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

# Plug-In Electric Vehicle Handbook

## *for Workplace Charging Hosts*


Clean Cities

U.S. Department of Energy


*Photo from Southern California Edison, NREL 26481*

### Clean Cities Helps Establish Charging Infrastructure

The U.S. Department of Energy's Clean Cities program supports local actions to reduce petroleum use in transportation. Nearly 100 Clean Cities coalitions across the country work to deploy alternative fuels, advanced vehicles, and fuel economy improvements. Each coalition includes a diverse and capable team of stakeholders from businesses, utilities, government agencies, vehicle manufacturers, fleets, and other organizations. Find your local Clean Cities coordinator by visiting *cleancities.energy.gov.*

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### Acknowledgements

Thanks to the Minnesota Pollution Control Agency (MPCA) and the Electric Vehicle Infrastructure Training Program (EVITP) for contributing information used in the development of this handbook. For information on MPCA, visit *www.pca.state.mn.us*. For information on EVITP, visit *eere.energy.gov/cleancities/evitp.html*.

*Photo from The Coca-Cola Company, NREL 26455*

# Introduction

Plug-in electric vehicles (PEVs) have immense potential for increasing the country's energy, economic, and environmental security, and they will play a key role in the future of U.S. transportation. A full transition to electric-drive vehicles (including all-electric vehicles, plug-in hybrid electric vehicles, and hybrid electric vehicles) could reduce U.S. dependence on imported petroleum by more than 80% and greenhouse gas emissions by more than 60%.[1] By providing PEV charging at the workplace, employers are perfectly positioned to contribute to and benefit from the electrification of transportation. To help you get started, this handbook answers basic questions about PEVs and charging equipment, helps you assess whether your organization should offer workplace charging for employees, and outlines important steps for implementation.

1. *DOE analysis:* eere.energy.gov/vehiclesandfuels/electric_vehicles/index.html

## Join the Workplace Charging Challenge

The U.S. Department of Energy (DOE) is inviting employers to advance the deployment of PEVs by signing the Workplace Charging Challenge Pledge. Partners that sign the pledge commit to the following:

- Assessing employee charging demand and developing a plan to install charging stations
- Implementing workplace charging plans
- Sharing best practices and progress on meeting plan milestones.

DOE recognizes Workplace Charging Challenge Partners' successes and provides them with technical assistance, information resources, and a forum for dialogue among Partners and industry stakeholders. Prospective Partners can find out which organizations within their industry and geographic area are already implementing workplace charging by visiting *electricvehicles.energy.gov*.

## Key Acronyms

**EVs (all-electric vehicles)** are powered by one or more electric motors. EVs plug into off-board sources of electricity and store the energy in a battery. These vehicles produce no tailpipe emissions.

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

**HEVs (hybrid electric vehicles)** are powered by an ICE that runs on conventional or alternative fuel and an electric motor that uses energy stored in a battery. HEV batteries are charged by the ICE and through regenerative braking. HEVs are not plugged in to charge.

**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 propulsion technology for on-road vehicles today.

**PEVs (plug-in electric vehicles)** derive all or part of their power from off-board sources of electricity. They include EVs and PHEVs.

**PHEVs (plug-in hybrid electric vehicles)** are powered by an ICE and by an electric motor that uses energy stored in a battery. PHEVs can be plugged into off-board sources of electricity to charge the battery.

Among U.S. households that own at least one car, about half park their vehicles at locations with access to electrical outlets,[2] providing a great foundation for the country's PEV charging infrastructure. And employers across the country are beginning to offer charging access in workplace parking areas, the second-most-likely place a vehicle will spend time parked. The ability to charge at work can potentially double a PEV driver's all-electric daily driving range. This untapped resource represents a significant opportunity to expand the country's PEV charging infrastructure.

To support the deployment of this infrastructure, the U.S. Department of Energy (DOE) launched the Workplace Charging Challenge in 2013. This challenge aims to achieve a tenfold increase in the number of U.S. employers offering workplace charging by 2018. The initiative is part of DOE's EV Everywhere Grand Challenge, which focuses on the United States becoming the first nation in the world to produce plug-in electric vehicles that are as affordable and convenient for the average American family as today's gasoline-powered vehicles by 2022.[3]

2. *EIA. 2009 Residential Energy Consumption Survey:* eia.gov/consumption/residential/data/2009
3. *EV Everywhere Grand Challenge:* eere.energy.gov/vehiclesandfuels/electric_vehicles/index.html

## PEV Basics

Before learning about charging stations, it's useful to learn a little about the vehicles that will use them. A PEV has the ability to be charged by an off-board electric power source. Put simply, PEVs can be "plugged in." This feature distinguishes them from HEVs, which supplement power from an internal combustion engine (ICE) 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 electrical energy that powers one or more motors. The batteries are charged by plugging the vehicle into an electric power source. EVs can also be charged in part through 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 driving range than conventional vehicles have. Most light-, medium-, and heavy-duty EVs have a range of about 100 miles on a fully charged battery, although a few models have longer ranges. An EV's range varies based on driving conditions and driving habits. Extreme outside temperatures tend to reduce range, because energy from the battery must power climate control systems in addition to powering the motor. Speeding, aggressive driving, and heavy loads can also reduce range.

