

Plug-In Electric Vehicle Handbook

for Consumers



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Clean Cities advances the nation's economic, environmental, and energy security by supporting local actions that reduce petroleum consumption in transportation. Clean Cities carries out this mission through a network of nearly 100 coalitions, which bring together stakeholders in the public and private sectors to deploy alternative and renewable fuels, idle-reduction measures, fuel economy improvements, and emerging transportation technologies. The program also administers the Alternative Fuels Data Center (AFDC) website (afdc.energy.gov) and contributes to the FuelEconomy.gov website (fuelconomy.gov).



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

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Introduction

Plug-in electric vehicles (PEVs), like the Nissan Leaf, Tesla Model S, Chevy Volt, and Toyota Plug-in Prius, are everywhere these days. Perhaps you're considering buying one, but wonder 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 about whether an electric-drive vehicle is right for you.

More than 100 years ago, all-electric vehicles (EVs) held much of the U.S. car market. Their popularity waned as interest rose in cars with internal combustion engines (ICEs). The ICE vehicle had a longer driving range, petroleum fuel costs were low, and the electric starter and manufacturing assembly line improved the affordability and usability of these vehicles.

Today, PEVs are ready to compete with—and complement—the ICE-based technology that currently dominates the U.S. market. Technology advances led to hybrid electric vehicles (HEVs), which integrate an ICE with batteries, regenerative braking, and an electric motor to boost fuel economy. Continued advances have spawned plug-in hybrid electric vehicles (PHEVs), which integrate small gasoline engines and grid-chargeable batteries that enable all-electric driving ranges of 10 to 80 miles. These same advances are applied in today's EVs, which don't use gasoline or ICEs and have driving ranges between 60 and 265 miles.

Today an EV or PHEV model is offered by nearly every original equipment manufacturer. This means that there is a configuration and range option to meet any driving need.

What drivers notice is that these PEVs perform as well as or better than conventional vehicles in most categories. They are safe and convenient and can save you money on fuel costs while slashing emissions and increasing the nation's energy security. Drivers are also being rewarded by a growing charging infrastructure of more than 22,000 charging outlets at some 10,000 stations across the country. Finally, federal, state, and local incentives are in place to potentially shave thousands of dollars off the price of these vehicles.

This all represents a growing commitment to see this vehicle technology succeed. As far back as 1990, California passed the nation's first zero emission vehicle



Photo from Atlantic County Utilities Authority/PIX 18311

Key Acronyms

EVs (all-electric vehicles) are powered 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 and produce no tailpipe emissions. EVs are also referred to as battery-electric vehicles (BEVs).

EVSE (electric vehicle supply equipment) delivers electrical energy from an electricity source to charge a vehicle's batteries. EVSE 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. HEVs rely on a petroleum-based or alternative fuel for power and are not plugged in to charge. HEV batteries are charged by the ICE 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 the ICE. Some types of PHEVs are also called extended-range electric vehicles (EREVs).

(ZEV) mandate requiring that auto makers produce a certain percentage of ZEVs (which include PEVs and hydrogen fuel cell vehicles) for sale in California. More recently, in October 2013, the governors of California and seven other states signed a memorandum of understanding and committed to having at least 3.3 million ZEVs operating on their highways by 2025. See the agreement at nescalum.org/documents/zev-mou-8-governors-signed-20131024.pdf.

Understanding “Range”

Driving range, or simply “range,” is the total distance a vehicle can travel on a full charge (or full tank of fuel, for traditional ICE-powered vehicles). So, charging a PEV or PHEV adds range just as adding fuel to a conventional car adds range. The amount of range added depends on the charge level as well as the amount of time that charge is applied. This is discussed in more detail in the Charging Your PEV section.

Plug-In Electric Vehicle Basics

A PEV can 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.

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 are charged in part by regenerative braking, which generates electricity from some of the energy normally lost when braking.

According to the U.S. Department of Transportation’s Federal Highway Administration (FHWA), the mainstream EV range target is approximately 100 miles on a fully charged battery. Some EVs can reach ranges of up to 265 miles. The range depends on driving conditions and driver habits, among other factors. According to the FHWA, a 100-mile range is sufficient for more than 90% of all household vehicle trips in the United States.

EVs must be charged during longer trips. The time required for charging depleted batteries—which can range from 15 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.

Plug-In Hybrid Electric Vehicles

PHEVs (sometimes called extended range electric vehicles or EREVs) use batteries to power an electric motor and also use an ICE (powered by gasoline, for example).



