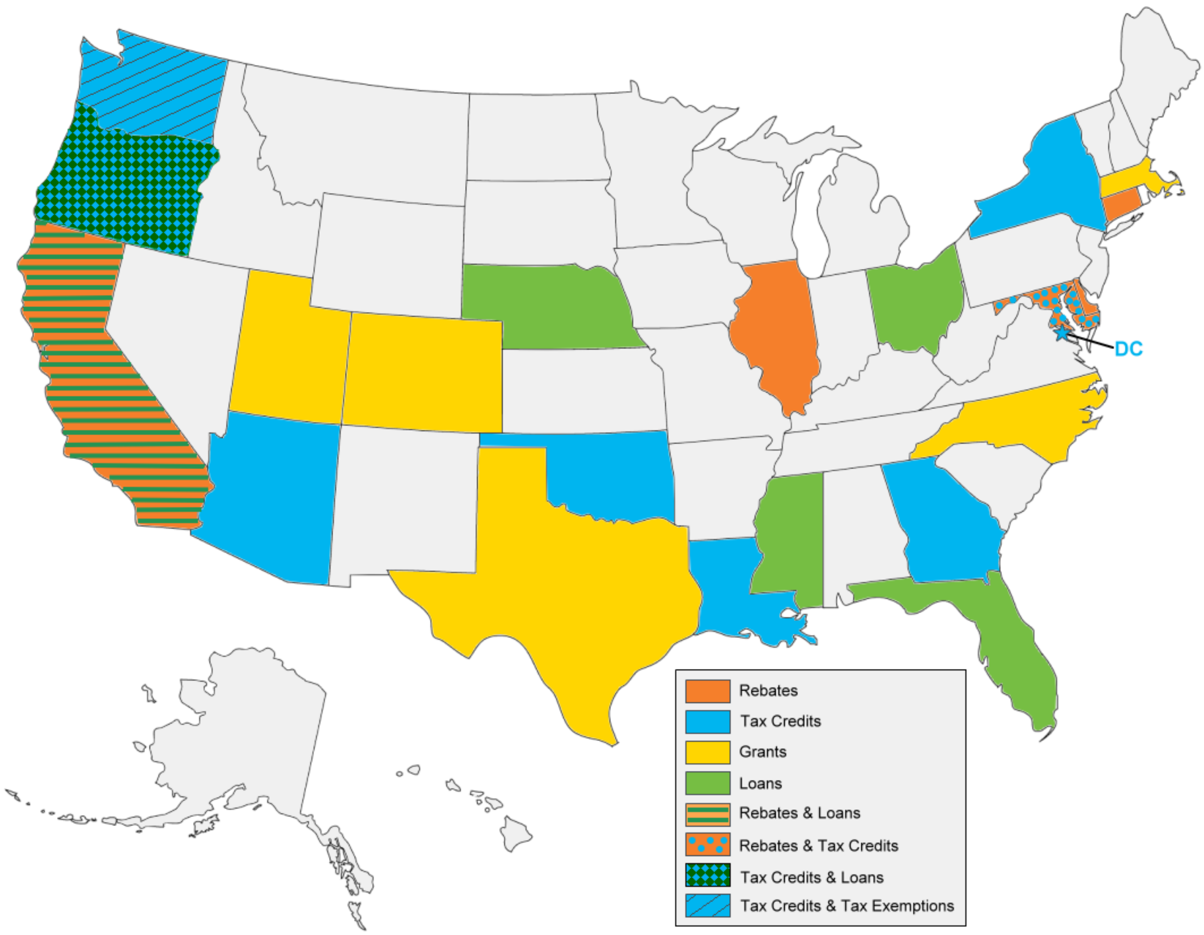

Figure 10. This map illustrates the types of EVSE incentives offered in each state as of July 22, 2015. Appendix D provides details about these incentives. This information is frequently changing; visit http://www.afdc.energy.gov/laws for latest incentive information. *Graphic from Oak Ridge National Laboratory.*

Table 3 describes some current state incentives and provides examples of how they can affect the cost of an EVSE unit.

Incentive Example	Incentive Description	Base EVSE Unit Cost	EVSE Unit Cost after Incentive
Income Tax Credit	Income tax credit for 20% of the cost of the EVSE, up to $2,500.	$4,000	$3,200
Level 2 Rebate	$1,000 rebate for the purchase and installation of Level 2 EVSE	$3,000	$2,000
DCFC Rebate	$15,000 rebate for the purchase of DC fast charge EVSE.	$30,000	$15,000

Table 3. Example incentives for purchasing and/or installing EVSE units.

Permitting and Inspection

Permitting costs vary by state, county, and/or municipality. The local AHJ requires permits and inspections for commercial electrical upgrades. The costs may be fixed or determined on a site-by-site basis. Some localities are moving to streamline the permitting process as PEV adoption increases. In addition to the permit fee charged by the AHJ, there may also be a cost for the contractor's time spent to obtain the permit. Level 2 EVSE installed by the EV Project had permitting costs ranging from $14-$821 (Francfort 2013). Depending on the permitting authority, commercial installations might require engineered drawings for the permitting process. Engineering drawings can cost about $1,000-$3,000 (INL 2015a).

