INSTALLATION GUIDE FOR ELECTRIC VEHICLE CHARGING EQUIPMENT

An Introduction to EVCE

Prepared by:
The Massachusetts Division of Energy Resources
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Electric Vehicle Charging Equipment Installation Guide

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Preface

The Massachusetts Division of Energy Resources (DOER) manages the **Massachusetts Electric Vehicle (EV) Demonstration Program** – one of the largest, longest running EV programs in the United States. This program is a vital component of the national endeavor to become "EV ready." Increasing numbers of manufacturers are announcing plans for the sale of new, technologically advanced EVs. These vehicles must have access to properly sited, safe, and effective **Electric Vehicle Charging Equipment (EVCE).** DOER developed this guide to ensure that future EVCE **infrastructure** meets these objectives.

Whether you are a private EV owner, fleet manager, electrical contractor, inspector, utility manager, manufacturer or vendor, this Guide will introduce EVCE applicable code requirements and other useful information. The Guide addresses the issues of all potential EVCE installation sites including single family homes, multi-family buildings, employee/fleet locations, and public charging stations.

In preparing the Guide, DOER drew on a number of sources including the National Electrical Code (NEC), the Massachusetts Electrical Code, numerous trade publications, and the practical experiences of those involved in the EV industry. Although this Guide is a useful introduction to EVCE, it is imperative that Guide users consult applicable codes, code officials, manufacturers, and suppliers to obtain the exact information relevant to your application.*

The EV market is moving ahead rapidly and many technical and regulatory changes are likely to occur. We hope to update this Guide periodically. We welcome your comments, questions, and suggestions at any time. Please contact:

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Introduction

Background

In the early years of the automobile industry -- around the turn of the century -- battery-powered electric vehicles were quite popular. More than 360 electric recharging stations dotted the landscape in and around Boston alone! Despite the advantages of cleanliness, convenience, and virtual silence, electric vehicles fell from favor because of their slow acceleration, low speeds, and limited range between recharges. This is no longer the case with EVs. A new generation of electric vehicles has come to market with the technical sophistication and performance able to serve the needs of many of today's drivers.

In addition to advanced EVs from startup manufacturers such as Solectria Corp. of Massachusetts, major automakers including General Motors, Ford, DaimlerChrysler, Toyota, Honda, and Nissan now market EVs in the United States. Current Massachusetts regulations require the placement of as many as 3,750 advanced, battery-powered vehicles in service across the state between 1998 and 2000. Starting in 2003, auto manufacturers must demonstrate that at least 10 percent of the vehicles offered for sale to consumers in Massachusetts are "zero emission vehicles" (ZEV), such as electric vehicles. A proposed change in the California program (on which the Massachusetts ZEV program is based) would allow up to 60 percent of the ZEV requirement to be satisfied with so-called "partial ZEV" technologies such as hybrid vehicles, and ultra low emission vehicles. Still forty percent of the electric vehicles offered for sale must be true zero emission vehicles.

As the EV industry reemerges at the end of the 20th century, the development of an infrastructure for recharging at home, at work, and at public locations has developed as an imperative need. Generally, EV charging infrastructure consists of three components: (1) electrical service from the local utility, (2) on-site wiring, and (3) charging facilities. Because electrical service is available almost everywhere, the widespread development of EV charging facilities is technically feasible. For installation of EVCE to occur, EV users will need to learn about the EV equipment and the requirements for proper installation subjects covered in the Guide. Users of EV charging equipment can be assured that EVCE is designed with multiple safety features, preventing the possibility of electric shock, even if the person charging the vehicle is exposed to rain, snow, or inadvertently touches the EVCE connector.

In most cases, EV users seeking the economy and convenience of on-premises charging facilities will have to assume responsibility for installing the EVCE. While the process of installing the EVCE at a home or business is not complicated, important procedures must be followed. We hope this guide will make these measures easier.

