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

Plug-In Electric Vehicle Handbook

for Consumers

Clean Cities
U.S. Department of Energy

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Photo from Kathy Boyer, Triangle Clean Cities Coalition, NREL/PIX 18520

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Introduction

Photo from Atlantic County Utilities Authority, NREL/PIX 18311

You've heard about the new generation of plug-in electric vehicles (PEVs) like the Chevy Volt and Nissan Leaf. Perhaps you're considering buying one, but you're wondering how they measure up to conventional vehicles. This handbook is designed to answer your basic questions and point you to the additional information you need to make the best decision.

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 cars with internal combustion engines (ICEs) rose. The ICE vehicle had a longer driving range, petroleum fuel costs were declining, and the electric starter and manufacturing assembly line improved the affordability and usability of ICE vehicles. Gasoline- and diesel-powered ICE vehicles ended up dominating transportation in the 20th century.

However, concerns about the environmental impacts of 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 it at the forefront of that decade's deployment of PEVs, such as the General Motors EV1, Chrysler EPIC, and Ford Electric Ranger. 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 commercialization of hybrid electric vehicles (HEVs), which integrate an ICE or other type of propulsion 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 types of propulsion sources) and large, grid-chargeable batteries that enable 10- to 40-mile all-electric driving ranges. Advanced technologies have also created a new breed 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 most performance categories. They are safe and convenient, and they can save you money while slashing emissions and increasing the nation's energy security.

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.

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 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.

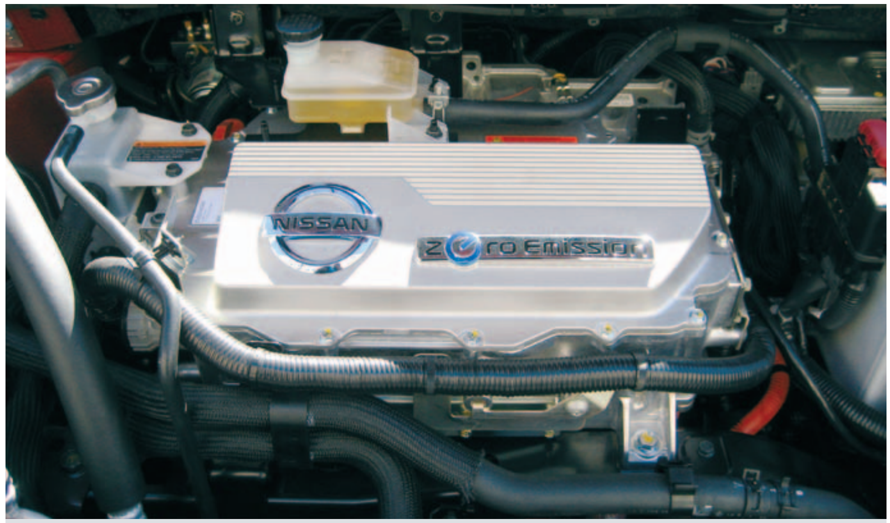
ICEs (internal combustion engines) generate mechanical power by burning a liquid fuel (such as gasoline, diesel, or a biofuel) or a gaseous fuel (such as compressed natural gas). They are the dominant power source for on-road vehicles today.

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 alternative fuel to power an ICE or other propulsion source.

PEV Basics

A PEV has the ability to charge from an off-board electric power source—PEVs can be "plugged in." This feature distinguishes them from HEVs, which supplement ICE power 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 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. EVs use no petroleum-based fuel while driving and produce no tailpipe emissions.

Mainstream EVs are targeting an approximately 100-mile range on a fully charged battery. The range depends in part on driving conditions and habits. According to the U.S. Federal Highway Administration, 100 miles of range is sufficient for more than 90% of all household vehicle trips in the United States.

For longer trips, EVs must be charged again. The time required for charging 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 Your PEV* section.

Neighborhood electric vehicles (NEVs), also called low-speed vehicles, are a type of EV with limitations. NEVs are commonly used for neighborhood commuting, light hauling, and delivery. They are often restricted 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.

Plug-In Hybrid Electric Vehicles (PHEVs)

PHEVs (sometimes called extended range electric vehicles or EREVs) use batteries to power an electric motor and use a fuel, such as gasoline, 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. On an empty battery, PHEVs perform like HEVs, consuming less fuel and producing fewer emissions than similar ICE vehicles.

PHEVs have larger battery packs than HEVs, which provide an all-electric driving range of about 10 to 40 miles. During typical urban driving, most of a PHEV's power can be drawn from stored electricity. For example, you might drive your PHEV to and from work on all-electric power, plug in to charge it at night, and be ready for another all-electric commute the next day. The ICE powers the vehicle when the battery is mostly depleted, during rapid acceleration, or when intensive heating/air conditioning is required.

Like EVs, PHEVs can be plugged into the grid and charged, though the time required to charge depleted batteries is typically lower for PHEVs because most have smaller battery packs than EVs. In addition, PHEVs are charged by their ICEs and regenerative braking.

