Plug-in Electric Vehicle Handbook

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U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Plug-In Electric Vehicle Handbook

for Public Charging Station Hosts

Clean Cities

U.S. Department of Energy

Photo from George Beard, Portland State University, NREL/PIX 18564

Clean Cities Helps Establish PEV Charging Stations

Establishing plug-in electric vehicle (PEV) charging stations requires unique knowledge and skills. If you need help, contact your local Clean Cities coordinator. Clean Cities is the U.S. Department of Energy's flagship alternative-transportation deployment initiative. It is supported by a diverse and capable team of stakeholders from private companies, utilities, government agencies, vehicle manufacturers, national laboratories, and other transportation-related organizations. These stakeholders, organized into nearly 100 Clean Cities coalitions nationwide, are ready to help with specific charging station challenges. Contact your local coordinator by visiting the Clean Cities website at *www.cleancities.energy.gov*.

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Acknowledgement

Thanks to the Electric Vehicle Infrastructure Training Program for assisting with the production of this handbook. See *www.eere.energy.gov/cleancities/evitp.html*.

Introduction

Photo from Electric Vehicle Infrastructure Training Program

You've heard about the new generation of plug-in electric vehicles (PEVs) like the Chevy Volt and Nissan Leaf. You manage a location that could host a PEV charging station—such as a retail business, office or municipal building, utility, or parking garage—and you're wondering how you can be part of the electric transportation revolution. This handbook is for you. If you have a property suitable for hosting an electric charging station, you are perfectly positioned to contribute to—and benefit from—the fast-growing PEV sector. This handbook answers your basic questions about PEVs and charging infrastructure and points you to the additional information you need to decide about participating in this new venture.

More than 100 years ago, all-electric vehicles (EVs) held much of the U.S. car market, but their popularity waned as the interest in conventional cars with internal combustion engines (ICEs) rose. The ICE vehicle had a longer driving range, petroleum fuel costs were declining, and the introduction of the electric starter and manufacturing assembly line improved the usability and affordability of ICE vehicles. Gasoline- and diesel-powered ICE vehicles ended up dominating transportation in the 20th century.

However, concerns about the environmental impacts of conventional ICE vehicles sparked a PEV renaissance at the end of the 20th century. In 1990, California passed the nation's first zero emission vehicle mandate, putting the state at the forefront of that decade's deployment of PEVs such as the General Motors EV1, Chrysler EPIC, Ford Ranger EV, and Toyota RAV4 EV. Many vehicles from this generation were discontinued in the early 2000s, and the number of non-residential charging stations—which had peaked at nearly 900 in 2002—dwindled to about 400 by 2008. However, California's vision helped set the stage for the next generation of PEVs and charging stations.

Today, PEVs are back and ready to compete with—and complement—the ubiquitous ICE technology. First, advances in electric-drive technologies enabled commercialization of hybrid electric vehicles (HEVs), which integrate an ICE or other power source with batteries, regenerative braking, and an electric motor to boost fuel economy. Continued technological advances have spawned plug-in HEVs

Key Acronyms

EVs (all-electric vehicles) are powered only by one or more electric motors. They receive electricity by plugging into the grid and store it in batteries. They consume no petroleum-based fuel while driving and produce no tailpipe emissions.

EVSE (electric vehicle supply equipment) delivers electrical energy from an electricity source to charge a PEV's batteries. It communicates with the PEV to ensure that an appropriate and safe flow of electricity is supplied. EVSE units are commonly referred to as "charging stations."

HEVs (hybrid electric vehicles) combine an ICE or other propulsion source with batteries, regenerative braking, and an electric motor to provide high fuel economy. They rely on a petroleum-based or an alternative fuel for power and are not plugged in to charge. HEV batteries are charged by the ICE or other propulsion source and during regenerative braking.

ICEs (internal combustion engines) generate mechanical power by burning a liquid fuel (such as gasoline, diesel, or biofuels) or a gaseous fuel (such as compressed natural gas). They are the dominant power source for on-road vehicles today.

PEVs (plug-in electric vehicles) derive all or part of their power from electricity supplied by the electric grid. They include EVs and PHEVs.

PHEVs (plug-in hybrid electric vehicles) use batteries to power an electric motor, plug into the electric grid to charge, and use a petroleum-based or an alternative fuel to power an ICE or other propulsion source.

(PHEVs), which integrate small ICEs (or other power sources) and large, grid-chargeable batteries that enable all-electric driving ranges of 10 to 40 miles or more. Advanced technologies have also enabled manufacturers to introduce a new generation of EVs that don't use an ICE at all. At the same time, charging station technologies have evolved to facilitate a range of charging options and business models.

Only a few models of new-generation PEVs are available today. However, because of the benefits they offer, PEV market penetration and availability are growing quickly. President Obama set a goal of having 1 million PEVs on the road by 2015. Many of these vehicles will charge primarily at drivers' homes, but a large and widely distributed network of public and workplace charging stations is essential for providing the convenience, range, and confidence required by the majority of drivers. The proliferation of non-residential charging units has accelerated already—surpassing 7,000 in 2012—with the help of government-supported deployment projects. As a potential station owner or host, you have the opportunity to benefit from this trend while helping drive PEV deployment in the United States.

PEV Basics

Before learning about charging stations, it's useful to learn a little about the vehicles and drivers that will use them. What makes a PEV a PEV is the ability to charge from an off-board electric power source—PEVs can be "plugged in." This feature distinguishes them from HEVs, which supplement power from an ICE or other propulsion source with battery power but cannot be plugged in. There are two basic types of PEVs: EVs and PHEVs.

Under the hood of a Nissan Leaf. An EV contains no ICE; instead, the battery supplies electricity to the electric motor. *Photo from Margaret Smith, DOE, NREL/PIX 18215*

All-Electric Vehicles (EVs)

EVs (also called battery-electric vehicles, or BEVs) use batteries to store the electrical energy that powers one or more motors. The batteries are charged by plugging the vehicle into an electric power source. In addition, EVs can be charged in part by regenerative braking, which generates electricity from some of the energy normally lost when braking. It's as simple as that—EVs have no ICEs and produce no tailpipe emissions.

Today's EVs typically have a shorter range than conventional vehicles have. Most light-, medium-, and heavy-duty EVs are targeting a range of about 100 miles on a fully charged battery. The range depends in part on driving conditions and habits.

The time required to charge depleted batteries—which can range from less than 30 minutes to almost a full day—depends on the size and type of the batteries, as well as the type of charging equipment used. Learn more about charging in the *Charging Basics* section.

Neighborhood electric vehicles (NEVs), also called low-speed vehicles, are a type of EV with range and speed limitations. NEVs are commonly used for neighborhood commuting, light hauling, and delivery. They are often limited to use on roads with speed limits up to 35 miles per hour, making them ideal for college campuses and similar applications. There are also specialty EVs, such as airport ground support equipment and personal transporters, which are not intended for road use. Although these types of vehicles are valuable for the niches they serve, this handbook focuses on EVs designed for highway use.

Why Drivers Choose PEVs

The reasons drivers choose PEVs range from a desire to improve the world to a desire to save money. The following list of PEV benefits illustrates why the demand for PEVs—and thus for charging stations—has been growing rapidly.

High Fuel Economy, Low Operating Cost: PEVs are highly efficient, and they have much lower operating costs compared with conventional gasoline and diesel vehicles.

Flexible Fueling: Compared with conventional vehicles, PEVs offer additional fueling options, including charging at home, work, commercial charging stations, other public locations, private fleet facilities, or a combination of these sites.