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Section 1
EV Charging Systems Basic Concepts and Code Requirements

A. The Elements of EV Infrastructure

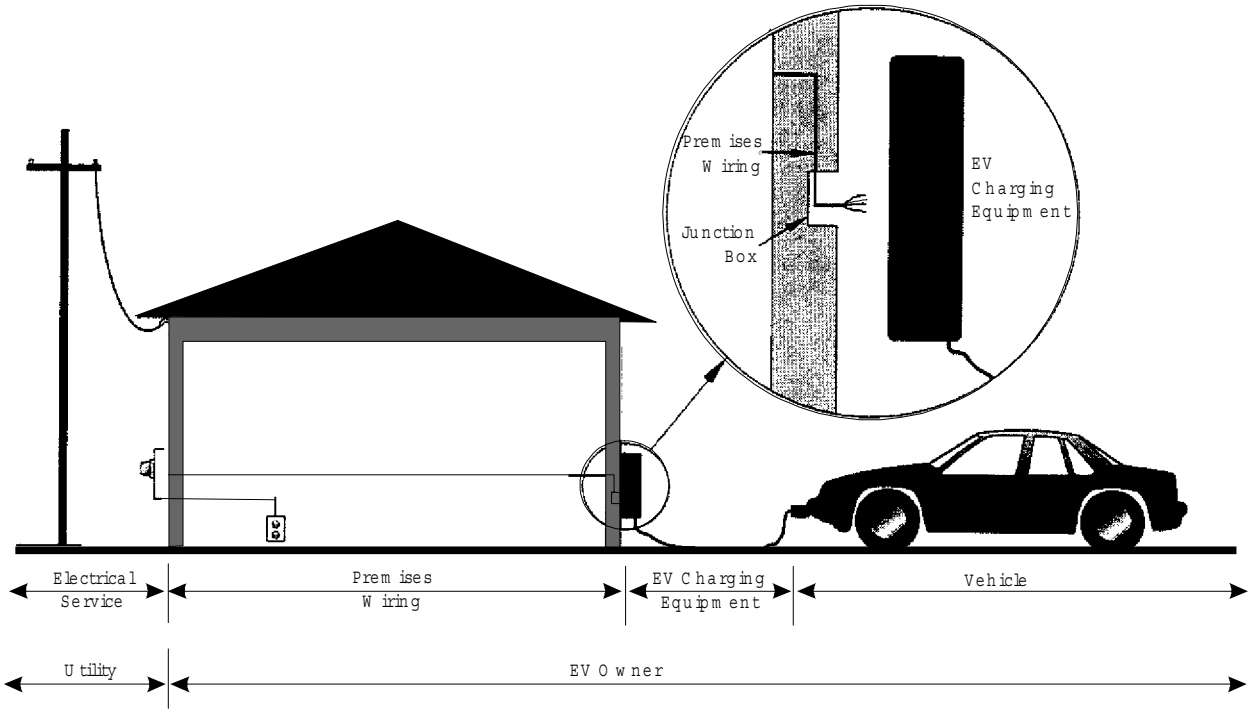
EV infrastructure has three distinct elements:

(1) Electric Vehicle Charging Equipment
(2) Premises wiring
(3) Electrical service.

A.1 Electric Vehicle Charging Equipment (EVCE)

Whether an EV uses an internal (**on-board)** or external (**off-board**) charging system, the EVCE consists of a power supply device, power cord and connector, with some variations in equipment specifications.

Figure 1: EVCE Infrastructure Overview



(Illustration used with permission of Southern California Edison Company)

On-board Charging EVCE

- ***power supply device*** - must be a polarized, non-interchangeable, grounded electric vehicle **coupler** to comply with Article 625, Section 9, Paragraph 5 (a) through (f) of the National Electric Code. It also must have a dedicated circuit or a sophisticated power delivery station with microprocessor-controlled features. The power flowing to the vehicle is **alternating current** (AC).

- ***power cord*** **-** cable that carries current from the power source to the connector.

- ***connector*** - interfaces the power cord to the EVCE; conductive paddle.

Off-Board Charging EVCE

- ***power supply device*** **-** includes a **rectifier** to convert alternating current to direct current (DC) for replenishing the EV battery. It may include microprocessor-controlled system diagnostics and other features.

- ***power cord*** **-** cable that carries current from the power source to the connector.

- ***connector*** **-** interfaces the power cord to the EVCE; inductive paddle.

A.2 On-Site Wiring

On-Site Wiring is the premises wiring that runs from the electric meter through a service panel (or board) to the EVCE. The facility owner/operator (or designee) is responsible for providing the on-site wiring necessary to install the EVCE in the desired location. Some EV vendors have established installation assistance programs to help an EV owner find a knowledgeable and licensed electrician or electrical contractor. (See Appendix 1.)