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.


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 18218*

Neighborhood electric vehicles (NEVs), also called low-speed electric vehicles, are a type of EV with range and speed limitations. NEVs typically have a top speed of 25 mph, and they 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, that are not intended for on-road use. These types of vehicles are valuable for the niches they serve, but this handbook focuses on EVs designed for highway use.

## Why Drivers Choose PEVs

PEVs offer a number of benefits that make them an attractive option for an increasing number of drivers.

**High fuel economy, low operating cost:** PEVs are highly efficient, and they generally have much lower operating costs than those of conventional vehicles.[4]

**Flexible fueling:** PEVs offer fueling options not typically available to conventional vehicles, including charging at home, work, public charging stations, 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 counterparts.

**Low emissions:** Compared with conventional vehicles, PEVs typically produce lower levels of air pollutants and greenhouse gases, even when taking into account the emissions associated with electricity production.


An increasing number of drivers is taking advantage of the financial, environmental, and energy benefits of PEVs.
*Photo by Dennis Schroeder, NREL 19699*

**Energy security:** Almost all U.S. electricity is produced from domestic coal, natural gas, nuclear power, and renewable sources, so choosing PEVs reduces reliance on imported petroleum.

*4. Alternative Fuels Data Center:* afdc.energy.gov/fuels/electricity_benefits.html

### 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. When running on battery power alone, PHEVs produce no tailpipe emissions. Even when the ICE is operating, PHEVs consume less fuel and typically produce lower emissions than similar conventional vehicles do.

PHEVs have larger battery packs than HEVs, providing an equivalent 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 electricity stored in the battery. The ICE powers the vehicle when the battery is mostly depleted, during rapid acceleration, at high speeds, or when intensive heating or air conditioning is required.

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. Their batteries are also charged by the ICE and through regenerative braking.

PHEV fuel consumption depends on the distance driven between battery charges. 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.


*Photo from the Hertz Corporation, NREL 26479*

## PEV Availability

PEV availability in the United States has grown rapidly in recent years, with more than a dozen models on the market in 2013. To find currently available PEVs, use the Light-Duty Vehicle Search (*afdc.energy.gov/vehicles/search/light*) on DOE's Alternative Fuels Data Center (AFDC).

# Charging Basics

If your organization is interested in providing employees with workplace charging, it will help to become familiar with electric vehicle supply equipment (EVSE). There are multiple types of EVSE, which differ based on their communication capabilities and how quickly they can charge a vehicle.

## Types of Charging Equipment (EVSE)

EVSE is the equipment used to deliver electrical energy from an electricity source to a PEV. EVSE communicates with the PEV to ensure that an appropriate and safe flow of electricity is supplied.

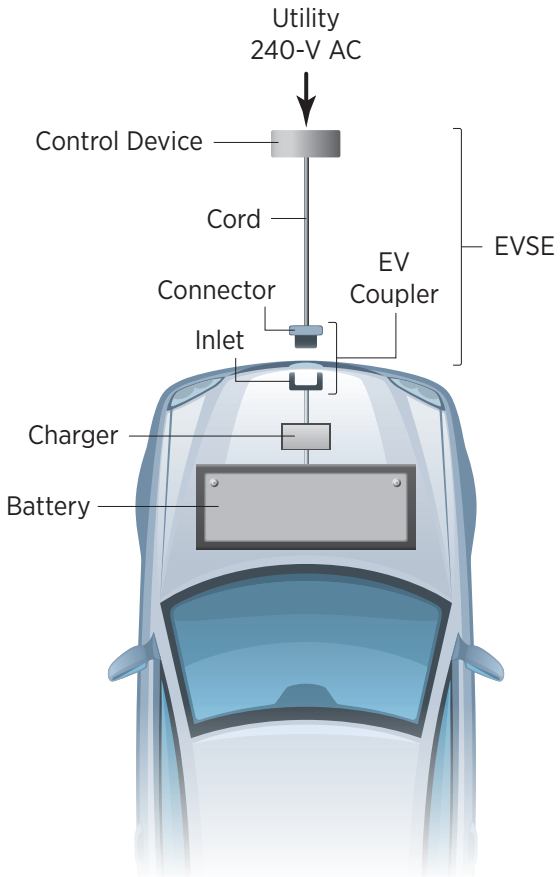



**Figure 1.** Level 2 charging schematic.

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

EVSE for PEVs is classified according to the rate at which the batteries are charged. Two types—Level 1 and Level 2—provide alternating-current (AC) 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 capacity, and how depleted it is; and the size of the vehicle's internal charger. EVs generally have more battery capacity than PHEVs, so charging a fully depleted EV takes longer than charging a fully depleted PHEV.

### *Level 1*

Level 1 EVSE provides charging through a 120-volt (V) AC circuit and requires electrical installation per the National Electrical Code. Most, if not all, PEVs come with a Level 1 EVSE cord set. On one end of the cord is a standard, three-prong household plug (NEMA 5-15 connector). On the other end is a J1772[5] standard connector, which plugs into the vehicle.