Engage the AHJ (e.g., permitting agencies, fire marshals, and zoning boards) early in the planning process to ensure that you understand the requirements and associated permitting costs.

Adhering to ADA requirements to ensure access to EVSE for people with disabilities are another project cost consideration. ADA compliance can require special curb cutouts, van accessible parking spaces, level parking spaces, and specific connector heights, all of which affect the design and cost of the EVSE. Photo 15 shows an EVSE unit with a connector designed to meet ADA requirements.

Photo 15. The connector on this EVSE unit is low to the ground to meet ADA accessibility requirements. *Photo from Ecotality.*

The US Access Board has established accessibility standards for public facilities, such as parking areas and fueling stations, but there are not specific ADA requirements for EVSE. Some sites may not be able to fully meet accessibility standards and will be encouraged to meet the requirements to the extent possible (Chittenden County RPC 2014). Work with your local AHJ to determine how ADA requirements affect your site.

Workplace, Public, and Fleet EVSE Costs

According to the EPRI study comparing Level 2 installation costs, fleet EVSE stations had the lowest installation cost, followed by workplace charging, and public sites had the highest cost. The average cost per port and per EVSE unit for each of these venues is shown in Figure 11. The higher costs for public and workplace settings are due to complex siting issues, high visibility parking locations, constraints on available parking spaces, ADA requirements, and available electrical capacity (EPRI 2013).

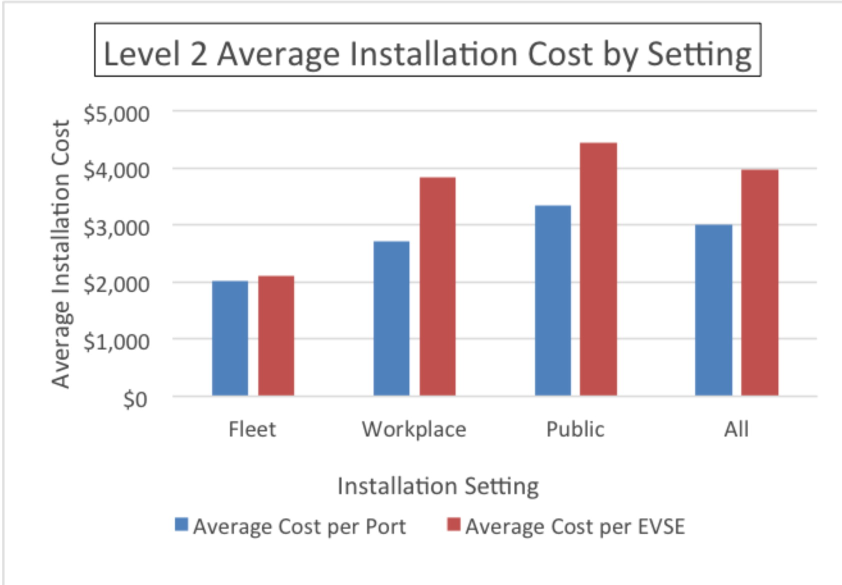

Figure 11: Level 2 installation cost by public, workplace, and fleet settings from EPRI study. *Graph from EPRI.*

Cost Factors to Consider for Workplace Charging

While many PEV drivers charge their vehicles primarily at home, the availability of EVSE at work can help owners nearly double their vehicles' all-electric daily commuting range. Visit the DOE Workplace Charging Challenge website for more resources on installing and managing EVSE in the workplace: energy.gov/eere/vehicles/ev-everywhere-workplace-charging-challenge

Charging Level

Workplace EVSE are typically Level 1 or Level 2 single or dual port units. Employers can provide Level 1 charging either through offering electrical outlets (shown in Photo 16) or hardwired Level 1 EVSE units. For many employees, Level 1 charging has sufficient power to replenish their vehicles' batteries during work hours.

Photo 16. Electrical outlets are available along a row of parking stalls for PEV drivers to charge their vehicles using a Level 1 cordset. *Photo from Jonathan Kirchner, Coca-Cola.*

If an employer chooses to provide Level 2 EVSE, multiple employees may be able to charge their vehicles during the day using a single port. This requires a management policy that covers disconnecting the connector from one vehicle and moving it to another vehicle. Level 2 EVSE decreases the vehicle charge time, but requires a higher power circuit for operation. As the quantity of EVSE units at a workplace increases, electrical upgrades may be required, which could increase costs. Talk with an electrical contractor to determine how much power is available from your electrical service. The amount of available power will affect the quantity and type of EVSE that can be installed at your location without the need for extensive electrical upgrades.

EVSE Features

While some employers will choose the most basic system, others may want networking, access control, point of sale, and energy monitoring/management. Employers can minimize their costs by not paying for features that they do not need or are unlikely to use.

Some employers offer free charging to employees and do not need POS capabilities. An employer that wishes to charge employees for PEV charging could purchase an EVSE unit with POS capability or simply charge employees a flat monthly rate. Careful consideration should be given to access control and pricing policies. If an access control mechanism is not in place to limit free EVSE use to employees and guests, an employer might unintentionally attract other PEV drivers to charge their vehicles after business hours.