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/PIX 18215*

Powering the vehicle with electricity from the grid reduces operating costs, cuts petroleum consumption, and reduces tailpipe emissions compared with conventional vehicles. When driving distances are longer than the all electric range, PHEVs perform like traditional HEVs, consuming less fuel and producing fewer emissions than similar conventional vehicles.

The PHEV’s larger battery pack (compared to an HEV’s pack) gives it an all-electric driving range of about 10 to 80 miles. This enables the vehicle to travel a moderate distance without using its ICE. For example, you might drive your vehicle to and from work on all-electric power, plug in to charge it at night and/or while at work, and be ready for another all-electric commute the next time you drive. The ICE powers the vehicle when needed, such as when the battery is mostly depleted, during rapid acceleration, or when using heating/air conditioning. Like the EV, the PHEV can be charged by plugging in to the grid and also captures some energy from regenerative braking. Compared to the EV, the

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 via 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.

PHEV takes less time to reach a full charge because of its smaller battery pack.

PHEV fuel consumption depends on the distance driven between battery charges. If the vehicle is driven less than its all-electric range and plugged in to charge, it is possible to use only electric power. If the vehicle's battery is depleted and not recharged, fuel economy on gasoline will be about the same as for a similarly sized HEV.

Plug-In Electric Vehicle Benefits

What can PEVs do for you? They can save you money, while helping to keep your community, country, and world clean and secure.

High Fuel Economy, Low Fuel Cost

PEVs can reduce your fuel costs dramatically. Because they rely in whole or part on electric power, their fuel economy is measured differently than that of 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 mile or per 100 miles for EVs and the electric mode of PHEVs, and miles per gallon (mpg) for the ICE mode of PHEVs. Depending

Factors That Affect All-Electric Range

As with conventional vehicles, the efficiency and driving range of electric drive vehicles varies substantially based on driving conditions and driving habits. Range may also be reduced by:

- Extreme outside temperatures requiring more energy to be used to heat or cool the occupants.
- Using other electrical equipment such as seat heaters.
- Extremely cold batteries, which have greater resistance and diminished capacity.

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 and driving uphill reduces range. PHEVs are affected similarly by these factors, with the added characteristic that the ICE kicks in when driving demands exceed the capacity of the all-electric propulsion system.

PEV manufacturers are improving the technology to compensate for some of these issues. For instance, several models are now available with battery heaters or other technology to heat the battery and improve efficiency in cold climates. FuelEconomy.gov's Tips for Hybrids, Plug-In Hybrids, and Electric Vehicles (fuelconomy.gov/felevtips.shtml) provides information and resources for maximizing fuel economy and range.

on how they're driven, today's EVs (or PHEVs in electric mode) can exceed 100 mpge. However fuel economy is stated, you can compare information and get a feel for the significant cost and emissions savings of these technologies.

High efficiency translates to low fuel cost. In electric mode, charging most PEVs costs only 3 to 6 cents per mile. In contrast, fueling a gasoline car that has a fuel economy of 30 mpg costs about 11 cents per mile. If you drive 15,000 miles per year, you could save \$750 to \$1,200 in annual fuel costs by driving in all-electric mode instead of driving a conventional gasoline car.¹ If your utility offers lower electric rates for PEV owners or

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 30 mpg (combined city and highway) assuming a gasoline cost of \$3.36/gallon (based on U.S. national average in 2014) versus PEVs operated in electric mode at 3 to 6 cents per mile (which assumes an electricity cost of 12 cents/kWh).

Comparing Fuel Costs

On a national average, it costs less than half as much to travel a given distance using electricity compared to gasoline or diesel. But that cost can vary widely depending on where you are in the United States, because gasoline, diesel, and electricity prices vary by region. In addition, it's not easy to equate the energy in a kilowatt of electricity to that in a gallon of gasoline.

The U.S. Department of Energy has simplified this comparison for consumers with eGallon (energy.gov/maps/legallon). In addition to accurately comparing the cost of electricity to that of gasoline in dollars per gallon, the tool allows you to select a particular state to see that comparison on a local level.

for electricity during off-peak times, you may be able to reduce your electricity costs even further. For information on PEV charging rates available from utilities, refer to the AFDC's Federal and State Incentives and Laws database (afdc.energy.gov/laws). To calculate the overall cost of ownership, visit the AFDC's Vehicle Cost Calculator (afdc.energy.gov/calc).