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

### *Level 2*

Level 2 EVSE can easily charge a typical EV battery overnight, and it is a common installation for residential, workplace, fleet, and public facilities. Level 2 EVSE offers charging through a 240-V (typical in residential applications) or 208-V (typical in commercial applications) electrical service. These installations are generally hard-wired for safe operation (although a wall plug connection is possible). Level 2 EVSE requires installation of charging equipment and a dedicated circuit of 20 to 80 amp (A) depending on the EVSE requirements (Figure 1). Most Level 2 EVSE uses a dedicated 40 A circuit. As with Level 1 equipment, Level 2 equipment uses the J1772 connector. Based on the battery type, charger configuration, and circuit

*5. J1772 is a trademark of SAE International.*

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 19558*

The standard EVSE connector fits into the standard receptacle. *Photo by Andrew Hudgins, NREL 17634*

capacity, Level 2 charging adds about 10 to 20 miles of range to a PEV per hour of charging time, depending on the power level of the onboard charger.

### *DC Fast Charging*

DC fast-charging EVSE (sometimes referred to as DC Level 2 EVSE) enables rapid charging and is generally located at sites along heavy traffic corridors and at public fueling stations. Some DC fast-charging units are designed to use 480-V AC input, while others use 208-V AC input. A DC fast charger can add 60 to 80 miles of range to a light-duty PEV in 20 minutes. DC fast-charging is not commonly used as a workplace charging option. Workers' vehicles are typically parked for several hours at a time, so they don't require rapid charging at work.

## Connectors and Plugs

Today's EVSE and PEVs have standard connectors and receptacles based on the J1772 standard developed by SAE International. Vehicles with this receptacle can use any Level 1 or Level 2 EVSE. Most major vehicle and charging system manufacturers in the United States support this standard, which should eliminate concerns about vehicles' compatibility with charging infrastructure. Most currently available PEVs that are equipped to accept DC fast charging are using the CHAdeMO connector (see image above). SAE International recently developed 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.


Minnesota-based 3M aims to provide workplace charging to every employee who drives a PEV at its St. Paul headquarters. *Photo from 3M, NREL 26453*

### EVSE Ownership and Payment Models

A growing number of vendors not only sell Level 2 equipment but also offer installation and ongoing service and maintenance. Some vendors of EVSE units require drivers to subscribe to a charging service that uses credit card, cash, or radio-frequency identification (RFID) devices to control access to the EVSE and to enable the owner of the EVSE to collect usage data and payments for charging. Owners can also set up charging to be free for all or some users. Some EVSE vendors share in the revenue generated by the EVSE and charge service fees for managing payment transactions, maintenance, and trouble-shooting services.

Some workplace charging hosts may decide to purchase, install, and operate stations themselves. This model gives the host or owner control of the station and its revenues. For example, a parking lot owner might buy and operate a pay-for-use charging station as part of its business strategy.

## Benefits of Workplace Charging

Workplace PEV charging offers many benefits to employers, employees, and building owners. For a project to be successful, it is important for all stakeholders to understand these benefits.

### Benefits for Employers and Building Owners

**Employee recruitment and retention:** The availability of charging conveys that your organization stays on the leading edge of technological development, even to workers who don't drive PEVs. And employers that offer charging may be better positioned to attract and retain employees who do drive PEVs.

**Furthering sustainability goals:** The availability of PEV charging can be a strong addition to an organization's larger portfolio of sustainability practices, particularly if the organization has existing objectives related to employee commuting practices, greenhouse gas reductions, and/or transportation emissions reductions.

**Public image:** Providing workplace charging can help demonstrate an organization's leadership in supporting cutting-edge, clean transportation technologies to customers, consumers, and the surrounding community.

**Employee satisfaction:** Workplace charging can be an attractive addition to your organization's existing employee benefits package. Employees will likely appreciate that their employer is proactive in seeking out ways to enhance their experience at the workplace.

**Tenant attraction and retention:** Building owners who offer workplace charging at their facilities send the message that they are interested in providing smart, proactive solutions for their tenants' present and future needs. Entering this fast-growing niche market today may yield significant benefits in the long run.


The Hartford offers workplace charging at various locations across Connecticut, helping the company make progress toward its goal of reducing greenhouse gas emissions 20% by 2017. *Photo from The Hartford, NREL 26470*

### Benefits for Employees

**Range security:** The opportunity to charge at work can help alleviate "range anxiety," a driver's uncertainty about the vehicle's ability to reach a destination before depleting the battery's charge.

**Range extensions:** Workplace charging can potentially double daily all-electric driving range, accommodating longer commutes and additional trips between the workplace and the home.

**Thermal preconditioning:** On very hot or cold days, workplace charging allows PEV drivers to achieve a comfortable cabin temperature and to preheat or precool the battery while the vehicle is still plugged in. This extends the vehicle's range by reducing the climate-control load on the battery. Preconditioning can also help extend battery life.[6] (Note that this capability is not available in all PEV models.)