Location Selection

Choosing a wall mounted unit close to an existing electrical panel will typically be the lowest cost installation option. Keep in mind that PEV drivers do not need prime parking spots near a building's entrance, although this is sometimes done as an added incentive for drivers to adopt PEV technology. If that prime location is far from the electrical service, there will be a significant cost to connect the EVSE to the electrical service. Choosing a less prominent, but easier to install location will minimize costs. Consult resources on the DOE Workplace Charging Challenge website for information on how to choose EVSE locations. The EVSE in Photo 17 are close to the building which reduces trenching costs.

Photo 17. These two EVSE are located close to the building, reducing trenching costs. *Photo from NYSERDA.*

Installation

The EPRI study found that Level 2 EVSE at workplace sites cost, on average, $2,704 per port and $3,842 per EVSE (refer to Figure 11). For the EV Project Level 2 workplace EVSE, the installation of pedestal units cost $2,305 on average and the installation of wall mounted units cost $2,000 on average. Workplace charging sites frequently involve the installation of two or more EVSE, which lowers the installation cost per unit. Workplace installations typically cost less than public installations because they have a higher percentage of stations with wall mounted units and there is more flexibility to place EVSE close to the electrical service panel (INL 2015c).

Cost Factors to Consider For Public Charging

Public charging locations include, but are not limited to, parking garages, transportation hubs, retail stores, and leisure destinations.

Charging Level

Public charging is typically a mix of Level 2 and DCFC units, although Level 1 EVSE may make sense for some sites. It is important to take into consideration the amount of time a vehicle will stay parked in the location and the amount the vehicle will likely need to replenish its battery. A DCFC unit may be the best choice close to an interstate highway, while Level 2 EVSE may be appropriate for a shopping mall.

EVSE Features

Some public EVSE providers may require POS and billing capabilities to charge consumers for the electricity. EVSE units with more features will be at the higher end of the cost range. Other public EVSE providers may not need these features because they incorporate the charging service into a parking fee or provide free charging. Offering free PEV charging may provide intangible or indirect benefits such as positive public relations and increased revenue from purchases made by PEV owners waiting for their vehicles to charge. These intangible or indirect benefits may offset the cost of the electricity use. A networked station can allow the site host to provide free charging during business hours and charge a fee for charging after business hours. To minimize EVSE costs, it is important to identify your business model prior to determining the needed EVSE features.

Installation

Installation costs for public sites are generally higher than for workplace and fleet sites. This is due to higher permitting related costs, EVSE located far from the electrical service, and necessary electrical upgrades. Additionally, there are often more jurisdictions and overall entities involved making the process more complicated and expensive. Public charging sites frequently involve the installation of two or more EVSE which can lower costs per EVSE. The EPRI study showed that Level 2 EVSE at public sites cost on average $3,343 per port and $4,448 per EVSE (refer to Figure 11). The public Level 2 EVSE installed through the EV Project had an average installation cost of $3,108. Pedestal unit installation averaged $3,308 while wall mounted unit installation averaged $2,042 (INL 2015c).

Visibility and Signage

Developers at public sites often value high visibility locations for the EVSE to ensure that it is well utilized. This can significantly increase the costs for trenching, boring, and/or electrical upgrades. Rather than incurring larger installation costs for a high visibility EVSE location, site hosts are encouraged to place the EVSE unit close to the electrical service and use signage to help PEV drivers find it. Signage is used to help PEV drivers locate EVSE and to discourage drivers from using the parking space if they are not charging a vehicle. The cost to install signage is a minimal portion of the total installation costs.

Photo 18. This DCFC unit is part of the Arizona EV Highway corridor project linking Tucson to Phoenix. *Photo from Pima Association of Governments, NREL 24345.*

Transaction Costs

A public EVSE unit that uses a credit card payment system should expect to pay a transaction fee of about 5-7.5% (Botsford 2012).

Vandalism

Public EVSE units that provide unrestricted site access may be more subject to vandalism than workplace or fleet EVSE. Site owners may choose to build the cost of EVSE repairs or replacement into their financial plans.

Electrical Upgrades

For DCFC, the EVSE should be located in close proximity (preferably within 100 feet) to existing electrical service lines, to avoid the need for installing transformers. Work with your local utility to determine viable low cost locations for DCFC public charging.

Advertising

A public host may choose an EVSE unit that has a display screen and use that screen for advertisements. Advertising revenue can help offset the costs of providing PEV charging.

Cost Factors to Consider for Fleet Charging

There are a growing number of PEVs on the market that work well in fleet applications.

Photo 19. Fleet EVSE at Frito Lay Depot in Federal Way, Wash. *Photo from Mike Simpson/NREL, NREL 29587.*

Charging Level

Fleet charging will typically be a mix of Level 1 and Level 2 units and may include the use of multiple port units. The amount of time needed to charge all the fleet vehicles will be an important consideration when selecting the charging level. Medium- and heavy-duty vehicles will have larger batteries than light-duty vehicles and will therefore affect the EVSE selection. DCFC may be needed if fleet vehicles require higher power and/or faster charging because of their fleet vehicle usage patterns. Photo 19 shows the fleet EVSE at the Frito Lay Depot in Federal Way, Wash.