Fueling Location Diversity

We're used to driving to a gas station to fuel our cars, but PEVs open up other options. Most conveniently, your home can become a personal electric charging station, capable of recharging a PEV every night (see the Charging Your PEV section). In addition, a growing network of public PEV charging stations enables you to top off your PEV's batteries in a few hours while you work or shop. Many workplaces have started installing charging equipment as an employee benefit. The U.S. Department of Energy's Workplace Charging Challenge (energy.gov/leerel/vehicles/vehicle-technologies-office-ev-everywhere-workplace-charging-challenge) is designed to encourage employers to consider installing workplace charging for their employees. The Challenge aims to achieve a tenfold increase in the number of U.S. employers offering workplace charging within five years.

The old "gas station" concept also will remain an option—with an electric twist. Public fast-charging stations are becoming more widely available, which can boost a properly equipped PEV's battery in less than 30 minutes. Of course, if your vehicle is a PHEV, you can fuel with gasoline (or possibly other fuels in the future) when necessary at any gas station.²



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 life cycle. 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 driven in all-electric mode, PEVs 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, they yield direct emissions benefits even when relying on gasoline.

Life cycle 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 operat-

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/PIX 19545

ing the vehicles; and retiring them. Like direct emissions, life cycle emissions include a variety of harmful pollutants and GHGs. All vehicles produce substantial life cycle emissions, and calculating them is complex. However, PEVs typically have a life cycle emissions advantage because most categories of emissions are lower for electricity generation than for conventional vehicles running on gasoline or diesel. If PEVs use electricity generated by nonpolluting renewable sources, life cycle emissions are minimized. To calculate the life cycle GHG emissions of PEVs, as compared to conventional vehicles, based on the electricity generation mix in your area, visit the AFDC's Emissions from Hybrid and Plug-In Electric Vehicles webpage (afdc.energy.gov/vehicles/electric_emissions.php).

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 40% of our petroleum, and the transportation sector accounts for more than 70% of our petroleum consumption. 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.

Buying the Right PEV

As with any vehicle purchase, you should assess your driving requirements and price range, then compare your requirements 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 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 (fuelconomy.gov).

Availability

PEVs are widely available today, and the number of available models continues to grow. For information on currently available PEVs, see the AFDC Light-Duty Vehicle Search (afdc.energy.gov/vehicles/search/light). There are PEVs available to meet the needs of a wide range of consumers, from luxury vehicles to small compact vehicles. To find currently available and new and upcoming PEVs, visit FuelEconomy.gov. It is important to note that when new PEV models are first released, they may only be available in certain markets or at particular dealerships. However, availability typically increases over time. Models that have been on the market for some time can often be found everywhere in the country.

Prices and Incentives

Purchase prices for today's PEVs can be considerably higher than for similar conventional vehicles, though the prices for PEVs are coming down quickly as the

Example PEV Prices, 2015*

Chevy Volt (PHEV)	\$34,170
Toyota Prius Plug-In (PHEV)	\$29,990
Ford Focus Electric (EV)	\$29,170
Nissan Leaf (EV)	\$29,010

* Manufacturer's suggested retail price taken from manufacturer website, before incentives.

technology improves. For information on current prices, see the AFDC's Vehicle Cost Calculator (afdc.energy.gov/calc). While the up-front cost may be high, drivers are typically able to reduce the overall cost of owning a PEV through lower operating costs (see the PEV Benefits section), as well as incentives.

The federal Internal Revenue Service (IRS) Qualified Plug-In Electric Drive Motor Vehicle Tax Credit is available for PEV purchases until 200,000 qualified PEVs have been sold in the United States by each manufacturer, at which point the credit begins to phase out for that manufacturer. The tax credit is for \$2,500 to \$7,500 per new PEV purchased for use predominately in the United States, with the specific credit amount determined by the IRS based on the size of the vehicle and the capacity of its battery.

Depending on where you live, you may also be eligible for PEV incentives from your state, city, or utility. Monetary and non-monetary incentives may include additional tax credits, vehicle or infrastructure rebates or vouchers, electricity rate discounts, vehicle registration fee reductions, loans, and high-occupancy vehicle lane exemptions. To find relevant incentives, search the AFDC's Federal and State Incentives and Laws database (afdc.energy.gov/laws). For information specific to where you live, contact your local Clean Cities coalition (afdc.energy.gov/cleancities/coalitions/coalition_locations.php) or State Energy Office (naseo.org/members-states).