PHEV fuel consumption depends on the distance driven between battery charges. For example, if the vehicle is

PHEV System Designs

There are two categories of PHEV systems, which differ in how they combine power from the electric motor and the engine.

- **Parallel** PHEVs connect the engine and the electric motor to the wheels through mechanical coupling. Both the electric motor and the engine can drive the wheels directly.
- **Series** PHEVs use only the electric motor to drive the wheels. The ICE is used to generate electricity for the motor. The Chevy Volt uses a slightly modified version of this design: The electric motor drives the wheels almost all of the time, but the vehicle can switch to work like a parallel PHEV at highway speeds when the battery is depleted.

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 is possible to use only electric power.

Factors That Affect All-Electric Range

As with conventional vehicles, the efficiency and driving range of PEVs varies substantially based on driving conditions and driving habits. Extreme outside temperatures tend to reduce range because more energy must be used to heat or cool the cabin. In addition, cold batteries do not provide as much power as warm batteries. The use of electrical equipment, such as seat heaters, can reduce range. High driving speeds reduce range because more energy is required to overcome the increased air resistance. Aggressive driving—rapid acceleration and deceleration—reduces range compared with smooth acceleration and deceleration. In addition, hauling heavy loads or driving up significant inclines reduces range. The Nissan Leaf website (*www.nissanusa.com/leaf-electric-car*) provides examples of driving conditions and resulting ranges for the Leaf EV, as well as tips to help you maximize your range. PHEVs are affected similarly by these factors, with the added characteristic that the ICE is activated when driving demands exceed the capacity of the all-electric propulsion system.

PEV Benefits

What can PEVs do for you? As you'll see here, they can save you money and make your life easier—while helping keep your community, your country, and your world clean and secure.

High Fuel Economy, Low Fuel Cost

PEVs can reduce your fuel costs dramatically. Because PEVs rely in whole or part on electric power, their fuel economy is measured differently than in conventional vehicles. You might see it stated as miles per gallon of gasoline equivalent (mpge). Or it may be broken down by kilowatt-hours (kWh) per 100 miles for EVs and the electric mode of PHEVs, and miles per gallon (mpg) for the ICE mode of PHEVs. Depending on how they're driven, today's EVs (or PHEVs in electric mode) can exceed 100 mpge. In addition, PHEVs in ICE mode can attain fuel economies similar to highly efficient HEVs.

This high efficiency translates to low fuel cost. In electric mode, fueling a PEV costs only 3 to 5 cents per mile. In contrast, fueling a gasoline car that has a fuel economy of 27.5 mpg costs about 14 cents per mile. If you drive 15,000 miles per year, you could save $1,300 to $1,600 per year in fuel costs by driving a PEV in all-electric mode instead of driving a conventional gasoline car.[1] If your utility offers lower electric rates for charging during off-peak times, such as at night, you may be able to reduce your PEV fuel costs even further by charging during these times.

Flexible Fueling

All your life you've had to drive to a gas station to fuel your car, but with a PEV you have other options. Most conveniently, you can transform your home into your personal electric-charging station, capable of recharging your PEV every night (see the *Charging Your PEV* section). In addition, a network of public PEV charging stations is being established, which will enable you to top off your PEV's batteries in a few hours while you work or shop.

1 *Fuel cost savings depend on electricity and gasoline prices, as well as vehicle types and driving patterns. This example compares a gasoline car with a fuel economy of 27.5 mpg (combined city and highway) assuming a gasoline cost of $3.75/gallon versus PEVs operated in electric mode at 3 to 5 cents per mile (which assumes an electricity cost of 11 cents/kWh).*

The old "gas station" concept also will remain an option—with an electric twist. Public fast-charging stations are being established, which can boost your batteries in less than 30 minutes. Of course, if you own a PHEV, you'll be able to fuel with gasoline (or possibly other fuels in the future) when necessary at any gas station.[2]

High Performance

If you're like many people, the thought of electric-powered vehicles might still conjure up images of something like a golf cart. Rest assured, today's PEVs are state-of-the-art highway vehicles ready to match or surpass the performance of conventional gasoline and diesel vehicles. In addition, PEVs in all-electric mode are much quieter than conventional vehicles, and, unlike conventional vehicles, PEVs produce maximum torque and smooth acceleration from a full stop.

In all-electric mode, PEVs produce no tailpipe emissions. PEV lifecycle emissions are minimized when their source of electricity comes from nonpolluting resources like wind and sunlight. *Photo by Mike Linenberger, NREL/PIX 15141*

Low Emissions

PEVs can help keep your town and your world clean. There are two general categories of vehicle emissions: direct and lifecycle. Direct emissions are emitted through the tailpipe, through evaporation from the fuel system, and during the fueling process. Direct emissions include smog-forming pollutants, such as nitrogen oxides, other pollutants harmful to human health, and greenhouse gases (GHGs), primarily carbon dioxide. When PEVs are driven in all-electric mode, they produce zero direct emissions—a great pollution-reduction benefit for urban areas. PHEVs do produce evaporative emissions and, when running on gasoline, tailpipe emissions. However, because their gasoline or diesel operation is more efficient than comparable conventional vehicles, PHEVs yield direct emissions benefits even when relying on ICE mode.