**Greater flexibility:** By extending range, workplace charging opens up options drivers might not otherwise have, making it easier to manage special circumstances, urgent trips, and unexpected changes in plans or schedules, particularly for EV drivers. Workplace charging also provides flexibility in the location and timing of charging, which may be helpful for drivers whose residential charging options are somewhat limited or inconvenient.

**Increased incentive for PEV adoption:** The ability to charge at work may provide the encouragement and assurance an employee needs to make the switch from a conventional vehicle to a PEV, and to take advantage of the financial and environmental benefits of such a switch.

In 2013, the New York Power Authority installed three employee charging stations at its White Plains facility as part of the organization's workplace charging pilot program. *Photo from NYPA, NREL 26486*

Employers and employees seeking to take advantage of the benefits of PEVs should explore available incentives for early adopters. See page 13 for more information about finding relevant incentives.

6. *National Renewable Energy Laboratory (2012). NREL Reveals Links Among Climate Control, Battery Life, and Electric Vehicle Range.* www.nrel.gov/docs/fy12osti/53603.pdf

## Evaluating and Planning for Workplace Charging

In 2012, Eli Lilly installed several workplace charging stations at its two main campuses in Indianapolis. *Photo from Eli Lilly & Company, NREL 26480*

Successful implementation of workplace charging involves careful planning and a willingness to address potential challenges, many of which may be unique to the physical, cultural, and organizational characteristics of your workplace.

### Facilities Ownership Considerations

Implementing PEV workplace charging is easiest when the employer owns and operates its campus or facility. Planning and installation will be more straightforward processes if the employer has singular control of the critical pieces of real estate, including the affected parking area(s), building(s), and electrical infrastructure.

Planning and installation may be more complex when multiple stakeholders are involved, particularly in densely developed urban areas. For example, a business

may lease office space in a building that is owned by one entity, operated and maintained by another entity, with a parking facility operated by yet another entity.

For assistance with evaluating the scope of a project, organizations should contact their local Clean Cities coalitions. Find the nearest coalition by visiting the Clean Cities website at *eere.energy.gov/cleancities/coalitions.html*.

### Workplace Charging Scenarios

**Easiest:** The employer owns the building and parking lots; electricity is accessible, and upgrades are not needed.

**Easy:** The employer owns the building and parking lots; electricity is accessible, but upgrades may be needed.

**Moderate:** The employer leases building space and parking lots; electricity is accessible, but upgrades are needed.

**Challenging:** The employer leases building space and uses independently operated parking; electricity is inaccessible.

## Identifying Key Stakeholders

Some workplaces that decide to offer PEV charging may undertake their projects as top-down initiatives. But as PEV ownership rates continue to increase, many organizations will find that employees are driving the conversations early in the process. In small organizations, informal dialogue among colleagues and management are often enough to determine whether the organization should explore the possibility of providing workplace charging. Medium-sized and large employers may need to follow more formal processes and protocols.

Typically, key decision makers include a management-level designee, a sustainability lead, the building owner (if different from the employer), the parking lot operator (if different from the employer), facilities operations staff, human resources staff, and legal counsel. Employers and employees with complex building ownership and/or parking arrangements should engage all relevant stakeholders to ensure that EVSE planning, installation, and operations take all parties' interests and needs into account. See Figure 2 for more detail about relevant stakeholders and their roles and needs.

## Evaluating Employee Demand

Regardless of whether a workplace charging project is initiated by the employer or by employees, it will be useful to gauge potential employee demand. Employee surveys can be useful for this purpose. A survey should not only assess existing demand, but also help evaluate future demand.

Possible survey questions include:

- If you drive to work, how far is your trip (one-way)?
  - Less than 10 miles
  - 10–25 miles
  - 26–50 miles
  - More than 50 miles
- During the workday, what is your usual travel pattern?
  - I stay at the worksite and do not move my vehicle
  - I leave the worksite and move my vehicle once per day
  - I leave the worksite and move my vehicle more than once per day
- Do you drive a PEV, or are you considering acquiring one in the future?
  - I already drive a PEV
  - I'm considering acquiring a PEV within six months
  - I'm considering acquiring a PEV within 12–24 months
  - I'm considering acquiring one but not sure when
  - I'm not considering a PEV for personal use
- Do you have the ability to install PEV charging equipment at your residence? (Y/N)
- Do you think we should install PEV charging stations for employees? (Y/N)
- If charging stations were available at work, would you use them? (Y/N)
- Would you be willing to pay a fee to use a charging station at work? (Y/N)
- Would availability of workplace charging increase the likelihood that you would consider a PEV? (Y/N)
- Are you interested in participating in an employee task force on workplace charging? (Y/N)

