ELECTRIC VEHICLE INFRASTRUCTURE INSTALLATION GUIDE

March 1999
Edition

PG&E Pacific Gas and Electric Company™
Clean Air Transportation

Pacific Gas and Electric Company

Electric Vehicle Infrastructure Installation Guide

Electrical Contractors
City and County Building Inspectors
EVSE Installers
Architects and Engineers
Pacific Gas and Electric Company Employees

March 1999

1999 Edition

The Electric Vehicle Infrastructure Installation Guide is an overview of policies, requirements and codes for establishing electric service and for the installation of electric vehicle charging equipment.

In addition to the utility requirements, local or state officials may stipulate additional provisions for the installation of equipment and materials which are in their authorized areas of responsibility and jurisdiction.

Should you have any questions regarding this book, please contact the Clean Air Transportation Department of Pacific Gas and Electric Company at 800 684-4648.

Final customer electric service and meter installation requirements are subject to prior Pacific Gas and Electric Company review and approval

Pacific Gas and Electric Company
Clean Air Transportation Department
Mail Code H28L
P.O. Box 770000
San Francisco, CA 94177

Produced by
Clean Air Transportation Department

TABLE OF CONTENTS

Page

1. Introduction....1
   A. EV Infrastructure Essentials....1
   B. Information Resources....2
2. EV Charging Essentials....3
   A. Rules and Regulations Governing EV Infrastructure Installations....3
      1. The National Electrical Code (NEC)....3
      2. The California Electrical Code (CEC)....4
      3. Local Codes and Ordinances....4
      4. UL Listing....4
      5. Installation Plans....5
      6. Equipment Certification....5
   B. EV Charging Levels....5
      1. Level 1 Charging....5
      2. Level 2 Charging....6
      3. Level 3 Charging....6
   C. Charger Technologies: Conductive and Inductive....6
      1. Conductive Technologies....6
      2. Inductive Technologies....7
   D. Charging Equipment Currently Available....7
   E. PG&E EV Rates....9
3. Code Requirements for Installing EVSE....12
   A. EVSE Used in Level 1 Installations....12
   B. EVSE Used in Level 2 Installations....13
   C. Installations Where Ventilation is Required....14
   D. Codes Governing EVSE Siting....15
   E. Installations Located in Flood Zones....16
   F. Required Signage....16
   G. Lighting Recommendations....17
   H. Disable Access....18
4. EV Charging in Single Family Residences....19
   A. Step 1: Determine the Charging and Battery Types....19
   B. Step 2: EV Utility Rates and Meter Options....19
   C. Step 3: Determine the Home's Electrical Capacity....19
   D. Step 4: Determine EVSE Placement....19
      1. Safety Issues in Enclosed Garages....20
      2. Extending Electrical Service....20
      3. Outdoor Charging....20
   E. Step 5: Drawing Up the Installation Plans....20
   F. Step 6: Obtaining Permits, Performing the Installation, and Conducting a Site Inspection....21

G. Other Issues Pertaining to Single Family Residences 21
1. Insurance 21
2. Costs 21
H. Single-Family Residence EVSE Installation Checklist 23
I. Issues Related to Installations in Multifamily Residences 25
1. Ownership of EVSE 25
2. Apartments 25
3. Condominiums and Townhouses 25
4. Metering Arrangements 25
5. Electrical Capacity 26
6. Insurance 26
7. Costs 26
5. EV Charging at Fleet Facilities 27
A. Site Planning 27
1. Number of EVs and Chargers 27
2. Convenience 28
3. Cable Management 29
4. Ventilation Needs 29
5. Battery Operating and Charging Temperature Limits 29
6. Standing Water and Irrigation 29
7. Curbs, Wheel Stops, and Setbacks 29
8. Vandalism 29
9. Signs 29
10. Disabled Access 29
B. Checklist for Fleet Facility EVSE Siting 30
C. Engineering and Construction 30
D. Charging Equipment 31
E. Fleet Recharge Management Systems 31
F. Metering and Billing Systems 32
G. Electrical Service 33
H. Electric Rates 33
I. Site Installation Plan 33
J. Building Permits 34
K. Costs 34
L. Checklist for Vehicle Fleet Charging 36
6. Public Access and Commercial Charging Installations 39
A. Local Codes and Regulations 39
B. Payment of Charging Services 39
C. Types of Chargers and Level of Charging 39
D. EVSE Siting Decisions 39
E. Electrical Service Adequacy 40
F. Electric Rates 40
G. Prevention of Vandalism 40
H. Lighting 41
I. Creating the Site Plan 41

J. Installation Costs ... 41
K. Checklist for Public Access and Commercial Charging Installations ... 41
Appendix A. Public Charging Locations Currently in Operation ... 43
L. Inductive Sites ... 43
M. Conductive Charging Sites ... 44
Appendix B. Building Code Contacts in Major Cities ... 46
Appendix C. Glossary of EV Terms ... 47
Appendix D. References ... 50

. TABLE OF FIGURES

Figure 1: Typical Residential EV Charging Infrastructure..2
Figure 2: Conductive and Inductive Level 2 Connectors 7
Figure 3: Options for Installing Dual Meter Adapters (Where Allowable).......................................11
Figure 4: Typical Signs Used with EVSE and Charging Locations 16
Figure 5: Typical Parking layout for Disable access..18
Figure 6: Sample Residential EV Infrastructure Plan..22

1. INTRODUCTION

The introduction of electric vehicles (EVs) in Northern California brings a challenging set of planning, regulatory, and cost issues. Because EVs require a unique infrastructure—including specialized charging equipment and adequate electric service—most users, as well as infrastructure installers and PG&E staff, are not familiar with charging basics. This guide provides the necessary information all users, installers, and PG&E need to better handle the task of installing the appropriate equipment for residential and fleet EV customers.

The guide's introduction defines key terms and responsibilities, and gives other sources of information. Chapter 2 discusses the safety codes governing EV charging equipment, electrical requirements, equipment options, and PG&E rates for EVs. Chapter 3 details the electrical and building code requirements that apply to all installers and users of electric vehicle supply equipment (EVSE). The remaining chapters discuss the special needs of the different classes of EV users: homeowners (including multifamily residences), fleet facilities, and public access and commercial charging facilities.

For fleet users, the Energy Policy Act of 1992 (EPAct) requires fuel providers to include alternative fuel vehicles (AFVs) in their replacement vehicle purchases beginning in 1996. PG&E has opted to use EVs to meet part of this requirement. EPAct also sets guidelines for federal, state, local, and private fleets to include AFVs when purchasing replacement vehicles, and many of these organizations also plan to buy EVs. As a result, the installation of EVSE has become an important issue to many fleet managers today.

For residential customers, infrastructure issues are less complex in terms of siting, equipment selection, and load management. In addition, EV manufacturers provide ample information and assistance concerning EVSE placement and installation. However, municipalities in PG&E's service territory treat metering issues differently. This guide addresses the practices in a few cities and provides names of relevant code officials.

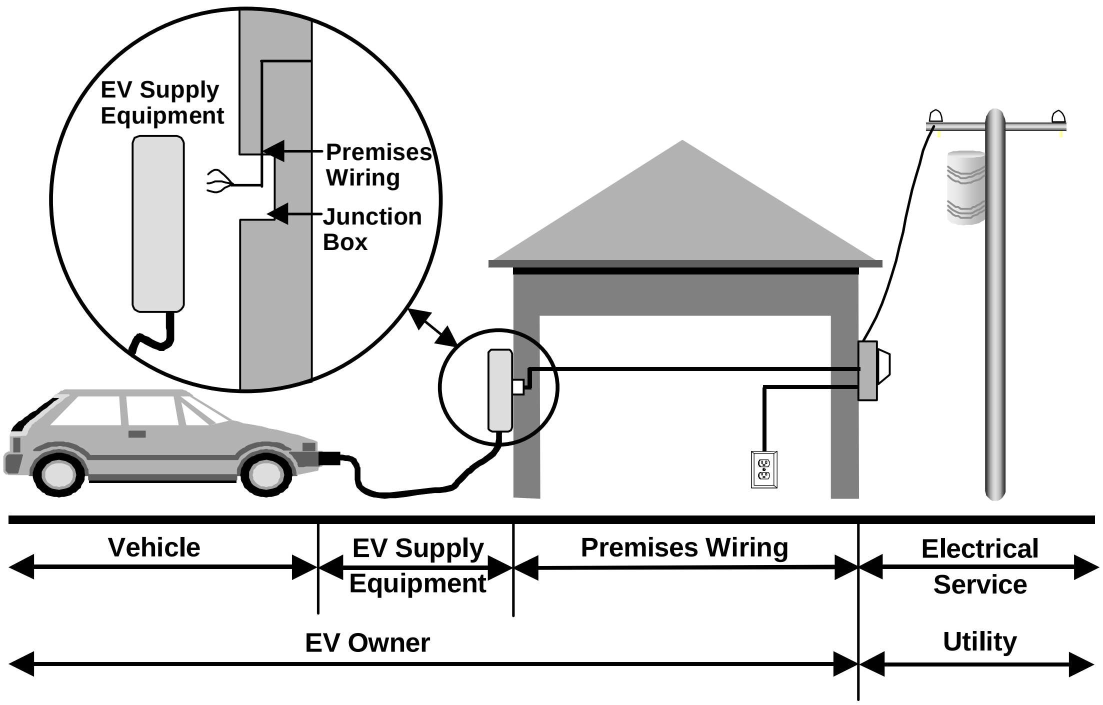
A. EV Infrastructure Essentials

EV infrastructure is comprised of the following components:

- EVSE, including a charger, cable, and connector
- Premises wiring that runs from the customer meter to the EVSE
- Electrical service, including PG&E power lines and the customer meter

PG&E provides installation advice and assistance (call PG&E's Clean Air Transportation Hotline at 800-684-4648) but the EV owner is ultimately responsible for the installation and operation of the EVSE, as well as for any upgrades or improvements to the premises wiring. EV owners must obtain the appropriate building permits and ensure that a qualified licensed contractor or electrician performs the installation. EV dealerships offer assistance in finding contractors for these installation services. The following figure illustrates a typical residential charging set-up and the responsibilities of each component.

Figure 1: Typical Residential EV Charging Infrastructure



PG&E owns, installs, and maintains the electric service to the customer meter, in addition to providing electricity. For residences, PG&E offers special EV time-of-use (TOU) rates that provide incentives to charge EVs off-peak. To take advantage of some of the special rates, the EV owner may want install a second meter for the EVSE circuit (see Chapter 2E, *PG&E EV Rates*, for more information).

B. Information Resources

These guidelines should not be considered the sole source of information related to installing EVSE and charging equipment. EV and EVSE manufacturers and dealers are the best sources of information on the infrastructure needs and regulatory requirements particular to their equipment. They can also provide information on ordinances in local jurisdictions, which may impose additional requirements.

Any EV infrastructure installer should follow guidelines provided by manufacturers of the EV, the charging equipment, and the EV battery. In almost all cases, EV infrastructure installation requires permits and inspection by local building or electrical code officials. Installations should always be performed by licensed contractors.

2. EV CHARGING ESSENTIALS

The codes, standards, and ordinances governing EVSE design, manufacturing, and installation make EV charging safe. The person performing the charging is protected against electrical shock through the use of protection systems. Nationally recognized testing laboratories such as the Underwriters Laboratory (UL), have approved and listed EV charging components to ensure their durability and safety.

The following is a list of standard EVSE safety features:

- An EV will not start if it is still plugged into the charger
- Before the charger can be disconnected, the cable must de-energized
- The vehicle inlet is de-energized until the driver attaches the unique connector to the vehicle
- The EV connector cannot be used with other appliances
- Monitors and a ground-fault circuit interrupt (GFCI) shut down the electricity supply if they sense a potential problem
- For the few battery types that emit potentially explosive gases, building codes require ventilation to eliminate risks.

Any variation from relevant building codes and regulations can create a potential hazard. Abusing the equipment can also lead to trouble. All EV owners and EVSE installers must note that a building permit is required for EVSE installations and should adhere strictly to the applicable codes, standards, and ordinances.

A. Rules and Regulations Governing EV Infrastructure Installations

In most circumstances, local building officials will not issue permits for installing EVSE without first seeing plans showing compliance with applicable codes and ordinances. Compliance with local and state regulations is necessary to pass the building inspector's post-installation inspection. California and federal codes that regulate charger installation are described below.

1. The National Electrical Code (NEC)

The National Fire Protection Association's National Electrical Code (NEC) sets standards for electrical construction and operation. The NFPA revises and publishes a new *National Electrical Code Handbook* every three years. The 1999 NEC update covers EV charger installation issues in Chapter 6, Article 625.

The 1999 NEC update has added new language to two sections of Article 625. Article 625-22 calls for personnel protection systems for EV charging systems to replace ground-fault current interrupter devices to protect from shock. Article 625-29(d)(3) provides an alternate method for determining indoor ventilation levels.

2. The California Electrical Code (CEC)

The 1998 California Electrical Code (CEC), administered by the California Building Standards Commission and the state Fire Marshall's office, mirrors the NEC. Variations with the NEC were reconciled in 1998.

Chapter 3 provides a summary of the CEC.

3. Local Codes and Ordinances

Local jurisdictions can either adopt the national or state codes, or enact regulations that are more stringent. Some California counties, such as Sacramento County, passed ordinances requiring conduits for EV charging in new residential construction. These ordinances will save owners time and money when they want to install EVSE.