High Performance: Today's PEVs are state-of-the-art highway vehicles ready to match or surpass the performance of their conventional gasoline and diesel counterparts.

In all-electric mode, PEVs produce no tailpipe emissions. PEV life cycle emissions are minimized when their source of electricity comes from nonpolluting resources like wind and sunlight. *Photo from Atlantic County Utilities Authority, NREL/PIX 18311*

Low Emissions: Compared with conventional vehicles, PEVs typically produce lower levels of smog-forming emissions (such as nitrogen oxides), other pollutants harmful to human health, and greenhouse gases.

Energy Security: Because almost all U.S. electricity is produced from domestic coal, nuclear power, natural gas, and renewable sources, using PEVs instead of conventional vehicles reduces U.S. dependence on imported petroleum.

Compliance with Fleet Requirements: PEVs can help fleets comply with federal, state, and local transportation policies.

Plug-In Hybrid Electric Vehicles (PHEVs)

PHEVs (sometimes called extended range electric vehicles, or EREVs) use batteries to power an electric motor and use another fuel, such as gasoline or diesel, to power an ICE or other propulsion source. Powering the vehicle some of the time with electricity from the grid cuts petroleum consumption and tailpipe emissions, compared with conventional vehicles. When running on gasoline, PHEVs, like HEVs, consume less fuel and typically produce lower emissions than similar ICE vehicles.

PHEVs have larger battery packs than HEVs, providing an all-electric driving range of about 10 to 40-plus miles for current light-duty models. During typical urban driving, most of a PHEV's power can be drawn from stored electricity. For some urban fleet applications, a PHEV could be driven on all-electric power all day and then charged at night or even during a down time like lunch. The ICE powers the vehicle when the battery is mostly depleted, during rapid acceleration, or when intensive heating or air conditioning is required. Some heavy-duty PHEVs work the opposite way, with the ICE used for driving to and from a job site and electricity used to power the vehicle's equipment or control the cab's climate while at the job site. Because the vehicle would otherwise be idling at the job site for powering equipment or climate control, this PHEV strategy can result in significant fuel savings.

Like EVs, PHEVs can be plugged into the grid and charged, although the time required to charge depleted batteries is typically shorter for PHEVs, because most have smaller battery packs. In addition, battery charge is augmented by a PHEV's ICE and regenerative braking.

PHEV fuel consumption depends on the distance driven between battery charges. For example, if the vehicle is never plugged in to charge, fuel economy will be about the same as for a similarly sized HEV. If the vehicle is driven less than its all-electric range and plugged in to charge, it may be possible to use only electric power.

PEV Availability

As of the time this handbook was written, only a few light-duty PEVs were commercially available. PEV technology is just beginning to make inroads into the U.S. vehicle market, but the number of available vehicles is predicted to grow quickly. For comparison, only two HEV models were available in the late 1990s, compared with 29 models today. To find currently available PEVs, use the AFDC Light-Duty Vehicle Search (*www.afdc.energy.gov/afdc/vehicles/search/light*). Learn about anticipated PEV introductions from the Electric Drive Transportation Association (*www.electricdrive.org*) and FuelEconomy.gov (*www.fueleconomy.gov/feg/phevnews.shtml* and *www.fueleconomy.gov/feg/evnews.shtml*).

A larger number of medium- and heavy-duty PEV models are currently available, most of which are EVs. Applications include delivery trucks, step vans, transit and shuttle buses, and utility trucks. To find currently available medium- and heavy-duty PEVs, use the AFDC Heavy-Duty Vehicle and Engine Search (*www.afdc.energy.gov/afdc/vehicles/search/heavy*).

In addition to a limited number of PEV models, early PEV introductions (starting in 2010) have been limited to select geographic areas to match dealer and service preparation. However, it is expected that at least some PEVs will soon be available from select dealerships in all 50 states. Because of the popularity and limited initial production of PEVs, there may be a wait time involved in obtaining these vehicles.

Figure 1. A Chevy Volt charges up with public Level 2 EVSE at Los Angeles International Airport. *Photo from Coulomb Technologies*

Charging Basics

If you want to establish a charging station, you need to know about electric vehicle supply equipment (EVSE, Figure 1). There are various types of EVSE—which differ based on communication capabilities and how quickly they can charge a vehicle—and EVSE can be installed at homes, workplaces, private fleet facilities, and public stations. This section describes the typical EVSE options.

Types of Charging Equipment (EVSE)

EVSE is the equipment used to deliver electrical energy from an electricity source (such as the electricity running to the electrical outlets at a business) to a PEV. EVSE communicates with the PEV to ensure that an appropriate and safe flow of electricity is supplied.

Typical Charging Rates

The rate at which charging adds range to a PEV depends on the vehicle, the battery type, and the type of EVSE. The following are typical rates for a light-duty vehicle:

Level 1: 2 to 5 miles of range per hour of charging

Level 2: 10 to 20 miles of range per hour of charging

DC fast charging: 60 to 80 miles of range in 20 minutes of charging

EVSE for PEVs is classified into several categories by the rate at which the batteries are charged. Two types—Level 1 and Level 2—provide alternating-current (AC) electricity to the vehicle, with the vehicle's onboard equipment (charger) converting AC to the direct current (DC) needed to charge the batteries. The other type—DC fast charging—provides DC electricity directly to the vehicle. Charging times range from less than 30 minutes to 20 hours or more, based on the type or level of EVSE; the type of battery, its energy capacity, and how depleted it is; and the size of the vehicle's internal charger. EVs generally have more battery capacity than PHEVs, so charging a fully depleted EV takes longer than charging a fully depleted PHEV.

Many medium- and heavy-duty PEV manufacturers are adopting light-duty charging standards or commercially available standards developed for other uses. However, some manufacturers are introducing alternative charging configurations in their medium- and heavy-duty PEVs, so EVSE options and performance may be different for these vehicles.

Level 1

Level 1 EVSE provides charging through a 120-volt (V) AC plug and requires electrical installation per the National Electrical Code. Most, if not all, PEVs will come with a Level 1 EVSE cordset so that no additional charging equipment is required. On one end of the cord is a standard, three-prong household plug (NEMA 5-15 connector). On the other end is a J1772 standard connector (see the *Connectors and Plugs* section on page 8), which plugs into the vehicle.

Level 1 typically is used for charging when there is only a 120-V outlet available, such as at some residential locations. Based on the battery type and vehicle, Level 1 charging adds about 2 to 5 miles of range to a PEV per hour of charging time.

Level 2

Level 2 EVSE can easily charge a typical EV battery overnight, and it will be a common installation for home, workplace, fleet, and public facilities. Level 2 EVSE offers charging through a 240-V (typical in residential applications) or 208-V (typical in commercial applications) electrical service. These installations are generally hard-wired for safe operation (although a wall plug connection is possible). Level 2 EVSE requires installation of charging equipment and a dedicated circuit of 20 to 80 amp (A) depending on the EVSE requirements (Figure 2). Level 2 equipment uses the same connector on the vehicle as Level 1 equipment. Based on the battery type, charger configuration, and circuit capacity, Level 2 charging adds about 10 to 20 miles of range to a PEV per hour of charging time.

DC Fast Charging

DC fast-charging EVSE (480-V AC input to the EVSE) enables rapid charging at sites such as heavy traffic corridors and public fueling stations (Figure 3, next page). A DC fast charger can add 60 to 80 miles of range to a PEV in 20 minutes.