Driving and Maintaining Your Vehicle

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

Vehicle Maintenance

Because PHEVs have gasoline engines, 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 (like oil and transmission fluid) to change and far fewer moving parts.



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/PIX 19557*

Battery Life

Like the engines in conventional vehicles, the advanced batteries in PEVs are designed for extended life, but will wear out eventually. Currently, most manufacturers are offering 8-year/100,000-mile warranties for their batteries. Nissan has additional battery capacity loss coverage for 5 years or 60,000 miles. Manufacturers have also extended their coverage in states that have adopted the California emissions warranty coverage periods, which require at least 10-year coverage for batteries on partial ZEVs. Check with your dealer for specific information about battery life and warranties. Although manufacturers do not publish pricing for replacement batteries, if the batteries need to be replaced outside the warranty, it will likely 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 design 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. The National Highway Traffic Safety Administration (NHTSA) is studying ways to address this issue, such as requiring PEVs to emit audible sounds at low speeds. For more information, see NHTSA's rulemaking ([nhtsa.gov/SampleSounds](https://www.nhtsa.gov/SampleSounds)). This option is already available on many PEVs, including the Chevrolet Volt and Nissan Leaf. In any case, you should use extra caution when driving your PEV in pedestrian areas.

Charging Your Vehicle

Charging your PEV requires plugging in to electric vehicle supply equipment (EVSE). EVs must be charged regularly, and charging PHEVs regularly minimizes the amount of gasoline they consume. Whether publicly available or installed in your home, there are various types of charging infrastructure. One important variation is how quickly they can charge a vehicle. This section describes the EVSE options so you can choose what's best for you.

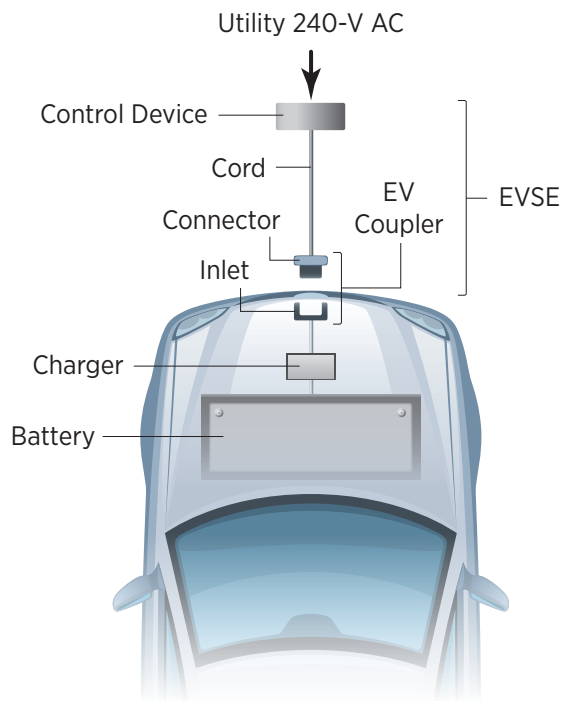


Figure 1. Level 2 Charging Diagram. Source: eTec (2010), *Electric Vehicle Charging Infrastructure Deployment Guidelines for the Oregon I-5 Metro Areas of Portland, Salem, Corvallis and Eugene*. EV Project publication, www.theevproject.com/documents.php. Illustration by Dean Armstrong, NREL

Types of Charging Equipment

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 it supplies an appropriate and safe flow of electricity.

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 typically 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 per the National Electrical Code (NEC). Most, if not all, PEVs will come with a portable Level 1 EVSE cord-set, which does not require installation of additional charging equipment. Typically, on one end of the cord is a standard, three-prong household plug (NEMA 5-15 connector). On the other end is a standard SAE J1772 connector (see Connectors and Plugs section below), which plugs into the vehicle.

Level 1 works well for charging at home, work, or when 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 vehicle per hour of charging time.

Level 2

Level 2 EVSE offers charging through a 240 V (typical in residential applications) or 208 V (typical in commercial applications) AC plug. This requires installing charging equipment and a dedicated electrical circuit of 20 to 100 amperes (amps) (Figure 1).