Lifecycle emissions include all emissions related to fuel and vehicle production, processing, distribution, use, and recycling/disposal. For example, for a conventional gasoline vehicle, emissions are produced at each stage: extracting petroleum from the ground, refining it to gasoline, distributing the fuel to stations, and burning it in vehicles. Similarly, emissions are produced when extracting raw materials for the production of vehicles; manufacturing, distributing, maintaining, and operating the vehicles; and retiring them. Like direct emissions, lifecycle emissions include a variety of harmful pollutants and GHGs. All vehicles produce substantial lifecycle emissions, and calculating them is complex. However, PEVs typically have a lifecycle emissions advantage because most categories of emissions are lower for electricity generation than for ICEs running on gasoline or diesel. If PEVs use electricity generated by nonpolluting sources, PEV lifecycle emissions are minimized.

Energy Security

PEVs can help make the United States more energy independent. Today, our cars—and the highly mobile way of life they support—depend almost entirely on petroleum. However, U.S. petroleum production hasn't kept pace with demand, so we import more than 60% of our petroleum. The transportation sector accounts for two-thirds of our petroleum consumption. With much of the world's petroleum reserves located in politically volatile countries, our reliance on petroleum makes us vulnerable to price spikes and supply disruptions. PEVs help reduce this threat because almost all U.S. electricity is produced from domestic coal, nuclear, natural gas, and renewable sources.

2 *In the future, PHEVs may be capable of fueling with alternative fuels, such as E85 (a fuel composed of approximately 85% ethanol and 15% gasoline), compressed natural gas, or hydrogen.*

Today's EVs can typically travel about 100 miles on a full charge, sufficient for most commutes and other household trips. *Photo from Margaret Smith, DOE, NREL/PIX 19545*

Buying the Right PEV

As with any vehicle purchase, you should assess your driving requirements and price range before choosing a PEV. Then, you can compare your "wish list" with the available PEVs.

Driving Requirements

Many of your PEV driving requirements are similar to what they would be for any vehicle. Do you want two seats or four? A sedan or a hatchback? A commuter car or a long-distance cruiser? But PEVs raise other questions as well. Most importantly, do you want an EV, which typically drives about 100 miles on electricity, or a PHEV, which may have a much shorter all-electric range but can use gasoline for extended driving? Compare the fuel economy and range of PEVs and conventional vehicles using FuelEconomy.gov (*www.fueleconomy.gov*).

Availability

At the time this handbook was written, only a few light-duty PEVs were commercially available. PEV technology is only 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, visit the Light-Duty Vehicle Search on the Alternative Fuels and Advanced Vehicles Data Center (AFDC) at *www.afdc.energy.gov/afdc/vehicles/search/light*. Learn about anticipated PEV introductions from the Electric Drive Transportation Association (*www.electricdrive.org/ht/d/sp/i/11551/pid/11551*) and FuelEconomy.gov (*www.fueleconomy.gov/feg/phevnews.shtml* and *www.fueleconomy.gov/feg/evnews.shtml*).

In addition to limited availability 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 be available in all 50 states by the end of 2011. Because of the popularity and limited initial production of PEVs, you may also have to sign onto a waiting list to get one.

Example PEV Prices, 2011*

Chevy Volt (PHEV)	$40,280
Nissan Leaf (EV)	$32,780

** Manufacturer's suggested retail prices, before incentives.*

Prices and Incentives

Purchase prices for today's PEVs are considerably higher than for similar conventional vehicles. However, you can reduce the cost of owning a PEV through lower operating costs (see the *PEV Benefits* section) and government incentives.

The federal Qualified Plug-In Electric Drive Motor Vehicle Tax Credit is available for PEV purchases through 2014 (or until PEV manufacturers meet a certain level of mass production). It provides a tax credit of $2,500 to $7,500 for new PEV purchases, with the specific credit amount determined by the size of the vehicle and the capacity of its battery. All of the currently available light-duty PEVs qualify for a $7,500 credit.

Depending on where you live, you may also be eligible for PEV incentives from your state, city, or utility. To find relevant incentives, search the AFDC's Federal and State Incentives and Laws database (*www.afdc.energy.gov/afdc/laws*). For even more information specific to where you live, contact your local Clean Cities coalition (*www.afdc.energy.gov/cleancities/coalitions/coalition_locations.php*) or State Energy Office (*www.naseo.org/members/states/default.aspx*).

Driving and Maintaining Your PEV

PEVs are at least as easy to drive and maintain as conventional vehicles, but some special considerations apply.

Vehicle Maintenance

Because PHEVs have ICEs, maintenance requirements for this system are similar to those in conventional vehicles. However, the PEV electrical system (battery, motor, and associated electronics) likely will require minimal scheduled maintenance. Because of regenerative braking, brake systems on PEVs typically last longer than on conventional vehicles. In general, EVs require less maintenance than conventional vehicles because there are usually fewer fluids to change and far fewer moving parts.