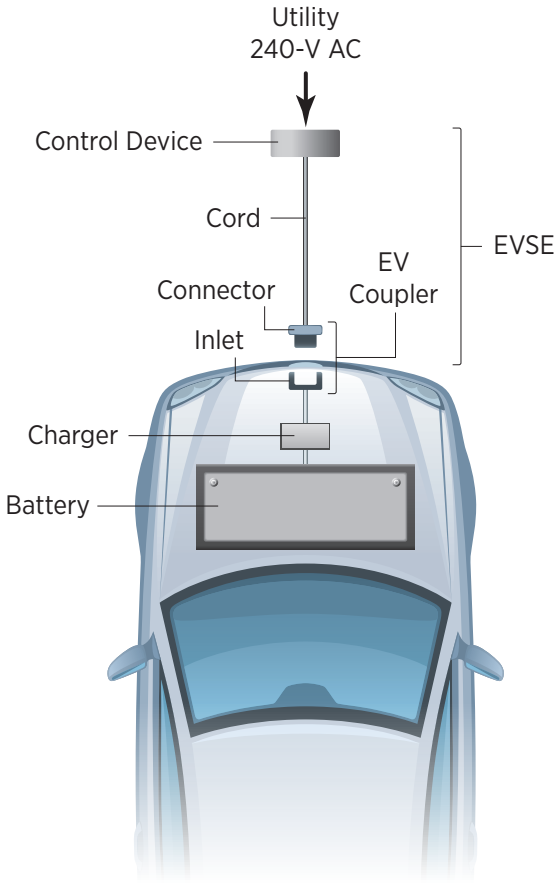


Figure 2. Level 2 charging schematic.

Source: eTec (2010), Electric Vehicle Charging Infrastructure Deployment Guidelines for the Oregon I-5 Metro Areas of Portland, Salem, Corvallis and Eugene. EV Project publication (www.theevproject.com/documents.php). Illustration by Dean Armstrong, NREL

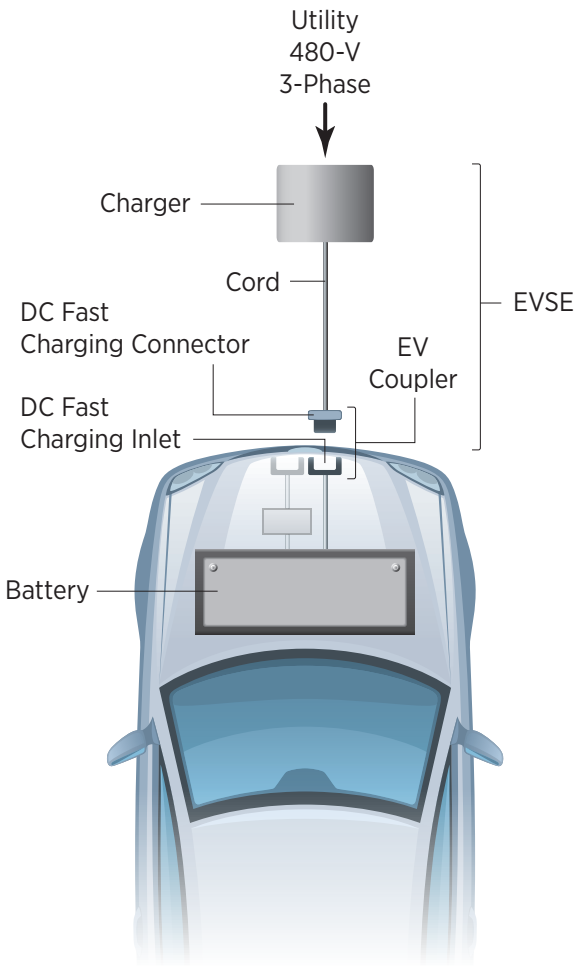


Figure 3. DC fast charging schematic.

Source: eTec (2010). Electric Vehicle Charging Infrastructure Deployment Guidelines for the Oregon I-5 Metro Areas of Portland, Salem, Corvallis and Eugene. EV Project publication, www.theevproject.com/documents.php. Illustration by Dean Armstrong, NREL

Inductive Charging

Inductive-charging EVSE, which uses an electromagnetic field to transfer electricity to a PEV without a cord, is still being used in some areas where it was installed for EVs in the 1990s. Currently available PEVs cannot use inductive charging, although SAE International is working on a standard that may apply to PEVs in the future.

Connectors and Plugs

Most modern EVSE and PEVs have a standard connector and receptacle based on the SAE J1772 standard developed by SAE International (Figure 4). Any vehicle with this receptacle can use any Level 1 or Level 2 EVSE. All major vehicle and charging system manufacturers support this standard, which should eliminate drivers' concerns about whether their vehicles are compatible with available charging infrastructure. Most currently available PEVs that are equipped to accept DC fast charging are using the CHAdeMO connector, developed in coordination with Tokyo Electric Power Company, which is not standard in the United States. Manufacturers may offer the CHAdeMO DC fast charge receptacle (Figure 5) as an option on fast-charge capable vehicles until a standard is in place. SAE International is also working on a "hybrid connector" standard for fast charging that adds high-voltage DC power contact pins to the J1772 connector, enabling use of the same receptacle for all levels of charging.

Figure 4. The standard SAE J1772 EVSE connector fits into the standard SAE J1772 receptacle. *Photo by Andrew Hudgins, NREL/PIX 17634*

Figure 5. The standard J1772 receptacle (right) can receive charge from Level 1 or Level 2 equipment. The CHAdeMO DC fast charge receptacle (left) uses a different type of connector. *Photo by Andrew Hudgins, NREL/PIX 19558*

Benefits and Costs of Hosting a Charging Station

Now that you know the basics about PEVs and charging infrastructure, this section helps you explore the benefits and costs of hosting a charging station.[1] To tailor this benefit-cost exploration to your situation, use the Rocky Mountain Institute's Project Get Ready Charging Infrastructure Tool, available at *www.rmi.org/pgr_resources#infrastructure*.

Charging Station Benefits

There are many benefits to owning or hosting a charging station, which depend on your site characteristics as well as your goals and values. For example, a retail business may host a charging station to increase customer visits and revenue, whereas a municipality may host a station for the public health benefits associated with increased PEV use. Each benefit in the following list is—or may become—available to one or more types of station host.

Customer Attraction and Retention, Corporate Branding

Offering charging is a direct way to attract and retain new, PEV-driving customers. In addition, many consumers believe it is important to purchase products with environmental benefits and to frequent environmentally responsible companies. Hosting a charging station is a highly visible way to state your organization's environmental values, which may help contribute to a "green" image that attracts and retains customers who share these values.

User Charging and Parking Fees

Charging-station hosts have the opportunity to generate revenue directly from people who use their services. Although the selling of electricity by non-utility organizations is prohibited in most parts of the United States, there are various ways to collect revenue for charging, such as subscription-based, pay-per-charge, and pay-for-parking systems. Using these types of systems typically requires installation of advanced EVSE products.

Raleigh, North Carolina, is among the many U.S. cities installing EVSE in public places. *Photo from Kathy Boyer, Triangle Clean Cities Coalition, NREL/PIX 18520*

Employee Attraction and Retention

Companies that offer charging may be able to attract and retain employees who want to charge PEVs during the day. In addition, it is very important to many employees—even those who don't drive PEVs—that their employers are proactive with transportation planning.

1. *This discussion of benefits and costs is primarily drawn from Rocky Mountain Institute (2009). Plugging In: A Stakeholder Investment Guide for Public Electric-Vehicle Charging Infrastructure (www.rmi.org/pgr_resources#infrastructure) and BC3 (2011). Electrify Your Business: Moving Forward with Electric Vehicles—A Bay Area Business Guide (www.bc3sfbay.org/ev-guide-for-businesses.html). See those reports for additional details.*

Fleet Cost Savings

An organization may want to serve its own fleet with charging stations in addition to serving the public. A PEV fleet can realize substantial operating-cost savings.