Most houses have 240 V service for appliances such as clothes dryers and electric ranges. Because Level 2 EVSE can easily charge a typical EV battery overnight, this will be a common installation for single-family

houses. Workplace charging typically uses Level 2 equipment as well. Level 2 and Level 1 equipment use the same type of connector on the vehicle. 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 about 60 to 80 miles of range to a PEV in 20 minutes or less. This type of charging uses a separate type of plug than the J1772 Level 1 and Level 2 EVSE.

Wireless Charging

Wireless or “inductive” charging EVSE uses an electromagnetic field to transfer electricity to a PEV without a cord. This method was used for EVs in the 1990s and is becoming available again with newer EVs as an aftermarket add-on. SAE International is working on a wireless charging standard (SAE J2954, standards.sae.org/wipl/j2954) that will provide guidance on specifications for inductive charging equipment. Currently, several wireless chargers are available or under development for use with the Nissan Leaf, Chevrolet Volt, and Cadillac ELR.

Connectors and Plugs

Most modern chargers and vehicles have a standard connector and receptacle (Figure 2) known as the “SAE J1772.” 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, some currently available PEVs (like the Nissan Leaf and Mitsubishi i-MiEV) use the CHAdeMO connector, developed in coordination with Tokyo Electric Power Company. However, not all vehicles are available with the CHAdeMO receptacle, and it is an option on some vehicles. SAE International has also finalized a “combo connector” standard for fast charging that adds high-voltage DC power contact pins to the SAE J1772 connector. This connector enables use of the same receptacle for all levels of charging, and is available in some models. The Chevrolet Spark EV, for example, is compatible with the SAE J1772 combo connector. Lastly, Tesla’s Supercharger EVSE provides DC fast charging specifically for Tesla EVs. Tesla also has vehicle adapters that are compatible with the CHAdeMO connector.



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*

Typical Charging Rates

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

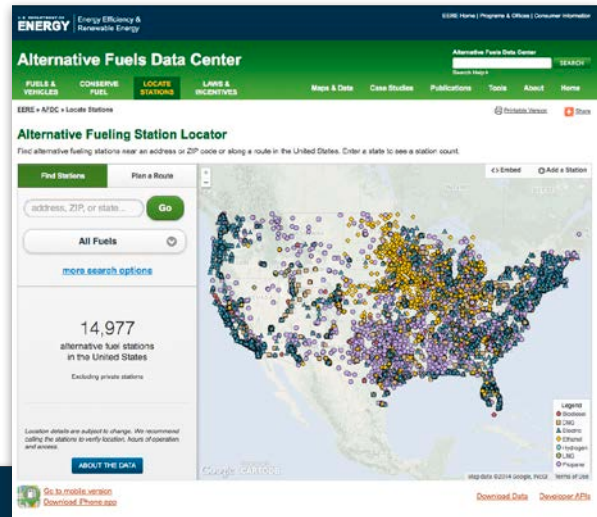
Level 1: 2 to 5 miles of range per hour of charging

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

Find a Charging Station

The AFDC's Alternative Fueling Station Locator (afdc.energy.gov/locator/stations) 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 under "more search options." The Locator generates a map of station locations and provides information for each station, including operating hours, phone numbers, and driving directions. Using certain search terms, you may also download a list of stations that populate on the map. Some electric vehicles also come with station-locator features built into their navigation systems.



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A

CITY OF TAMPA
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Fuel: Electric
Electric charging types: Level 1, Level 2
Distance: 0.2 mi

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

Charging at a Single-Family Home

As a PEV driver, you likely will charge your vehicle overnight at home using Level 1 or Level 2 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. Several states are enacting laws to support charging at multi-unit dwellings and additional efforts are underway to educate owners and management companies, but charging at these locations may be more similar to public charging than to charging at a single-family home. Refer to the AFDC Electric Vehicle Charging for Multi-Unit Dwellings webpage (afdc.energy.gov/fuels/electricity_charging_multi.html) and Plug-In Electric Vehicle Handbook for Public Charging Stations Hosts (afdc.energy.gov/pdfs/51227.pdf).

Installing EVSE in Your Home

Level 1 charging does not require 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 Level 2 residential EVSE varies, but typically ranges from \$500 to \$2,000 before installation and incentives. The most basic AC Level 2 products have standard safety features and status lights. More advanced, “smart” products have features such as enhanced displays, charging

timers, communications capabilities (e.g., for being controlled by “smart” phones), and keypads. There are many options available for residential charging infrastructure, and your PEV manufacturer should be able to recommend which Level 2 EVSE might work best for you. For more information on available residential EVSE, see Plug-In America’s Accessory Tracker webpage (pluginamerica.org/accessories).