Some of the larger cities in Northern California have regulations prohibiting residences from installing dual meter adapters. These adapters are necessary to take advantage of certain special time-of-use rates (see Chapter 2E), which are particularly important to EV users.

A selection of cities in PG&E's service territory were contacted regarding their permitting practices for EV charging facilities and EVSE. The following table illustrates their policies toward residential dual meter adapters.

City	Dual Meter or Adapter?		Reason		
	Yes	No	Not Allowed *	UL Listing	Comments
San Francisco		X	X		
Oakland		X	X		
San Jose	X				Allowed for vehicles only
Bakersfield	X				
Fresno		X		X	
Stockton		X	X		
Modesto		X	X		Homeowners can apply for variance

* Ordinance or building code restrictions due to zoning, etc.

EV purchasers and installers should contact their local City/County Building Department to verify that dual meter adapters are allowed in their area if considering separately metering the EVSE.

4. UL Listing

Dual meter adapters are currently not listed by Underwriters Laboratory (UL). UL is performing tests on the equipment and hopes to complete the listing by the end of 1999. However, their use is regulated by local building authorities as illustrated in the previous table. While only one of the cities contacted restrict dual meter adapter use on the basis of non-listing by UL, several prohibit the use of multiple meters in order to protect against illegal housing units ("in-law" units).

5. Installation Plans

Most local jurisdictions require EV owners to submit building or electrical plans as part of the permit process. These plans can include:

- A plan or one-line diagram showing the service panel schedule and branch circuit location
- A diagram describing the ventilation system, including location of the EVSE, air inlet, and exhaust fan may be required when EV batteries requiring ventilation are used.

6. Equipment Certification

The local building inspector will verify that components are approved, or UL-listed and labeled. According to NEC, *approved* means "acceptable to the authority having jurisdiction."

B. EV Charging Levels

EV charging is performed at three voltage and current levels. The levels are defined to meet the current EV's needs, to meet anticipated future technologies' needs, and to provide compatibility with the nation's electric transmission and distribution system. The 1999 *NEC Handbook* describes the three charging levels. Levels 2 and 3 require dedicated EVSE. The sections below describe each charging level in greater detail. The following table summarizes the electrical requirements of the three charging levels.

	Voltage (VAC)	Current (Amps)	Power (kVA)	Freq. (Hz)	Phase	Standard Outlet
Level 1	**120**	**12**	**1.44**	**60**	**single**	**NEMA 5-15R**
Level 2	**208/240**	**32**	**6.7/7.7**	**60**	**single**	**SAE J1772/3**
Level 3	**480**	**400**	**192**	**60**	**three**	**N/A**

1. Level 1 Charging

Level 1 charging uses a common 120-volt, single-phase outlet for a three-prong grounded (NEMA 5-15R) connector with ground-fault circuit interrupt. Level 1 charging requires 8 to 14 hours to fully charge a vehicle, depending on the EV and battery type. One advantage of Level 1 charging equipment is that it eliminates the need for upgrades to the current electrical service. The main disadvantage is that it is insufficient to provide a full charge to an EV within 4 to 6 hours.

Level 1 charging electrical specifications include:

- 120-volt ac single-phase maximum nominal supply
- 12 amps maximum continuous current with 15 amps (minimum) branch circuit protection

The maximum continuous current and branch circuit protection values are based on compatibility with the existing electric supply infrastructure.

2. Level 2 Charging

When using Level 2 charging, an EV can be charged in 4 to 6 hours, depending on the EV, battery type, and capacity.

Level 2 charging electrical specifications include:

- 208-240 volts ac single-phase maximum nominal supply
- 32 amps maximum continuous current with 40 amps branch circuit protection

Other required features for Level 2 charging include grounding or electrical isolation, personnel protection from shock, a no-load make/break interlock, and a safety breakaway for the cable and connector.

3. Level 3 Charging

Level 3, or fast charging, requires high levels of voltage and current to replenish more than half of an EV's battery capacity in as quickly as ten minutes. Tests of Level 3 charging have taken place and a commercial charger was recently made available. However, there are no public charging sites using Level 3 charging in PG&E's service territory as of March 1999.

Level 3 chargers use a 480-volt ac, 400-amp, three-phase electrical service and require the same safety features as Level 2 EVSE.

C. Charger Technologies: Conductive and Inductive

Currently there are two technologies being used to connect EVs to the EVSE: conductive and inductive. Both are available for all levels of charging.

EVs will only use one of these technologies since they are incompatible. A vehicle using one technology typically cannot be connected to a charger with the other technology because they employ different connectors. Each technology has its strengths and weaknesses as listed in the following table:

Issue	Inductive	Conductive
Safety	No difference	No difference
Energy Efficiency	Not as efficient as conductive charging	More efficient
Cost	Complexity of system makes it more expensive	Simpler system makes it less expensive

1. Conductive Technologies

Conductive charging uses physically connecting contacts, similar to methods used by common appliances. It is the method used by most on-board chargers, or systems that place the charging circuitry and control on the vehicle. The connector for these systems is usually a butt-type connector.

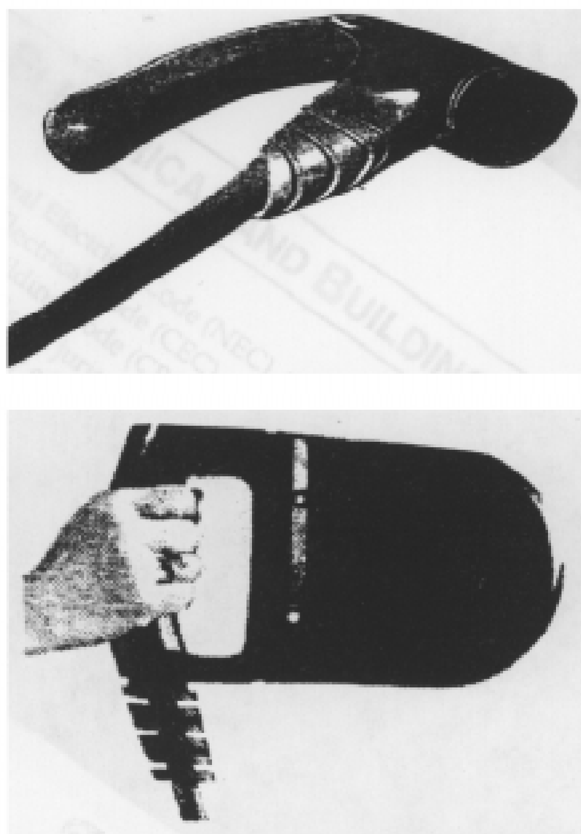
Some off-board chargers, or systems that place the charging circuitry and controls off-board the vehicle in a charging stand, also use conductive coupling. In this case, the charger communicates with the battery and vehicle electronics over the communications wiring in the connector.

2. Inductive Technologies

Inductive charging systems transfer ac power by magnetically coupling a primary winding on the supply side to a secondary winding on the vehicle side. Current flows through the primary inductor coil, or paddle, and the resulting magnetic flux induces an alternating current through the magnetic field and across the secondary coil, completing the circuit. The ac current is converted to dc for storage in the vehicle battery.

Inductive chargers keep most of the charging circuitry and controls in an off-board charging stand, and communicate with the battery and vehicle electronics via infrared or radio frequencies.

Figure 2: Conductive and Inductive Level 2 Connectors



D. Charging Equipment Currently Available

As of March 1999, the following EVSE are available in PG&E’s service territory (listed by manufacturer):

- **AVCON**

Product Name: EV Power Pak
Charging Type: Conductive
Charging Level: Level II
Price: $295
Contact: Kristine Todryke, AVCON - 800/433-7642
Comments: Price includes shipping and handling

- **Aerovironment**

Product Name: PosiCharge
Charging Type: Conductive
Charging Level: Level III (fast charge)
Price: Model PC 60100 (60 kW) - $40,000 available with 240v and 480v utility connections; (120 kW) - $80,000 available with 240v and 480v utility connections
Contact: Jon Bertolino, Sacramento Municipal Utility District (SMUD), 916/732-6980 for Northern California and Nevada; Marc Cortez, Aerovironment, 626/357-9983 x311 for Southern California and Arizona
Comments: The 60 kW unit has a UL listing but the 120 kW unit does not. Aerovironment also offers battery management systems (BMS) for OEM electric vehicle and EV conversions so they can use PosiCharge. The cost of a BMS unit starts at $2,200.

- **Electric Vehicle Infrastructure, Inc. (EVI)**

Product Name: Model ICS-200B
Charging Type: Conductive
Charging Level: Level II
Price: Model ICS-200B, single outlet, wall mounted - $1,800; Model ICS-200B, single outlet with pedestal - $2,205; Model ICS-200B dual outlets, with pedestal - $4,120
Contact: Edison EV - 888/890-GOEV or ETEC - 888/383-2387
Comments: EVI 's chargers can come with additional options

- **General Motors ATV**

Product Name: Magne Charge
Charging Type: Inductive
Charging Level: Level II
Price: Wall mounted unit - $1,995; Floor/pedestal unit - $3,285
Contact: Edison EV - 888/890-GOEV
Comments: Chargers are 7.5 kW. GM ATV has a fast charger in demonstration but not available for purchase.

- **Lockheed Martin**

Product Name: 14.4 kW Conductive Charger Station
Charging Type: Conductive
Charging Level: Level II
Price: Not available. See comments below
Contact: Edison EV - 888/890-GOEV or ETEC - 888/383-2387
Comments: The charger is included with the purchase of Chrysler's EPIC minivan only and not available for general purchase.

- **Norvik**

Product Name: Minit Charger
Charging Type: Conductive
Charging Level: Level II and Level III (fast charge)
Price: Ranges from $35,000 for a 35 kW charger to $125,000 for the 250 kW fast charger.
Contact: Janet Vogt, Norvik Traction, Inc., 905/828-7700
Comments: Price varies depending on model features

- **SCI Systems**

Product Name: Stylized Wall Mount; Pedestal
Charging Type: Conductive
Charging Level: Level II
Price: Stylized Wall Mount, single outlet - $1,800; Pedestal, single outlet - $2,695; Pedestal, dual outlets - $3,995
Contact: ETEC - 888/383-2387
Comments: Custom configurations are available

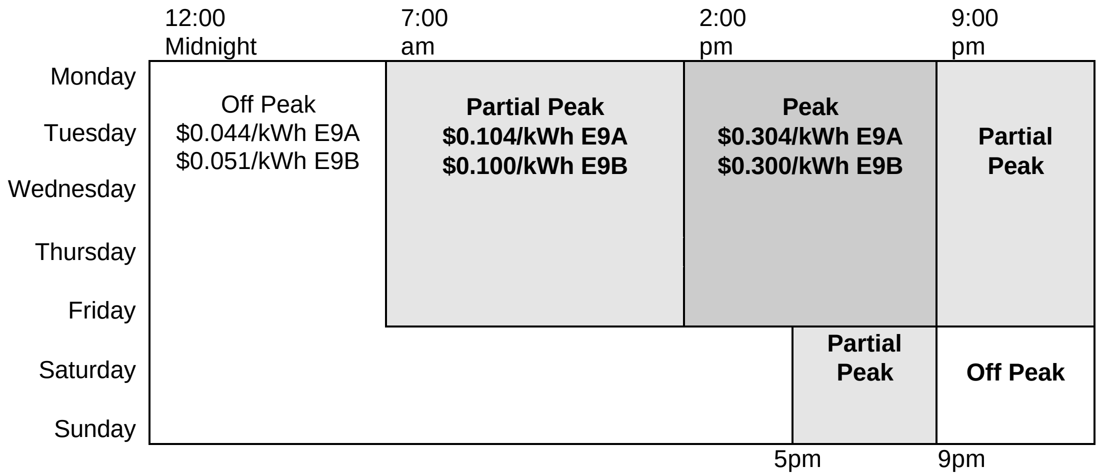
E. PG&E EV Rates

PG&E offers special rates to encourage EV market development and electricity use during night-time, off-peak hours when the utility has surplus distribution capacity. EV charging is a natural match for time-of-use rates since most EV users—in both residences and fleets—find that the most convenient (and sometimes the only) time to charge their vehicle is overnight.

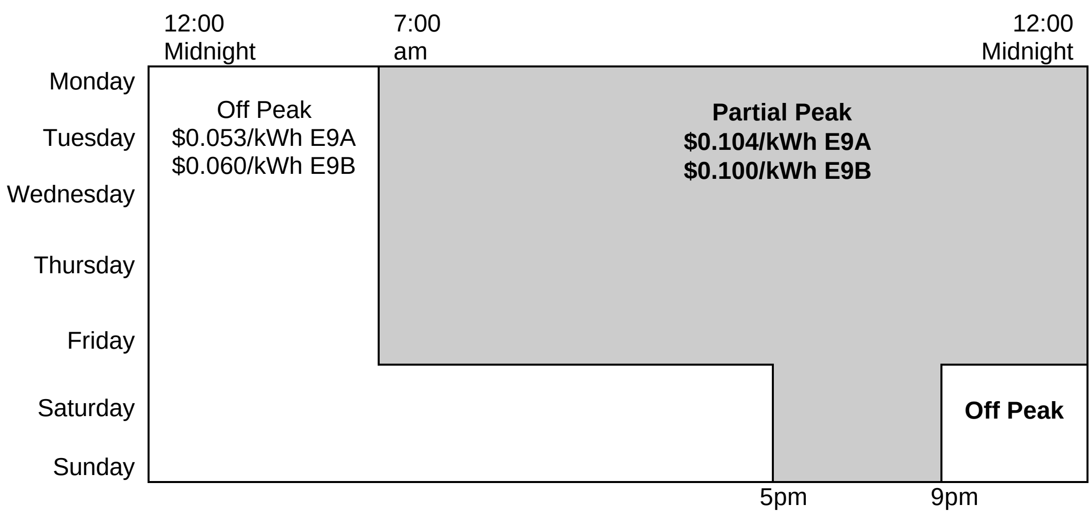
There are two options available to homeowners seeking to use TOU rates. First, the entire house—including the EVSE—can be metered under the special EV rates (see below). An alternative is to meter the EVSE separately from the rest of the house. To accommodate this, a second meter panel or a special dual-meter adapter is required. The adapter may not work in all residential installations. In such cases, the customer may have to pay a licensed electrician to install a second meter conforming to local jurisdiction or utility requirements. When the customer has the meter installed, requirements for city permits and inspections apply (see section on local regulations).