Advertising Opportunities

Each time a PEV driver visits a charging station is an opportunity to advertise to that driver. A station host could advertise its own products or services in this way or sell advertising space to another organization.

Contribution to LEED Certification

Installing a charging station contributes toward attaining LEED (Leadership in Energy and Environmental Design) certification. LEED is an internationally recognized system for rating the energy and environmental performance of buildings. Becoming LEED certified may contribute to improving an organization's image and thus attract environmentally conscious customers and employees.

Value of Avoided Carbon Emissions

With a growing number of local and regional carbon-reduction policies, charging station owners may be able to benefit from the value of carbon emissions offset by their stations.

Improved Public Health

Governments have a responsibility to protect public health, and facilitating the pollution-reduction benefits of PEVs (depending on the source of electricity) by hosting charging stations can contribute to this aim.

Increased Energy Security

Many station owners have an interest in promoting the energy-security benefits of PEVs by making charging stations available. See the *Why Drivers Choose PEVs* section.

Charging Station Costs

The costs of owning and operating a charging station include equipment, installation, maintenance, and electricity costs. You can reduce these costs by taking advantage of discounts and incentives.

Public charging stations that incorporate renewable energy, such as these solar panels, can be particularly appealing to environmentally conscious drivers. *Photo from IKEA Orlando, NREL/PIX 18709*

Equipment

EVSE products vary in the types of features they offer and the corresponding prices.[2] Prices shown here are for equipment only and do not include installation costs. The price of Level 2 EVSE is approximately $1,000 to $7,000 (before incentives) depending on the level of sophistication. The most basic Level 2 products have only standard safety features and status lights. More advanced, "smart" Level 2 products have features such as enhanced displays, charging timers, communications capabilities, and keypads. "Intelligent" or networked Level 2 products have enhanced durability and ergonomics as well as features like payment card readers, billing software, advanced displays, wireless communication, automated diagnostics, computer-controlled power flow, internal metering, and smart-grid compatibility. DC fast-charging products are similar to intelligent or networked Level 2 products but cost substantially more (typically $20,000 to $50,000) because of the additional hardware requirements associated with their high-power operation. However, manufacturers are working to decrease costs substantially.

2. This discussion is primarily drawn from Rocky Mountain Institute (2009). Plugging In: A Stakeholder Investment Guide for Public Electric-Vehicle Charging Infrastructure (www.rmi.org/pgr_resources#infrastructure) and BC3 (2011). Electrify Your Business: Moving Forward with Electric Vehicles—A Bay Area Business Guide (www.bc3sfbay.org/ev-guide-for-businesses.html).

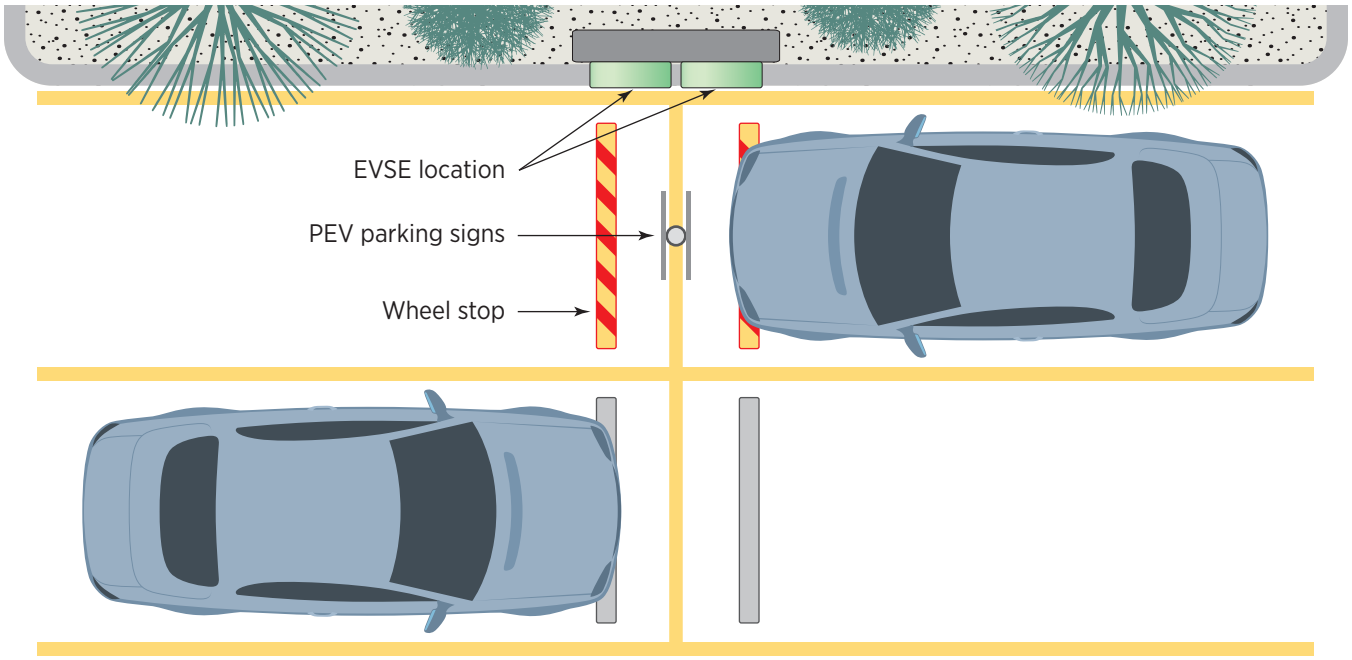


Figure 6. Example public charging station design showing EVSE, wheel stop, and sign locations. *Source: eTec (2010), Electric Vehicle Charging Infrastructure Deployment Guidelines for the Oregon I-5 Metro Areas of Portland, Salem, Corvallis and Eugene. EV Project publication, www.theevproject.com/documents.php. Illustration by Dean Armstrong, NREL*

Installation

EVSE installation costs vary considerably, so be sure to do your homework and get a number of price quotes before moving forward. For example, the City of Houston reported installation costs of $860 to $7,400 per EVSE unit, not including the cost of the units themselves.[3] Factors affecting the cost (and installation time) include the number of circuits and EVSE units installed, indoor versus outdoor installation, required electrical upgrades, required ventilation, and the use of DC fast-charging EVSE. If required, trenching and adding electrical service or panels add the most cost.

Total Installed Cost Estimates

Various organizations have estimated the total cost of installing a typical public charging station, including equipment and installation costs. One organization's estimate is $15,000 to $18,000 for a Level 2 station like the one shown in Figure 6; for a DC fast-charging station, the estimate increases to $65,000 to $70,000.[4] Another's estimate is $12,000 for a station with one Level 2 EVSE unit (plus $4,000 to $8,000 per additional unit) and $45,000 to $100,000 or more for a station with one DC fast-charging EVSE unit.[5] These prices are expected to trend downward as EVSE production volumes increase.