The cost of installing Level 2 EVSE varies considerably. Typically, installation is relatively inexpensive for homes that already have adequate electrical service. In addition, some state and local laws require that all new home construction be “EV ready.” 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. NEC Article 625 contains most of the information applicable to charging equipment. Your local building, fire, environmental, and electrical inspecting and permitting authorities may also require permits. In many areas, installers

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. Raleigh applied its existing "stand alone" permitting and inspection process to EVSE installations. In this "walk through" process, permitting personnel and the applicant complete the application together. Getting a permit takes about one hour, and inspections can be performed the day after installation. As a result, the entire assessment, permitting, installation, and inspection process for a simple home-based EVSE project can be completed in as few as two days (this process can take much longer 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 (afdc.energy.gov/case) and the Clean Cities Electric Vehicle Readiness Projects (eere.energy.gov/cleancities/electric_vehicle_projects.html).

Step 1: Connecting Customers with EVSE Providers

PEV customers can contact automakers, dealers, or their utility for a list of licensed electricians to help with EVSE installation.

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 or any other licensed electrician to determine whether the capacity of their electrical panel is adequate for EVSE installation. Results of a survey by utility Duke Energy indicate that Level 2 (240 V) 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 \$81.



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Step 4: Installing EVSE

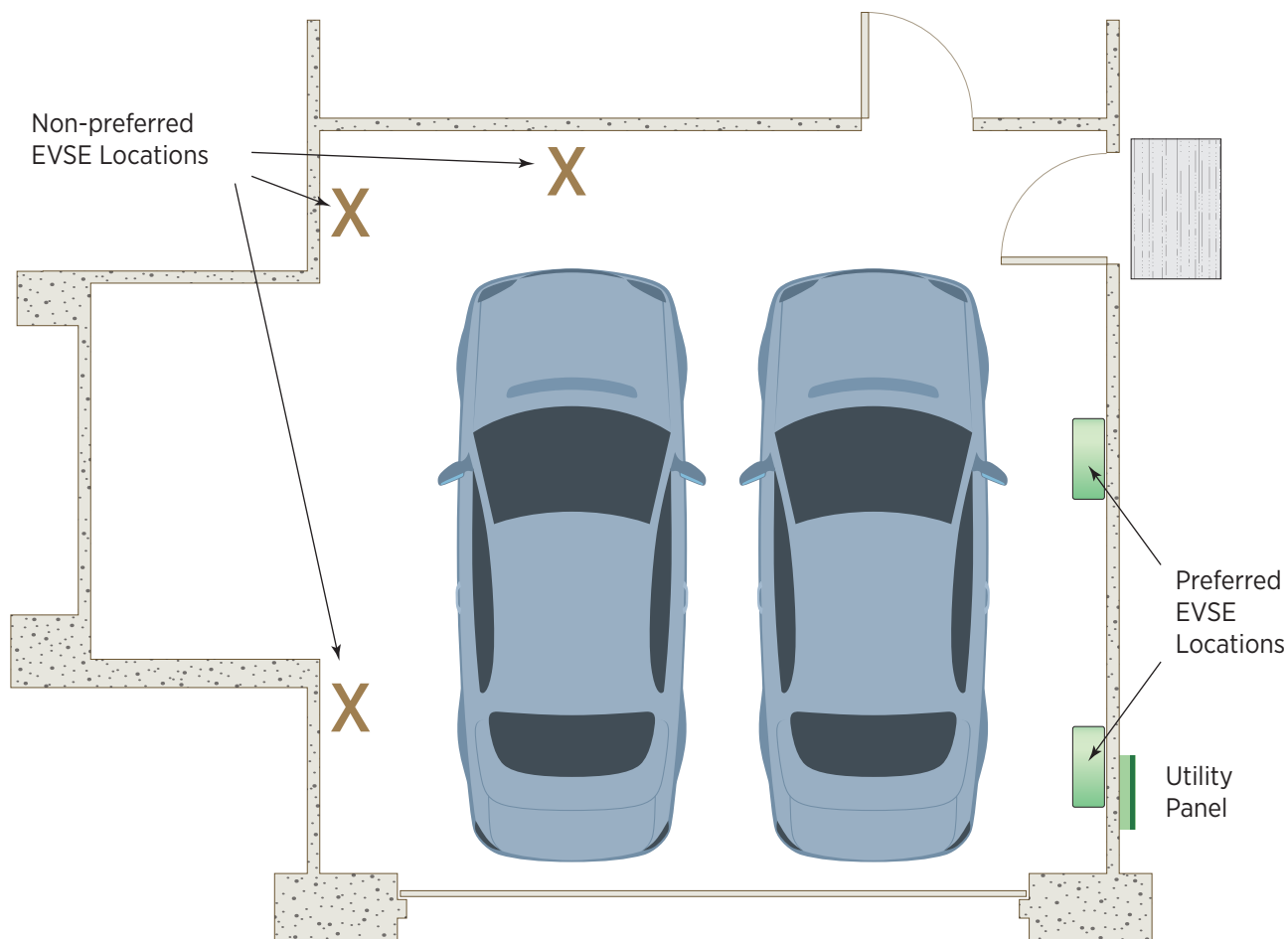
The licensed electrician or the customer/homeowner installs the EVSE. In the rare cases in which a utility service upgrade is required, the electrician or customer contacts Duke Energy to coordinate the upgrade. The customer can give authority to Duke Energy to work directly with the electrician, which 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 p.m., the inspection is performed the next day. The EVSE is approved for use as soon as it passes inspection.