Demand Charges

A fleet that is installing many EVSE units and operating them all at the same time may face demand charges. However, overnight charging of fleets may avoid peak demand issues. Some fleets may be able to utilize a fixed schedule for charging PEVs and have a staff person manually plug in vehicles on a timetable that avoids demand charges. It is important for fleet managers to contact the utility before purchasing EVSE to understand both the utility's pricing structure for demand charges and the full cost impact of PEV charging on demand charges.

EVSE Features

After assessing the fleet's charging needs, the fleet manager will work with an EVSE manufacturer, electrician, and utility to determine the lowest cost solution to meet the fleet's needs. For example, if tracking the fleet's energy consumption is desired, the fleet manager may compare the cost of purchasing a sophisticated

EVSE unit with energy monitoring capabilities to the option of using a basic EVSE unit and a third party or aftermarket metering and data collection system.

Installation

Installation costs for fleet sites are generally lower than workplace and public sites. This is partly due to installation without public access, lower permitting related costs, and because fleets typically are better able to minimize cost through optimal siting choices. The EPRI study determined that Level 2 EVSE at fleet sites cost, on average, $2,018 per port and $2,109 per EVSE (refer to Figure 11).

Tips for Minimizing EVSE Costs

EVSE Unit Selection

- Choose the EVSE unit with the minimum level of features that you will need.
- Choose a wall mounted EVSE unit, if possible, so that trenching or boring is not needed.
- Choose a dual port EVSE unit to minimize installation costs per charge port.
- Determine the electrical load available at your site and choose the quantity and level of EVSE units to fit within that available electrical capacity.

Location

- Place the EVSE unit close to the electrical service to minimize the need for trenching/boring and the costs of potential electrical upgrades.
- Instead of locating the EVSE at a highly visible parking spot a great distance from the electrical panel, use signage to direct PEV drivers to the EVSE unit.
- If trenching is needed, minimize the trenching distance.
- Choose a location that already has space on the electrical panel with a dedicated circuit.

Long Term Planning

- Contact your utility early in the planning stages to discuss electricity consumption and demand charges as well as electrical service needs. Avoid utility demand charges by balancing charging time windows with other electricity usage and working closely with your utility.
- Consider the quantity and location of EVSE that you plan to install over the next 10-20 years when installing your first unit. Upgrade your electrical service for your anticipated long term EVSE load and run conduit to your anticipated future EVSE locations. This will minimize the cost of installing future units.
- Consider the electricity infrastructure for EVSE when building a new facility. It is less expensive to install extra panels and conduit capacity during initial construction than to modify the site later.

Summary

As is discussed in this report, many factors lead to highly variable costs associated with EVSE. Utilizing best practices for choosing EVSE types, quantities, and locations will help minimize the financial impact of buying and installing EVSE. Ballpark cost ranges for EVSE units and installation are shown in Table 4, which reproduces the information in Table 1 and Table 2. Within each charging level (Level 1, Level 2, and DCFC), the EVSE unit cost depends on the mounting system, number of charge ports, communications system, and additional features. Installation costs have the most significant variability and are influenced by how much electrical work is needed, how much trenching or boring is needed, permitting, labor rates, and ADA requirements. Contact your utility, EVSE manufacturers, and EVSE installers for a site assessment and cost estimate.

Ballpark EVSE Unit and Installation Costs

EVSE Type	EVSE Unit* Cost Range (single port)	Average Installation Cost (per unit)	Installation Cost Range (per unit)
Level 1	$300-$1,500	not available	$0-$3,000** *Source: Industry Interviews*
Level 2	$400-$6,500	~$3,000 *EV Project (INL 2015b)*	$600-$12,700 *EV Project (INL 2015b)*
DCFC	$10,000-$40,000	~$21,000 *EV Project (INL 2015d)*	$4,000-$51,000 *EV Project (INL 2015d) and (OUC 2014)*

Table 4. Ballpark costs for EVSE units and installation.

**EVSE unit costs are based on units commercially available in 2015.*

***The $0 installation cost assumes the site host is offering an outlet for PEV users to plug in their Level 1 EVSE cordsets and that the outlet already has a dedicated circuit.*

There is general industry consensus that the cost of EVSE units is trending downwards and will continue to decrease. Installation costs, however, are highly variable and there is no consensus among industry stakeholders about the direction of future installation costs.

State and local incentives will continue to influence and aid in establishing EVSE installations. In addition to funding assistance, the organizations offering incentives (such as state agencies and utilities) will likely offer technical assistance, recommend vendors, and conduct or suggest individuals to conduct site evaluations. There are many organizations that can guide an EVSE host through the evaluation of site, selection of EVSE unit, and installation.

It is important for employers, business owners, and fleet operators to understand the costs involved in installing, operating, and maintaining EVSE in order to make informed decisions regarding long term EVSE development. Thoroughly evaluating the needs and opportunities for PEV charging, as well as strategically determining the optimal EVSE features, location, and quantity are critical for finding the best EVSE solution for a specific site. Utilizing incentives, cost saving approaches, and innovative ownership models will make installing EVSE more attractive to potential site hosts.

Technology is always evolving and future advancements in PEV charging are inevitable. Wireless PEV charging, also called inductive charging, is currently being developed. With wireless charging, drivers will simply park over a charging pad and will not need to plug a connector into the vehicle. The future may also bring bidirectional charging, allowing a vehicle to both charge its battery from the utility and provide power back to the utility via the electrical grid. The timeframe for when these advancements will penetrate the market and the impact on the cost of PEV charging is currently unclear.