Maintenance

Typically, there are relatively few EVSE maintenance requirements. In general, the charging cord should be stored securely so it is not damaged, the accessible EVSE parts should be checked periodically for wear, and the system should be kept clean. See the EVSE manufacturer's guidelines for specific requirements. Periodic inspection, testing, and preventive maintenance by a qualified electrical contractor may be recommended. One estimate of annual maintenance costs ranges from $25 to $50 per EVSE unit.[6]

3. *See the Project Get Ready website (www.rmi.org/pgr_resources#infrastructure).*
4. *Estimates and figure from eTec (2010). Electric Vehicle Charging Infrastructure Deployment Guidelines for the Oregon I-5 Metro Areas of Portland, Salem, Corvallis and Eugene. EV Project publication (www.theevproject.com/documents.php).*
5. *From BC3 (2011). Electrify Your Business: Moving Forward with Electric Vehicles—A Bay Area Business Guide (www.bc3sfbay.org/ev-guide-for-businesses.html).*
6. *From Rocky Mountain Institute (2009). Plugging In: A Stakeholder Investment Guide for Public Electric-Vehicle Charging Infrastructure (www.rmi.org/pgr_resources#infrastructure).*

Electricity

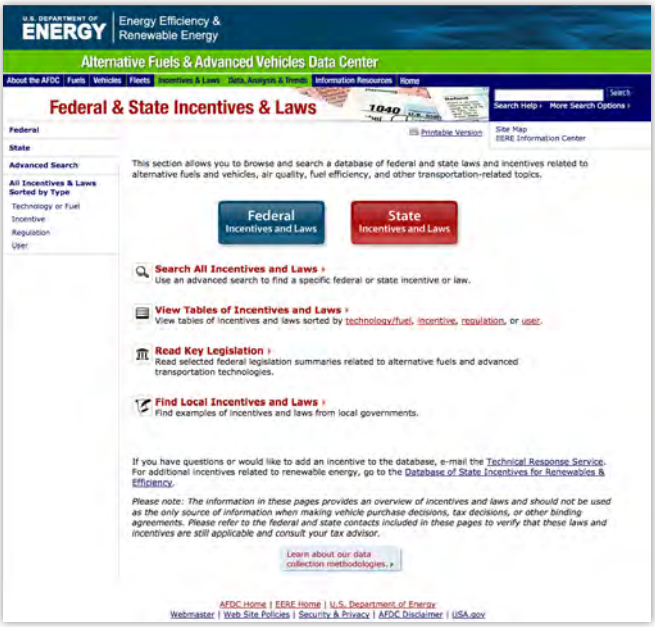
Electricity costs will depend on the type of EVSE installed at a charging station as well as the amount and timing of PEV charging. For example, a station at a retail store might charge vehicles for short periods that include peak hours, i.e., the hours at which the utility may charge the highest electricity rate. On the other hand, a parking-garage station might charge vehicles for longer periods covering peak and off-peak hours. It is important to discuss the effects of PEV charging on electricity rates and loads with your utility. The advanced capabilities of some EVSE products can be useful for optimizing load management. In general, charging-station electricity costs are lower than equipment and installation costs.[7]

Discounts and Incentives

Discounts and incentives can lower charging station costs. You may be eligible for incentives from the state, city, or utility. To find current incentives, search the AFDC's Federal and State Incentives and Laws database (*www.afdc.energy.gov/afdc/laws*). For even more information about incentives in your area, contact your local Clean Cities coalition (*www.cleancities.energy.gov*), state energy office (*www.naseo.org/members/states/default.aspx*), and utility.

Charging Station Locations and Hosts

Various business and government sites are suitable for hosting a charging station. An ideal station location is convenient and highly visible to a large number of potential or actual PEV drivers. It is also important to align the location and capabilities of the EVSE with the characteristics of the drivers visiting the station and the goals of the station host. For example, visitors to a retail store may park for several hours while shopping, and encouraging an extended stay benefits the business. Thus, Level 2 charging, which provides a substantial charge over several hours, is well suited to retail stores as well as other locations with similar characteristics, such as restaurants, theaters, hotels, shopping malls, and museums. Level 2, or even Level 1, charging may be appropriate to long-term-parking locations, such as office parks, airports, parking garages, and parking lots. Stations with DC fast charging are most suitable for places where drivers park for less than a half hour,



The AFDC's Federal and State Incentives and Laws database lists currently available incentives that can reduce the cost of EVSE.

such as convenience stores, coffee shops, drug stores, and fast food restaurants.

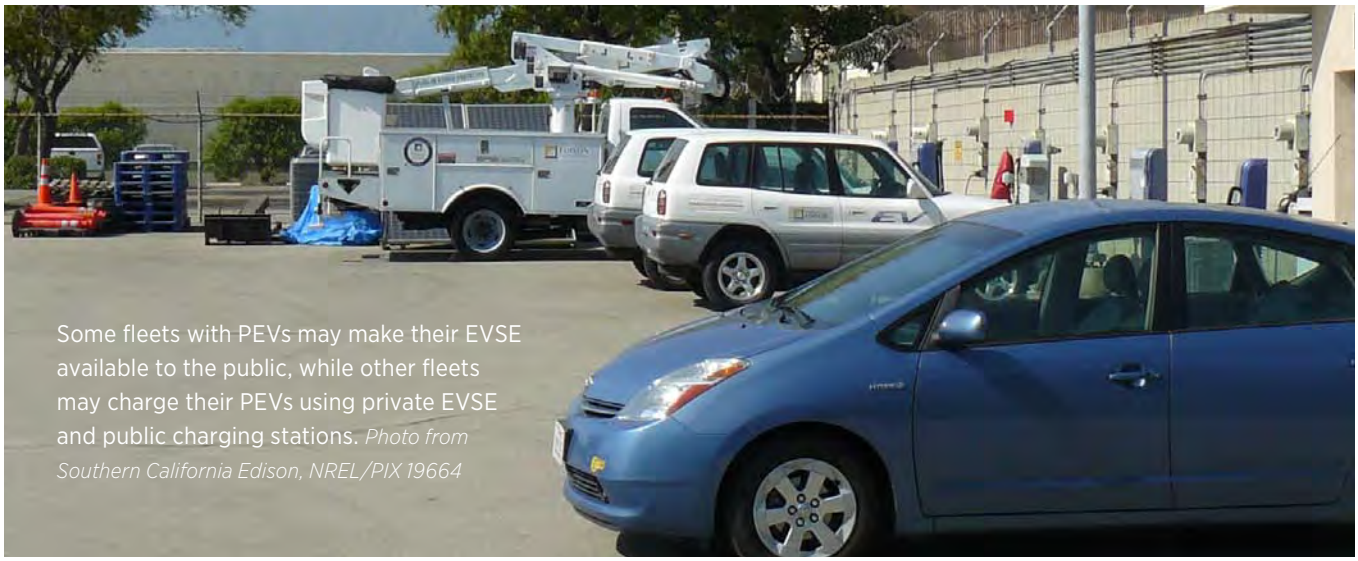
Types of Station Hosts

This section explores considerations relevant to several potential station owners and hosts.[7] These are only examples. Many other organizations and locations could host charging stations as well.

Retail Stores

Retail stores can reap many of the benefits discussed in the *Charging Station Benefits* section, including customer and employee attraction and retention, corporate branding, user charging and parking fees, fleet cost savings, advertising opportunities, and contribution to LEED certification. Each retailer must decide which benefits are most important and design its station and business model accordingly. For example, some may offer free charging to maximize customer attraction, whereas others may generate revenue directly via charging or parking fees.

7. *This discussion is largely summarized from Rocky Mountain Institute (2009). Plugging In: A Stakeholder Investment Guide for Public Electric-Vehicle Charging Infrastructure* (www.rmi.org/pgr_resources#infrastructure).



