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

Plug-In Electric Vehicle Handbook

for Electrical Contractors

Clean Cities
U.S. Department of Energy

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

Clean Cities Helps Deploy PEV Charging Infrastructure

Installing plug-in electric vehicle (PEV) charging infrastructure 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 infrastructure challenges. Find your local coordinator by visiting *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

You've heard about the new generation of plug-in electric vehicles (PEVs) like the Chevy Volt and Nissan Leaf. Perhaps some of your residential customers have asked you about home charging, or some of your commercial or fleet customers have inquired about how they can accommodate PEVs. As an electrical contractor,[1] you may be interested in these new opportunities and would like to know more about getting involved. This handbook is for you. It's designed to answer your basic questions—and your customers' basic questions—about PEVs and charging infrastructure and to point you to the additional information you need to participate in this fast-growing industry.

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 (ZEV) mandate, putting it 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. Although many vehicles from this generation were discontinued in the early 2000s, California's vision helped set the stage for the next generation of PEVs.

Today, PEVs are back and ready to compete with—and complement—the ubiquitous ICE technology. First, advances in electric-drive technologies enabled

1. *In this handbook, the term "electrical contractor" refers to professionals licensed to contract to perform electrical work, i.e., those licensed to run an electrical contracting business. Much of the information in this handbook will also be informative for electricians, who work for electrical contractors. In addition, some of the information may be useful for electrical inspectors, who will be working with charging infrastructure more and more as the PEV market expands.*

Photo from Electric Vehicle Infrastructure Training Program

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 used in 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.

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 (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.

Only a few models of new-generation PEVs are available today, but because of the benefits they offer, their market penetration and availability are growing quickly. PEVs are as good as or better than conventional vehicles in some performance categories. They are safe and convenient, and they can save drivers money while providing environmental and energy security benefits. President Obama set a goal of having 1 million PEVs on the road by 2015. These vehicles will charge at drivers' homes, workplaces, private fleet facilities, and public stations. All of these charging sites will require high-quality equipment and installation, providing substantial new business opportunities for electrical contractors. The need for widespread, reliable charging infrastructure makes well-trained electrical contractors vitally important to the success of PEV deployment in the United States.

PEV Basics

Because your customers may have many questions about the capabilities and requirements of PEVs, it's useful to have some basic knowledge about these vehicles. What makes PEVs unique is their 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 PEVs* 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 their fuel and maintenance costs are lower 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 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.

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

Charging Basics

Understanding the characteristics of various PEV charging options will help you discuss the choices with your customers. Charging a PEV requires plugging in to 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 electrical outlets) to a PEV. EVSE communicates with the vehicle to ensure that an appropriate and safe flow of electricity is supplied.

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.

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 light-duty vehicles:

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

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. 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 offers charging through a 240-V (residential applications) or 208-V (commercial applications) electrical service. These installations are generally hardwired for safe operation (though a wall plug connection is possible). Level 2 EVSE requires installation of charging equipment and a dedicated electrical circuit of 20 to 80 amp (A) depending on the EVSE requirements (Figure 2). Because Level 2 EVSE can easily charge a typical EV battery overnight, this will be a common installation for home, workplace, fleet, and public facilities. 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). A DC fast charger can add 60 to 80 miles of range to a PEV in 20 minutes.

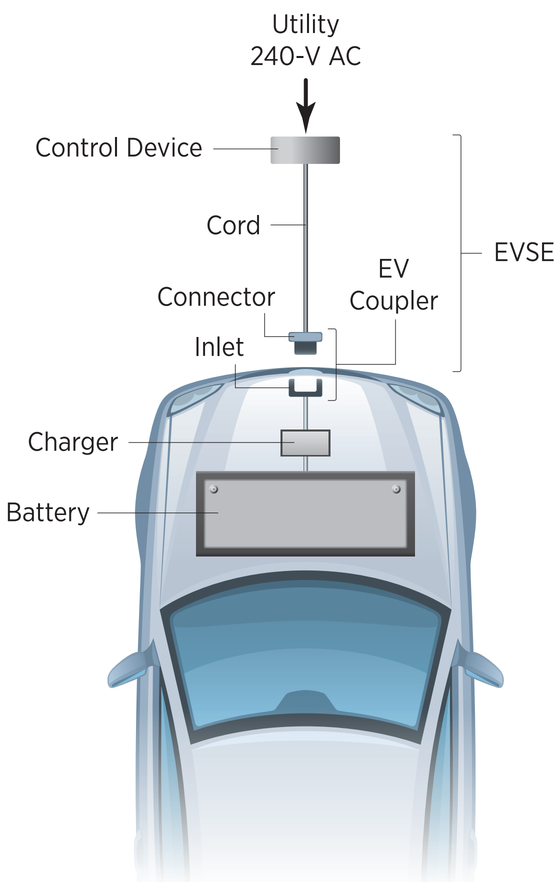

Figure 2. Level 2 charging schematic.