Step 6: Connecting with the Grid

Duke Energy has been an active participant in Raleigh's PEV efforts. Through modeling and planning, the utility 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.



must submit a site installation plan to the permitting authority for approval before installation. Your contractor should know the relevant codes and standards and should check with the local planning department before installing EVSE. You should consult PEV manufacturer guidance for information about the required charging equipment and understand the specifications before purchasing equipment and electric services.

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 in the rain. 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.

Your electrical contractor should be familiar with all applicable EVSE safety standards, but you should

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

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.

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.

Electricity Costs for Charging

As discussed in the PEV Benefits section, fuel costs for PEVs are lower than for conventional vehicles. If electricity costs 12.3 cents per kWh,³ charging an EV with a 100-mile range (assuming a fully depleted 20 kWh battery) will cost about \$2.46 to reach a full charge. This cost is about the same as operating an average central air conditioner for five-and-a-half 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.

As an added benefit, electricity rates have historically been much more stable than either gasoline or diesel fuel costs (see Figure 1). This stability makes PEVs an attractive option.

Charging in Public

Public charging stations make PEVs even more convenient. They increase the useful range of EVs and reduce

³ The average U.S. residential electricity price is about 12.3 cents per kWh. See U.S. Energy Information Administration (2014): *Annual Energy Outlook 2014*. eia.gov/forecasts/laeo, accessed June 26, 2014

the amount of gasoline consumed by PHEVs. With more than 10,000 EVSE locations covering almost every state, station availability is increasing rapidly. Publicly and privately funded projects are accelerating the deployment of public stations; for more information, visit the AFDC's Deployment of Hybrid and Plug-In Electric Vehicles webpage (afdc.energy.gov/vehicles/electric_deployment.html). To find charging stations near you, visit the AFDC's Alternative Fueling Station Locator. You can also access the Locator using your mobile device—the mobile site and iPhone app are accessible from the Station Locator webpage (afdc.energy.gov/locator/stations).

Most public charging uses Level 2 or DC fast-charge EVSE, and is 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 or a workplace may operate much like a public charging station. Today, some charging stations offer free charging, although most public stations are evolving toward a pay-for-use system as PEVs become more mainstream. A number of payment models have been implemented, all designed to make paying for charging as easy as paying for parking. You might use a network card such as ChargePoint, Blink, or SemaCharge; swipe your credit card; use your smart phone; enter a charging account number; or even insert coins or bills to charge your PEV. While some companies require membership to use their EVSE or obtain a discount, in many cases, you may only be charged a single fee for parking and charging.

Choosing Electric

Now you know the basics of PEVs, which should help you decide whether buying one is right for you. In a world of fluctuating 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 new developments, visit the AFDC (afdc.energy.gov/fuels/electricity.html) and FuelEconomy.gov (fuelconomy.gov).



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Prepared by the National Renewable Energy
Laboratory (NREL), a national laboratory of the
U.S. Department of Energy, Office of Energy
Efficiency and Renewable Energy; operated by
the Alliance for Sustainable Energy, LLC.

DOE/GO-102015-4616 • February 2015

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Pat Corkery, NREL/PIX 18182, George Beard, Portland State
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U.S. Department of Energy