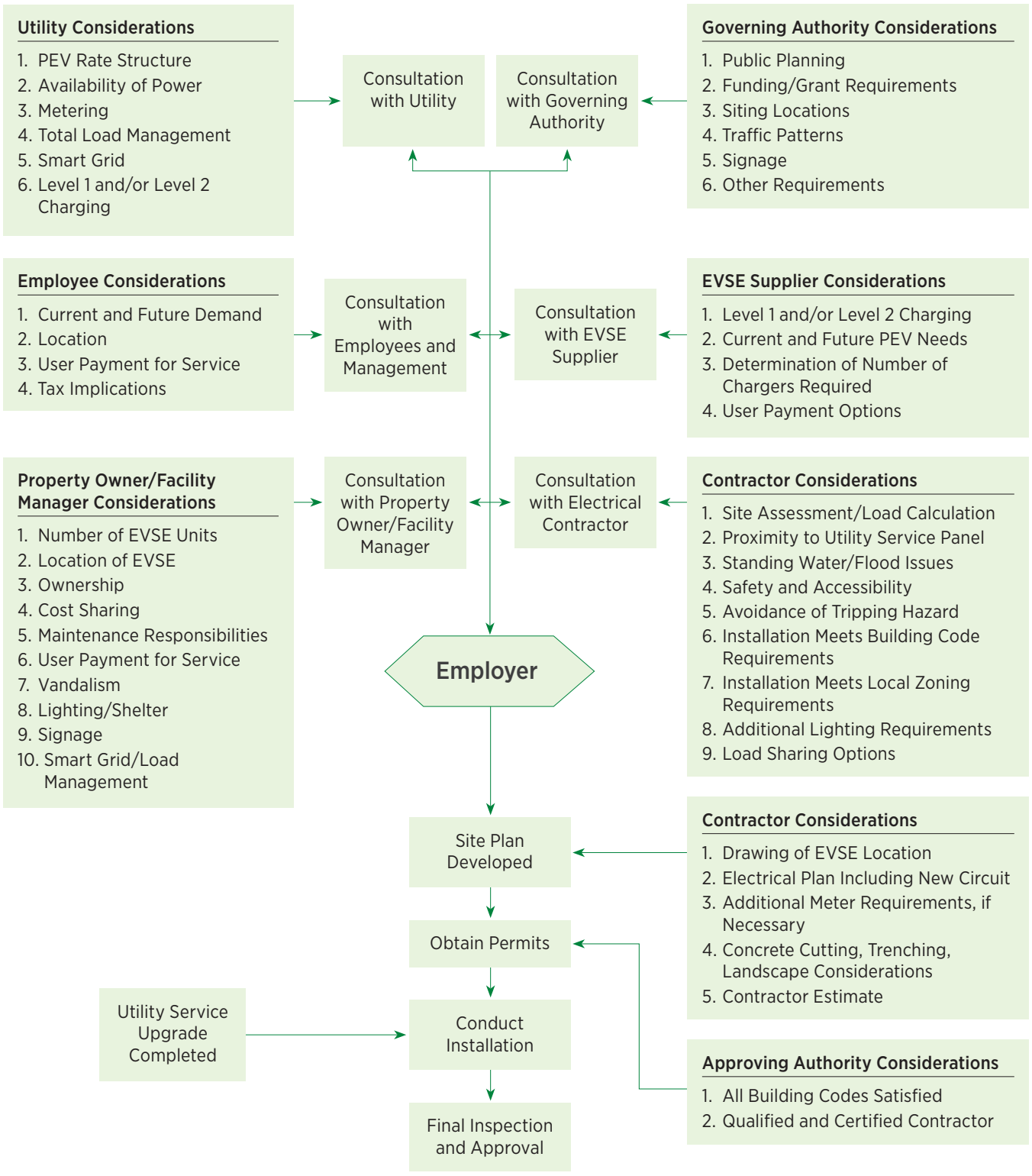



**Figure 2.** General outline for implementation of workplace charging. A successful project requires thoughtful planning and involvement by all relevant stakeholders. *Adapted from: eTec (2010). Electric Vehicle Charging Infrastructure Deployment Guidelines for the Oregon I-5 Metro Areas of Portland, Salem, Corvallis and Eugene. EV Project publication (*theevproject.com/documents.php*).*

The organization's decision makers should evaluate survey results to help determine the number of charging stations that may be needed. PEV production and ownership are expected to grow rapidly over the coming decade, so employers may want to allow for the possibility of future expansion when developing their workplace charging plans. This may include upgrading a facility's electrical service beyond what is necessary for short-term demand.

To find a template for an employee survey, visit *electricvehicles.energy.gov*.

## Selecting a Level of Charging for Your Workplace

When determining which type(s) of charging equipment to provide at your workplace, important considerations include EVSE system cost, proximity of electricity service to parking areas, potential electrical upgrade requirements, EVSE security, and potential maintenance. Perhaps most importantly, employers must take into account the commuting distances of their employees.

Level 2 charging (providing 10 to 20 miles of range per hour of charging) at the workplace can provide PEV drivers with a high level of range security. A single Level 2 EVSE unit could potentially serve multiple vehicles throughout the day, as long as each PEV driver makes room for another after charging is complete. Many available mobile applications notify PEV drivers when their batteries are fully charged. Employers must consider whether it is feasible for employees to take the time to move their cars during the work day.

Level 1 charging (providing 2 to 5 miles of range per hour of charging) is also a viable option, given that PEV drivers are likely to be parked at work for several consecutive hours, and that PEVs used for commuting will most likely have a partially charged battery when they arrive at the workplace. Because Level 1 EVSE can be as simple as a three-pronged extension cord and a standard electrical outlet on a dedicated branch circuit, implementing Level 1 charging is a relatively easy and low-cost strategy to rapidly expand EVSE infrastructure at workplaces.