Source for both figures: 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). Illustrations by Dean Armstrong, NREL

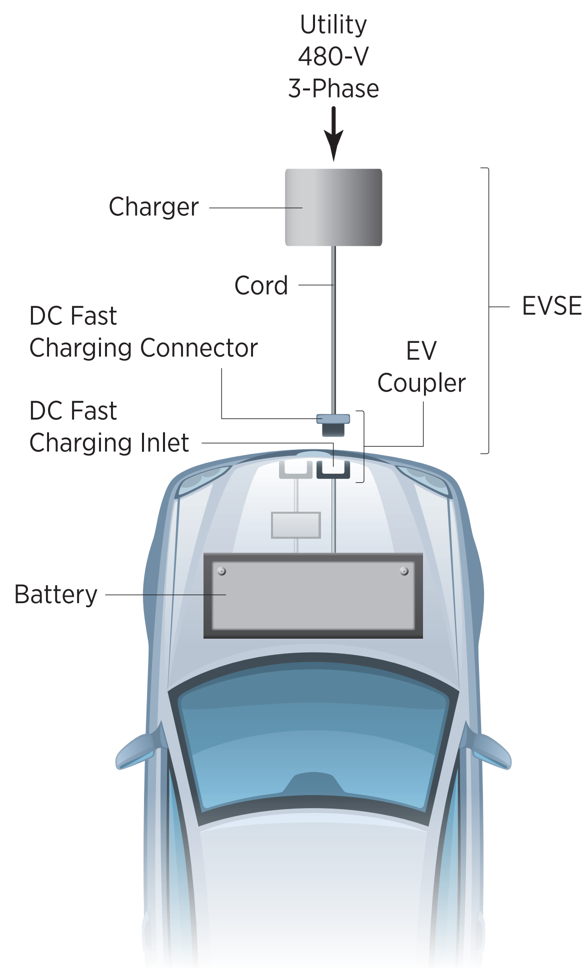

Figure 3. DC fast charging schematic.

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 (Figure 4). This connector is based on the SAE J1772 standard. Any vehicle with this plug 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 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 Co., 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*

EVSE Product Choices

Numerous 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 company recommended by the manufacturer or dealer of the PEV that will be served. It can also be useful to discuss EVSE options with the relevant electrical utility. 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*).

Why Your Customers May Want EVSE

People install EVSE for a variety of reasons based on their characteristics, goals, and values.

Convenience: Many drivers who choose a PEV for personal use want EVSE for the convenience of charging at home. Similarly, fleets may find installing their own EVSE convenient and cost effective.

Revenue Generation and Business Differentiation: By installing publicly available EVSE, businesses can generate revenue; attract, retain, and advertise to new customers; and project a "green" image that differentiates them from their competitors and appeals to environmentally conscious customers and employees.

Public Health and Energy Security: Government agencies have an interest in protecting public health and enhancing energy security, and hosting fleet and public EVSE contributes to these aims.

Many fleets with PEVs will need electrical contractors to help install and maintain EVSE at fleet facilities. *Photo from Southern California Edison, NREL/PIX 19664*

Installing and Maintaining EVSE

EVSE installations range from simple to complex. This section provides a brief overview of the issues you will need to consider when installing EVSE, but it is not intended to be a comprehensive instructional guide. Before becoming involved with EVSE installations, you should receive training from a reliable organization (see *EVSE Training for Electrical Contractors* on page 18).

Complying with Regulations

EVSE installations must comply with local, state, and national codes and regulations. Appropriate permits may be required from the local building, fire, environmental, and electrical inspecting and permitting authorities.

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*) and from EVSE training (see *EVSE Training for Electrical Contractors*). EVSE is considered a continuous load by the National Electrical Code (NEC). Knowledge and application of the current NEC is required for a safe and code-compliant installation. NEC Article 625 contains most of the information applicable to EVSE.

If possible, consult PEV manufacturer guidance for information about the required EVSE and learn the specifications before the customer purchases 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 may require the proposed 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. Your customer may ask you to develop this plan.

Site Assessment and Planning

Thorough site assessment and planning by the electrical contractor and customer is essential to a successful EVSE installation. Following is a brief summary of the guidelines provided in Advanced Energy's *Charging Station Installation Handbook for Electrical Contractors and Inspectors*.

As the contractor, you should first assess the site characteristics and customer's charging needs. You can then assist the customer by making suggestions that will facilitate the installation process and by helping implement the suggestions. This includes contacting the utility, determining the current electrical service and upgrade requirements, and identifying all local regulations that apply to the installation (e.g., the permitting process and load calculation requirements). After helping with selection of appropriate EVSE and design of the charging site, you can prepare for installation via the following steps:

- ☐ Submit price quote for all work to customer and obtain customer approval
- ☐ Order necessary equipment (EVSE, wiring, breakers, panels, etc.)
- ☐ If necessary, have engineering calculations performed and stamped
- ☐ Complete site modification plan as necessary
- ☐ Apply and obtain approval for permit
- ☐ Complete service upgrade and/or new service assessment as necessary
- ☐ Coordinate work by all parties involved, including construction contractors and utility personnel
- ☐ Have utility infrastructure marked before installation begins (use "call before you dig" services)

General Installation and Inspection Process

Although installations will vary widely based on the type of site and user and the number and type of EVSE units, much of the installation and inspection process will be similar for all installations. These common steps, from Advanced Energy's *Charging Station Installation Handbook for Electrical Contractors and Inspectors*, are summarized below. See that document for additional details, requirements, and lessons learned.

- ☐ Post permit in visible location at site
- ☐ Excavate material to allow installation of wiring, conduit, and EVSE (remove drywall, insulation, pavers, concrete, etc., and perform hand digging, trenching, drilling, etc.)
- ☐ Run conduit from power source to station location (residential garages may not require conduit)
- ☐ Obtain rough inspection and correct deficiencies as needed
- ☐ Pull wires, including a neutral and a ground
- ☐ Prepare mounting surface per EVSE manufacturer instructions
- ☐ Mount EVSE
- ☐ Install impact-protection devices (e.g., bollards and/or wheel stops) as necessary
- ☐ Install electrical panels and sub-panels as necessary
- ☐ Have utility work performed as necessary, including new or upgraded service and/or meter
- ☐ Make electrical connection
- ☐ Obtain final inspection
- ☐ Verify EVSE performance
- ☐ Perform finish work

Residential Installations

Many PEV drivers will charge their vehicles overnight at home using Level 1 or Level 2 EVSE. Home-based EVSE frequently will be installed in garages, but outdoor installation and use are also safe, even if the PEV is being charged outdoors in the rain. Note that you can install indoor-rated EVSE in a garage, but outdoor installations require outdoor-rated EVSE. Charging at a multi-family residential complex requires additional considerations and may be more similar to public charging than to charging at a single-family home.