Installing more public, workplace, and fleet EVSE is critical for providing a robust charging infrastructure network needed for the growing PEV market. Workplace and public charging will enable drivers to purchase PEVs even if they do not have access to residential charging infrastructure. By purchasing PEVs and EVSE, fleets can have a significant impact on advancing the PEV market, as well as reducing greenhouse gas and other emissions that contribute to climate change and smog. With more PEVs on the road, we are making progress towards the Clean Cities goal to reduce our dependence on petroleum and advance our nation's energy security.

Additional Resources

For more information about EVSE, visit the resources below.

1. Alternative Fuel Data Center EVSE page: http://www.afdc.energy.gov/fuels/electricity_stations.html

2. Clean Cities' Plug-In Electric Vehicle Handbook for:
    - Workplace Charging Hosts: http://www.afdc.energy.gov/uploads/publication/pev_workplace_charging_hosts.pdf
    - Fleet Managers: http://www.afdc.energy.gov/pdfs/pev_handbook.pdf
    - Public Charging Station Hosts: http://www.afdc.energy.gov/pdfs/51227.pdf
    - Consumers: http://www.afdc.energy.gov/uploads/publication/pev_consumer_handbook.pdf
    - Electrical Contractors: http://www.afdc.energy.gov/pdfs/51228.pdf

3. Clean Cities Electric Vehicle Community Readiness Projects summary reports and 16 individual community readiness plans: http://www1.eere.energy.gov/cleancities/electric_vehicle_projects.html

4. INL Lessons Learned papers from the EV Project: http://avt.inl.gov/evproject.shtml

5. Electric Vehicle Supply Equipment Installed Cost Analysis study by EPRI: http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002000577

6. DOE Workplace Charging Challenge: http://energy.gov/eere/vehicles/ev-everywhere-workplace-charging-challenge

7. Workplace Charging Request for Proposal Guidance: http://energy.gov/eere/vehicles/downloads/request-proposal-guidance

8. Amping Up California Workplaces: Case Studies by California Plug-In Electric Vehicle Collaborative http://www.ct.gov/deep/lib/deep/air/electric_vehicle/CAPEV_-_Amping_Up_California_Workplaces.pdf

9. Center for Climate and Energy Solutions' study "Business Models for Financially Sustainable EV Charging Networks": http://www.c2es.org/publications/business-models-financially-sustainable-ev-charging-networks.

10. Clean Cities YouTube Channel: https://www.youtube.com/user/CleanCitiesTV

Appendix A: Acronyms, Definitions, and Equipment Overview

Acronyms

AC – Alternating current

ADA – Americans with Disabilities Act

AHJ – Authorities having jurisdiction

DC – Direct current

DCFC – Direct current fast charger

EPRI – Electric Power Research Institute

EV – Electric vehicle

EVSE – Electric vehicle supply equipment

GFCI – Ground-fault circuit interrupter

NEC – National Electrical Code

NEMA – National Electrical Manufacturers Association

NFPA – National Fire Protection Association

NREL – National Renewable Energy Laboratory

NYSERDA – New York State Research and Development Authority

OUC – Orlando Utilities Commission

INL – Idaho National Laboratory

PEV – Plug-in electric vehicle

PHEV – Plug-in hybrid electric vehicle

POS – Point of sale

RFID – Radio-frequency identification

SAE – Society of Automotive Engineers

TOU – Time-of-use

UL – Underwriters Laboratories

WCEH – West Coast Electric Highway

WSDOT – Washington State Department of Transportation

EVSE Charging Types

AC Level 1 EVSE, commonly referred to as Level 1, provides charging through a 120-volt (V) alternating current (AC) circuit and requires a dedicated branch circuit. Most plug-in electric vehicles (PEVs) come with a Level 1 EVSE cordset. One end of the cord is a standard, three-prong household plug. The other end is an SAE J1772 standard connector that plugs into the vehicle. Level 1 EVSE that can be wall mounted or pedestal mounted at parking spots is also available. Depending on the battery and vehicle type, Level 1 charging adds about 2 to 5 miles of range per hour of charging time.

AC Level 2 EVSE, commonly referred to as Level 2, provides charging through a 240V (typical in residential applications) or 208V (typical in commercial applications) electrical service. Level 2 EVSE requires installation of a dedicated circuit of 20-80A, in addition to the charging equipment. Most Level 2 EVSE uses a dedicated 40A circuit. As with Level 1 equipment, Level 2 equipment uses the SAE J1772 connector. Depending on the vehicle and circuit capacity, AC Level 2 adds about 10-20 miles of range per hour of charging time.

DCFC (Direct Current Fast Charger) enables rapid charging and is generally located at sites along heavy traffic corridors and at public fueling stations. It is sometimes called DC Level 2 or DC fast charging. Some DC fast charging units are designed to use 480V input, while others use 208V input. PEVs equipped with either a CHAdeMO or SAE DC fast charge receptacle can add 50 to 70 miles of range in about 20 minutes.