Using Level 1 as a stepping stone, a business can gain experience and information about how its employees are using workplace charging and gauge employee satisfaction with Level 1 EVSE. The business can then use that information to determine whether to provide faster charging options.


At San Diego Gas & Electric, 37 employees drove PEVs as of May 2013. *Photo from SDGE, NREL 26485*

A number of manufacturers offer EVSE, and product offerings vary in the types of features they include and the corresponding prices. Level 1 equipment ranges in cost from $500 to $1,000. The price of Level 2 equipment ranges from about $500 to $7,000 (before incentives), depending on the level of sophistication. The most basic products have only standard safety features and status lights. More advanced products have features such as enhanced displays, charging timers, communications capabilities, keypads, and enhanced durability and ergonomics. "Intelligent" or "smart" products may have features like payment card readers, billing software, advanced displays, wireless communication, automated diagnostics, internal metering, and smart-grid compatibility and controllability.

## Cost Considerations

Employers seeking to provide workplace charging must consider costs associated with equipment, installation, maintenance, and electricity. As noted above, equipment costs for Level 1 and Level 2 EVSE range from about $500 to $7,000.

Installation costs and services vary considerably, so employers should obtain a number of quotes before moving forward. Factors affecting installation cost (and time) include the number of circuits and EVSE units installed, indoor versus outdoor installation, required electrical upgrades, and permitting and inspection


JLA Public Involvement has on-site charging that is available for use both by employees' personal vehicles and by a PEV in the company's corporate vehicle pool, which can be used for work-related trips. *Photo from JLA, NREL 26460*

costs. If necessary for a project, trenching and adding electrical service or panels may add the greatest cost. If an organization anticipates expanding the number of EVSE units in the future, it should consider adding extra circuits, electrical capacity, and conduit from the electrical panel to potential EVSE locations during initial installation. It is less expensive to install extra panel and conduit capacity during initial construction than to modify the site later. For the same reason, it is a good idea to consider electricity infrastructure for EVSE during the planning phases of new facilities.

A typical budget for a workplace EVSE project might include the following line items:

- EVSE unit(s)
- Contracted labor
- In-house labor
- Material/incidentals
- Equipment rental (backhoe, jackhammer, etc.)
- Sidewalk demolition and repair
- Optional EVSE equipment (e.g., RFID card reader)
- Signage and paint
- Permitting and inspection costs
- Incentives (if available)

Typically, there are fairly few EVSE maintenance requirements, and associated costs are relatively low. Cords should be properly stored and inspected periodically for damage. Periodic EVSE inspection, testing, and preventive maintenance by a qualified technician may be recommended by the equipment manufacturer. Employers should have a clear process, budget, and schedule in place to abide by the recommendations.

Electricity costs will depend upon the type of EVSE and the extent to which it is used by PEV drivers, as well as the electricity rate structure applied to the site. Maximum potential electricity use from Level 1 EVSE will total about 4,000 kWh/year. At Level 2, use could range from 6,500 kWh to 13,000 kWh per year, depending on the vehicles using the EVSE and the electrical circuit's capacity. Charging PEVs during peak electricity demand periods may move a customer into a higher rate category and result in higher electricity costs. However, the advanced capabilities of some EVSE products can be useful for optimizing load management. It is important to discuss the effects of PEV charging on electricity rates and loads with your utility. Ask the utility whether it offers special PEV charging rates.

### Electricity Demand Charges

Demand for electricity rises and falls depending on the time of day and time of year. Electricity production, transmission, and distribution capacity must be able to meet demand at peak times of use, but most of the time, the electricity infrastructure is not operating at its full capacity.

Some utilities have implemented demand charges that encourage customers to use electricity during off-peak times. Utilities apply demand charges as a price per kilowatt (rather than kilowatt-hour) for power used during peak consumption periods. Charging vehicles during peak times may increase a commercial utility customer's peak monthly demand, thereby increasing the demand-charge portion of its utility bill.

#### *Identifying Incentives*

Discounts and incentives can lower the costs associated with establishing workplace charging. Your organization may be eligible for incentives from the state, city, or utility. To find current incentives, search the Alternative Fuels Data Center's database of federal and state laws and incentives at *afdc.energy.gov/laws*. For information about incentives in your area, contact your local Clean Cities coordinator (*cleancities.energy.gov*), state energy office (*naseo.org*), and utility.

# Workplace Charging Management and Policy Planning

It is important for employers that provide workplace charging to develop a clear internal policy that governs access, security, usage, and other issues.

### Access to EVSE

Employers providing workplace charging can maximize the benefits of their investment by designating EVSE parking spaces for use only by vehicles that are actively charging. If an employer adopts such a policy, parking signage should clearly indicate the requirements. The employer may decide to limit EVSE use to employees only or to allow visitor use as well. An employer or building owner may decide to place a daily limit on the amount of time a given vehicle can occupy a charging space. Access policies should identify the parties responsible for enforcement. Some smart EVSE products can control access through badges or other identification systems.