The NEC requires that all EVSE protect against shock, therefore Level 1 charging requires no special equipment installation if using a listed Level 1 charging cord and a properly installed 120-V outlet. This should be confirmed by a site assessment.

Level 2 charging requires the purchase and installation of Level 2 EVSE. It is best to install the Level 2 EVSE recommended by the manufacturer of the PEV that will use it.

Typically, home installation is relatively simple for homes that already have electrical service that can accommodate Level 2 EVSE. However, if an electrical service upgrade is required, the installation can be more complex. A site assessment and load calculation are required to make a proper and safe determination. This is important because many homes have 100-A service, and Level 2 EVSE can draw 30 to 80 A as a continuous load. Even a home with 200-A service may not have adequate power if the home has many other loads. An open slot in an electrical panel is not indicative of adequate service.

You and the customer should check with the electrical utility before installing EVSE or modifying the electrical system. Figure 6 summarizes the process for installing EVSE in a residential garage or carport. Also see page 12 for a home EVSE installation example in Raleigh, North Carolina.

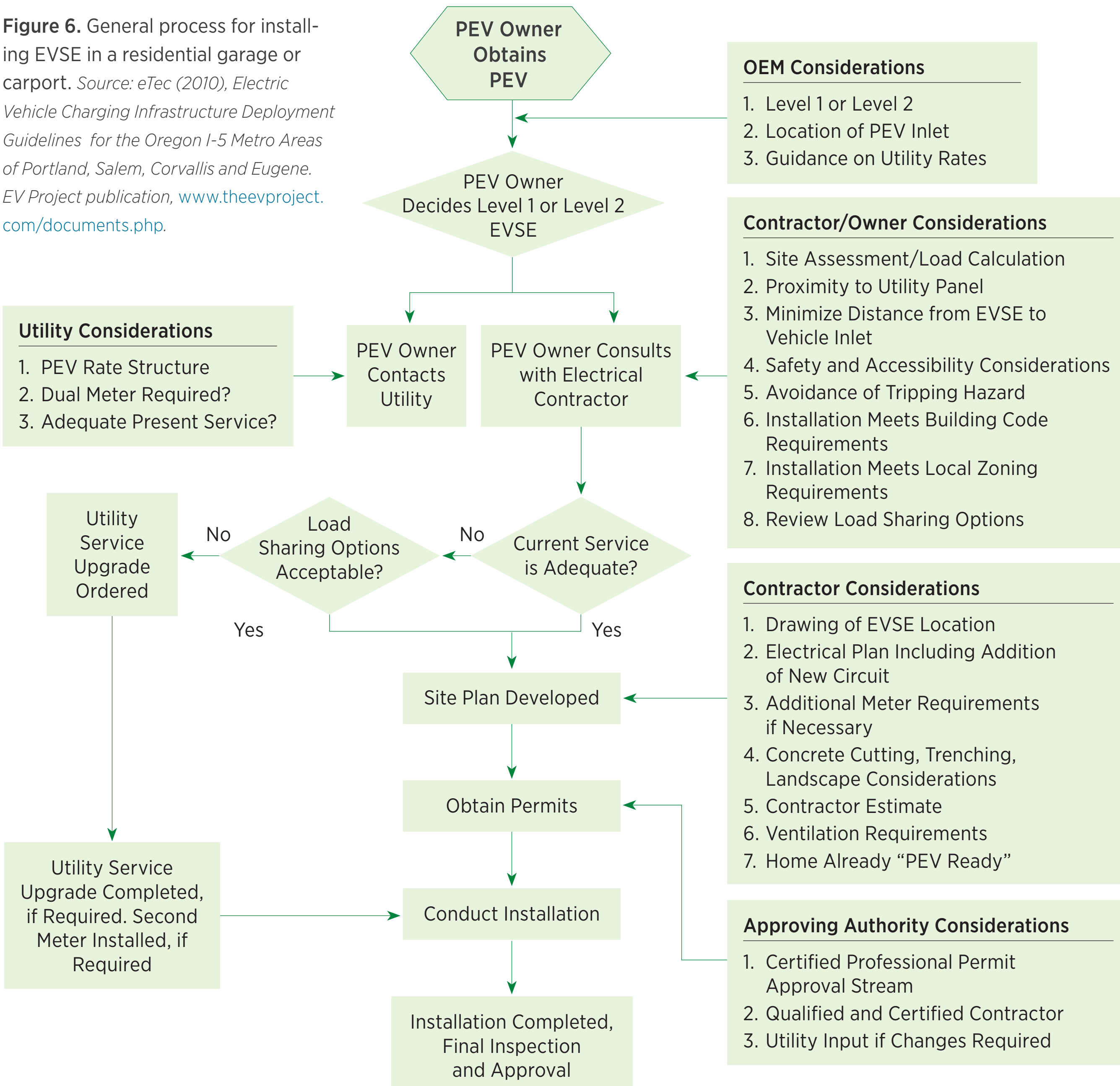

Figure 6. General process for installing EVSE in a residential garage or carport. *Source: eTec (2010), Electric Vehicle Charging Infrastructure Deployment Guidelines for the Oregon I-5 Metro Areas of Portland, Salem, Corvallis and Eugene. EV Project publication,* www.theevproject.com/documents.php.