A.3 Electrical Service

Electric Service includes the utility distribution lines and the customer's electric meter. This equipment is owned and controlled by the local electric utility. Any EVCE installations requiring new or upgraded electrical service should be coordinated with the local utility through an electrician or electrical contractor.

B. Codes Affecting EV Charging Equipment Installation and Operation

Use properly designed equipment listed and labeled by a nationally recognized testing laboratory such as Underwriters Laboratories (UL) Inc. Observe the requirements of the National Electrical Code, the Massachusetts Electrical Code, SAE EV charging standards and DOER's recommended practices.

Follow EVCE safety requirements. The EV connector and vehicle inlet (called an **EV coupler**) must be constructed in a manner that prevents inadvertent user exposure to contact points that can carry live current from the EVCE or EV battery system.

While most EVCE is mass manufactured, **all charging equipment should incorporate the following features:**

- The EV coupler must be engineered to prevent inadvertent disconnection.
- The EV coupler must have a grounding pole that is the first to make contact and the last to break contact.
- A ground fault circuit interrupter (GFI) must shut off the electricity supply if it senses a potential problem that could result in electrical shock to the user.
- The vehicle power inlet must be de-energized until it is attached to the EVCE connector.
- The EV connector must be unique to the vehicle inlet and cannot be used with other household appliances.
- The EV coupler must contain an interlock device, which prevents vehicle startup while charging occurs.
- All EVCE must be tested and approved for use by Underwriters Laboratory (UL), a nationally recognized, independent testing lab.

Failure to observe applicable code requirements and operating instructions for the vehicle and the EVCE can jeopardize the user's safety and the durability of the EV and EVCE. DOER strongly urges strict compliance with applicable codes and standards as summarized below and in Section 3.

B.1 Massachusetts Electric Code

The Massachusetts Electric Code (MEC) is based on the National Electric Code. Article 625 of the NEC applies to Electric Vehicle Charging Equipment and is controlling in Massachusetts for EVCE installation. (A summary of important sections of Article 625 in the 1999 update follows in Section 3)

B.2 Local Implementation of the MEC

MEC is a uniform code, meaning that all municipalities must follow the code. MEC is administered at the local level by a municipal wiring inspector. The installation of EVCE, like other electrical wiring, appliances and equipment requires that the building owner or agent, along with a licensed electrician, submit an application for a permit to perform electrical work. At the discretion of the local wiring inspector, a rough and/or final inspection may be made of the installation to ensure its compliance with MEC requirements.

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Section 2
Charging Systems Overview

A. EV Charging Technologies

While regulatory requirements play a large part in the development and growth of electric vehicles, competition in the EV industry has created several technologies in the area of battery systems and charging options. Consequently, there is no single EV battery and charging technology standard. On the other hand, a number of organizations have fostered the development of EV technical and safety standards, and have assisted the industry in establishing some important common parameters. For information on successful systems used in the Massachusetts EV Demonstration Program, visit the DOER web site: http://www.state.ma.us/doer/programs/ev/factsht.htm.

In most cases, electric vehicles come with a standard charging system rather than a set of options. Before they make their purchase, consumers can ensure they obtain an EV that best meets their needs by learning about different charging system technologies and their characteristics described in this section.

B. EV Charging Levels

Due to the variety of motors and battery systems used by EV manufacturers, there was concern that the establishment of safety standards would be difficult. To address this and other EV infrastructure concerns, the Electric Power Research Institute (EPRI), with the cooperation of the auto and electric utility industries, formed the Infrastructure Working Council (IWC) in 1991. The IWC includes representatives of the electric utility industry, the auto industry, electrical equipment manufacturers, code officials, and government agencies.

The IWC coordinates the exchange of information among those involved in developing EV infrastructure. Based on their recommendations, the 1999 National Electric Code Handbook (page 780) identified three basic types of charging known as **charging levels**.

Table 1: EV Charging Levels

	Voltage (V. AC)	**Max. Continuous Current** (Amps)	**Min. Branch Circuit Protection** (Amps)	**Frequency** (Hz)	**Phase**
Level 1	120, 120, 120	12, 16, 24	15, 20, 30	60, 60, 60	single, single, single
Level 2	208/240	32	40	60	single
Level 3	480	400	500	60	three

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B.1 Level 1 Charging

Level 1 charging typically uses a standard electrical outlet (NEMA 5-20R), which in the United States is 120 volt, single-phase, and grounded. It uses a standard 3-prong plug (NEMA 5-20P) with a ground-fault circuit interrupter (or other listed interrupting personnel protection system) located in the power supply cable within 12 inches of the plug. The electrical specifications are shown in Table 1.