PG&E's rate schedule E9 is based on time-of-use and season. Residential customers have the option of selecting one of two rates from rate schedule E9, depending on their meter set-up. Rate E9A applies to electricity used in the entire residence, including the EV and does not require separate meters. Rate E9B requires separate meter or a dual meter adapter since it applies only to electricity used by the EV. PG&E representatives are available to review the rates with EV owners and EVSE installers and discuss specific energy use issues and patterns that will assist in choosing the most cost-effective E9 rate option. The E9 rates are as follows:

Summer (May 1 through October 31)



Winter (November 1 though April 30)

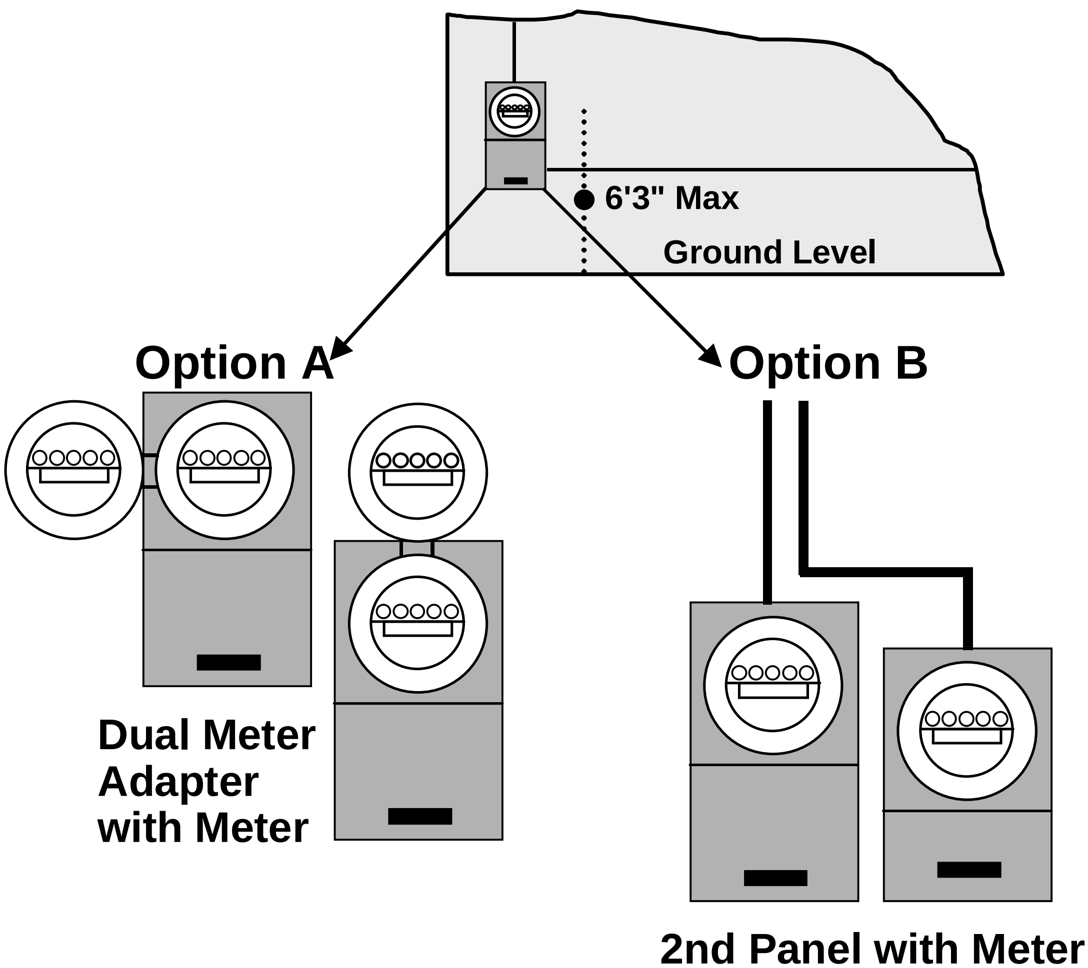


In addition to the energy charges, rate E9 contains a daily meter charge and a daily minimum energy charge. To be consistent with other residential customer rate schedules, E9 customers receive a rate reduction bond credit and rate E9A customers receive a specific credit for usage for up to the baseline allocation they are entitled, which is based on climate zone.

EV buyers should review the most current E9 rates and options by requesting a copy of the rate schedule from PG&E , or downloading a copy from the company's website at *www.pge.com*. Call PG&E's Customer Service Call Center at 800-743-5000 or the Clean Air Transportation Hotline at 800-684-4648 to receive additional information on the E9 rate schedule or to set up the E9 rate schedule at their residence.

If a residential customer can use dual meters or a dual meter adapter and chooses rate E9B, the dual meter set-up will be similar to the following graphic.

Figure 3: Options for Installing Dual Meter Adapters (Where Allowable)



3. CODE REQUIREMENTS FOR INSTALLING EVSE

As with any electrical installation, EV charging infrastructure is governed by various federal, state, and local building codes and requirements. In PG&E's service territory, the National Electrical Code (NEC), the California Electrical Code (CEC), and the California Building Code (CBC) are standards for local jurisdictions to follow to ensure the safe operation of equipment. As mentioned earlier, these codes are minimum standards, and some municipalities impose additional safeguards.

EVSE installations require building permits. Permit costs vary by municipality, and a service panel upgrade will add to the cost.

Currently, only Level 1 and Level 2 charging are allowed for personal use. The NEC and the CEC both require that all components (materials, devices, fittings, etc.) be listed or labeled. However, because some of the EVSE on the market today are still undergoing UL evaluation prior to UL listing and approval, installers are advised to contact local building officials if questions arise concerning equipment usage.

A. EVSE Used in Level 1 Installations:

The following code and regulatory issues are associated with the use of Level 1 EVSE:

- *Cords and Plugs:* The EVSE can be fastened in place or be cord-and-plug connected, but it should have no exposed live parts (CEC §625.13) and must be grounded (CEC §625.24).

- *EV Connectors:* (For Conductive Connection Only) Connectors shall be polarized, protected by double insulation, and non-interchangeable with receptacles in other electrical systems; made to avoid inadvertent contact between the user and live parts; designed to prevent unintentional disconnection; and have a grounding pole which connects first and disconnects last (CEC §625.9). The charger or vehicle manufacturer normally supplies this cable and connector to match the connector on the vehicle.

- *Markings:* All EVSE must be marked "For Use With Electric Vehicles" (CEC §625.15).

- *Overcurrent Protection:* EVSE feeders and branch circuits must be sized for continuous duty and have a rating no less than 125% of the maximum load of the EVSE. Where noncontinuous loads are supplied from the same feeder or branch circuit, such as the ventilation system, the overcurrent device must have a rating no less than the sum of the noncontinuous loads plus 125% of the continuous loads (CEC §625.21). For Level 1 charging, either a 15 or 20 amp single-pole circuit breaker at the beginning of the circuit, located in the meter-panel breaker section, will meet this requirement. Note that with a 15 to 20 amp circuit breaker, charging at 12 amps will overload the circuit if an additional 4 to 9 amp load is also on the branch.

- *Receptacle and Wall Plug:* A standard 15 or 20 amp residential wall plug and receptacle are acceptable for Level 1 charging. The receptacle should be wired with the correct polarity and a safety ground. (Depending on local code requirements and type of EV charging equipment installed, most charging equipment will be directly wired, eliminating the need for an in-wall receptacle.)

- *Personnel Protection:* The 1999 NEC has been modified to address this issue. According to the NEC, the EVSE shall have a listed system of protection against electric shock of people using the equipment. The personnel protection system shall be made up of listed protection devices and construction features. Regarding cord-and plug-connected EVSE, the interrupting device of a listed personnel protection system shall be provided and be an integral part of the attachment plug or be located in the power supply cable not more than 12 inches from the attachment plug. The change from the 1996 NEC is that personnel protection systems replace ground fault current interruption (GFCI) devices for protection from shock (NEC §625.22). The 1998 CEC still mirrors the language of the 1996 NEC (CEC §625.22).

- *Electricity Back-Feed to Residence Prohibited:* The EV must not be used as a standby power supply for the house, and a means must be provided to prevent power backfeed to the residence (CEC §625.25).

B. EVSE Used in Level 2 Installations

The code and regulatory requirements that affect Level 2 EVSE (apart from those listed in the section on Level 1 EVSE) include:

- *Overcurrent Protection*: To meet the loads associated with Level 2 charging, a minimum 40 amp, two-pole circuit breaker at the beginning of the circuit located in the meter-panel breaker section will be necessary if no additional loads are on the circuit.

- *Safety Switch*: For EVSE rated at more than 60 amps or more than 150 volts to ground, a means of disconnect must be installed in a readily accessible location and within sight of the electric charging connector. If the disconnect is not in sight of the equipment, it must be capable of being locked in the open position (CEC §625.23). Depending on local code requirements, a fused switch may be needed if the switch is not readily accessible, or is not visible from the main panel.

- *Receptacle and Wall Plug*: Where the EVSE calls for an in-wall receptacle, a 50 amp, 240 volt, 3- or 4-wire wall plug configuration is required. However, most charging equipment will be directly wired, eliminating the need for an in-wall receptacle. Level 2 EV connectors are designed so that they cannot be used with receptacles for other electric equipment, and the EVSE is labeled “For Use With Electric Vehicles” (CEC §625.15, 625.16).

- *Cables and Connectors*: EV charging cables must not exceed 25 feet in length, and they cannot have mid-cord couplings. Cables must be type EV, EVJ, EVE, EVJE, EVT, or EVJT flexible cable. EV charging cables and connectors come with the charger (CEC §625.17). The connector must include an interlock to de-energize it when it is unplugged from the vehicle, or when it is subjected to stress that may rupture or break it, or when it becomes a shock hazard (CEC §625.18). The grounding pole for conductive connectors are the first contact made and last broken (CEC §625.9). For inductive charging, the EV and EVSE are electrically isolated, which prevents shock hazard.

- No Back-Feed of Electricity to Residence: The EV cannot serve as a standby power supply for the house, and a means must be provided to prevent power from being fed back to the residence (CEC §625.25).

C. Installations Where Ventilation is Required

The need for ventilation in indoor charging facilities is very rare. Few current EV batteries are flooded lead-acid or nickel-iron batteries, the two technologies that release hydrogen. The current industry battery standards are sealed lead-acid or nickel-metal hydride (NiMH). In the sealed lead-acid batteries, hydrogen and oxygen recombine into water, eliminating the ventilation requirement. In NiMH advanced batteries, the battery electrodes absorb and store the hydrogen for later electrochemical reaction. Other new batteries such as lithium-ion and lithium-polymer advanced batteries depend on the electrochemical activity of lithium ions, a light metal, involving no gases. Very few batteries will require ventilation during charging.

In the few circumstances where non-sealed batteries are used, electrolysis (the separation of water into hydrogen and oxygen) can be caused when a flooded lead-acid or a nickel-iron battery is fully charged and additional current is added to the battery. The gas mixture is potentially explosive in certain concentrations, therefore ventilation is required when such batteries are charged in enclosed spaces. Since hydrogen is lighter than air and therefore rises, ventilation must be provided above the EV if it is charged in an enclosed garage. The lower flammability limit (LFL) of hydrogen in air is a 4% mixture by volume; locations are classified as hazardous wherever 25% of the hydrogen LFL (a 1% hydrogen/air mixture) is exceeded.

Even though the newer generation of batteries have overcome the need for ventilation, both the NEC and CEC have provisions for ventilation when the situation warrants. California includes the ventilation requirements and table in the California Building Code (CBC §1202.2) and as of 1998, in the California Electrical Code as well (CEC §625.29). The ventilation table provided below is taken from the CEC. When a ventilation system is installed, receptacles and power outlets should be marked "For Use with All Electric Vehicles." When ventilation is not provided, the EVSE, receptacles, and power outlets must be clearly marked "For Use Only with Electric Vehicles Not Requiring Ventilation." The following table is based on CEC Table 625-29(c). "Minimum Ventilation Required in Cubic Feet per Minute (cfm) for Each Parking Space Equipped to Charge an Electric Vehicle."

Branch Circuit Ampere Rating	Branch-Circuit Voltage						
	Single Phase					3 Phase	
	120 V	208 V	240 V or 120/ 240 V	208 V or 208 Y/ 120 V	240 V	480 V or 480 Y/ 277 V	600 V or 600 Y/ 347 V
15	37	64	74	--	--	--	--
20	49	85	99	148	171	342	427
30	74	128	148	222	256	512	641
40	99	171	197	296	342	683	854
50	123	214	246	370	427	854	1066
60	148	256	296	444	512	1025	1281
100	246	427	493	740	854	1708	2135
150	--	--	--	1110	1281	2562	3203
200	--	--	--	1480	1708	3416	4270
250	--	--	--	1850	2135	4270	5338
300	--	--	--	2221	2562	5125	6406
350	--	--	--	2591	2989	5979	7473
400	--	--	--	2961	3416	6832	8541

For other single-phase values, cubic feet per minute can be calculated by multiplying volts times amperes and dividing by 48.7: $cfm = (volts \times amps)/48.7$.