Example Home EVSE Permitting and Installation Process: Raleigh, North Carolina

EVSE permitting and installation processes vary across states and municipalities. However, the key steps are similar in most areas that have planned for PEV introduction. Raleigh, North Carolina, is one of the nation's leaders in PEV deployment. Its entire assessment, permitting, installation, and inspection process for a simple home-based EVSE project can be completed in as few as two days (this time requirement varies substantially in other areas). The following is a brief description of the process. For additional examples, see the AFDC's Plug-In Hybrid and All-Electric Vehicle Deployment Case Studies (*www.afdc.energy.gov/plugin_case_studies*).

Step 1: Connecting Customers with EVSE Providers

PEV customers contact automakers, dealers, or their utility, which can provide a list of licensed electrical contractors to help with EVSE installation. For example, all Nissan Leaf purchases are facilitated through the Nissan Leaf website. The site sends information about Raleigh's Leaf customers to Nissan's EVSE provider, AeroVironment, and AeroVironment contacts the customers about EVSE options. As more vehicle choices enter the Raleigh market, the manufacturers of those vehicles likely will partner with EVSE providers to serve their customers.

Step 2: Assessing a Customer's Site

PEV customers can obtain a home assessment from an electrical contractor in an EVSE provider's preferred-contractor network (such as AeroVironment's network for Nissan Leaf customers) or any other licensed electrical contractor to determine whether the capacity of their electrical panel is adequate for installation of EVSE. Results of a survey by Raleigh's utility, Progress Energy, indicate that Level 2 EVSE could be installed in the majority of homes without upgrades to the homes' utility service. However, informing the local electric utility about EVSE installation is still essential.

Step 3: Getting a Permit

The licensed electrical contractor or EVSE customer/homeowner visits one of two City of Raleigh inspection centers to obtain a permit. The process to apply for and receive a permit takes approximately one hour and costs $74.

Photo from iStock/9350517

Step 4: Installing EVSE

The licensed electrical contractor installs the EVSE. In the cases in which a utility service upgrade is required, the electrical contractor or customer contacts Progress Energy to coordinate the upgrade. The customer can give authority to Progress Energy to work directly with the electrical contractor, which can expedite the process.

Step 5: Inspecting the Installation

The licensed electrical contractor or customer/homeowner calls the City of Raleigh to schedule an inspection. If the call is received by 4 p.m., the inspection is performed the next day. The EVSE is approved for use as soon as it passes the inspection.

Step 6: Connecting with the Grid

Progress Energy has been an active participant in Raleigh's PEV efforts. Through modeling and planning, it is confident that Raleigh's current grid can manage near-term EVSE-related demand. Residential electrical equipment, such as EVSE, is not metered separately, so energy used to charge a PEV is simply added to a customer's electricity bill. However, customers can opt into time-of-use electric rates on a whole-house basis, which could promote off-peak PEV charging.