Battery Life

Like the ICEs in conventional vehicles, the advanced batteries in PEVs are designed for extended life but will wear out eventually. Currently, Nissan and General Motors are offering 8-year/100,000 mile warranties for the batteries in the Leaf and the Volt. Check with your PEV dealer for specific information about battery life and warranties. Although manufacturers have not published pricing for replacement batteries, if the batteries need to be replaced outside the warranty, it is expected to be a significant expense. Battery prices are expected to decline as the benefits of technological improvements and economies of scale are realized.

Safety

PEVs must undergo the same rigorous safety testing and meet the same safety standards required for conventional vehicles sold in the United States. In addition, a PEV-specific standard sets requirements for limiting chemical spillage, securing batteries during a crash, and isolating the chassis from the high-voltage system to prevent electric shock. PEV manufacturers have designed their vehicles with safety features that deactivate the high-voltage electric system in the event of an accident. In addition, EVs tend to have a lower center of gravity than conventional vehicles, making them less likely to roll over while often improving ride quality. One safety concern specific to PEVs is their silent operation: pedestrians may be less likely to hear a PEV than a conventional vehicle.

PEVs must meet the same safety standards that apply to conventional vehicles. Because these vehicles are much quieter than conventional vehicles, drivers should exercise caution in areas with pedestrian traffic. *Photo from George Beard, Portland State University, NREL/PIX 19557*

The National Highway Traffic Safety Administration is studying ways to address this issue, such as requiring PEVs to emit audible sounds at low speeds. This option is already available on some PEVs, including the Volt and Leaf. In any case, you should use extra caution when driving your PEV in pedestrian areas.

Charging Your PEV

Charging your PEV requires plugging in to electric vehicle supply equipment (EVSE). EVs must be charged regularly, and charging PHEVs regularly will minimize the amount of gasoline they consume. There are various types of EVSE, which differ based on how quickly they can charge a vehicle, and EVSE can be accessed at home or in public. This section describes the EVSE options so you can choose what's best for you.

Types of Charging Equipment (EVSE)

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

EVSE for PEVs is classified into several categories by the maximum amount of power provided to the battery. Two types—Level 1 and Level 2—provide alternating-current (AC) electricity to the vehicle, with the vehicle's onboard equipment 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 of EVSE, as well as the type of battery, how depleted it is, and its energy capacity.

EVs have more battery capacity than PHEVs, so charging a fully depleted EV takes longer than charging a fully depleted PHEV.

Level 1

Level 1 EVSE provides charging through a 120-volt (V) AC plug and requires a dedicated branch circuit. Most, if not all, PEVs will come with a portable Level 1 EVSE cordset that does not require installation of additional charging equipment. Typically, on one end of the cord is a standard, three-prong household plug. On the other end is a connector, which plugs into the vehicle.

Level 1 works well for charging at home, work, or 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.

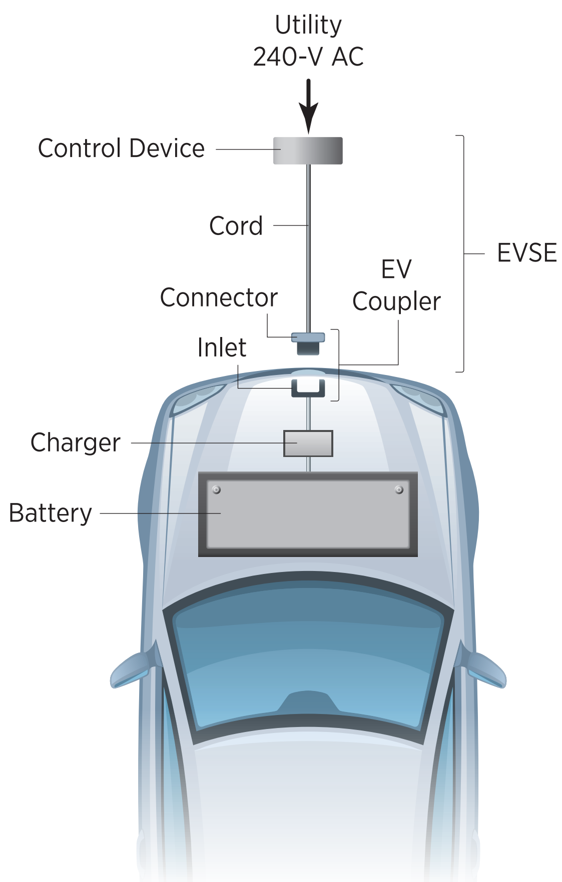


Figure 1. Level 2 Charging Diagram. *Source: eTec (2010), Electric Vehicle Charging Infrastructure Deployment Guidelines for the Oregon I-5 Metro Areas of Portland, Salem, Corvallis and Eugene. EV Project publication,* www.theevproject.com/documents.php. *Illustration by Dean Armstrong, NREL*

Level 2

Level 2 EVSE offers charging through a 240-V, AC plug and requires installation of charging equipment and a dedicated electrical circuit (Figure 1). Because most houses have 240-V service available and Level 2 EVSE can easily charge a typical EV battery overnight, this will be a common installation for single-family houses. 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. A DC fast charger can add 60 to 80 miles of range to a PEV in 20 minutes.