PEV Charging Components

Charger* – An electrical device that converts alternating current energy to regulated direct current for replenishing the energy of an energy storage device (i.e., battery), and may also provide energy for operating other vehicle electrical systems. A PEV charger is located on the vehicle.

Cord – An EVSE component that transmits electricity from the control box to the connector.

Cordset – The cordset provides AC Level 1 charging and includes the connector, cord, control box, and standard three prong household plug (NEMA 5-15 connector). The cordset can connect a vehicle to an electrical outlet that is rated for the appropriate voltage.

Connector* – A conductive device that, by insertion into a vehicle inlet, establishes an electrical connection to the electric vehicle for the purpose of transferring energy and exchanging information. This is part of the coupler.

Coupler* - A mating vehicle inlet and connector set.

EVSE (electric vehicle supply equipment) consists of all the equipment needed to deliver electrical energy from an electricity source to charge a PEV's battery. It communicates with the PEV to ensure that an appropriate and safe flow of electricity is supplied.

Handshake – A colloquial term for the communication protocol between the EVSE and the vehicle. The handshake ensures the connector is not energized until it is inserted in the inlet and the proper communication has taken place between the vehicle and EVSE.

Photo 20. An electrical meter mounted alongside the EVSE and connected with conduit. *Photo from NYSERDA.*

Vehicle inlet/receptacle* is the device on the electric vehicle into which the connector is inserted for the purpose of transferring energy and exchanging information.

*SAE Definitions

Electrical Hardware

Conduit - The electrical conduit is a tube or piping system for enclosing electric wiring. If the conduit needs to be placed underground for EVSE installation, then the installation will require trenching or boring.

Meter/Sub-Meter – Electric utilities use meters to measure the amount of electricity provided to a customer and bill for that usage. Sub-meters may be used to measure the electricity consumed by the EVSE, separate from electricity delivered to the rest of the premise. Sub-meters allow for advanced data collection and specialized electricity pricing based on the time of day.

Panel – The electrical panel (also known as breaker panel, service panel, or load center) is a box containing the circuit breakers that are wired to circuits that distribute power to the EVSE. The circuit breakers turn the power to the EVSE on and off to protect equipment from damage in the event of an electrical short or overcurrent. The circuit breaker is also used to turn off power to the EVSE when it is being serviced.

Photo 21. Electrical panel.
Photo from NYSERDA.

Photo 22. Step-down transformer located at the utility service point.
Photo from Don Karner.

Step-down Transformer – The step-down electrical transformer converts high voltage electricity from power lines to a lower voltage that can be used by consumers. It is typically located at the utility pole but can also be placed on a concrete pad. A transformer may need to be upgraded to accommodate the electricity consumed by EVSE.

EVSE Connector Standards

CHAdeMO is a DC fast charging standard proposed as a global industry standard by the CHAdeMO association starting in 2009. It is used by the Nissan Leaf and Mitsubishi vehicles to quickly charge a vehicle with direct current through a CHAdeMO connector. CHAdeMO connectors are not compatible with SAE J1772 vehicle receptacles. Most DCFC connectors currently available in the United States uses the CHAdeMO standard.

SAE J1772 is the Society of Automotive Engineers (SAE) Recommended Practice that covers the general physical, electrical, functional and performance requirements to facilitate conductive charging of PEVs in North America. It defines the physical configuration of how the EVSE connector attaches to the vehicle receptacle and the communication process for safely providing power to the vehicle. All major vehicle and EVSE manufactures support this standard in the U.S. and use SAE J1772 compatible connectors and receptacles for Level 1 and Level 2 charging.

SAE J1772 Combined Charging System (CCS) is a revised SAE Recommended Practice that uses a single port for either AC Level 1 and 2 or DC fast charging. This standard came to market in 2014 through the Chevy Spark and BMW i3. Most major vehicle manufacturers in the United States utilize or plan to utilize connectors and receptacles based on the SAE J1772-CCS standard.

Photo 23. SAE J1772 CCS connector (left) and CHAdeMO connector (right). *Photo from Margaret Smith.*

Tesla SuperChargers are DCFCs based on Tesla's own connector and currently only charge Tesla vehicles. Tesla is rapidly expanding their supercharger network across the country.

Connector Standard	Charging Level	Vehicle
SAE J1772	Level 1 and Level 2	All PEVs available in the U.S.
SAE J1772-CCS	Level 1, Level 2, and DCFC	Currently available: GM Chevrolet Volt and Spark EV, BMW i3, Volkswagen eGolf, and Ford C-Max Energi Products pending: Chrysler, Daimler, Toyota, Honda and others
CHAdeMO	DCFC	Nissan Leaf, Mitsubishi iMIEV
Tesla SuperCharger	DCFC	Tesla Model S

Table 5. Connector standards for each charging level and the corresponding vehicles.

Photo 24. This public parking lot in Charlottesville, VA offers DC fast charging using SAEJ1772 CCS and CHAdeMO connector standards as well as a Tesla Level 2 connector. *Photo from Margaret Smith..*

Appendix B: Codes and Standards

Check with your local fire marshal or authority having jurisdiction to ensure that you are aware of the local codes and standards for installing EVSE and selling electricity. The technical bulletin located at http://www.afdc.energy.gov/bulletins/technology-bulletin-2015-08.html reviews the role that zoning, permitting and codes, and parking ordinances can play within a comprehensive PEV and EVSE deployment strategy, and it includes a variety of state and local examples.