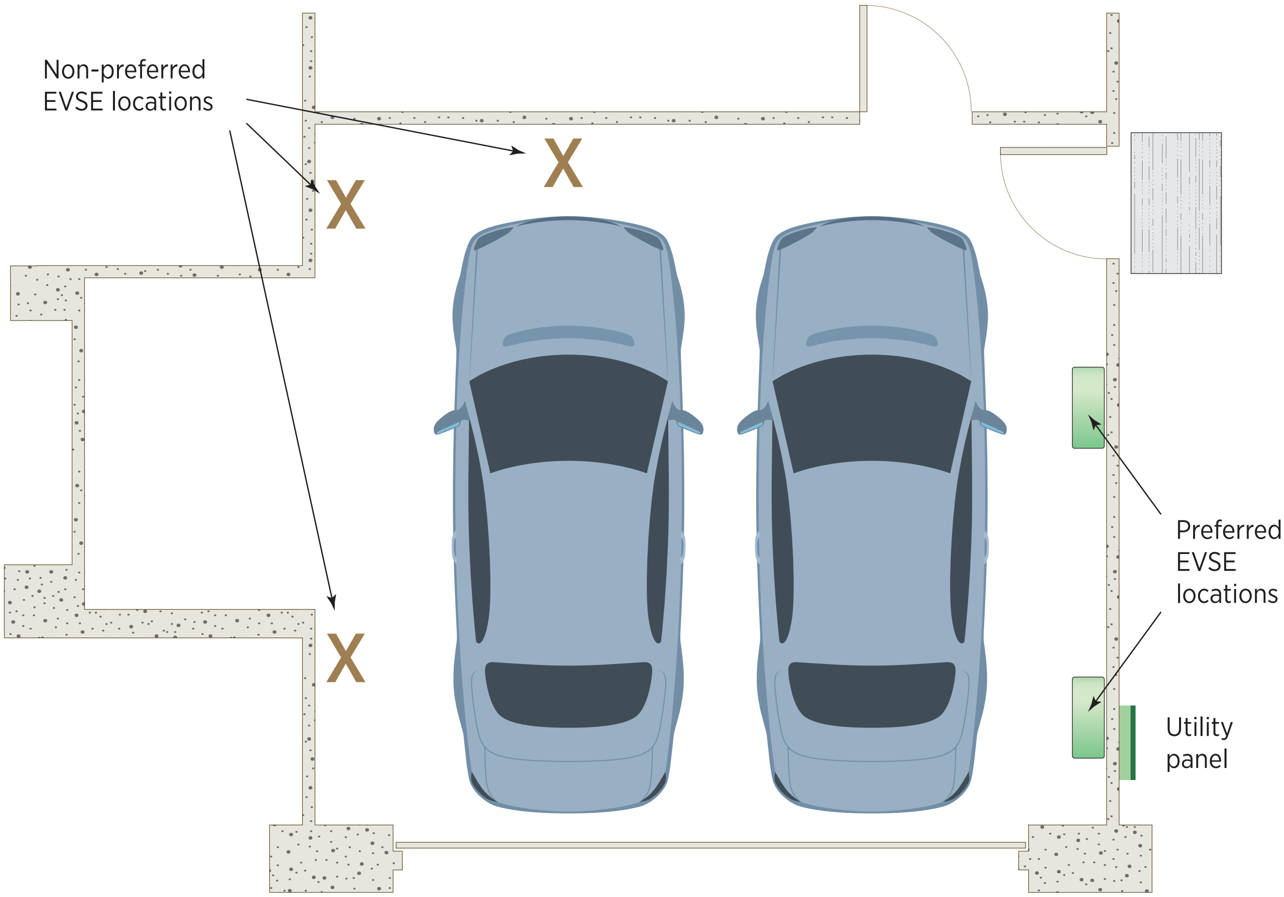

Figure 7. EVSE installation points to avoid tripping over the cord. *Source: eTec (2010), Electric Vehicle Charging Infrastructure Deployment Guidelines for the Oregon I-5 Metro Areas of Portland, Salem, Corvallis and Eugene. EV Project publication,* www.theevproject.com/documents.php. *Illustration by Dean Armstrong, NREL*

The safety risks of installing and using home EVSE are low but somewhat different than those associated with other large appliances like clothes dryers, because charging a PEV is a continuous load. The EVSE wall unit should be protected from contact with the vehicle —a wheel-stop can be useful for this purpose. The EVSE wall unit also should be positioned to minimize the hazard of tripping over the power cord. In general, this means keeping the cord out of walking areas (Figure 7) and positioning the wall unit as closely as possible to the vehicle's electrical inlet. Another option is to install a listed and labeled overhead support that keeps the cord off the floor. EVSE cords are built to withstand some abuse—even being run over by a car—and the power flow through the cord is cut off when the vehicle is not charging.

Non-residential Installations

A variety of non-residential locations can accommodate EVSE, including vehicle fleet facilities, businesses that offer charging to their employees, commercial parking lots and garages, retail stores, pay-for-use charging stations, and government-sponsored free charging stations. Figures 8 and 9 summarize the processes for installing fleet and public EVSE, and the following sections address some of the considerations related to installing and operating EVSE at non-residential facilities.[2]

*2. These recommendations are primarily summarized from Pacific Gas and Electric's Electric Vehicle Supply Equipment Installation Manual (*http://evtransportal.org/evmanual.pdf*) 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.*

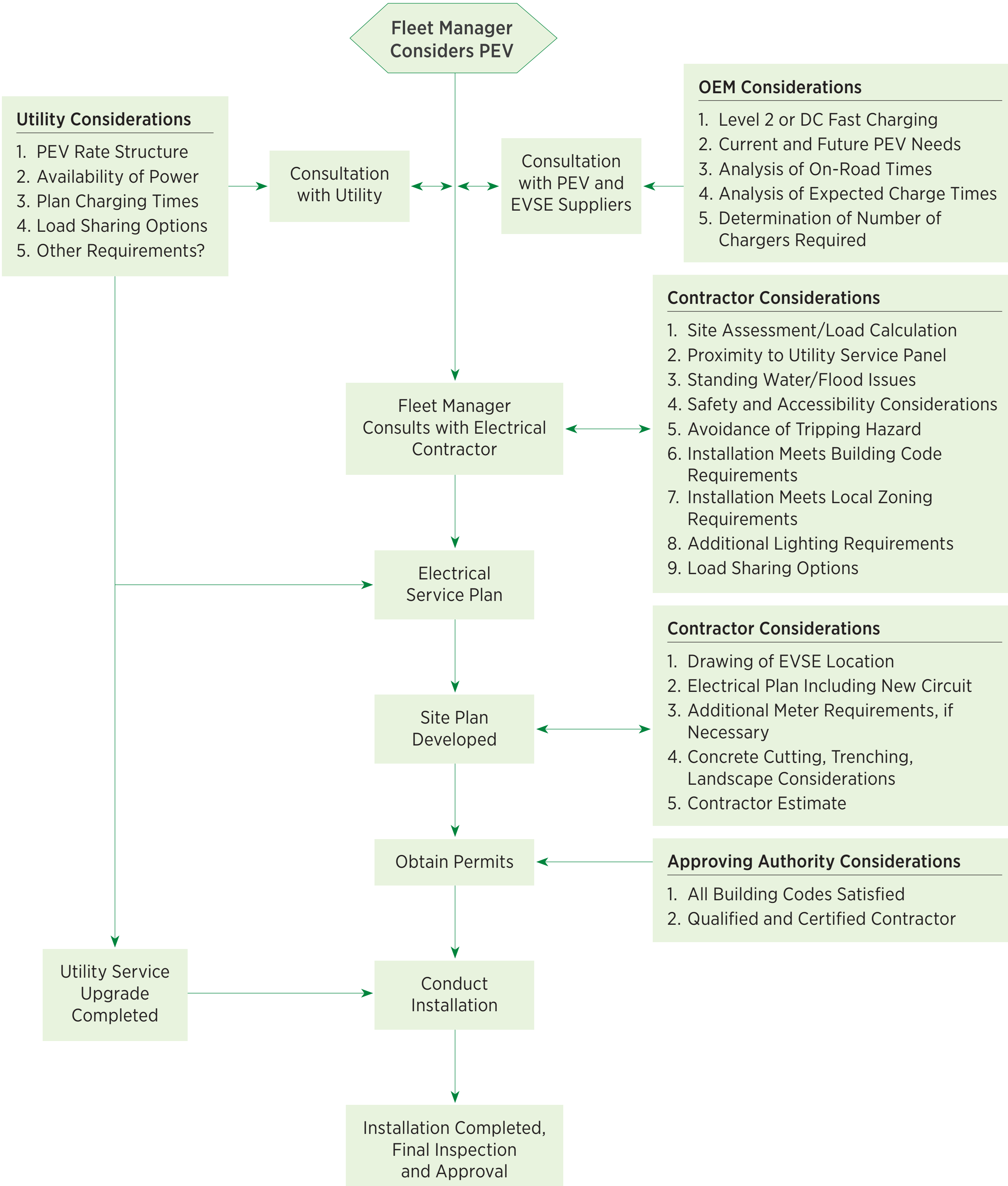

Figure 8. General process for installing EVSE at a fleet facility. *Source: eTec (2010), Electric Vehicle Charging Infrastructure Deployment Guidelines for the Oregon I-5 Metro Areas of Portland, Salem, Corvallis and Eugene. EV Project publication (www.theevproject.com/documents.php).*