Inductive Charging

Inductive-charging EVSE, which uses an electromagnetic field to transfer electricity to a PEV, 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.

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:

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

Connectors and Plugs

Most modern EVSE and PEVs have a standard connector and receptacle (Figure 2). This connector is based on the SAE J1772 standard developed by SAE International. 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. To receive DC fast charging, most currently-available PEVs 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 3) as an option on 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 2. The standard EVSE connector fits into the standard receptacle. *Photo by Andrew Hudgins, NREL/PIX 17634*

Figure 3. 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*

Charging at a Single-Family Home

As a PEV driver, you likely will charge your vehicle overnight at home using Level 1 (for PHEVs) or Level 2 (for EVs and PHEVs) EVSE. Charging at a single-family home—typically in your garage—gives you the benefit of low, stable residential electricity rates. 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.

Installing EVSE in Your Home

Level 1 charging requires no special equipment installation, and most PEVs come standard with a portable Level 1 cordset. For Level 2 charging, you must purchase and install Level 2 EVSE. The price of currently available Level 2 residential EVSE varies but typically is in the range of $1,000 to $2,000 before incentives. You should choose the Level 2 EVSE recommended by the manufacturer of your PEV. A 30% federal tax credit (up to $1,000) is available to consumers who purchase qualified residential fueling equipment through the end of 2011. To find current incentives, search the AFDC's Federal and State Incentives and Laws database (*www.afdc.energy.gov/afdc/laws*).

The cost of installing Level 2 EVSE varies considerably. Typically, installation is relatively inexpensive for homes that already have electrical service that can accommodate Level 2 EVSE. However, if an electrical service upgrade is required, the installation cost can be substantial. Check with your utility and a trusted electrical contractor—and get cost estimates—before installing EVSE or modifying your electrical system. See the sidebar on the next page for an EVSE installation example in Raleigh, North Carolina.

Complying with Regulations

EVSE installations must comply with local, state, and national codes and regulations, and installation usually requires a licensed electrical contractor. Your contractor should know the relevant codes and standards and to check with the local planning department before installing EVSE. You should consult PEV manufacturer guidance for information about the required charging equipment and learn the specifications before purchasing equipment and electric services.

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, who can provide a list of licensed electricians to help with EVSE installation. For example, all Nissan Leaf purchases are facilitated through the Nissan Leaf website. The website 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 electrician in an EVSE provider's preferred-contractor network (such as AeroVironment's network for Nissan Leaf customers) or any other licensed electrician 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 encouraged.

Step 3: Getting a Permit

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

Step 5: Inspecting the Installation

The licensed electrician or customer/homeowner calls the City of Raleigh to schedule an inspection. If the call is received by 4:00 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 appliances, such as EVSE, are 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.