Some fleets with PEVs may make their EVSE available to the public, while other fleets may charge their PEVs using private EVSE and public charging stations. *Photo from Southern California Edison, NREL/PIX 19664*

Parking Garages

Because they already charge customers for parking, parking garages are ideally situated to generate revenue directly from PEV-driving customers. In addition, the existing electrical wiring and structure (e.g., walls and low ceilings) of many garages can reduce station installation complexity and cost.

Office Parks

As noted in the *Charging Station Benefits* section, charging stations can help companies attract and retain employees, enhance "green" corporate branding, and serve their own fleet of PEVs. Employees based at office parks are likely to charge for several uninterrupted hours consistently, which should make charging station use relatively predictable.

Utilities

Utilities have a vested interest in guiding the development of PEV charging infrastructure, and they are implementing various charging-related strategies. Utilities that are not required to decouple electricity sales may receive direct financial benefits from increased PEV charging and may even establish their own charging stations. "Smart-charging" incentives provide PEV owners with convenient, low-cost charging in exchange for giving the utility some control over the charging schedule for grid-stabilization purposes. When designing charging strategies, utilities must work within the restrictions created by their state Public Utility Commissions.

Home Owners' Associations

Like office parks, multi-family housing units host long-term parking. Level 2 or even low-cost Level 1 EVSE may be appropriate for meeting overnight charging needs. The presence of charging stations could add value to the residences and entice environmentally conscious buyers. However, because not all residents benefit directly from the charging stations, home owners' associations have to determine how to distribute the costs equitably.

Governments

Government entities have led the early development of PEV charging infrastructure. Although governments install charging stations to benefit their jurisdictions rather than generate profits, they may charge fees as a way to offset costs of station installation and operation.

Existing Station Network

When thinking about establishing a charging station, knowing the location of existing stations is important. Although the current availability of public charging stations is limited, it is increasing rapidly. Publicly and privately funded projects are accelerating the deployment of public stations, including several supported by the U.S. Department of Energy. For more information, visit the AFDC's Deployment page (*www.afdc.energy.gov/afdc/vehicles/electric_deployment.html*). To find charging stations near you, visit the AFDC's Alternative Fueling Station locator (*www.afdc.energy.gov/afdc/fuels/stations.html*), or access the locator with a mobile device at *www.afdc.energy.gov/afdc/locator/m/stations*.

Ownership and Payment Models

Today, many charging stations are publicly funded and offer free charging to encourage early adopters of PEVs. However, many public stations will evolve toward a pay-for-use system as PEVs become more mainstream. In most parts of the United States, only utilities are allowed to sell electricity directly, so most non-utility-owned stations likely will charge a service fee instead of charging for electricity use. A number of payment models are being explored, all designed to make paying for charging simple and convenient. Drivers might subscribe to a charging service, swipe their credit card, enter a charging account number, or insert coins or bills into a meter to charge their PEVs. In many cases, drivers will only be charged a single fee for parking and charging. "Smart cards" or radio-frequency identification (RFID) devices programmed with user information enable the station host to collect usage data in addition to payment.

Charging station ownership models also vary. Some charging station hosts may purchase, install, and operate stations themselves. This model gives the host or owner control of the station and allows them to keep all revenues. For example, a parking lot owner might buy and operate a pay-for-use charging station as a central part of its business strategy. Other organizations will contract with a third party who pays the station equipment, installation, and maintenance costs and manages the logistics in return for lease payments or a share of the station's revenue. This model minimizes the host's upfront costs and administrative responsibilities. For example, a retail business wanting the customer-attraction benefits of hosting a station without handling all the details might contract with a third party to install and operate a station on its property.

Through its ChargePoint Network, Coulomb Technologies supports charging stations hosted by various organizations worldwide. *Photo by Andrew Hudgins, NREL/PIX 17834*

Two Payment Models

Coulomb Technologies and NRG Energy exemplify two different charging station payment models. Coulomb supports a network of charging stations—the ChargePoint Network—hosted by various organizations worldwide. For a fee, Coulomb provides turnkey services to collect, process, and forward payments from PEV drivers to the station hosts. This allows each host to set the station's pricing system based on parameters such as amount of charging time, amount of electricity consumed, time of day, and day of week. For example, a municipal station might set one price per hour of charging during business hours and a second price after hours, while giving free access to municipal vehicles at all times. PEV drivers can pay for charging at these stations with major credit cards or Coulomb's ChargePass smart card. For more information, visit the Coulomb website (*www.coulombtech.com*).

NRG Energy's eVgo charging station network is being deployed initially in the Houston and Dallas/Fort Worth areas. In this model, PEV drivers subscribe to eVgo for a flat monthly fee. The most comprehensive subscription package provides installation of home EVSE, a three-year service agreement, unlimited charging at eVgo network stations, and unlimited charging at home with no additional electricity cost during non-peak hours. Public eVgo stations are hosted at retail, workplace, and multi-family housing locations. NRG manages the station installation and maintenance. Station hosts are responsible for few or no upfront costs but pay a monthly membership fee. For more information, visit the eVgo website (*www.evgonetwork.com*).

Installing and Maintaining Charging Stations

The Electric Vehicle Infrastructure Training Program is one of the organizations that trains electrical contractors in EVSE installation. *Photo from Electric Vehicle Infrastructure Training Program*

Public charging station installations range from the simple to the complex. Figure 7 (next page) summarizes the processes for installing EVSE at a public station, and the following sections address some of the considerations related to establishing and operating public stations.[8] As Figure 7 shows, it is important to consult with your utility, governing authority, electrical contractor, PEV provider, EVSE provider, and other stakeholders early in the EVSE installation process. For additional details about installing EVSE, see the Clean Cities *Plug-in Electric Vehicle Handbook for Electrical Contractors*. Also see the Raleigh, North Carolina, public charging station installation video at *www.youtube.com/watch?v=jvPLvsg9y2o*.

Choosing an EVSE Provider and Electrical Contractor

Several companies manufacture and sell EVSE. Some have partnered with a PEV manufacturer to become a "preferred EVSE provider," so one way people choose EVSE is to use the companies recommended by the manufacturers or dealers of the PEVs that will be served. Because public stations will serve a variety of PEVs, one option is to install a variety of EVSE products at these stations when possible. You can also discuss EVSE options with your electrical contractor and utility. If you choose an EVSE provider before choosing an electrical contractor, you can discuss potential electrical contractors with your EVSE provider—they likely will have a preferred-contractor list for your area. A viable EVSE product should be listed by a nationally recognized testing laboratory, such as Underwriters Laboratories or CSA International. Find links to EVSE provider websites on the AFDC's Related Links page (*www.afdc.energy.gov/afdc/related_links.html*). In addition, Plug In America lists EVSE products on its Accessory Tracker page (*www.pluginamerica.org/accessories*). To find licensed electrical contractors trained in EVSE installation, contact the Electric Vehicle Infrastructure Training Program at *Info@EVITP.org*. In addition, your state's licensing board likely will provide a list of licensed electrical contractors (though not specifically those that have received EVSE training).

Energy Audit

Before planning and installing a charging station, it may be useful to have an audit of your site's entire energy footprint. An audit can identify opportunities for energy savings in your facility, and these savings could be used to offset the increased electricity load associated with adding a charging station. An audit may also help ensure that your station works well in your facility's energy system.