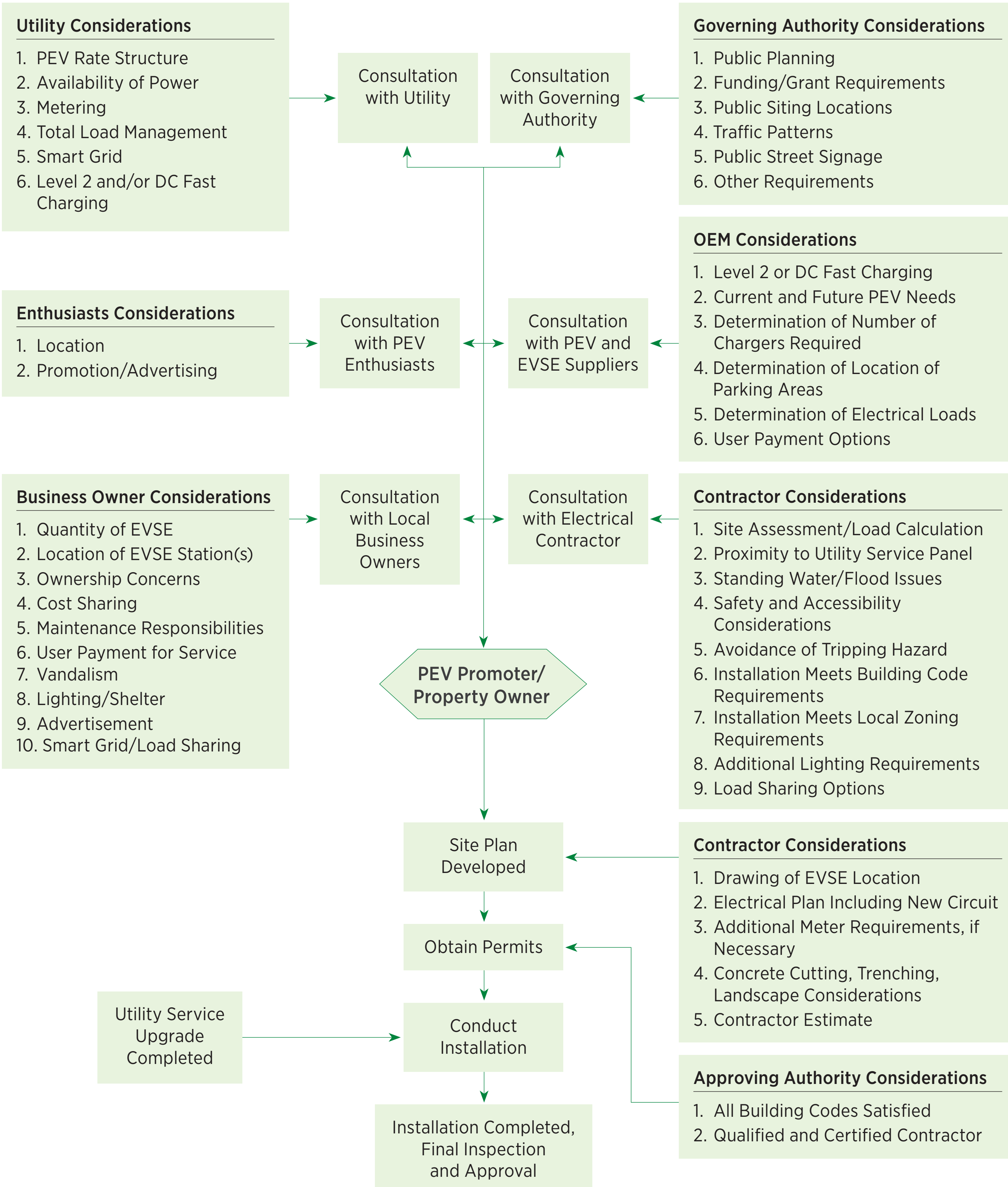

Figure 9. General process for installing EVSE at a public facility. *Source: eTec (2010), Electric Vehicle Charging Infrastructure Deployment Guidelines for the Oregon I-5 Metro Areas of Portland, Salem, Corvallis and Eugene. EV Project publication (www.theevproject.com/documents.php).*