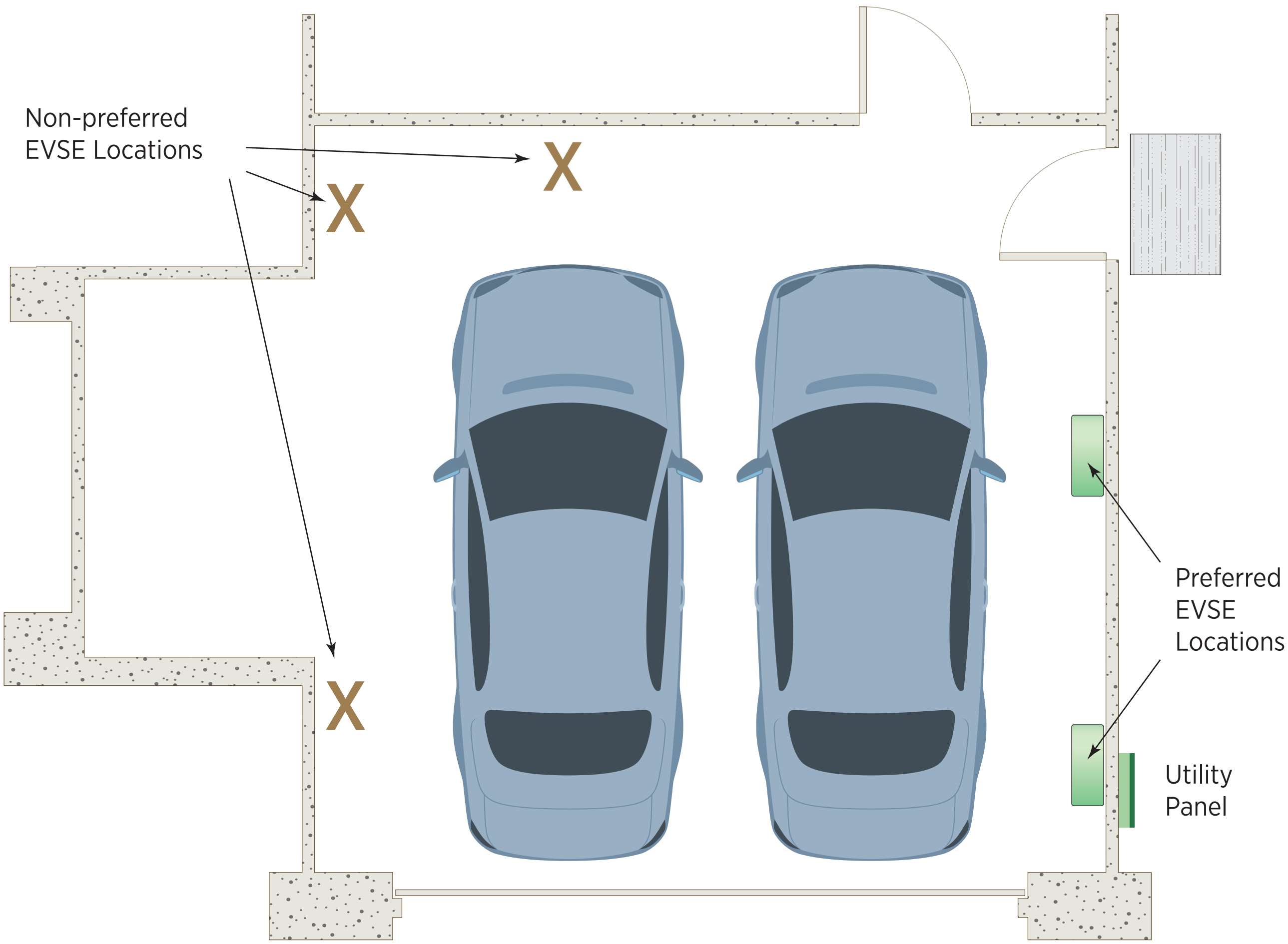


Figure 4. EVSE Installation Points to Avoid Tripping over the Cord. *Source: eTec (2010), Electric Vehicle Charging Infrastructure Deployment Guidelines for the Oregon I-5 Metro Areas of Portland, Salem, Corvallis and Eugene. EV Project publication,* www.theevproject.com/documents.php. *Illustration by Dean Armstrong, NREL*

Home EVSE Safety and Maintenance

The safety risks of installing and using home EVSE are very low, similar to those associated with other large appliances like clothes dryers. Home-based EVSE frequently will be installed in garages, but outdoor installation and use are also safe, even if you're charging your PEV outdoors in the rain.

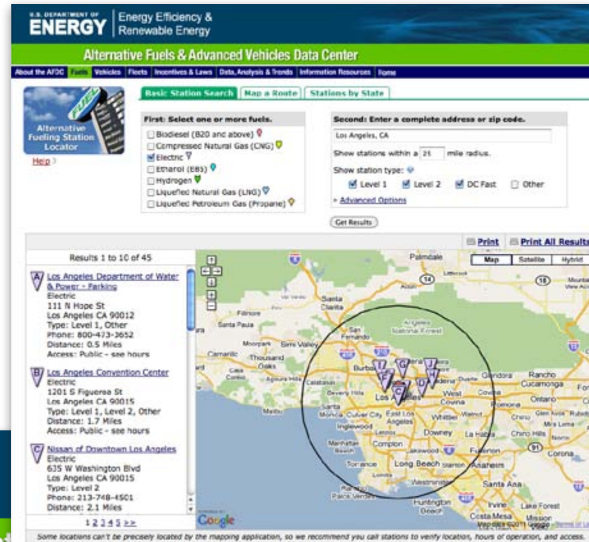
Your electrical contractor should be familiar with all applicable EVSE safety standards, but you should understand the basics of EVSE safety as well. Your EVSE product should be certified for PEV use by a nationally recognized testing laboratory (such as Underwriters Laboratory). You can install indoor-rated EVSE in your garage, but outdoor installations require outdoor-rated EVSE.