### Registration and Liability

Some workplace charging programs require users to register to use the equipment and sign a standard waiver of liability. A registration form could include language requiring vehicle owners to agree that the employer is not responsible for any costs related to vehicle purchase or repairs or for any damage to the vehicle that occurs while it is parked at the charging station. It could also specify a timeframe within which the employer is obligated to address maintenance issues with the charging stations upon notice of the problem.


Lynda.com offers no-cost charging to employees to reward them for choosing alternative transportation options. *Photo from Lucas Deming, lynda.com, NREL 26461*

Google is aiming to provide charging at 5% of its parking spaces; it has already deployed more than 300 stations across the country. *Photo from Rob Kalmbach, Google, NREL 26459*

### Hours of Use

An employer may decide to limit EVSE use to normal business operating hours. If the employer chooses not to institute such a limitation, it should decide whether any restrictions (such as per-vehicle time limits on charging or employee-only access) are applicable outside of regular business hours.

### Payment for EVSE Use

Employers that provide workplace charging must decide whether and how employees will pay for EVSE use. Many existing workplace charging programs are free for employees. As the market penetration of PEVs expands, providing free charging may merit reconsideration. Check with your accountant or chief financial officer to determine any tax implications of providing free charging to employees.

Some employers charge their employees a fee for using workplace charging equipment. Fees can help offset capital and operational costs associated with workplace charging. Fees may also address issues of fairness, since not all employees can take advantage of charging. Fees may take the form of a charge-per-use or a monthly or annual subscription rate. If an employer does decide to institute a payment system, it is important to develop a fee structure that doesn't discourage use of the EVSE.


Facebook has committed to supplying free PEV charging to its Menlo Park, California, employees as part of the company's transportation-demand management program. *Photo from Lauren Bonar Swezey, Facebook, NREL 26457*


As part of the Las Vegas Sands Corporation's ECO 360° Global Sustainability program, the Venetian and the Palazzo hotels provide charging for both employees and guests. *Photo from the Venetian and the Palazzo hotels, NREL 26484*

### Security of Equipment

It is important for the employer and/or building owner to identify any necessary measures to prevent vandalism and theft of EVSE. The employer should also ensure that the communications and information technologies of the EVSE comply with the organization's cyber security policies.

### Etiquette for Shared EVSE

The employer should consider developing a policy that guides drivers in cases where the number of PEVs exceeds the number of EVSE parking spaces available. The organization may encourage drivers to make room for another PEV once they have finished charging.

### Administration of EVSE Operation and Maintenance

Employers that provide workplace charging should designate the party responsible for ongoing operation and maintenance issues and any related costs. For example, in the case of a damaged cord, the employer's policies should clearly indicate which stakeholder should arrange for the repair and how it will be paid for.

# Workplace Charging Installation

Many of your key stakeholders will be involved in the installation of workplace charging. It is important to consult with your utility, governing authority, electrical contractor, EVSE provider, and other stakeholders early in the process (Figure 2).

## EVSE Site Considerations

The following are some of the site and equipment issues organizations must consider when installing EVSE for workplace charging. An employer should discuss these and any site-specific issues with its electrical contractor, utility, and EVSE provider, all of whom should be familiar with these topics.

- **Convenience:** Locate EVSE and associated PEV parking as close as possible to the electrical service while also ensuring that spaces are conveniently located for drivers.
- **Avoiding hazards:** Cords 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:** Most of today's advanced batteries do not require ventilation during charging. But if your station will be enclosed, there must be adequate ventilation, which may include installation of fans, ducts, and air handlers. Depending on the installation, the National Electrical Code may require ventilation.
- **Pooled water and irrigation:** Most EVSE is designed to operate safely in wet areas. However, users may be more comfortable if it is not located where water pools or irrigation systems spray.
- **Preventing impact:** Curbs, bollards, wheel stops, and setbacks should be used to prevent vehicles from colliding with EVSE. However, accessibility issues must also be considered.
- **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.


MetLife has installed PEV charging stations for employee use at 14 of its locations across the country. *Photo from Josh Weiner, MetLife, NREL 26465*

- **Lighting and shelter:** Provide lighting and shelter as necessary for the safety and convenience of EVSE users. Lighting should enable users to read signs and instructions and to operate the equipment easily.

## Working with an Electrical Contractor

A certified electrical contractor should carry out the installation of EVSE at your workplace. When hiring a contractor, select one who is familiar with the National Electric Code Guidelines found in NEC Article 625, which pertain to EVSE installation. You can discuss potential electrical contractors with your EVSE provider. Your state's licensing board likely will provide a list of licensed electrical contractors (though not specifically those who have received EVSE training).