Although 3-prong standard electrical outlets are present almost everywhere, Level 1 charging is not the preferred means of charging. Depending on the battery type and capacity, it can take from 8-30 hours to fully recharge a battery. In addition, several studies conclude that for some battery systems, Level 1 charging shortens battery life and reduces performance.

B.2 Level 2 Charging

Level 2 charging employs a permanently wired and fastened EVCE sited at a fixed location. It requires grounding, ground fault protection for users, a no-load make/break interlock (which prevents vehicle startup while charging takes place), and a safety breakaway for the cable and connector. Depending on the battery type and capacity, Level 2 can recharge an EV in 2-6 hours. See Table 1 for electrical specifications.

B.3 Level 3 Charging

Still under development, these **fast-fill** chargers are expected to recharge 50 percent of an EV's battery capacity in 10 minutes or less. Level 3 systems will rely on an off-board charger that converts AC to DC. The high power involved in Level 3 Charging (480-Volt, three-phase electric service) is beyond the capacity of most utility transformers that serve residential areas and even some that serve commercial areas. Utility distribution system upgrades may be required to accommodate Level 3 charging.

C. Conductive and Inductive Charging

The most fundamental distinction between EV charging systems is that some use **conductive** and others use **inductive** technology. To date, EVs and EVCE can use either conductive or inductive technology, but not both. To prevent the conductive-inductive technology issue from hampering the development of the EV industry, some public recharging sites offer both types of charging facilities (though this can add to the cost of EVCE site development). At present, GM, Nissan and Toyota support an inductive charging standard, while DaimlerChrysler, Ford, and Honda advocate for the adoption of a conductive charging standard.

C.1 Conductive Charging

Conductive charging systems use **metal to metal** contact between the EVCE connector and the EV's charge inlet (or **charge port**). Similar to most household appliances that use metal-to-metal contact between a power outlet and plug/connector, the use of this system is most common on EVs with **on-board** charging equipment. Safety concerns including inclement weather and incorrectly linked EV-EVCE were successfully addressed for Level 1 and Level 2 charging systems now on the market.

Figure 2: Conductive Charge Port

C.2 Inductive Charging

Inductive charging is the transfer of power between the EVCE and EV. It relies on the magnetic induction of electricity rather than metal-to-metal contact. Certain household appliances such as cordless shavers and toothbrushes use inductive charging. This system avoids live contact between the charger connection and vehicle inlet, limiting the possibility of electric shock.

Inductive charging works in a manner similar to a transformer. The EVCE connector (a paddle-shaped device that is completely encased in non-conductive plastic) has a primary coil consisting of copper wound around a core of ferrite. The vehicle inlet or **charge port** contains a secondary coil. When the paddle is inserted into the charge port, electrical power passes through the electromagnetic field between the paddle and the charge-port. At this point, the vehicle, through two-way radio frequency communication with the off-board controller, initiates power flow. The incoming AC power is converted to DC and is stored in the vehicle's battery. Recently, GM and Toyota announced plans to develop a smaller charging **paddle** than the current version. The smaller paddle should help reduce the weight and cost of an inductive charging system.

Figure 3: Inductive EVCE Connector

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Section 3
Massachusetts Electrical Code Requirements

The Massachusetts Electrical Code (MEC) follows the National Electrical Code (NEC) standards and is implemented at the municipal level. Only licensed electricians or contractors should perform installation of EVCE, wiring, and other electrical tasks requiring a permit. Typically, a permit for the installation of charging equipment costs $30, but can vary from town to town.

Most Level 1 and Level 2 charging equipment on the market is Underwriters Laboratories (UL) listed for safety and durability. A few Level 3 inductive systems are also UL approved. If equipment is not UL listed, the local wiring inspector (under the MEC) has the authority to approve unlisted or unlabeled equipment and materials only if he/she is confident that safety can be achieved (MEC §90-4).