For three-phase values, cfm can be calculated by multiplying volts by the square root of three (1.73), then by amps, and dividing by 48.7: $cfm = (volts \times \sqrt{3} \times amps)/48.7$.

Required ventilation equipment includes both supply and mechanical exhaust which intakes from, and exhausts directly to, the outdoors. The passive intake vent should be placed low on one side of the enclosed space, and the exhaust fan in the ceiling on the other side. The ventilation system must be interlocked with the EV charger to turn on when the charger starts, and should continue to operate at least five minutes after charging is completed.

D. Codes Governing EVSE Siting

The following regulatory and code issues affect the placement of EVSE:

- The NEC calls for indoor EV charging receptacles/coupler to be stored or located between 18 and 48 inches above the floor.
- In outdoor charging locations, chargers must be stored or located at least 24 inches above the grade. The same is true for mounting outdoor power outlets.
- All explosive materials, flammable vapors, liquids and gases, combustible dust or fibers, and materials that ignite spontaneously on contact with air should be kept away from all EVSE.

The installer is referred to NEC Articles 500 to 516 (equipment and procedures for installation of electrical systems in hazardous locations) if the location has been designated as a Classified (Hazardous) Location.

E. Installations Located in Flood Zones

If a charging station is in a flood zone, all chargers must be installed above the base flood elevation or waterproofed to include personnel protection so that it complies with codes for electrical equipment which may become submerged.

F. Required Signage

To ensure safety and proper operation of EVSE, signs containing safety warnings have been designated by the NEC, CEC, and the EV industry through their Infrastructure Working Council (IWC).

Figure 4: Typical Signs Used with EVSE and Charging Locations

G. Lighting Recommendations

The NEC and CEC do not set requirements for lighting at EV charging facilities. However, designers and installers should use common sense to ensure that enough light be available for security reasons and safe operation of the EVSE. Using best practices for similar settings, a minimum of 300 lux and 30 footcandles of lighting should be provided. Additional lighting may be necessary depending on the size and importance of written instructions, special needs of operators, and the contrast of objects illuminated.

H. Disabled Access

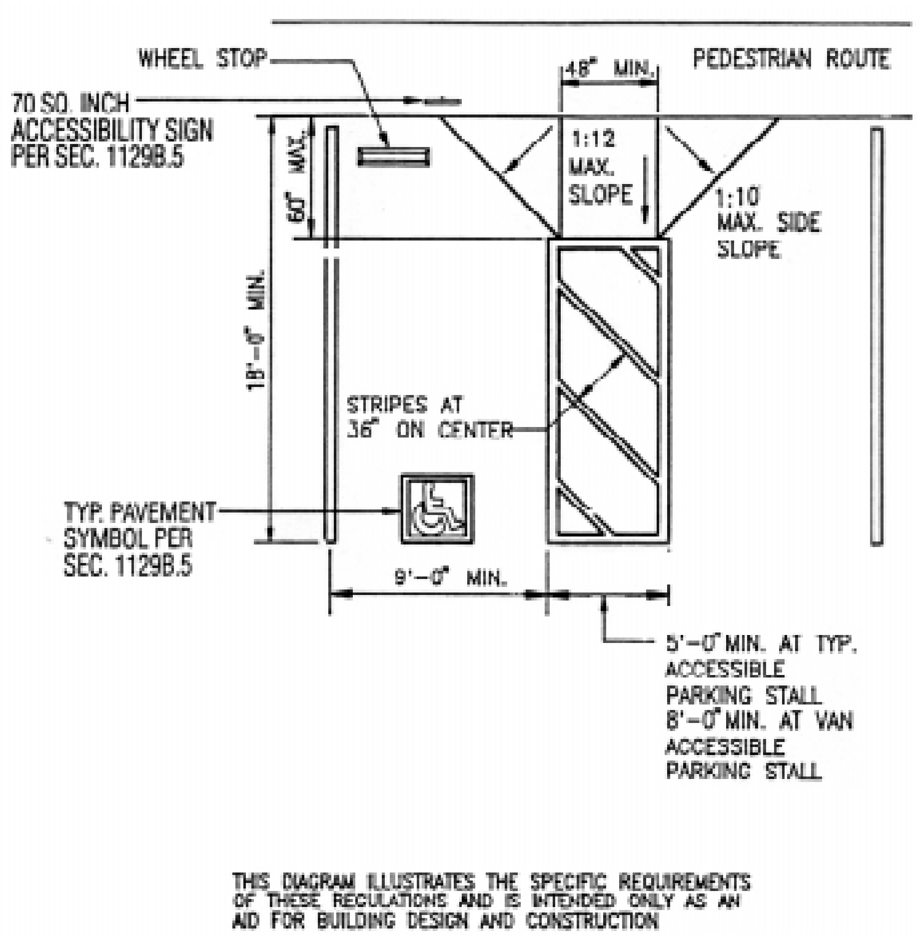
ADA Compliance: Connector and receptacle heights, special curb cutouts, and disabled parking access are some of the measures that may be necessary to make a charging station fully accessible for the disabled. Each operator must assess their compliance with the federal Americans with Disabilities Act, as well as state and company policies regarding disabled access.

The State of California's Division of the State Architect has issued "Interim Disabled Access Guidelines for Electric Vehicle Charging Stations" (Policy #97-03). EV charging stations are required to be accessible because they offer a service to the general public. When EV charging is coupled with regular parking, the EV charging is considered the primary service. The following table should be used in determining the required number of accessible chargers:

Number of Chargers Provided at a Site	Number of Accessible Charger Spaces Required
1 to 25	1
26 to 50	2
51 to 75	3
76 to 100	4

A 9-foot wide space by 18-foot deep space is required. An access aisle of 5 feet on the passenger side is also required. One in every eight accessible chargers, but not less than one, should be van accessible with an 8-foot access aisle. Accessible charging spaces are not reserved exclusively for people with disabilities. It is also recommended that accessible spaces be located in close proximity to the facility they serve. For new construction, an accessible path from the charger to the other services provided at the site is required.

FIGURE 5: TYPICAL SINGLE PARKING STALL LAYOUT FOR DISABLED ACCESS



4. EV CHARGING IN SINGLE FAMILY RESIDENCES

Residential EV users are fortunate in that suppliers of EVs and EVSE provide substantial assistance in setting up charging infrastructure. PG&E also provides assistance to those who have questions about the adequacy of their current electrical service. In addition, electrical contractors should be familiar with technical and permitting issues. This chapter provides an overview of the necessary steps in the installation process.

As mentioned in earlier sections, charging facilities must comply with all local, state, and national codes and regulations, regardless of the type of installation, and all work requires a permit and should be handled by appropriately licensed contractors. Contractors should make sure to check with the local planning department before starting work. It is important to note that PG&E will not energize a new meter without a properly signed building inspection.

This chapter is presented as a step-by-step process that should be followed to ensure proper EVSE installation. This chapter also includes information specific to multi-family residences.

A. Step 1: Determine the Charging and Battery Types

Before any equipment purchases and electrical services changes are made, the homeowner should determine the type and model of EVSE the EV manufacturer provides or specifies, and that equipment's electrical requirements. As discussed in Chapter 2, conductive and inductive charging equipment require different connectors and are installed in a different manner. The EV dealership will also know if the vehicle's battery requires ventilation during charging.

B. Step 2: EV Utility Rates and Meter Options

Before installing the EVSE, contact PG&E for more information about its special EV rate schedules (see Chapter 2E *PG&E EV Rates*). It is the homeowner's responsibility to sign up for rate schedule E9 with PG&E. For the homeowner to take advantage of PG&E's E9B rate schedule, the residence must be able to separately meter EV charging. As mentioned earlier, some municipalities do not allow separate meters to be installed in a residence. Homeowners are advised to check with their city's building inspection department.

C. Step 3: Determine the Home's Electrical Capacity

The installation contractor can tell the homeowner if the home has adequate electrical capacity for EV charging. Many people will want to use Level 2 EVSE due to the quicker charging times, but many older homes may not have sufficient electrical capacity. In those instances, they must add a new electrical service panel to handle the 240 volt, 40 amp Level 2 charging circuit needed for Level 2 charging. A quick survey by an electrical contractor can determine if a service panel upgrade—generally the most costly step in installing charging facilities—is necessary.

D. Step 4: Determine EVSE Placement

The following factors should be considered when determining where to place EVSE:

1. Safety Issues in Enclosed Garages

Enclosed garages offer convenience, safety and security. Most single family residences will employ this option. Some of the factors to consider when planning an EVSE installation in an enclosed garage include:

- The EV charger should be placed where the cable will stretch the shortest distance, where the user can easily reach the charger handle, and where it does not block entry or exit. Therefore, check the location of the charging port on the EV before planning the EVSE location.
- Avoid having the cords and cables cross areas with heavy foot traffic.
- If practical, use cable management to prevent accidents.
- As mentioned in Chapter 3, EVSE must not be installed near explosive material; flammable vapors, liquids and gases; combustible dust or fibers; and materials that ignite spontaneously on contact with air. See NEC Articles 500 to 516 for more information.

2. Extending Electrical Service

If a detached garage does not have electrical service, the installer should help the homeowner decide where to place the wiring for the EVSE: overhead, which is less expensive but visually less attractive option; or underground which can be more expensive but is also more attractive.

3. Outdoor Charging

Charging equipment is weatherproof and can be placed outdoors, but it should be protected from damage. It is also recommended that EVSE be installed in a secure location to protect against vandalism. In addition, EV buyers should check the EV manufacturer's recommended operating and charging temperature range for the battery pack and site the EVSE accordingly. This applies to both indoor and outdoor locations.

E. Step 5: Drawing Up the Installation Plans

After determining the electrical equipment needs and the optimal location of the EVSE, the next step involves drawing up precise plans for the branch circuit and EVSE installation. Part of this step involves checking that the planned installation complies with the code requirements as summarized in Chapter 3. Most importantly, local building code officials should be contacted regarding special requirements and documentation needed to obtain the permit and pass the building inspection. Then, the EV buyer should select a currently licensed electrical contractor.

The contractor will help draw up any installation plans to be submitted as part of the permit applications. For a residential permit, most jurisdictions require a drawing that shows:

- The electrical panel schedule
- The wiring of the new branch-circuit, including the meter, charger, and all receptacles
- If ventilation is required, the location of the vent fan, its specifications, and air inlet and air flow in cubic feet per minute
- The location of the EVSE in the garage and any potential hazards

The installation plan should be detailed enough for the local code official to determine that the installation meets code requirements, is safe, and meets all federal, state, and local requirements. Drawings should be complete but not overly detailed.

Above all, the EV owner and contractor should follow the instructions provided by the EV and EVSE manufacturers to ensure safe and proper equipment operation.

F. Step 6: Obtaining Permits, Performing the Installation, and Conducting a Site Inspection

When the installation plan is drawn up, the EV owner then applies for the permit, which varies in price by task and jurisdiction. The contractor can begin installation when the permit is issued. When the installation is complete, the owner should arrange for an inspection with the local building inspector, and then make any required changes. Figure 4 on the following page illustrates a typical residential EV infrastructure site plan using a separate meter for the EVSE.

G. Other Issues Pertaining to Single Family Residences

In addition to following the process outlined above, the homeowner should be aware of other issues that can affect their EVSE installation:

1. Insurance

According to insurance companies contacted, EVSE in a single-family residence does not require a rider to the existing insurance policy or separate coverage. EV owners should check insurance requirements with their insurance agent.

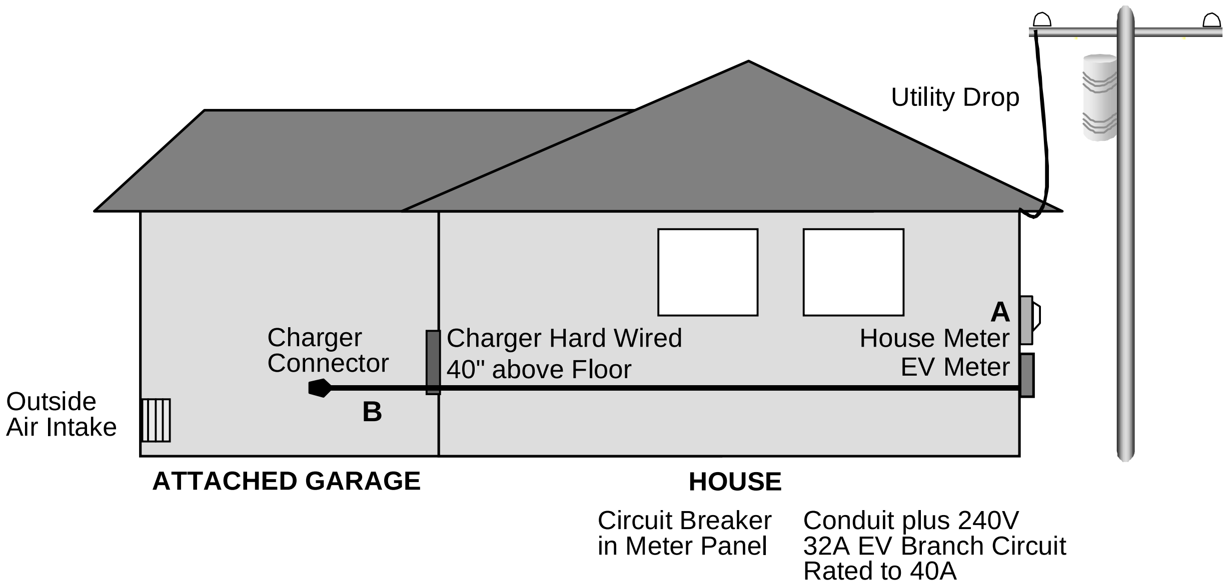
2. Costs

In general, the cost of an EVSE installation ranges from $500 to $1,500 if an electrical panel upgrade is not required. If a panel upgrade is needed, the installation cost will be approximately $2,500. These costs do not include the EVSE itself. Some EV manufacturers include EVSE equipment in their vehicle lease price. As mentioned earlier, check with the EV dealer first before starting with the installation planning.