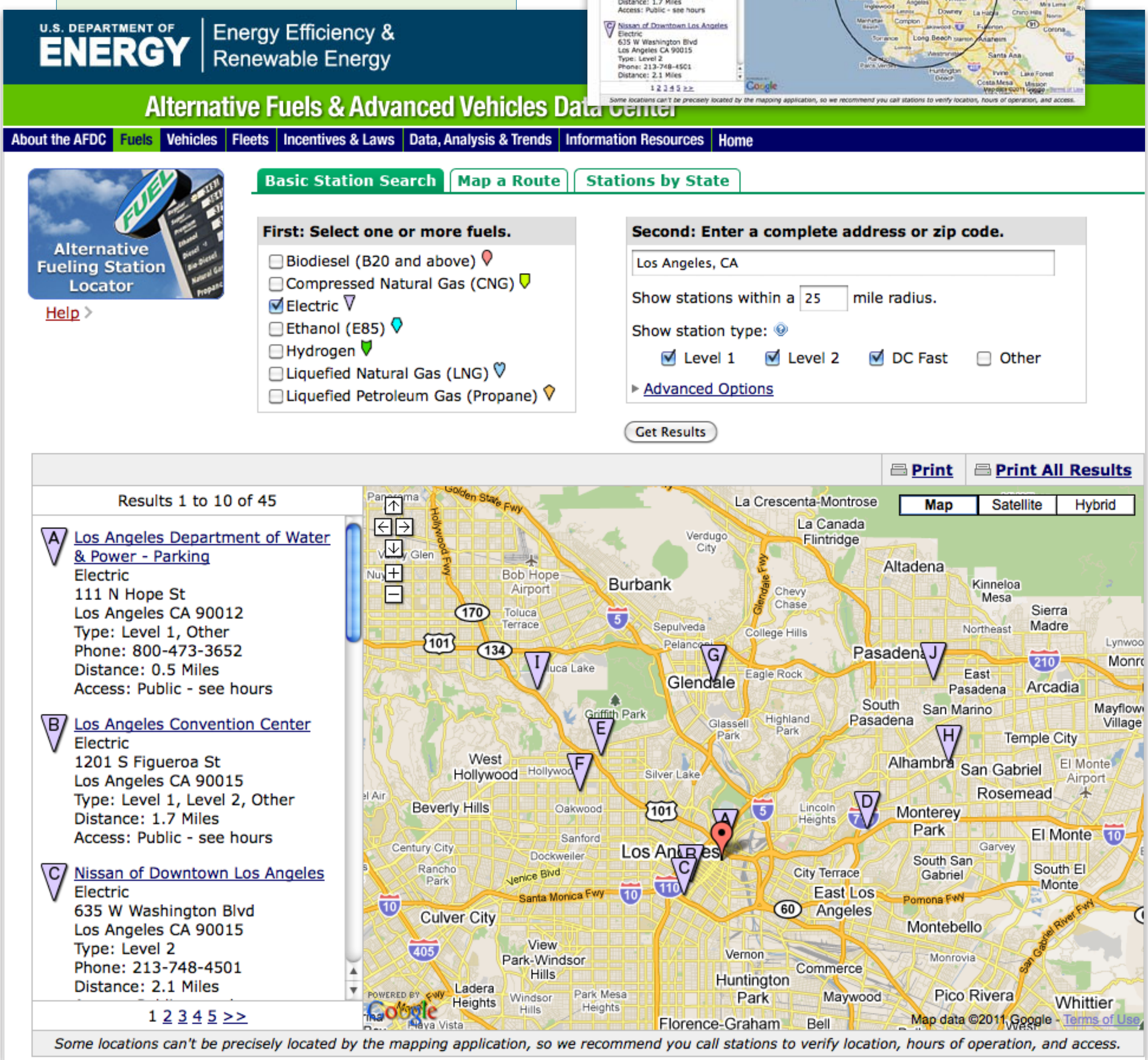
The EVSE wall unit should be protected from contact with the vehicle—a wheel-stop can be useful for this purpose. The EVSE wall unit also should be positioned to minimize the hazard of tripping over the power cord (Figure 4). In general, this means keeping the cord out of walking areas and positioning the wall unit as close as possible to the vehicle's electrical inlet. Another option is to install an 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.

Typically, there are relatively few home EVSE maintenance requirements. In general, you should store the charging cord securely so it is not damaged, check the accessible EVSE parts periodically for wear, and keep the system clean. See the EVSE manufacturer's guidelines for specific requirements.

Find a Charging Station

The AFDC's Alternative Fueling Station Locator (*www.afdc.energy.gov/afdc/fuels/stations.html*) helps you find charging stations near you, along a route you are driving, or within a state. Simply select "Electric" from the list of fuels, enter your location or route, and specify the type of station you're looking for. The Locator generates a map of station locations and provides information for each station, including operating hours, phone numbers, and driving directions.





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

Electricity Costs for Charging

As discussed in the *PEV Benefits* section, fuel costs for PEVs are lower than for conventional vehicles. If electricity costs 11 cents per kWh,[3] charging an EV with a 100-mile range (assuming a 20 kWh refill) will cost about $2.20 to reach a full charge. This cost is about the same as operating an average central air conditioner for 5 hours. General Motors estimates the annual energy use of the Chevy Volt will be 2,520 kWh, which is less than that required for a typical water heater or central air conditioning.

For EV and PHEV charging, the stability and planning benefits of household electricity rates offer an attractive alternative compared to traditional petroleum-based transportation. Learn more from Idaho National Laboratory's report: *Comparing Energy Costs per Mile for Electric and Gasoline-Fueled Vehicles* (*http://avt.inel.gov/pdf/fsev/costs.pdf*).

