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.

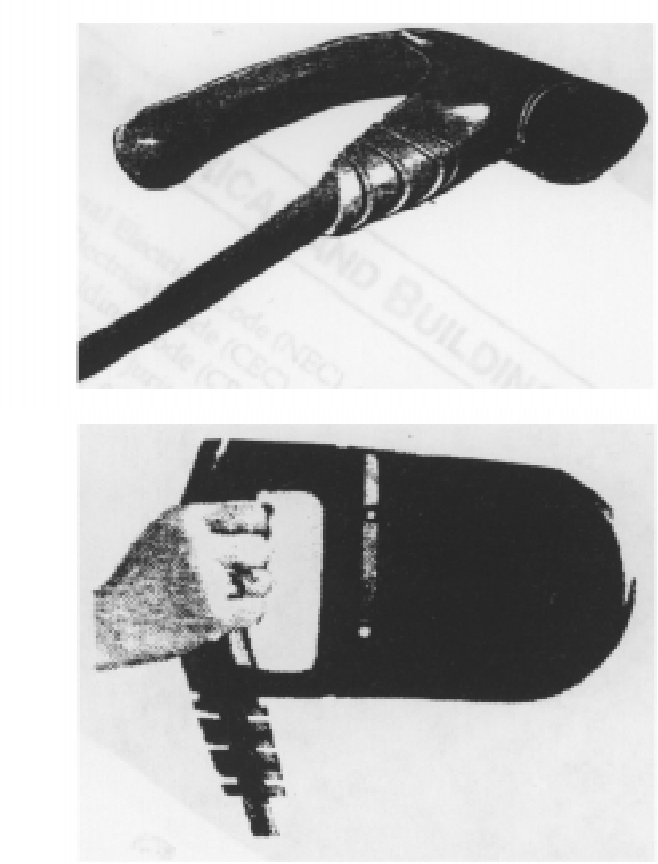
Some off-board chargers, or systems that place the charging circuitry and controls off-board the vehicle in a charging stand, also use conductive coupling. In this case, the charger communicates with the battery and vehicle electronics over the communications wiring in the connector.

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

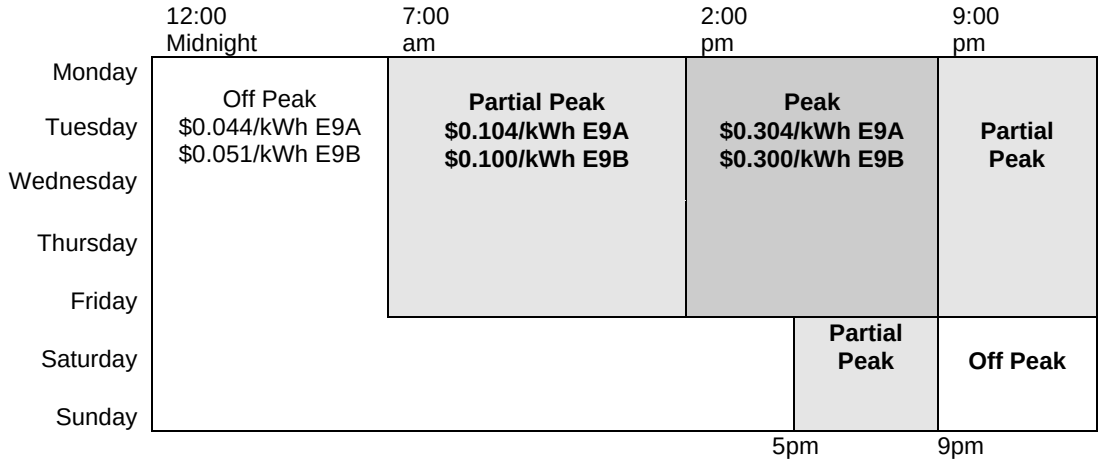
PG&E offers special rates to encourage EV market development and electricity use during night-time, off-peak hours when the utility has surplus distribution capacity. EV charging is a natural match for time-of-use rates since most EV users—in both residences and fleets—find that the most convenient (and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

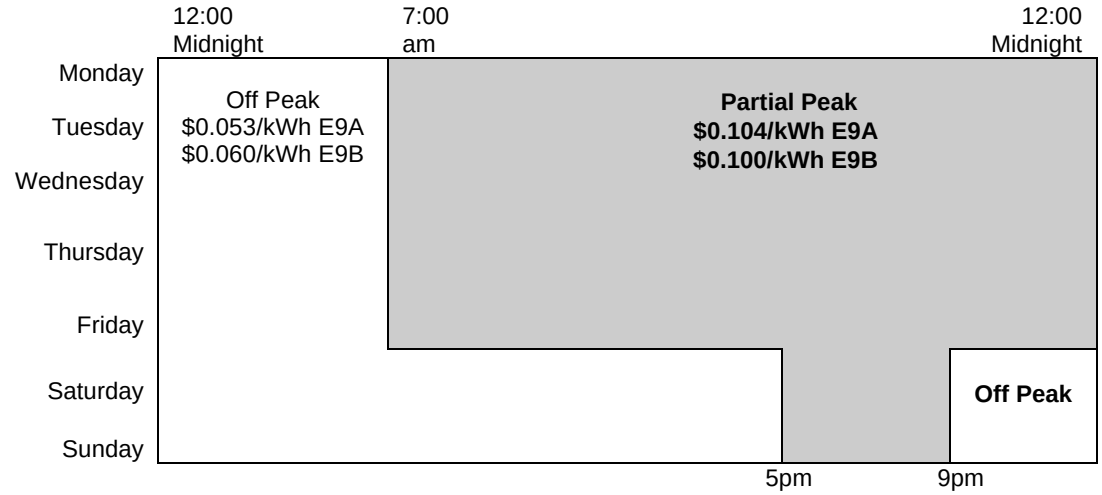
PG&E's rate schedule E9 is based on time-of-use and season. Residential customers have the option of selecting one of two rates from rate schedule E9, depending on their meter set-up. Rate E9A applies to electricity used in the entire residence, including the EV and does not require

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)