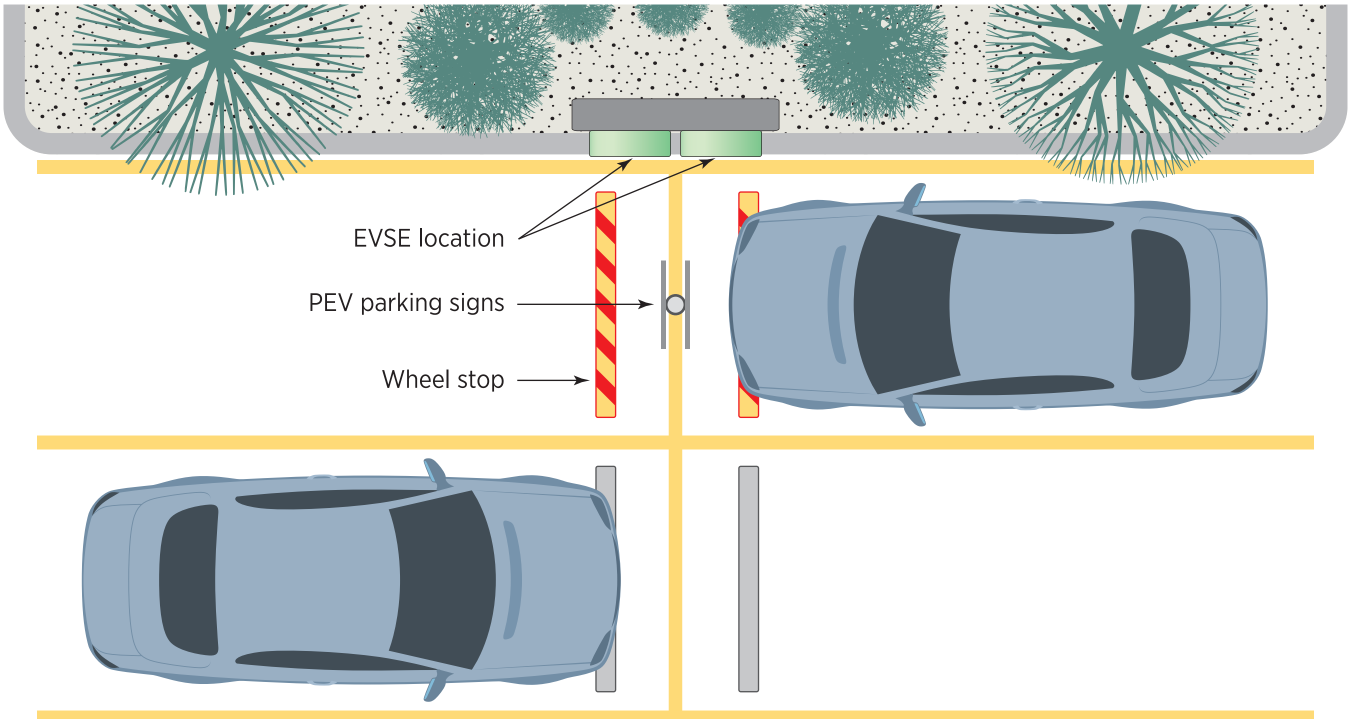

Figure 10. Example public charging station design showing EVSE, wheel stop, and sign locations. *Source: eTec (2010), Electric Vehicle Charging Infrastructure Deployment Guidelines for the Oregon I-5 Metro Areas of Portland, Salem, Corvallis and Eugene. EV Project publication (www.theevproject.com/documents.php). Illustration by Dean Armstrong, NREL*

Amount and Type of EVSE

For charging stations that will be serving multiple vehicles, it is important to determine EVSE requirements over at least the next several years. This should include planned PEV acquisitions for fleet sites and projected charging volume increases for public sites. 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 than to modify the site later. Electricity and charging-time needs can be analyzed by plotting electricity-use and time requirements for all PEVs served. This will enable assessment of electrical-upgrade needs and determination of the appropriate number and type of EVSE units.

Convenience

Site EVSE and associated PEV parking as close as possible to the electric service while accommodating other activities at the site, keeping 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 PEVs with these types of batteries are charged in an enclosed space, there must be adequate ventilation, which may include installation of fans, ducts, and air handlers. Depending on the installation, the NEC also may 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 10). 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

For public stations that require payment for their charging services, a number of payment models are being considered. In the near future, drivers might swipe their credit card, enter a charging account number, or even insert coins or bills to charge their PEVs. In many cases, drivers may only be charged a single fee for parking and charging. 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 public EVSE should be able to report it or contact support. For example, the host's telephone number or the number of a service that monitors multiple public stations could be posted, or customers needing help could be directed to a specific office or store location.

Engineering and Construction

Because EVSE installations involve specialty equipment, electrical work, and civil engineering work, well-qualified contractors with experience in the relevant engineering and construction areas are needed. The condition and location of existing electrical equipment will determine the complexity of the required electrical installations.

Installation Costs

EVSE installation costs vary considerably. The City of Houston reported installation costs of $860 to $7,400 per unit, not including the cost of the EVSE 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. According to the Rocky Mountain Institute's Project Get Ready, the cost of Level 2 EVSE is approximately $1,000 to $7,000 (before incentives) depending on the level of sophistication.[4] DC fast-charging EVSE units are projected to cost

3. See the Project Get Ready website (www.rmi.org/pgr_resources#infrastructure).

$20,000 to $50,000, but manufacturers are working to decrease costs substantially.

Discounts and incentives can lower costs to the customer. State, city, or utility incentives may be available for a given project. To find current incentives, search the AFDC's Federal and State Incentive and Laws database (*www.afdc.energy.gov/afdc/laws*). As described in the *PEV Benefits* section, operating costs are lower for PEVs than for conventional vehicles, which also helps offset EVSE costs.

Electric Rates

Charging PEVs during peak electricity demand periods may move a customer into a higher rate category and result in higher electricity costs. It is important that the customer discusses with his or her utility the effects of charging on electricity rates and loads. The advanced capabilities of some EVSE products can be useful for optimizing load management.

Maintaining EVSE

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.

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4. *From Rocky Mountain Institute (2009). Plugging In: A Stakeholder Investment Guide for Public Electric-Vehicle Charging Infrastructure (www.rmi.org/pgr_resources#infrastructure).*

EVSE Training for Electrical Contractors

Establishing a well-trained, nationally distributed group of electrical contractors able to install PEV infrastructure is essential to the widespread deployment of PEVs. To meet this need, a number of organizations offer PEV infrastructure training for electrical contractors. One such organization is the Electric Vehicle Infrastructure Training Program (EVITP).