The following factors will influence the total installation cost:

- The particular EVSE selected
- Whether the garage is attached or detached
- Electrical service panel upgrade requirements
- The use of trenching vs. use of existing conduit or raceway
- The electrical panel location relative to the EVSE
- Type of construction (slab or crawlspace)
- Ease of installing new wiring

Figure 5: Sample Residential EV Infrastructure Plan



A
Electrical Panel Schedule

1
240V 30A
Garage Dryer

2
240V 40A
EV Meter

3
120V 15A
House
Lighting

4
120V 15A
Bedroom
Receptacles

5
120V 15A
Dining Room
Living Room
Receptacles

6
120V 15A
Kitchen
Receptacles

7
Available

8
Available

B
Electrical Vehicle Supply Equipment

- Level 2 Conductive or Inductive Charger 240V, 32A, All Components and Cables New
- Connector Interlock Includes Automatic De-energizer for Vehicle, Cable and Connector
- Circuit Breaker in Meter Panel
- Charger Installed 40 Inches Above Floor

For reference only, the following table lists some sample costs for specific components. Actual costs will vary and all costs may not apply to all installations.

ITEM	COST	ITEM	COST
Permits	$45—$110	*240 V outlet and 30 ft. wiring*	$195 installed
Circuit breaker panel boards		*Drywall labor 6 ft x 8 ft*	$225
- 100A	$450—$685 installed	*400 ft trenching*	$225
- 225A	$940—$1,300 installed	*Cut and patch concrete - 221 ft^2*	$525
- 60A subpanel	$385 installed	*Ventilation*	$275 + installation
- 40 A circuit breaker	$23—$75 installed	*EVSE*	$100—$3,000

H. Single-Family Residence EVSE Installation Checklist

In summary, the following steps should be taken to successfully install EVSE in a single family residence:

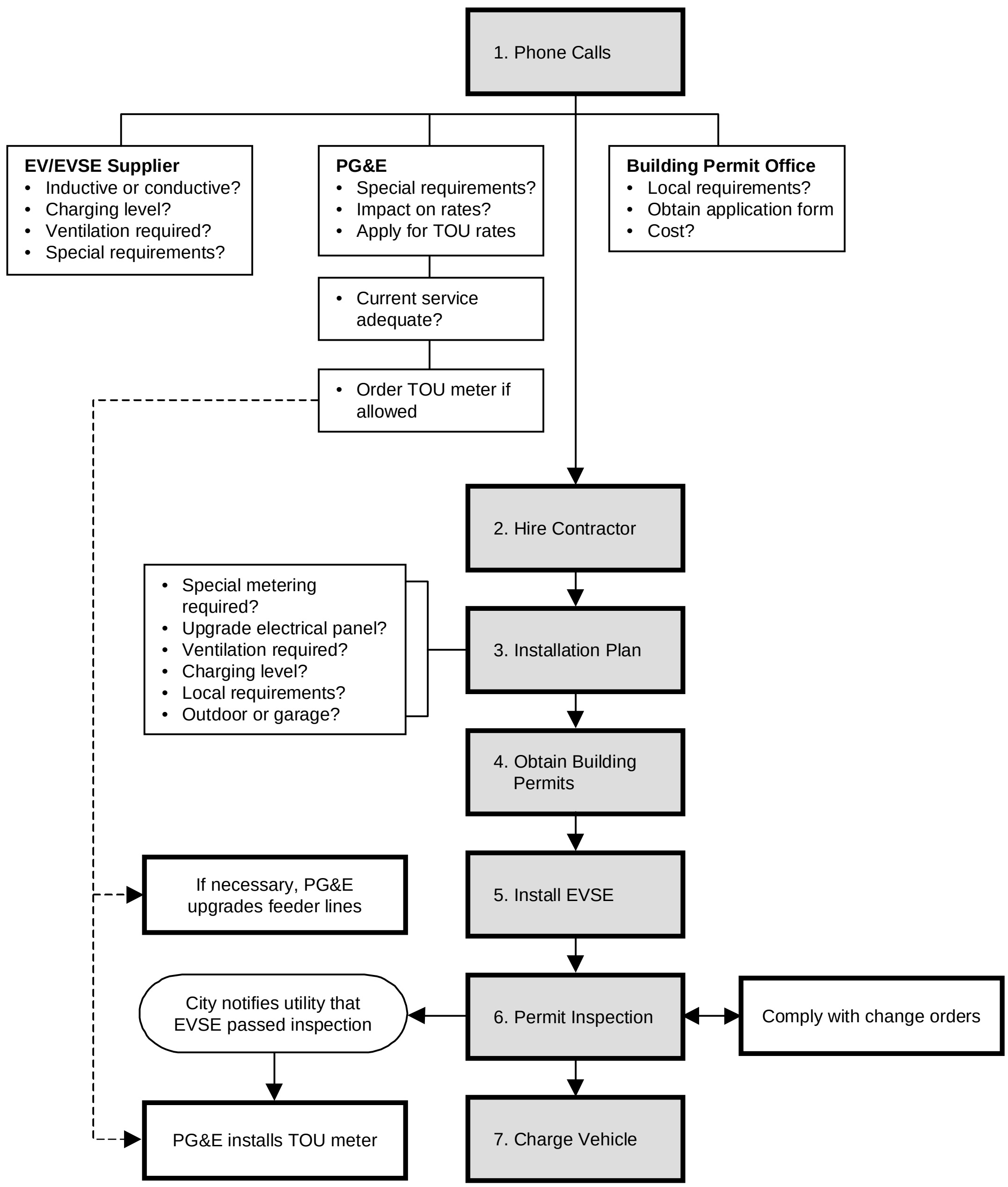
1. Determine from EV dealer whether vehicle requires conductive or inductive EVSE
2. Determine from EV dealer whether the vehicle battery requires ventilation during charging
3. Check with PG&E about special time-of-use rates, metering, and electrical service requirements.
4. Check with local building inspection office about the use of dual meters
5. Decide whether to place the EVSE in the garage or outdoors
6. Determine whether the home's electrical service is adequate for the charging needs
7. Determine whether the local jurisdiction, EV, or EVSE manufacturer has any special requirements
8. Select an electrical contractor and ensure that the contractor's license for electrical work is current
9. Develop an installation plan, including drawings, panel schedule, lists of materials, and ventilation diagram if ventilation is required
10. Apply for a building permit. Do not begin installation until the permit is issued
11. Order necessary components and supplies
12. Install EVSE (and ventilation if required)

13. Notify building department that the installation is ready for inspection

14. Comply with inspector's change orders, if any are issued. The city will notify PG&E that the circuit is ready to be energized after it passes inspection

15. Charge and drive the EV.

The following flowchart illustrates the process.



I. Issues Related to Installations in Multifamily Residences

Many of the steps taken to complete an EVSE installation at a single-family residence will apply to multifamily residences. However, the following issues are specific to this customer segment and must be addressed before installation begins:

- The ownership of the electrical work and circuit from the meter to the charger, which a tenant cannot take when moving
- How the EVSE will be connected to existing circuits if a separate meter is not possible, along with arrangements for paying electricity bills
- The ownership of the EVSE
- Determining responsibility for any increased insurance costs related to the EVSE
- The location of the charger
- Determining payment arrangements for any mechanical, civil and electrical engineering work and landscaping required for the site

1. Ownership of EVSE

Ownership of EVSE becomes a potentially contentious issue in apartment buildings and condominiums. The EV buyer must settle the issue before any additional planning starts. How this is resolved will affect who pays for the installation, who is responsible for permits, metering issues, electricity payments, and whether or not the EV owner can keep the EVSE upon vacating the building. The following sections examine how these issues might be discussed and resolved for two different types of residences.

2. Apartments

In virtually all situations, the landlord must approve any EVSE installation. Tenants should discuss installation cost with the property owner or manager to see if the property owner will install the EVSE and make an appropriate rent adjustment to cover its cost. One possible arrangement is having the apartment owners pay for installation of the circuit, while EV owners could pay for the charging equipment and take it with them when they move. Also, some municipalities allow only one meter per unit plus one for common areas. This can negate the use of a dual meter setup.

3. Condominiums and Townhouses

Some of the issues are similar in condominiums. The EV owner in a condo or townhouse will probably need the homeowners' association approval to install the EVSE. The homeowner should discuss installation cost with the homeowners' association to see if the association, which may be eligible for a tax deduction, will install the EVSE and make an appropriate adjustment to association dues or fees to cover its cost.

4. Metering Arrangements

Depending on the municipality, the property owner/manager, or homeowners' association, must determine whether to:

- Run the service from the relevant residential unit
- Meter each EV parking space separately

- Run all chargers off one meter

5. Electrical Capacity

Since many multifamily dwellings are built up to the full capacity of their electrical service, building owners/operators must determine whether they have adequate electrical service for the number of planned EV charge stations. The owner/operator should also take any future EV charging needs into consideration. They may necessitate the upgrading of the feeder lines and transformers serving the site, which can delay the service. If upgrades to the transformers or the electrical panel on site are required, the party paying for the installation may incur significant expenses.

6. Insurance

Owners of multifamily residences, condos, and townhouses may need additional insurance to cover the cost of the EVSE and liability. Property damage insurance should cover EVSE and installation costs. Determining who pays for the coverage and the extent of coverage are issues for negotiation between the apartment owner and tenant, or between a condo/townhouse owner and the homeowners' association. A local insurance agent should be contacted for specific details.

7. Costs

As with any EVSE installation, the cost will depend on the type of EVSE, number of spaces required, and siting requirements. the following table lists. For reference only, the table in the next chapter lists some sample costs for specific components in typical EVSE installations at multifamily residences. Actual costs will vary and all costs may not apply to all installations.

5. EV CHARGING AT FLEET FACILITIES

Government, utility, and private fleets are currently the largest market for EVs. Federal and California clean air regulations specifically target fleets in their attempts to increase the number of clean air vehicles. PG&E has been a leader in introducing both EVs and natural gas vehicles into their fleet and can provide considerable assistance to other organizations attempting to meet clean air mandates.

The process of establishing EV charging infrastructure in fleet facilities is more complicated than in residential settings but many of the underlying issues are the same. This chapter outlines issues that are specific to fleet applications.

A. Site Planning

Many siting issues influence the successful planning of a charging facility:

1. Number of EVs and Chargers

Planners must be realistic when determining the number of EVs a fleet will include, because that number will determine each facility's charging requirements. Estimates must include the number of fleet vehicles to be added over the next three to five years, with special attention to meeting upcoming state and federal AFV mandates. The facility operator should also consider planned flexibility that allows the site to grow with developing technologies or changes in charging requirements. Planners should seriously consider installing extra circuits and additional electrical capacity during initial construction, when costs are minimal.

Fleet managers should analyze what the fleet's charging schedule will be by developing a charging curve for each vehicle in the fleet (see next page). The curve matches the time of day a vehicle is recharged with the amount of energy used. After developing a curve for each vehicle, they can be aggregated to get a facility-wide fueling curve. This calculation will determine the frequency of charging and the energy required to service the entire facility. It will also facilitate equipment scheduling by helping determine the amount of time needed to recharge each vehicle. Based on the information taken from the charging curve, a facility manager can plan: charging needs (number of chargers), facility energy needs, and the necessary mix of Level 2 and Level 3 charging. The vehicle manufacturer and EVSE supplier can provide fleet managers with sample charging time and electricity consumption figures in order to develop a charging curve.

Several factors must be considered when deciding between Level 2 or Level 3 charging. Because of the length of time necessary to complete Level 2 charging, a facility will most likely need one charger per vehicle, as charging will take place overnight. This scenario may require additional land, island construction, cabling, and transformers—and will require the installation of appropriate EVSE. These factors can increase capital costs significantly. Installing Level 3 charging will raise costs for cabling, transformers, and chargers, but possibly lower land and construction costs.

How a fleet uses its vehicles will determine the appropriate charging method. Vehicles requiring expanded range may require a fast mid-day charge, requiring rapid Level 3 charging. However, Level 3 charging will raise equipment and electricity costs. In addition, some EV manufacturers will void the vehicle's warranty if the owner uses Level 3 charging. Each facility manager must carefully assess their fleet use and weigh the cost differences before deciding on using one charging level or a combination of both.

As mentioned earlier in this section, the following table shows a sample aggregated charging curve for a fleet facility.