A U.S. National Work Group (USNWG) is developing proposed requirements for devices used to measure and sell electricity dispensed at EVSE. The group seeks to ensure that the methodologies and standards facilitate measurements that are traceable to the International System of Units. For more information including the NIST Handbook 130 "Method of Sale for Electrical Energy as Vehicle Fuel" and the NITS Handbook 44 "Device Code Requirements for Electric Vehicle Fueling," visit http://www.nist.gov/pml/wmd/usnwg-evfs.cfm.

It should be noted that safety standards for standard residential and commercial outlets were not developed with repeated operations for charging plug-in electric vehicles in mind. The current safety standard that covers 120 volt/20 amp electrical outlets is UL 498, the Standard for Safety for Attachment Plugs and Receptacles. The protocol recommends that these electrical outlets (which are the type typically used for AC Level 1 charging) complete a number of tests to pass safety standards. These include tests wherein the receptacle has a plug inserted and removed 250 times in various conditions without sustained flaming of the material in excess of five seconds duration. Ideally, PEVs will charge more than 250 times per year and thus would plug in many times the UL 498 standard in their operational lifetime.

The National Fire Protection Association (NFPA) addresses the safe interface between PEVs and EVSE in the NEC Article 625, "Electric Vehicle Charging System." The NEC also provides minimum requirements for performing site assessments. Specifically, NEC Articles 210, 215, and 220 contain rules that relate to calculations and loading of services, feeders, and branch circuits in all occupancies.

Appendix C: Electricity Consumption Examples

The scenarios below are based on specified assumptions and provide an example of annual electricity cost for Level 1, Level 2, and DCFC EVSE.

Level 1, Single Port Scenarios	Annual Electricity Consumption & Cost	Installation Cost Amortized Over 10yrs/kWh & cost/yr.*	Assumptions
Workplace charging • 1 light-duty vehicle • Charging 6hrs/day • 5 days/week	• 2,184 kWh/yr • $218/yr	$0.000-$0.023/kWh $0-$50/yr	• EVSE Type: Level 1 120 VAC • Power Level: 1.4kW (12A) • 4 miles added range/hr. of charging • Electricity Cost: $0.10/kWh • Installation Cost $0-$500
Fleet charging • 1 light-duty vehicle • Charging 14hrs/night • 5 days/week	• 5,096 kWh/yr • $510/yr	$0.000-$0.010/kWh $0-$50/yr	

Level 2, Single Port Scenarios	Annual Electricity Consumption & Cost	Installation Cost Amortized Over 10yrs/kWh & cost/yr.*	Assumptions
Workplace charging • 2 light-duty vehicles • Each charging 3hrs/ day • 5 days/week	• 10,296 kWh/yr • $1,030/yr	$0.006-$0.123/kWh $60-$1,270/yr	• EVSE Type: Level 2 240 VAC • EVSE Amperage: (30A) • Vehicle Power Acceptance Rate: 6.6kW • 20 miles added range/hr. of charging • Electricity Cost: $0.10/kWh • Installation Cost: $600-$12,700
Public charging • 1 light-duty vehicles • Each charging 5hrs/ day • 4 days/week	• 6,864 kWh/yr • $686/yr	$0.009-$0.185/kWh $60-$1,270/yr	
Fleet charging • 2 medium-duty vehicles • Each charging 5hrs/ night • 5 days/week	• 17,160 kWh/yr • $1,716/yr	$0.003-$0.074/kWh $60-$1,270/yr	

DCFC, Single Port Scenario	Annual Electricity Consumption & Cost	Installation Cost Amortized Over 10yrs/kWh & cost/yr.*	Assumptions
Public charging • 2 light-duty vehicles • Each charging 20 min/ day • 7 days/week	• 11,278 kWh/yr • $1,128/yr	$0.035-$0.452/kWh $400-$5,100/yr	• EVSE Type: DCFC 480 VDC • Power Level: 48kW (100A) • 50 miles added range/20 min of charging • Electricity Cost: $0.10/kWh • Installation Cost: $4,000-$51,000

**The installation cost amortized over 10yrs/kWh provides the cost per kWh that would need to be added to the electricity consumption rate in order to recoup the installation costs. This calculation assumes a 10 year lifespan for the EVSE and does not account for potential borrowing costs.*

Appendix D: State and Utility EVSE Incentives

These incentives were compiled from the Alternative Fuel Data on July 22, 2015 by Stacy Davis, Oak Ridge National Laboratory. This information accompanies Figure 10, the State EVSE Incentive map. For current incentive information, visit the Laws and Incentives database at http://www.afdc.energy.gov/laws.