Charging in Public

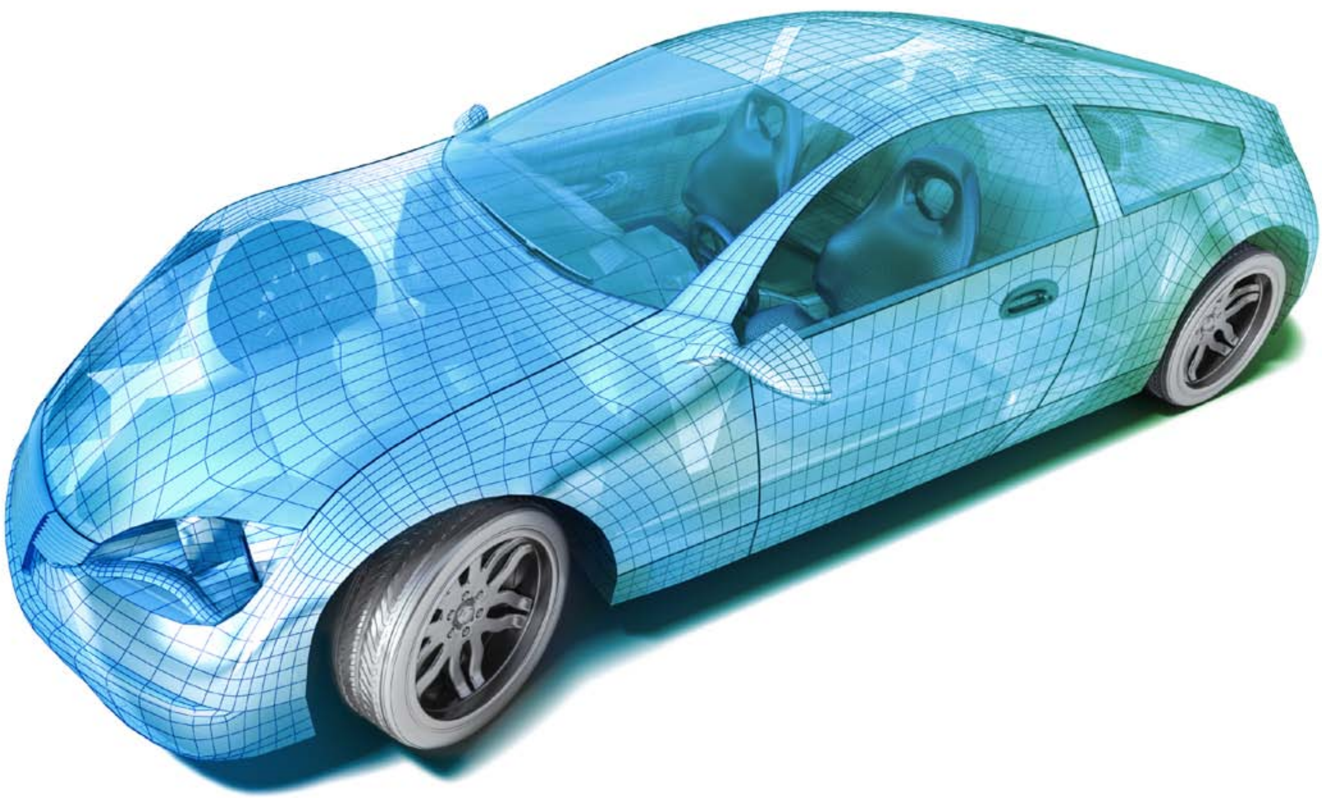
Public charging stations make PEVs even more convenient. They increase the useful range of EVs and reduce the amount of gasoline consumed by PHEVs. Although the current availability of public charging stations is limited, it is increasing rapidly. Publicly and privately funded projects are accelerating 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 your mobile device at *www.afdc.energy.gov/afdc/locator/m/stations*.

Most public charging will use Level 2 EVSE, and be located in spots where vehicles are highly concentrated, such as shopping centers, city parking lots and garages, airports, hotels, government offices, and other businesses. In addition, EVSE at a multi-family residential complex may operate much like a public charging station. Today, many charging stations offer free charging to encourage early adopters of PEVs. However, most public stations will evolve toward a pay-for-use system as PEVs become more mainstream. A number of payment models are being considered, all designed to make paying for charging as easy as paying for parking. You might swipe your credit card, enter a charging account number, or even insert coins or bills to charge your PEV. In many cases, you may only be charged a single fee for parking and charging.

3 *The average U.S. residential electricity price is about 11 cents per kWh. See U.S. Energy Information Administration (2011): Annual Energy Outlook 2011. www.eia.gov/forecasts/aeo, accessed April 2011.*

Choosing Electric

You now know the basics of PEVs, which should help you decide whether buying one is right for you. In a time of volatile petroleum prices and growing environmental concerns, PEVs are an affordable and convenient transportation solution. What's more, the number of available PEV models and the public-charging station network are expanding rapidly—making PEVs a better choice every day. To keep up with all the new developments, visit to the AFDC (*www.afdc.energy.gov/afdc/vehicles/electric.html*) and FuelEconomy.gov (*www.fueleconomy.gov*).



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