Time	Number of vehicles	Type of vehicle	Electricity dispensed (kWh)	Charge level	Total charge time per vehicle*
1:00					
2:00					
3:00					
4:00					
5:00					
6:00	2	Shuttle buses	200	3	1 hr. each
7:00					
8:00					
9:00					
10:00					
11:00					
12:00	2	Pass. cars	50	3	15 min. each
13:00					
14:00					
15:00					
16:00					
17:00					
18:00					
19:00					
20:00	4	Pickups	100	2	4.2 hrs. each
21:00					
22:00					
23:00	2	Pass. cars	50		4.2 hrs each
24:00					
Total			400 kWh		27.7 hrs.

** Charge time is determined by vehicle charging algorithm.*

2. Convenience

Locate the charging station so that it accommodates other activities within the fleet facility. It is advisable to locate the station in a low-traffic area of the facility, because EVs may be required to remain parked for several hours at a time and therefore could block the movement of other fleet vehicles.

3. Cable Management

Cords and cables associated with charging equipment should not cross sidewalks or pedestrian traffic patterns.

4. Ventilation Needs

As discussed in Chapter 2, most of today's advanced batteries do not require ventilation during charging. However, some earlier battery types do produce and emit gases during charging as a result of electrolysis. Due to the concerns related to these older battery types, the facility manager should ensure that adequate ventilation is in place when older battery types that do emit gases are included in their fleet.

The cost of ventilation equipment, including fans, ducts, and air handlers, ranges from $400 for a 320 cfm centrifugal roof exhauster to $2,550 for a 1000 cfm industrial exhauster. Equipment should be based on the specific enclosure and the number of chargers installed.

5. Battery Operating and Charging Temperature Limits

Some EV batteries have operating and charging temperature limits, so under some circumstances (such as cold climate conditions) it may be necessary to site the EVSE in an enclosed area.

6. Standing Water and Irrigation

Even though all EVSE have been designed for safe operation in wet areas, user comfort will be increased by not placing equipment in locations where water pools or within the spraying area of irrigation systems.

7. Curbs, Wheel Stops, and Setbacks

To avoid vehicles from inadvertently driving into the EVSE, provide curbs, wheel stops, and setbacks. Consider user access and mobility issues when installing this equipment (see section 10 in this chapter – Disabled Access).

8. Vandalism

Planners should site EVSE to avoid the risks of vandalism or tampering. Consider including motion detectors, security lighting, tamper alarms, locked enclosures, and fences. The level of protection required will depend on the location of the EVSE, whether access is public or private, and the overall security requirements of the facility.

9. Signs

Fleet operators may want signage to designate EV-only parking spaces. These should be positioned high enough to be seen over parked vehicles.

10. Disabled Access

ADA Compliance: Connector and receptacle heights, special curb cutouts, and disabled parking access are some of the measures that may be necessary to make a charging station fully accessible for the disabled. Each operator must assess their compliance with the federal Americans with Disabilities Act, as well as state and company policies regarding disabled access.

The State of California's Division of the State Architect has issued "Interim Disabled Access Guidelines for Electric Vehicle Charging Stations" (Policy #97-03). EV charging stations are required to be accessible because they offer a service to the general public. When EV charging is coupled with regular parking, the EV charging is considered the primary service. The following table should be used in determining the required number of accessible chargers:

Number of Chargers Provided at a Site	Number of Accessible Charger Spaces Required
1 to 25	1
26 to 50	2
51 to 75	3
76 to 100	4

A 9-foot wide space by 18-foot deep space is required. An access aisle of 5 feet on the passenger side is also required. One in every eight accessible chargers, but not less than one, should be van accessible with an 8-foot access aisle. Accessible charging spaces are not reserved exclusively for people with disabilities. It is also recommended that accessible spaces be located in close proximity to the facility they serve. For new construction, an accessible path from the charger to the other services provided at the site is required.

B. Checklist for Fleet Facility EVSE Siting

Facility planners should answer the following facility planning questions before proceeding further:

- What level of charging will be used?
- What are the charger requirements?
- Is the existing electricity supply adequate for fleet needs?
- What is the location of the electrical service relative to the charging equipment siting?
- What will be the impact of electricity rates on choosing alternative approaches to fleet EV charging?
- What are the cost trade-offs between charging levels and equipment locations?
- Have I addressed all of the relevant federal, state, and local code requirements?

C. Engineering and Construction

Many pieces of equipment are unique to EV charging facilities, and fleet managers should be careful to select contractors familiar with their specifications. In addition to the standard civil engineering work required to construct any fueling facility, EV facilities will require considerably more electrical service and electrical equipment installation.

A primary consideration for the site designer and the facility manager is the condition and location of the existing electric utility equipment. These factors will govern the number and size of formers, necessary trenching or overhead cabling, conduits, amount of cabling, and associated installation costs.

The key component in the interface between the existing electrical system and the EVSE is the transformer. To provide adequate power for Level 2 charging equipment, existing electrical service must be stepped down to a level that can work with Level 2 charging equipment: 208–240 volts. If not already available at the site, it will be necessary to install an isolation transformer capable of stepping electricity to 208–240 volts for Level 2 charging, or up to 480 volts for Level 3 charging. Isolation transformers can cost between $7,200 to $8,500.

D. Charging Equipment

As discussed in Chapter 2, charging equipment decisions depend on the EV charging designation: inductive or conductive, Level 2 or Level 3. Until the market determines which charging technology dominates, it is likely that both inductive and conductive charging will develop in parallel. Until a charger and connector standard evolves, some fleets may select a mix of inductive and conductive chargers, depending on what their fleet EVs require.

Presently, there are several different manufacturers supplying different types of connectors for conductive charging equipment. Facility managers should ascertain that the connector is compatible with the receptacle on the vehicle. Vehicle manufacturers can supply the proper connector specifications for their vehicles.

E. Fleet Recharge Management Systems

Another component of a charging facility will be its Fleet Recharge Management System (FRMS). An FRMS is an integrated, computerized charging system that is designed to eliminate the costly process of managing electric vehicle charging for fleet applications by automatically sequencing multiple chargers. These systems are designed to accomplish the following goals:

- Automate recharging of fleet vehicles, thereby reducing the need for human intervention in the process
- Eliminate redundant charging infrastructure at charging locations where more than one vehicle will be charged
- Reduce overall fleet management labor costs
- Reduce electric charging costs through load management
- Reduce electric utility infrastructure needs, thereby lowering the cost to serve the load
- Allow fleet operators to choose all charging parameters

The key to an FRMS is its ability to manage charger sequencing. This functionality will determine the ultimate value of any system that is developed. It is likely that any successful system will be computer-controlled and be able to communicate with the local utility to take advantage of time-of-use rates or real-time pricing. By managing the electrical load in this manner, the FRMS will use electricity economically and will optimize fleet energy use.

One FRMS is currently under development by Southern California Edison and has been demonstrated using existing hardware. The goal of this pilot is to study the feasibility of the system, determine its strengths and weaknesses, determine fleet operator needs, and transform those needs into algorithms that can be improved in the future. This knowledge will be used to develop hardware that can be easily mass-produced to lower overall system costs.

The key component of this FRMS is the charge controller that automates the charging process. Through a PC-compatible computer, the controller distributes enough charge to maintain low overall peak electricity costs, while keeping connected vehicles in a state of full charge. It acts by interfacing with individual charging meters to perform the following tasks:

- Report on the required charge of each vehicle
- Determine the initial charge level of each plugged-in vehicle
- Determine the energy flow through the system
- Receive synchronization commands from the local utility through a communications device
- Display historical and real-time information
- Provide diagnostics

Other utilities are investigating different load management devices. The Electric Vehicle Research Network has sponsored a study of charge management systems in conjunction with Norvik. This system is a charge sequencer for fast chargers and does not have some of the enhanced features mentioned above.

The full costs of FRMS have yet to be determined but could be minimized by the use of existing computers, meters, communication devices, and kiosks. It is estimated that costs for a complete FRMS will range from $4,000 to $10,000 depending on the number and level of chargers. For more information on the SCE system, please contact Sam Katagi at (626-302-9515).

F. Metering and Billing Systems

While metering/billing systems are most often associated with public refueling systems, fleets may also want to investigate their use. Along with the FRMS, these systems can be very helpful in matching electricity consumption to individual vehicles. A typical system could incorporate advanced billing capabilities to help generate detailed monthly statements, including tracking by vehicle identification number. This system would allow fleet managers to track EV use, charging times, and associated energy costs. Several system options are available to fleet operators and are designed to accommodate individual access and reporting policies, including direct utility billing or point-of-sale billing. Metering and billing system prices vary, depending on which features are included. Prices range from $800 for a debit card system to $2,700 for a cashless voucher system to $14,000 for a TECH-21 proprietary card system. Fleet managers should assess their needs in this area to choose the appropriate system. Because the current billing systems are most compatible with gasoline and diesel fuels, charging equipment manufacturers would have to modify their systems for EV use. Recently, EVSE manufacturers have begun to make their equipment compatible with existing metering and billing systems.

G. Electrical Service

Generally, one charger will be required for each EV for overnight recharge (Level 2). The typical electrical demand for original equipment manufacturer vehicles using 240V single-phase service is 7 kW while charging for buses and fast chargers (using 480V three-phase service) can have demand levels of 50 kW or more. Actual kW demand is determined by the individual charging algorithm required by the vehicle. PG&E can help the fleet manager determine electricity requirements and compare them to existing service. If the feeder line must be upgraded and new transformers added, the organization should add sufficient capacity to meet the site's EV charging needs for several years. If the fleet manager plans to install Level 3 fast chargers, the electrical service requirements should also meet this load. When evaluating electrical service, managers should examine the following issues:

- **Service Level.** Determine the location, capacity and types of service panels and on-site transformers.
- **Distances Between Equipment.** Determine the distance between service entrance, transformers, panels, subpanels, and parking locations.
- **Identification of Potential Hazards.** Ensure that EV charging spaces are not located near potentially hazardous sites such as gasoline fueling areas.

When determining electrical needs for recharging, the fleet manager should contact PG&E to determine if existing feeder lines and equipment can provide the service, or if they must be upgraded.

Other factors to be considered include the costs of running three-phase power to the site and stepping it down to single phase, or using high-voltage single phase and a step-down transformer to the appropriate voltage. Again, local utilities will be able to assist facility planners in determining what service changes or upgrades will be necessary.

H. Electric Rates

The additional electrical demand for each EV charging during peak-demand periods may move a customer into a higher rate category. Charging multiple EVs may also trigger a surcharge for the reactive component of energy consumed. Fleet managers should discuss the impact of EV charging on rates with a PG&E representative. During the planning process, it is also important to discuss potential loads so that PG&E can assess their impact on PG&E’s overall system. Fleet charging may have some effect on peak power demand, especially when Level 3 charging is used. The integration of an FRMS at the fleet site can manage and minimize demand by scheduling charging at off-peak times whenever possible.

I. Site Installation Plan

Many municipalities require EV fleets to develop and submit an installation plan for engineering review and approval. Fleet managers may want to hire an electrical contractor for this task. A site plan typically describes:

- Location of the main electrical panel, branch circuits, and conduits
- Location of hazardous materials
- Location of charging stations
- Lighting
- Traffic flow
- Ventilation (if necessary)
- Description and locations of signs
- Curbing, wheel stops, cutouts, setbacks, and bumper guards
- Parking spaces, striping, driveways, and walkways
- Landscaping

J. Building Permits

Building and electrical permits are required for EVSE installations (see Chapter 3). Some utilities will not energize new charging circuits until they have passed inspection and the city or county notifies the utility. The cost of the permit and installation varies by municipality and depends on the scale of the upgrade.

K. Costs

The cost of installing fleet charging facilities can vary dramatically depending on the following factors:

- The number of circuits and chargers installed
- Whether the facility is indoors or outdoors
- The need to upgrade electrical service to the charging facility
- Whether ventilation is or is not required
- Whether Level 3 fast charge equipment is used or not
- Availability of discounts, tax deductions, and rebates from air districts and others.

In general, the cost to its fleet customers of installing EVSE range from $500 per vehicle per site to more than $5,000 per vehicle per site. The average cost per vehicle is $2,000.

For reference only, the following table lists some sample costs for specific components. Actual costs will vary and all costs may not apply to all installations. The costs quoted are applicable for fleet, public access, and multifamily charging installations.

Sample EV Charging Installation Costs for Public, Fleet, or Multifamily Buildings (all estimates are for installed costs)

Item	Cost
Power Distribution Sub-Panel -200A, 120/240 VAC single phase; three wires with main circuit breaker; six 40A/2P branch circuit breakers	**$1,435 ***
Transformer 50 kVA, 480/277 VAC primary, 120/240 VAC; 3 wires secondary; dry type NEMA 1 enclosure If power comes directly from utility distribution system: transformer pad; NEMA 3R, 200A, 120/240 VAC; 3 wires combination meter/main service and panelboard; ground rod (PG&E can furnish and install the transformer.)	**$ 3,975 *** **$ 5,300**
Cables/Conduits a) 40A branch circuit - Above ground installation - Underground installation b) 200A feeder circuit - Above ground installation - Underground installation	 **$3.85/linear ft **** **$6.85/linear ft **** **$13.25/linear ft **** **$21.00/linear ft ****
Lighting 250 watt, metal halide, parking lot lighting a) Wall or ceiling mounting b) On 16 ft galvanized steel pole, concrete base	 **$640 each *** **$2,750 each ***
Concrete Island In-place concrete island 6 in thick reinforced	**$7.20/ft^2 ****
Concrete Steel Pipe (Transformer or EVSE protection) Concrete fill steel pipe, 8 ft high, set 4 ft in ground, rounded top, painted	**$155 each ***
Concrete Bumper (EVSE protection) 4 ft long precast concrete bumper	**$88 each ***
Paving a) Demolition b) Asphalt paving composite	 **$1.95/ft^2 **** **$33.00/ft^2 ****
Signs 24 in x 24 in reflective signs; 2 in galvanized steel pole	**$200 each ***
Landscaping Soil preparation, irrigation system, sod (excludes trees and shrubs)	**$6.10/ft^2 ****

* Sample costs only. Actual cost may differ significantly depending on location, site requirements, installation, and equipment specification.