EVSE and Electrical Upgrades

For charging stations that will serve multiple vehicles, it is important to project EVSE requirements over several years. If expansion of EVSE use is projected, the addition of extra circuits, electrical capacity, and conduit from the electrical panel to future EVSE locations should be considered. It is less expensive to install extra panel and conduit capacity during initial construction

8. *These recommendations are primarily summarized from Pacific Gas & Electric's Electric Vehicle Supply Equipment Installation Manual (http://pge.com/mybusiness/environment/pge/electricvehicles) and eTec's Electric Vehicle Charging Infrastructure Deployment Guidelines for the Oregon I-5 Metro Areas of Portland, Salem, Corvallis and Eugene (www.theevproject.com/documents.php). See those documents for additional details.*

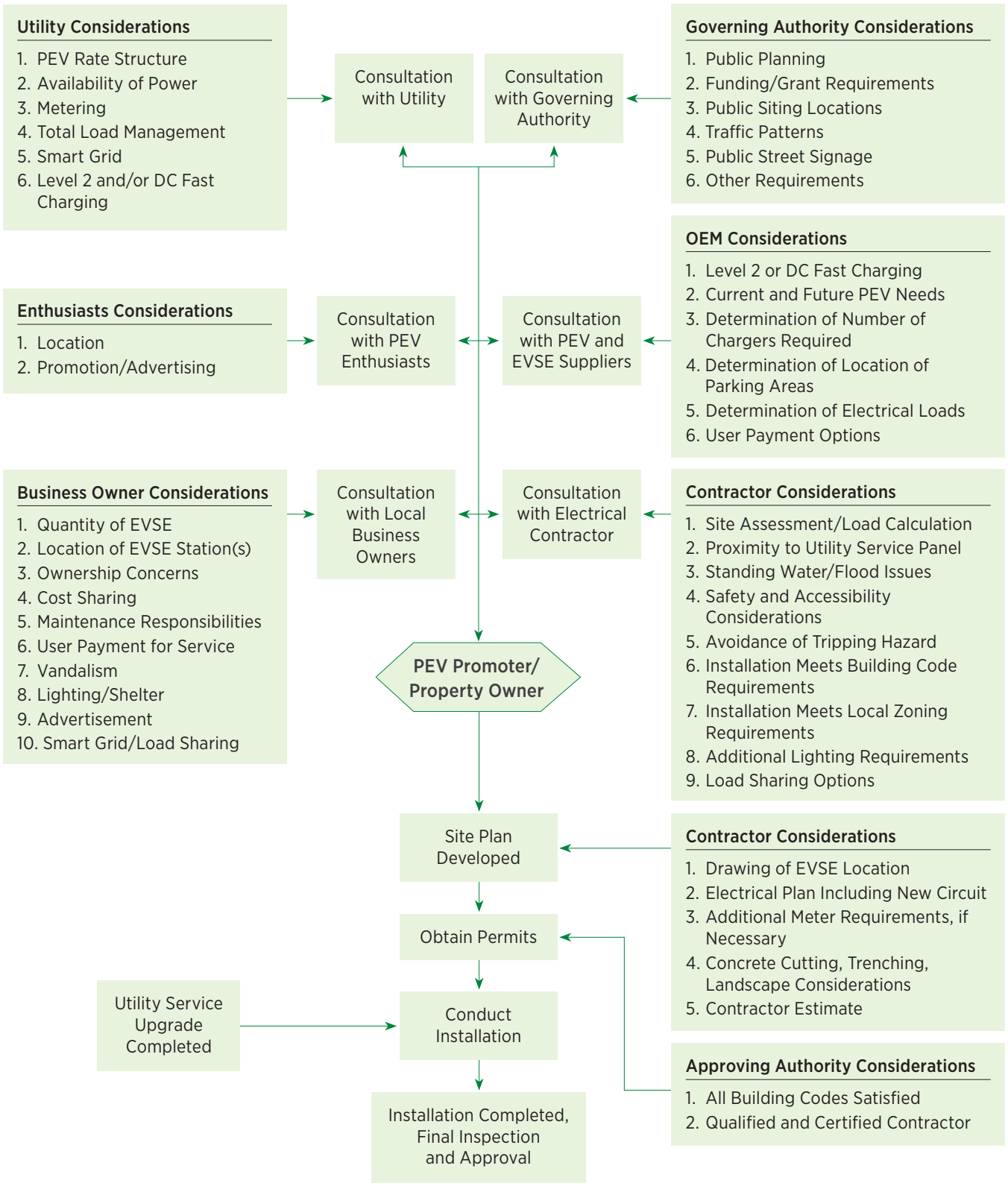


Figure 7. General process for installing EVSE at a public facility. *Source: eTec (2010). Electric Vehicle Charging Infrastructure Deployment Guidelines for the Oregon I-5 Metro Areas of Portland, Salem, Corvallis and Eugene. EV Project publication (www.theevproject.com/documents.php).*

than to modify the site later. Electricity and charging-time needs can be analyzed by estimating electricity-use and time requirements for all the PEVs that will be served. This will enable assessment of electrical-upgrade needs and determination of the appropriate number and type of EVSE units. Whether installing one or many EVSE units, the electrical contractor should conduct a thorough site assessment and load calculation to make a proper and safe determination of service capacity and prospective power needs. If upgrades to your electrical service are required, discuss the process and cost implications with your electric utility as soon as possible.

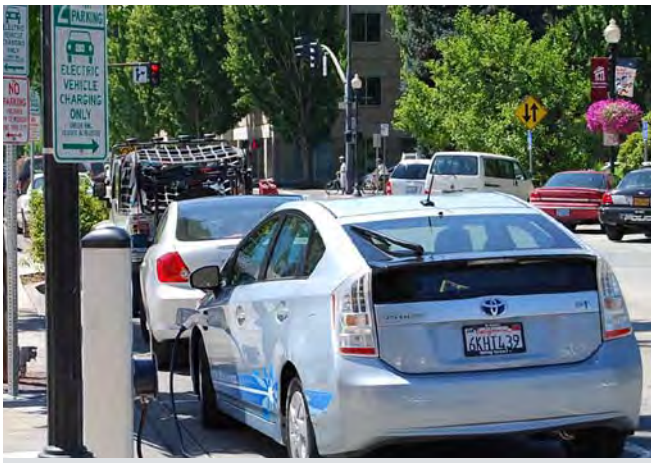
Engineering and Construction

Because EVSE installations involve specialty equipment and extensive electrical work—in addition to standard civil engineering work—select well-qualified contractors with experience in the relevant engineering and construction areas. The condition and location of existing electrical equipment will determine the complexity of the required electrical installations. If the existing electrical system does not support the required EVSE input voltage range, an isolation transformer is required to step electricity down to Level 2 or up to DC fast-charging voltage. To learn more about the types of considerations contractors must address, see the Clean Cities *Plug-in Electric Vehicle Handbook for Electrical Contractors*.

Complying with Regulations

Charging station installations must comply with local, state, and national codes and regulations, and installation requires a licensed contractor. Your contractor should know the relevant codes and standards and obtain approval from the local building, fire, environmental, and electrical inspecting and permitting authorities before installing EVSE.

You can learn about codes and standards typically used for U.S. PEV and infrastructure projects on the AFDC's Codes and Standards Resources page (*www.afdc.energy.gov/afdc/codes_standards.html*). To determine which codes and standards apply to your project, identify those that are in effect within your local jurisdiction. Some jurisdictions also have unique ordinances or regulations. EVSE is considered a continuous load by the National Electrical Code (NEC). An electrical contractor's knowledge and application of the current NEC is required for a safe and code-compliant installation.



Charging stations may soon become a common sight along U.S. streets. *Photo from Coulomb Technologies*

Consult PEV manufacturer guidance for information about the required EVSE and learn the specifications before purchasing equipment and electric services.