State EVSE Incentives as of July 22, 2015

State	Description	$ Value
AZ	Tax credit for individuals for the installation of EVSE in a house or housing unit that they have built.	up to $75
CA	Loans to property owners for purchasing and installing EVSE.	not stated
CA	Small business loans up to $500,000 on the installation of EVSE; rebate of 50% of loan under certain conditions.	up to $250,000
CO	Grants from the Charge Ahead Colorado Program provide 80% of the cost of an EVSE to local governments, school districts; state/federal agencies; public universities; public transit agencies; private non-profit or for-profit corporations; landlords of multi-family apartment buildings; and owners associations of common interest communities.	up to single port Level 2 $3,260; multiple ports Level 2 $6,260; single port DC $13,000; multiple port DC $16,000
CT	Funding up to 100% of EVSE installation cost dependent on certain conditions.	up to $10,000
DC	Income tax credit of 50% of equipment and labor costs for the purchase and installation of EVSE (publicly available commercial or residential).	Commercial up to $10,000; Residential up to $1,000
DE	Rebate available for purchase of EVSE (commercial or residential).	$500
FL	Assistance with financing EVSE installation from local governments.	not stated
GA	Income tax credit of 10% for purchase or lease of EVSE.	up to $2,500
IL	Rebates available to offset cost of EVSE for governments, businesses, educational institutions, non-profits, and individuals.	up to $50,000
LA	Corporate or income tax credit for 10% to 25% of the project costs of state-certified green projects, such as capital infrastructure for advanced drivetrain vehicles.	up to $1 million
LA	Income tax credit up to 50% of the cost of alternative fueling equipment.	not stated
MA	Grants from the Massachusetts Electric Vehicle Incentive Program for 50% of the cost of Level 1 or 2 workplace EVSE.	up to $25,000
MA	Grants from the Massachusetts Electric Vehicle Incentive Program provide for the purchase or lease of Level 2 EVSE by local governments, universities, driving schools, and state agencies.	up to $13,500
MA	Grants from the Department of Energy Resources' Clean Vehicle Project for public and private fleets to purchase alternative fuel infrastructure.	not stated

State	Description	$ Value
MD	Rebates available for governments, businesses, and individuals for the cost of acquiring and installing EVSE.	up to: Individual $900; Gov. or Bus. $5,000; Service Station $7,500
MD	Income tax credit of 20% for cost of EVSE.	up to $400
MS	Zero-interest loans for public school districts and municipalities to install fueling stations for alternative fuels.	up to $500,000
NC	Grant funding from the Clean Fuel Advanced Technology Project for fueling infrastructure related to emissions reduction.	not stated
NE	Low-cost loans through the Dollar and Energy Saving Loan Program for the construction or purchase of fueling station or equipment, up to $750,000.	not stated
NY	Income tax credit for 50% of EVSE.	up to $5,000
OH	Loans up to 80% of the cost for purchase and installation of fueling facilities for alternative fuels.	not stated
OK	Tax credit available for up to 75% of the cost of installing alternative fuel infrastructure.	not stated
OR	Tax credit of 25% of alternative fuel infrastructure purchase costs. A company that constructs the dwelling or a resident may claim the credit.	up to $750
OR	Tax credit for business owners of 35% of cost for alternative fuel infrastructure project.	not stated
OR	Low-interest loans for alternative fuel infrastructure projects.	not stated
TX	Grants from the Alternative Fueling Facilities Program provide for 50% of the cost of alternative fuel facilities.	up to $600,000
TX	Grants from the Emissions Reduction Incentive Grants Program provide for alternative fuel dispensing infrastructure.	not stated
UT	Grants from the Utah Clean Fuels and Vehicle Technology Grant and Loan Program provide for the cost of fueling equipment for public/private sector business and government vehicles.	not stated
WA	Leasehold excise tax exemption for public lands used for installing, maintaining, and operating PEV infrastructure.	not stated
WA	State sales and use taxes do not apply to labor and services installing, repairing, altering, or improving PEV infrastructure; those taxes do not apply to the sale of property used for PEV infrastructure.	not stated
WA	An additional 2% rate of return for a utility installing an EVSE for the benefit of ratepayers.	not stated
US Airports	The Zero Emissions Airport Vehicle and Infrastructure Pilot Program provides funding for public airports to install or modify fueling infrastructure to support zero emission vehicles.	not stated

Utility/Private Incentives as of July 22, 2015

State	Description	$ Value
AL	Alabama Power - Rebate for commercial customers installing EVSE.	$500
CA	Los Angeles Department of Water and Power - Rebates for Level 2 or DC fast charge EVSE (commercial or residents owning PEVs).	Commercial up to $15,000; Residential up to $750
CA	Glendale Water and Power - Rebate to first 100 single-family residential PEV owners to install a level 2 EVSE.	$200
FL	Orlando Utilities Commission - Rebate for the purchase and installation of commercial EVSE.	up to $750
GA	Georgia Water and Power - Rebate to business and residential customers installing a level 2 EVSE; Rebate for new home construction builders installing a dedicated circuit.	Residential $250; Business $500; New home construct $100
IN	NIPSCO - Credit to purchase and install residential EVSE.	up to $1,650
IN	NIPSCO - up to 50% of cost to install public EVSE.	up to $3,000
MI	Indiana-Michigan Power - Rebate to first 250 residential PEV owners/leasers installing level 2 EVSE with separate meter.	$2,500
TX	Austin Energy - Rebate of 50% of purchase cost for Level 2 EVSE for PEV owners.	up to $1,500
WA	Puget Sound Energy - Rebate to first 5,000 PEV owners for Level 2 EVSE.	$500

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Note: All reference web links accessed as of October 8, 2015.

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