** Sample costs provided by Ocampo Esta Corporation. Actual cost may differ significantly.

L. Checklist for Vehicle Fleet Charging

1. Estimate 3–5 year EV purchase plans.

. Determine recharging locations.

3. Estimate the electrical load at those locations.
   - Determine whether to use Level 2 or 3 charging and type of charging to be used: inductive and/or conductive
   - Obtain charger requirements from vehicle and charger suppliers
   - Develop charging curves
   - Determine the appropriate number of chargers

4. Contact vehicle and charger suppliers.
   - Confirm charging needs and types
   - Identify any special ventilation requirements
   - Identify any other special considerations for the specific equipment

5. Contact PG&E.
   - Assess existing electricity supply
   - Determine necessary electrical service upgrades
   - Review metering requirements
   - Determine the impacts of rates on choosing alternative charging methods
   - Determine if any other special requirements exist

6. Develop a detailed facility site plan.
   - Develop and review wiring diagrams
   - Develop and review ventilation diagrams
   - Determine if there are hazardous material locations at site
   - Review traffic, pedestrian flow, parking requirements, and ADA compliance issues
   - Determine additional retrofit needs, including landscaping

7. Contact pertinent permitting agencies.
   - Identify special local fire, construction, environmental, or building requirements
   - Obtain all applications
   - Determine additional permitting costs
   - Determine site plan requirements

8. Hire the prime contractor and verify contractor subcontractor credentials.

9. Obtain all pertinent building and use permits.

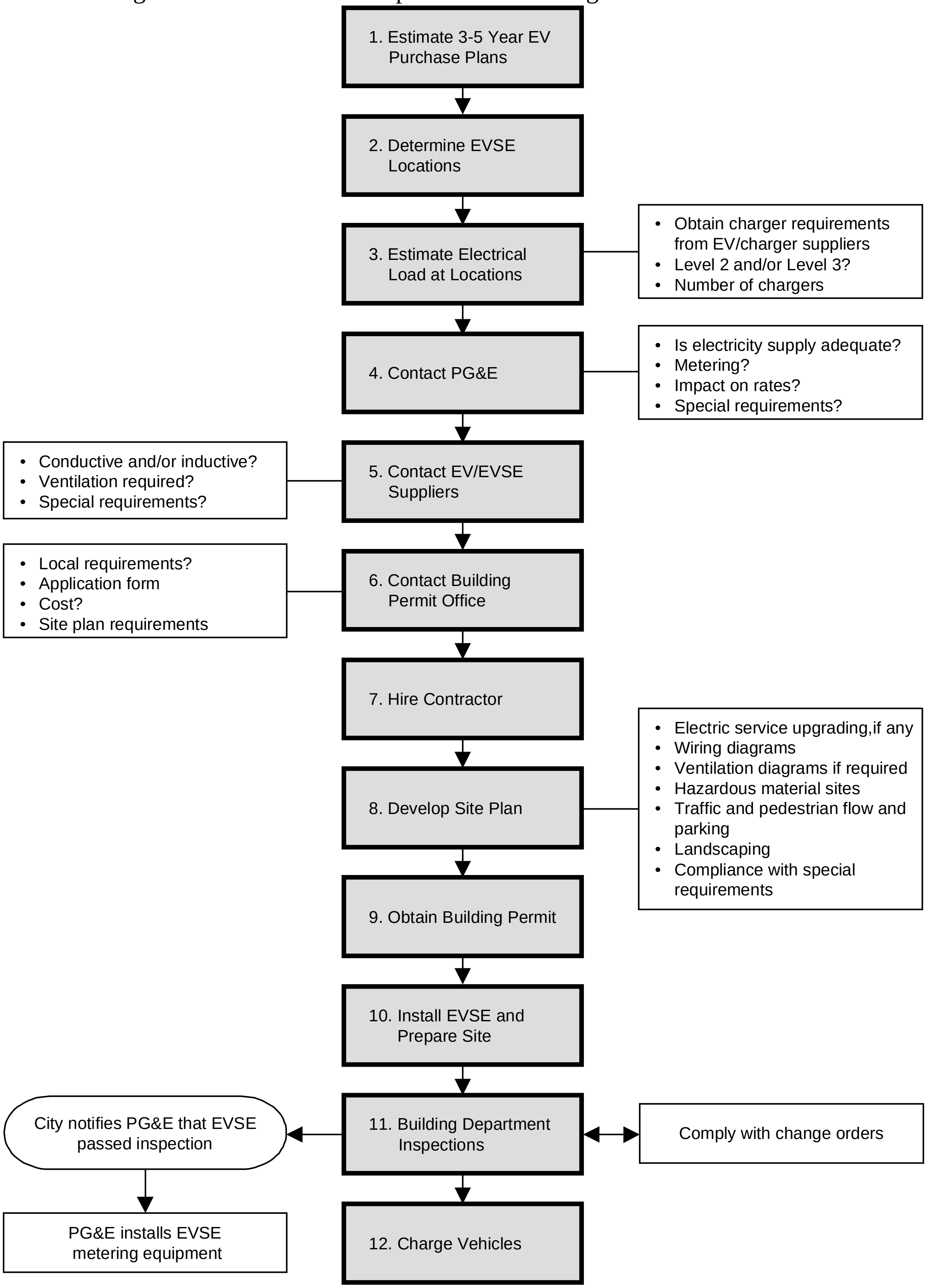
10. Perform any necessary electrical upgrades, install EVSE, and complete all site preparations.

11. Have the site inspected by pertinent building, fire, environmental, and electrical authorities.

- Comply with any change order, if necessary
- Notify PG&E that site has passed all inspections

12. Begin charging operations.

The following flowchart illustrates the process of installing EVSE infrastructure at a fleet facility:



6. PUBLIC ACCESS AND COMMERCIAL CHARGING INSTALLATIONS

The public access charging network is growing steadily. Currently there are 38 inductive and 17 conductive public charging sites in PG&E's service territory (see Appendix A). This chapter includes information specific to the installation of public access charging facilities.

A. Local Codes and Regulations

Some municipalities require a certain number of EV charging spaces at some public parking areas. These requirements may also specify the types of spaces to provide, such as disabled, most convenient, or covered parking.

B. Payment of Charging Services

Organizations interested in providing public EV charging must decide whether or not they will charge users to charge their EVs. Some commercial developers are not charging usage fees in an effort to attract customers. Other retail businesses are providing EV charging as a free service to patrons. However, since most public charging will occur during peak demand periods when the cost of electricity is highest, some form of billing system will eventually be required. Currently, credit cards, debit cards, and prepaid value cards are being evaluated to serve as point-of-sale and payment systems. When a viable payment system is available, EVSE suppliers will probably integrate the payment system with the EVSE.

C. Types of Chargers and Level of Charging

As mentioned in earlier chapters, the facility owner will need to decide which type of charging system to install: inductive, conductive, or both. Of course, this will be determined by the vehicles purchased. As in fleet facilities, public charging facilities currently offer Level 2 charging, which takes 3 to 6 hours to completely charge an EV battery pack, depending on the type and capacity of battery used. Level 2 charging is provided with both inductive and conductive connectors to serve all vehicles in the area.

It is anticipated that in the future, many public facilities will offer Level 3 charging so that their patrons can take full advantage of quick opportunity charging.

D. EVSE Siting Decisions

EVSE siting is especially important in public sites and can significantly affect the cost of the installation. There are many siting considerations relating to costs, safety, and aesthetics. These include:

- *Public Safety:* Chargers should be sited away from traffic and other hazards. Adequate lighting should be provided for security.

- *Convenience:* Chargers should be located conveniently near the main building or facility.

- *Proximity to Utility Equipment:* Siting charge stations near the electric utility's feeder lines or transformers may reduce installation costs.

- *Cable Management:* To avoid injury from tripping over cables, cords and cables should not cross sidewalks or pedestrian traffic patterns, and should be installed with the EV user's convenience in mind. Cable retractors should be considered for permanently wired cables.

- *Potential Hazards:* Ensure that EV charging spaces are not located near potential hazards. EVSE should not be installed near explosive material; flammable vapors, liquids and gases; combustible dust or fibers; and materials which ignite spontaneously on contact with air. NEC Articles 500 to 516 describe equipment and procedures for installation of electrical systems in hazardous locations. If charge stands are installed in an enclosed area, check ventilation requirements.

- *Curbs, Wheel Stops, and Setbacks:* Curbs, wheel stops, and setbacks should be provided so that EVs or other vehicles cannot inadvertently drive into the EVSE. When installing curbs, wheel stops, and setbacks, consider ease of access to the charger, mobility of users and foot traffic in the area.

- *Signs and Visibility:* The electrical codes require special signs for EVSE (see Figure 7.2). Signs may also be needed to designate parking spaces for EV-use only. These signs should be positioned high enough to be seen over parked vehicles.

- *Disabled Access:* See Chapter 3 for more details on disabled access and ADA compliance.

E. Electrical Service Adequacy

As with fleet facilities, the public site owner must determine whether the electrical service is sufficient to provide for EV charging. PG&E can help assess the current capacity and needed equipment upgrades. In public charging, the facility owner should also plan for the introduction of Level 3 charging and its related electrical demands.

F. Electric Rates

Property owners should discuss the impact of EV charging on rates with a PG&E representative.

G. Prevention of Vandalism

If the EVSE is situated in an outdoor parking lot, it should be sited to minimize the risk of vandalism. This includes consideration of lighting, alarms, traffic through the area, visibility from the security gate or desk, and fencing or enclosures.

H. Lighting

Public charge stations should have enough lighting to create an attractive environment and to provide safety for late-night charging. Lighting will vary according to the needs of the site and local ordinances. In all cases, lighting should promote security of EV drivers, EVs, and EVSE; safe operation of the charging equipment; and the attractiveness of the environment.

I. Creating the Site Plan

Similar to other types of installations, a site plan for engineering review and approval should be developed. A siting plan is necessary for a building permit, which is required for charger installation.

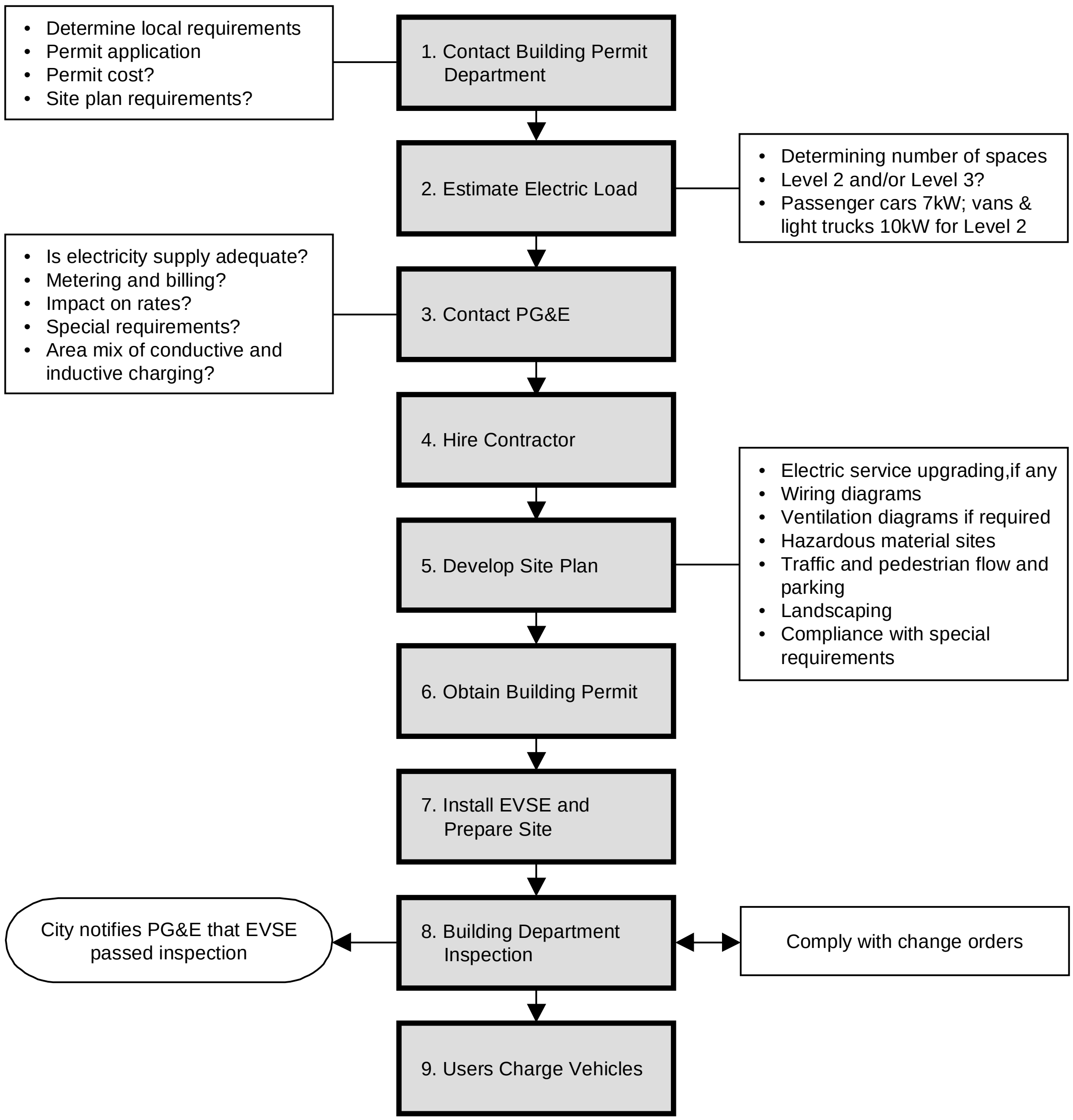
J. Installation Costs

The costs of installing EVSE will vary from site to site. The cost table in the previous chapter provides sample costs for reference only and is applicable to public access installations. Not all costs will apply to all sites.