In many areas, a site installation plan must be submitted to the permitting authority for approval before EVSE installation can proceed. A plan describes the use and locations of elements such as electrical system components, hazardous materials, EVSE, lighting, vehicle and pedestrian traffic flow, ventilation, signage and striping, safety and accessibility measures, and landscaping. You may want to work with your contractor to develop the plan.

Site and Equipment Considerations

The following are some of the site and equipment issues you should consider when installing a charging station. Discuss these and other issues applicable to your specific installation with your contractors, utility, and EVSE provider.

Convenience

Locate EVSE and associated PEV parking as close as possible to the electric service while accommodating other activities at the site. Keep in mind that PEVs can be parked for hours at a time for charging.

Avoiding Hazards

Cords and wires associated with EVSE should not interfere with pedestrian traffic or present tripping hazards. PEV charging spaces should not be located near potentially hazardous areas.

Ventilation

Although most of today's advanced batteries do not require ventilation during charging, some older types emit gases during charging. If your station will be enclosed, there must be adequate ventilation, which may include installation of fans, ducts, and air handlers. Depending on the installation, the NEC may also require ventilation. Verify the requirements with the PEV manufacturer's documentation.

Battery Temperature Limits

Because some PEV batteries have operating- and charging-temperature limits, EVSE may need to be located within an enclosed, climate-controlled area in extreme climates.

Pooled Water and Irrigation

EVSE is designed to operate safely in wet areas. However, users will be more comfortable if it is not located where water pools or where irrigation systems spray.

Preventing Impact

Curbs, wheel stops, and setbacks should be used to prevent PEVs from colliding with EVSE (Figure 6). However, accessibility issues must also be considered when using these strategies.

Vandalism

Assess the risk of vandalism and minimize risk through use of preventive strategies, such as motion detectors, security lighting, tamper alarms, locked enclosures, anti-vandalism hardware, and graffiti-resistant coatings.

Signage

Signs are particularly important for public charging stations. Mark PEV parking/charging areas clearly with distinctive patterns on the ground and signs that can be seen over parked vehicles.

Accessibility

Evaluate and address requirements for complying with the Americans with Disabilities Act, as well as state, local, and organizational accessibility policies. Compliance measures may include adjusting connector and receptacle heights, cutting curbs, and providing accessible parking spaces.

Lighting and Shelter

Provide lighting and shelter as necessary for the safety, comfort, and convenience of EVSE users. Lighting should enable EVSE users to read signs and instructions and to operate the EVSE easily. Although not typically required for outdoor-rated EVSE, shelter that blocks rain, snow, and wind can increase convenience and comfort associated with using EVSE.

Payment for Charging Services

If the station will require payment for charging, a payment system must be established (see the *Ownership and Payment Models* section). A payment system also can be used to collect data on station use. Some EVSE products have integrated payment and data collection/communication systems. EVSE products with billing capability (and many others) will require network communications. Be sure to verify whether the EVSE needs Ethernet (Cat5 or Cat6) or cell network access and plan accordingly.

Aesthetics

The aesthetics of charging stations can be important, especially for businesses trying to portray a positive image to customers. Where necessary, landscaping or walls can be used to screen equipment from view.

Trouble Reporting

Station users who have trouble with the EVSE should be able to report it or contact support. For example, you could post your organization's telephone number or the number of a service that monitors multiple public stations, or you could direct customers needing help to a specific office or store location.

Electrifying the Future

You now know the basics about PEVs and public charging stations. In a time of volatile petroleum prices and heightened environmental concerns, many people may see PEVs as a convenient way to reduce driving costs while being environmentally responsible. The number of available PEV models and the number of PEVs on the street are growing rapidly, as is the need for additional charging stations. Now may be a good time to consider hosting a charging station and becoming part of the electric transportation future. To keep up with new PEV developments, visit the AFDC (*www.afdc.energy.gov/afdc/vehicles/electric.html*) and FuelEconomy.gov (*www.fueleconomy.gov*) frequently.

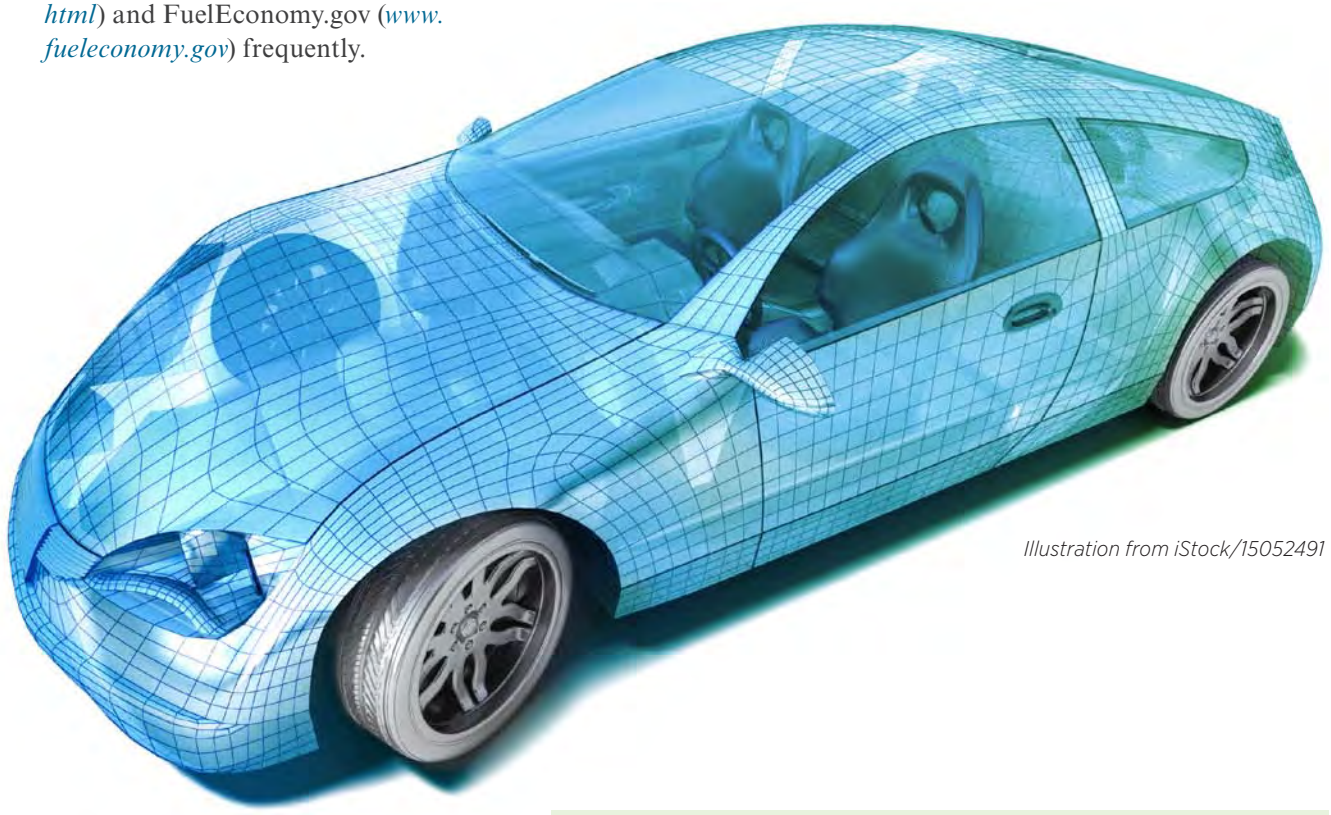


Illustration from iStock/15052491

Clean Cities Can Help

If you need help with your PEV project, contact your local Clean Cities coordinator by visiting *www.cleancities.energy.gov*.

U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

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