EVITP is a non-profit partnership of PEV stakeholders, including automakers, utilities, EVSE manufacturers, energy storage device manufacturers, electrical inspectors, electrical contractors, electrical workers, and first responders. It was established to provide a structured platform to facilitate training and certification for EVSE installation in the residential, commercial, and public markets. The EVITP training program addresses the technical, safety, and performance requirements of its stakeholders. Its goal is to create a nationally recognized training standard for EVSE installation, commissioning, maintenance, and customer service.

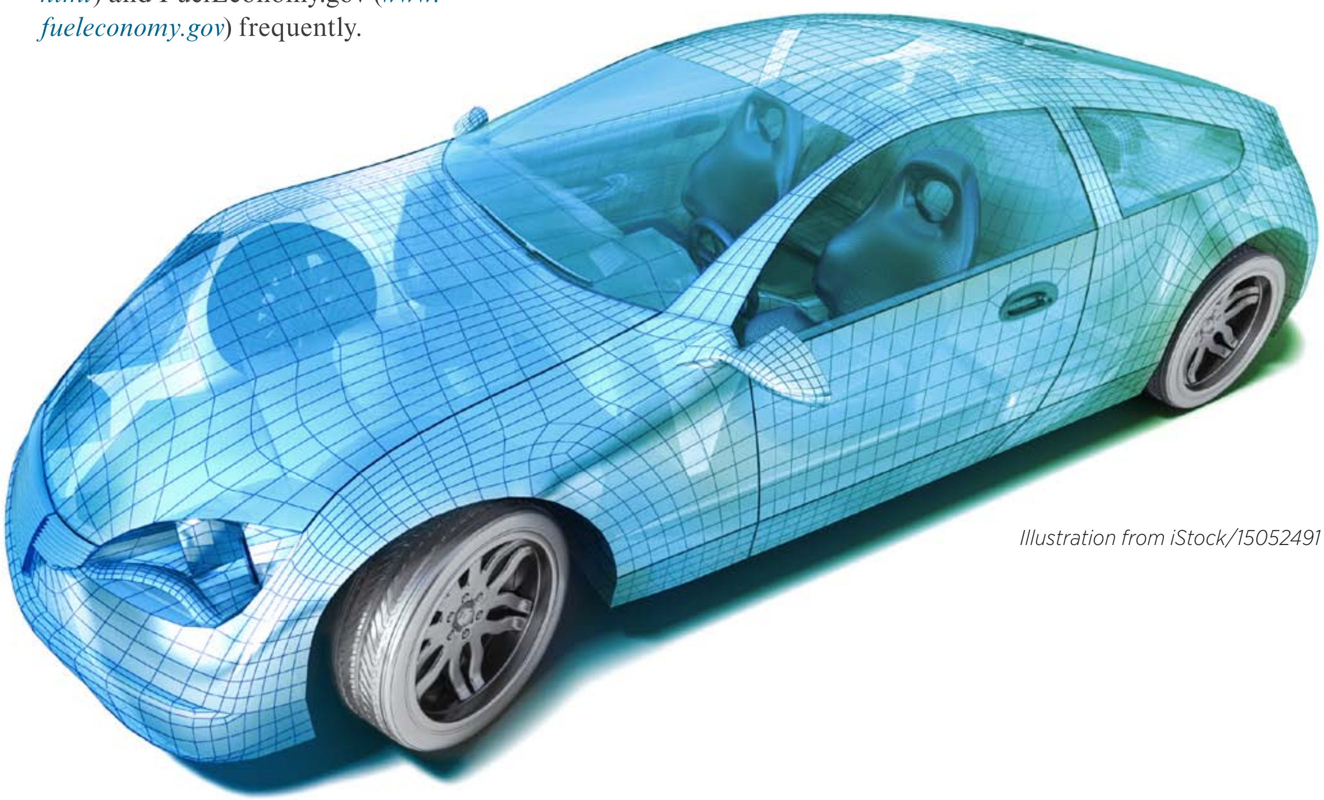
EVITP's training is offered at community colleges and electrical training centers nationwide and taught by experienced instructors. To learn more, contact EVITP at *Info@EVITP.org*.

EVITP Phase One Class List of Topics

- Overview of Electric Vehicles
- Types of Electric Vehicles – Present and Future
- Electric Vehicle Manufacturers
- EVSE Manufacturers
- Electrical Vehicle Charging Stations and Charging Load Requirements
- Electrical Vehicle Charging Site Assessment
- Electric Vehicle Rules and Regulations
- Code Officials and Inspection
- First Responders
- Utility Policy and Integration
- Renewable Energy and Electric Vehicles
- Customer Code of Excellence/Contractor's Role, Electrician's Role
- Electrical Codes, Electrical Safety Requirements, Other Regulations, and Standards
- Electric Vehicle Charging Installations
- Field Installation Practicum (Lab)
- Electric Vehicle Certification, Phase One

Electrifying the Future

You now know the basics about PEVs and charging infrastructure. In a time of volatile oil prices and heightened environmental concerns, your existing—and potential new—customers may see PEVs as an affordable and convenient way to reduce operating costs, demonstrate environmental responsibility, and perhaps even make money. The number of available PEV models and the number of PEVs on the street are growing rapidly, as is the need for additional charging infrastructure. Now may be a good time to get infrastructure training and be part of the electric transportation future. To keep up with all the new PEV developments, visit the AFDC (*www.afdc.energy.gov/afdc/vehicles/electric.html*) and FuelEconomy.gov (*www.fueleconomy.gov*) frequently.



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Clean Cities Can Help

If you need assistance with your PEV projects, 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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