K. Checklist for Public Access and Commercial Charging Installations

1. Investigate local requirements for EV charging, including number of spaces required, types of spaces (disabled, “most convenient,” covered parking, etc.). Also, determine whether the local jurisdiction, electric utility, or EV/EVSE manufacturer has any special requirements.
2. Determine number of spaces to add public-access EVSE.
3. Decide what levels of charging to install.
4. Estimate electrical load.
5. Contact PG&E to discuss adequacy of utility feeder line, equipment, impact of charging load on electric rates, and proper siting of new utility equipment.
6. Select an electrical contractor and ensure that the contractor's license for electrical work is current.
7. Develop a site plan, including location of hazardous materials; wiring diagrams; traffic flow, parking and landscaping drawings; lists of materials; and ventilation diagram (if ventilation is required).
8. Apply for a building permit. Do not begin installation until the permit is issued.
9. Install EVSE (and ventilation, if required).
10. Notify building department that the installation is ready for inspection.
11. Discuss insurance coverage with an insurance agent.

The following flowchart illustrates the process of installing EVSE infrastructure at public access locations.



APPENDIX A. PUBLIC CHARGING LOCATIONS CURRENTLY IN OPERATION

The following table lists public charging stations in operation as of March 1999 in PG&E's service territory.

L. Inductive Sites				
Alameda County				
BART	Eastern Lot	3100 Adeline Street	Berkeley	94703
Costco		40580 Albrae Street	Fremont	94538
Saturn of Fremont		39797 Balentine Drive	Fremont	94560
Saturn of Oakland		2355 Broadway	Oakland	94612
Saturn of Pleasanton		4340 Rosewood Drive	Pleasanton	94588
Stoneridge Shopping Center	Entrance by Nordstrom/JC Penney	One Stoneridge Mall	Pleasanton	94588
Costco		1900 Davis Street	San Leandro	94577
Jack London Square	Underground Parking	Broadway/Embarcadero	Oakland	94607
Jack London Square	AMC Movie Theaters	101 Washington	Oakland	94607
Contra Costa				
Sunvalley Shopping Center	By Macy's Home Store	One Sunvalley Mall	Concord	94520
Saturn of Concord		1330 Concord Avenue	Concord	94520
Hilltop Shopping Center	Green Lot by Macy's/JC Penney's	2200 Hilltop Mall Road	Richmond	94806
Costco		48801 Central Avenue	Richmond	94804
BART		200 Ygnacio Valley Blvd.	Walnut Creek	94596
Marin				
Saturn of Marin		535 San Francisco Blvd.	San Rafael	94901
Monterey				
Costco		1339 N. Davis Road	Salinas	93907
San Francisco				
Costco		450 10th Street	San Francisco	94103
Hyatt at Fisherman's Wharf	Valet Parking	555 North Point Street	San Francisco	94133
Mark Hopkins InterContinental Hotel		Number One Nob Hill	San Francisco	94108
Palace Hotel	Valet Parking	2 New Montgomery St.	San Francisco	94105
San Francisco Civic Center	Pay Parking	355 McAllister St.	San Francisco	94102

UC San Francisco	Millberry Union Garage, G level, pay parking	500 Parnassus Ave.	San Francisco	94143
San Mateo				
Saturn of Burlingame		198 California Drive	Burlingame	94010
BART		365 D. Street	Colma	94014
Saturn of San Francisco		711 Serramonte Blvd.	Colma	94014
Santa Clara				
Summit Micro Electronics	Water Tower Plaza (locked charger)	300 Orchard City Drive	Campbell	95008
Saturn of Sunnyvale		1088 W. El Camino Real	Mountain View	94086
Costco		5301 Almaden Expressway	San Jose	95118
Costco		2201 Senter Road	San Jose	95112
Saturn of Capital Expressway		755 W. Capitol Expressway	San Jose	95154
Costco		1601 Coleman Avenue	Santa Clara	95050
Saturn of Stevens Creek		4333 Stevens Creek Blvd.	Santa Clara	95051
Fry's Electronics		1077 Arques Avenue	Sunnyvale	94086
Solano				
Saturn of Fairfield		4850 Auto Plaza	Suisun City	94585
Costco		198 Plaza Drive	Vallejo	94591
Vacaville City Hall		650 Merchant St.	Vacaville	95688
Vacaville Regional Transportation Center		Hickory Lane and Davis St. @ I-80	Vacaville	95688
Sonoma				
Saturn of Santa Rosa		3001 Corby Avenue	Santa Rosa	95407

M. Conductive Charging Sites

Alameda				
BART Ashby Station	Eastern Lot	3100 Adeline St.	Berkeley	94703
Dublin Honda		7099 Amador Plaza	Dublin	94568
Costco		40580 Albrae St.	Fremont	94538
Costco		1900 Davis Street	San Leandro	94577
Costco		1900 Davis Street	San Leandro	94577
Stoneridge Shopping Center	Entrance by Nordstrom/JC Penney	One Stoneridge Mall	Pleasanton	94588
Contra Costa				
Sunvalley Shopping Center	Lower level, N. side of Macy's Home	One Sunvalley Mall	Concord	94520
Hilltop Mall	Green Lot By Macy's/JC Penney	2200 Hilltop Mall Rd.	Richmond	94806

BART Walnut Creek Station		200 Ygnacio Valley Blvd.	Walnut Creek	94596
Placer				
Electric Vehicle Infrastructure		11839 Industrial Ct.	Auburn	95603
San Francisco				
Hyatt Regency at Fisherman's Wharf	Valet Parking	555 North Point St.	San Francisco	94133
San Francisco Honda		10 South Van Ness Ave.	San Francisco	94103
San Mateo				
BART Colma Station		365 D St.	Colma	94014
Santa Clara				
Stevens Creek Honda		4590 Stevens Creek Blvd.	San Jose	95129
Costco		1601 Coleman Ave.	Santa Clara	95050
Solano				
Vacaville City Hall	One near Planning Dept., other by Public Works	650 Merchant St.	Vacaville	95688
Vacaville Regional Transportation Center Parking	Across from movie theaters, restaurants	I-80 @ Davis Street and Hickory Lane	Vacaville	95688

APPENDIX B. BUILDING CODE CONTACTS IN MAJOR CITIES

City	Contact	Phone Number
Bakersfield	Building Inspections Dept.	805-326-3720
Fresno	Electrical Inspections Dept.	559-498-2626
Modesto	Building Inspection Department	209-577-5232
Oakland	Calvin Wong, Electrical Inspector	510-238-4794
San Francisco	Frank Fong, Electrical Inspector	415-558-6030
San Jose	Joseph Boody, Electrical Inspector	408-277-4541
Stockton	George Davis, Electrical Inspector	209-937-8637

APPENDIX C. GLOSSARY OF EV TERMS

battery. Electrochemical cells electrically connected in a series and/or parallel arrangement.

battery pack. A group of battery cells or modules connected in serial or parallel arrangement, fully configured as a unit meeting the voltage and packaging requirements of a vehicle.

battery system. A completely functional complex battery which includes the battery pack and battery support equipment, such as thermal management and battery controls.

capacity. The total number of ampere hours (Ah) that can be withdrawn from a fully charged cell or battery for a specific set of operating conditions, including discharge rate, temperature, age, stand time, and discharge termination criteria.

charge. (*verb*) Conversion of electrical energy into chemical potential energy within a cell by the passage of a direct current. (*noun*) Coulombs or ampere-hours of energy available in a cell or battery.

charge coupling. A take-apart transformer for inductive charging operating between 80 kHz and 300 kHz, composed of two primary components—the vehicle inlet and the coupler.

charger. An electrical device that converts alternating current energy to a regulated direct current voltage for replenishing the energy of an energy storage device (i.e., battery) and operating other vehicle electrical systems.

conductive coupling. A recharge cord and plug that physically connect to the vehicle circuit (see *inductive coupling*).

connector. A conductive or inductive device that, by insertion into an inlet on the electric vehicle, establishes connection to an electric vehicle for the purpose of energy transfer and information exchange. It is part of a *coupling* (a mating vehicle inlet and connector set)

controller. A solid-state device that regulates the amount of power delivered to an EV's traction motor.

coupler. The device connected to the electric vehicle supply equipment that transfers power to the electric vehicle for charging the energy storage system and permits the exchange of information between the EV and the EV's supply equipment. The coupler contains the primary coil of the take-apart transformer, an antenna for communications, a magnet for connection check, and provisions for locking the coupler in the vehicle to prevent tampering.

coupling. A mating vehicle inlet and connector set.

electric vehicle. (EV) An automotive-type vehicle for highway use, such as passenger automobiles, buses, trucks, vans, and the like, primarily powered by an electric motor that draws current from a rechargeable storage battery, fuel cell, photovoltaic array, or other source of electric current. Electric motorcycles and similar type vehicles and off-road self-propelled electric vehicles, such as industrial trucks, hoists, lifts, transports, golf carts, airline ground support equipment, tractors, boats, and the like are not included. (EV definition from 1999 National Electrical Code Handbook® 625-2)

electric vehicle supply equipment. (EVSE) The conductors, including the ungrounded, grounded, and equipment grounding conductors, the electric vehicle connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of delivering energy from the premises wiring to the electric vehicle.

EV connector. Off-board component used to interface with the vehicle-mounted EV inlet to supply power and provide communication interface. (The power interface may be conductive, inductive, or other.)

EV cord. The off-board cable containing the conductors to connect the EV plug with the EV power controller to provide power for the vehicle and communications during charge.

EV inlet. Vehicle-mounted component which interfaces with the EV connector to receive power and provide communication interface.

ground fault. A short circuit to ground.

inductive charging system. A charging system that converts low frequency utility power to high frequency, transfers power across a take-apart transformer, and rectifies that power into DC voltage to the batteries.

inductive coupling. A recharge cord and plug that uses magnetic induction of electricity to transfer energy to the vehicle rather than using a physical connection (see *conductive coupling*).

infrastructure. All equipment and facilities required to generate, transmit, distribute, and deliver electricity to an EV.

Level 1 Charging. Charging from a common electrical outlet, which is 120 volts in the United States. The maximum power supplied for Level 1 Charging shall conform to the values shown: Nominal Supply Voltage 120 V. AC single phase; Maximum Continuous Current 12 amps; Branch Circuit Protection 15 amps (minimum); Nominal Continuous Power 1.44 kVA.

Level 2 Charging. High-power charging, which is 240 volts, 40 amps in the United States. The maximum power supplied for Level 2 Charging shall conform to the values shown: Nominal Supply Voltage 208-240 V. AC single phase; Maximum Continuous Current 32 amps; Branch Circuit Protection 40 amps; Nominal Continuous Power 6.66-7.68 kVA.

Level 3 Charging. Fast charging at 480 volts, 400 amps with three-phase power. This energy transfer method utilizes dedicated electric vehicle supply equipment capable of replenishing more than half of the capacity of an EV battery as quickly as in ten minutes. With this method, the electric vehicle accepts dc energy from an off-board power supply. The maximum power supplied for Level 3 charging equipment conforms to these values: Nominal Supply Voltage 600 V dc (maximum); Maximum Continuous Current 400 amps; Branch Circuit Protection As Required; Nominal Continuous Power 160 kW dc.

off-board charger. A charger with the intelligence and control in the charger stand, not on the vehicle.

on-board charger. A charger with the intelligence and control on the vehicle, not in the charger stand.

range. The maximum distance that an electric vehicle can travel on a single battery charge over a specified driving cycle to the battery manufacturer's recommended maximum discharge level. Alternatively, the distance reached when a specified minimum level of performance or other characteristic (such as battery depth of discharge) is attained.

time-of-use (TOU) rates. Discounted electricity rates established by utilities to encourage use of electricity during off-peak hours.

vehicle inlet. The device on the electric vehicle into which the connector is inserted for energy transfer and information exchange. This is part of the charge coupling.

APPENDIX D. REFERENCES

1998 California Electrical Code. California Building Standards Commission, December 1998.

EV Buyers Guide, California Energy Commission, Sacramento, March 1996.

EV Fleet Infrastructure Planning Guide. Electric Power Research Institute, TR-110702. 1998.

Electric Vehicle Charging Facility Installation Guidelines. Southern California Edison Co., 1996.

Electric Vehicle Community Market Launch Manual, Vol. II: Infrastructure, Electric Transportation Coalition et al., Washington, D.C., December 1995.

Electric Vehicle Resource Guide. U.S. Department of Energy, Office of Transportation Technologies. July 1998.

NEC© Changes 1999, M.W. Early, M.C. Ode, J.S. Sargent, D. Strube, N. Williams. National Fire Protection Association, Quincy, MA, 1998.

National Electrical Code 1999 Electronic Edition, National Fire Protection Association, Quincy, MA, 1998.