The electrical contractor will serve as the point of contact in coordinating local permitting, inspections, utility upgrades (if needed), equipment purchasing, and installation of the EVSE. Your contractor should understand the relevant codes and standards and obtain approval from the local building, fire, environmental,

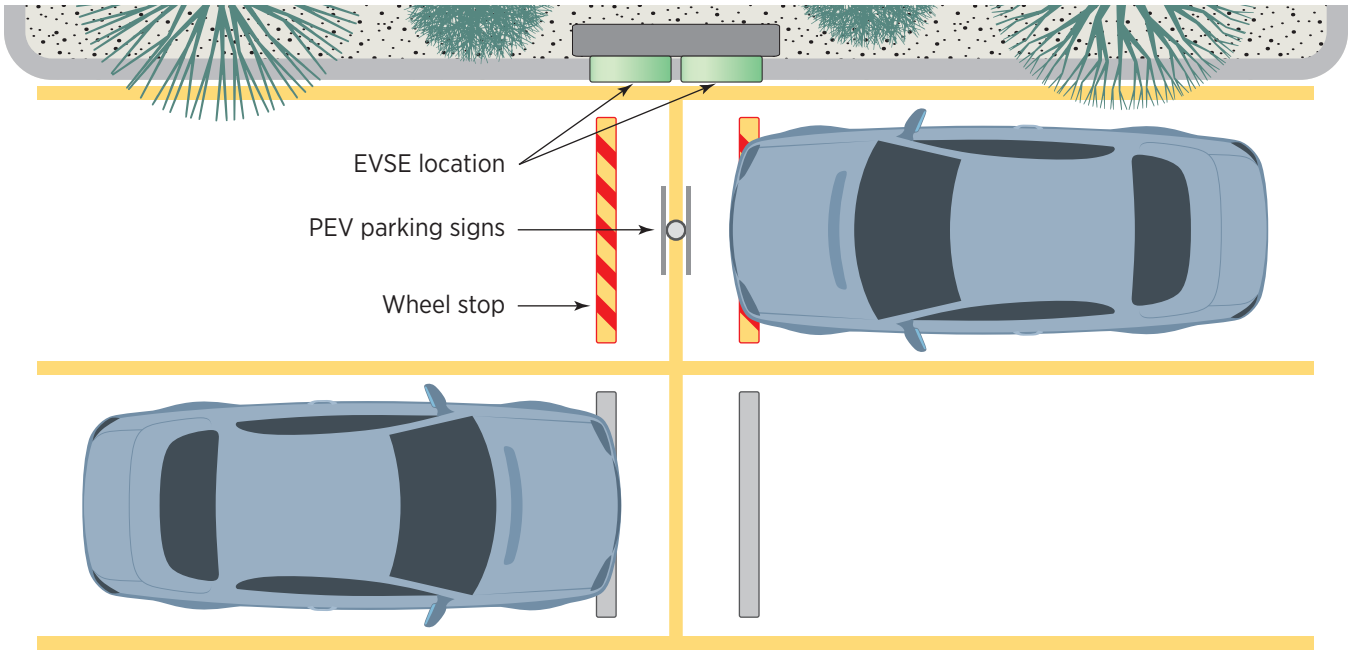



**Figure 3.** Example public charging station design showing EVSE, wheel stop, and sign locations. *Source: eTec (2010), Electric Vehicle Charging Infrastructure Deployment Guidelines for the Oregon I-5 Metro Areas of Portland, Salem, Corvallis and Eugene. EV Project publication, theevproject.com/documents.php. Illustration by Dean Armstrong, NREL*

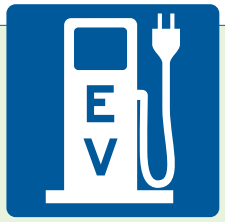
and electrical inspecting and permitting authorities before installing EVSE. After installation, the contractor should walk through the site and review the EVSE operation with the owner of the equipment.

## Engineering and Construction

Because EVSE installations involve specialty equipment, extensive electrical work, and standard civil engineering work, select well-qualified contractors with experience in the relevant fields. The condition and location of existing electrical equipment will determine the complexity of the required electrical installations. If the existing electrical system does not support the required EVSE input voltage range, a transformer may be required to step voltage up or down.

## Signage

Signage for PEV parking spaces should clearly communicate that the spaces are only to be used by PEVs, and preferably only by vehicles that are actively charging. It can also be useful to paint the pavement of the parking space to provide an additional visual cue. In facilities where enforcement is limited or non-existent, signage may be the only deterrent against parking by drivers of conventional vehicles.




The Federal Highway Administration has issued interim approval for this sign design (D9-11b) to help direct drivers to charging stations. Pending final approval, this sign will be included in the next edition of the agency's Manual on Uniform Traffic Control Devices. *Image from the Federal Highway Administration*


Signage can help maximize EVSE use by letting drivers know that spaces are for PEV use only. *Photo by Dennis Schroeder, NREL 26762*

*Photo from iStock 19431754*

## Electrifying Transportation

In a time of fluctuating petroleum prices and heightened environmental concerns, many workers see PEVs as a convenient way to reduce driving costs and environmental impacts. The number of PEVs on U.S. roadways is increasing rapidly, as is the need for charging infrastructure. Now is a good time to consider hosting workplace charging and becoming a leader in the electrification of transportation.

For more information on workplace charging, visit *electricvehicles.energy.gov*. For assistance with your local workplace charging project, contact your local Clean Cities coordinator at *cleancities.energy.gov*.

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