A. Summary of the Massachusetts Electrical Code Requirements for EVCE Installation

The following table highlights some of the key provisions of the MEC for Level 1 and Level 2 EVCE installation. Although the code provides some requirements that are relevant to Level 3 installations, the conductive systems have not been UL tested and approved and are not commercially available. The table also includes additional code provisions for Level 3 charging that reflect the specific features of commercially viable charging.

Table 2: Summary of Massachusetts Electrical Code Provisions for EVCE Installations

EVCE Characteristic	Level 1	Level 2 and Level 3
EVCE Couplers	Must be polarized and protected by a system of double insulation or its equivalent, in accordance with Article 250.	Polarized and non-interchangeable with non-EV receptacles on premises; protected by double insulation; constructed to prevent inadvertent contact with live parts; connector and inlet designed to prevent unintentional disconnection; must also have grounding pole that is first to make contact, last to break it. In addition, EVCE must have an interlock that de-energizes the connector and its cable when connector is uncoupled, or subject to stress.

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EVCE Characteristic	Level 1	Level 2 and Level 3
The EVCE may be permanently connected and fastened in place, or cord-and-plug connected. The EVCE must be grounded.	EVCE must be permanently connected and fastened in place, and grounded.	Level 2 Note: If EVCE calls for an in-wall receptacle, a 50 amp, 240 volt, 3- or 4-wire plug is required. EVCE will usually be directly wired with no in-wall receptacle. Inductive circuits require 3 wires: 2 hot conductors and 1 ground. Conductive chargers require a 4-wire circuit due to the need for the neutral lead in addition to the 2 hot leads and the ground.
Cables	Not to exceed 25 feet, and cannot have mid-cord coupling; Cables must be Type EV, EVJ, EVE, EVJE, EVT or EVJT flexible cable.	Same as Level 1.
Overcurrent Protection	EVCE feeders and branch circuits must be sized for continuous duty and have a rating no less than 125% of the maximum load of the EVCE. If non-continuous loads are supplied from the same feeder or branch circuit, the overcurrent device must have a rating no less than the sum of the non-continuous loads plus 125% of the continuous loads. (A 15 or 20 amp, single-pole circuit breaker at the beginning of the circuit in the meter panel breaker section will meet this requirement.)	Same as Level 1. Level 2 Note: A minimum 40 amp, two-pole circuit breaker located in the meter panel breaker section will meet this requirement if no additional loads are on the circuit.
Safety Switch	A single wall switch that supplies power to both the EVCE and mechanical exhaust equipment (if required) must control outlets for EVCE.	For EVCE rated at more than 60 amp or more than 150 volts to ground, the means of disconnecting shall be in a readily accessible location, and shall be capable of being locked in the open position.
Back-Feed of Electricity	Energy cannot be backfed through the EVCE to the premises wiring system as a standby power supply.	Same as Level 1.
Personnel Protection System	Must be essential to the attachment plug or on the power supply cable no more than 12 inches from attachment plug.	Must have a listed device to protect people from electric shock. When current to ground exceeds a set value that is less than the current required to operate the overcurrent protective device of the supply circuit, the system must de-energize to protect personnel.

EVCE Characteristic	Level 1	Level 2 and Level 3
Markings	EVCE must be marked "*For Use with Electric Vehicles*."	Same as Level 1.

B. Ventilation Requirements in the Massachusetts Electrical Code

With some EV batteries such as flooded lead-acid and nickel-iron, overcharges can result in the emission of hydrogen, a combustible gas in concentrations as low as 4% or as high as 74% by volume in air. This raises the possibility of an explosion in enclosed spaces such as residential garages and commercial parking facilities. To address this concern, the EV Infrastructure Working Council developed specifications for ventilation and other safety requirements that are now incorporated in both the NEC and the MEC**. Most batteries used in EVs today are totally sealed, and therefore do not emit hydrogen or require ventilation.**

If the EV battery is the type that can emit hydrogen during recharging, ventilation is required for all enclosed locations where the vehicle may be charged. An enclosed location is defined as having fewer than two open sides. Hydrogen is a colorless, odorless, tasteless and nontoxic gas that is lighter than air causing it to rise. Therefore, ventilation must be located above the EV. The following table shows the minimum ventilation required (per EV) in enclosed parking spaces where EV charging occurs.

Table 3: Minimum Requirements for Mechanical Ventilation (measured 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			
	120V	208V	240V or 120/240V	208V or 208Y/120V	240V	480V or 480Y/277V	600V or 600Y/347V
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

Ventilation equipment must include both air supply and mechanical exhaust equipment that is permanently installed and located to intake air from, and vent directly to the outdoors. The

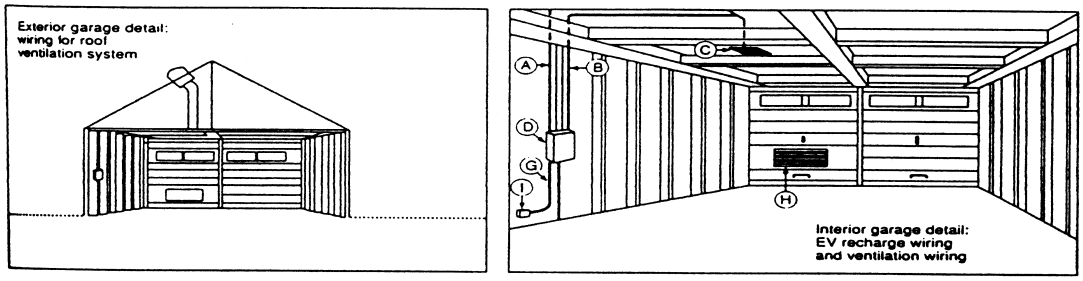
mechanical ventilation must be electrically interlocked with the EVCE to operate during the entire EV charging cycle and for at least five minutes after charging concludes.

Ventilation is not required for enclosed spaces if the EV batteries are non-vented, do not emit hydrogen, and are listed or labeled as such. If an enclosed EVCE installation is not equipped with mechanical ventilation, the EVCE, receptacles, and power outlets must be clearly marked **For Use Only with Electric Vehicles Not Requiring Ventilation**.

C. Siting Requirements

EVCE installations are permitted in indoor sites such as residential garages, enclosed and underground parking structures, commercial garages, and outdoor sites. The EVCE location must allow direct connection to the EV. EVCE should not be installed in hazardous environments (e.g. near explosive material, flammable vapors, liquids and gases, combustible dust or fibers, and materials that ignite spontaneously on contact with air) unless it is undertaken in accordance with MEC Articles 500 through 516. In flood zones, chargers must be either installed above the base flood elevation or waterproofed for compliance with ground-fault circuit interruption protection requirements that apply to equipment subject to submersion.

Figure 4: Electric Vehicle Charging Equipment with Ventilation



Indoor Sites — Ventilation Requirements*
for All Systems Other than 125-Volt, 15- or 20-Ampere, Single-Phase

Communication required from EV through EV supply cable G (on-bd. chg.) or from EVSE D (off-bd. chg.) to fan C causing fan C to operate for entire charging cycle. EVSE receptacles and power outlets D shall be clearly marked "For Use with All Electrical Vehicles."

A. AC power supply from premise wiring system
B. AC power line to fan
C. Exhaust fan to outside—sized per Table 3.1
D. EVSE (includes receptacles and power outlets)
G. Electric vehicle supply cable
H. Outside air intake
I. Electric vehicle connector

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C.1 Indoor Sites

The EV connector must be stored or located not less than 18 inches and not more than 4 feet above floor level.

C.2 Outdoor Site

The EV connector must be stored or located not less than 24 inches and not more than 4 feet above the floor of the parking space.

D. Recommended General Siting Practices

Beyond the requirements of the MEC, there are several recommended practices for most EVCE installations in both private and public locations:

- **Lighting:** To ensure personal safety, security, and proper EVCE operation, adequate lighting is necessary. The lighting should be sufficient for users to read written instructions and to view task objects with adequate clarity and contrast.

- **Security of the location:** To minimize hazards and potential vandalism to the EV or EVCE, secure charging locations are recommended.

- **Charging Site:** Choose a charging site near the beginning of the new dedicated EV circuit in the electrical panel or sub-panel. This will reduce the length of conduit, wiring, and cost of installation.

- **Position of Equipment*:*** The EVCE cable and connector must reach from EVCE to EV without being subject to disturbances, unnecessary wear, or abuse. The maximum length for EVCE cable is 25 feet (NECH 625-17 1999).

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Section 4
EV Charging in Single Family Residential Locations

This section provides a more focused look at some of the particular issues involved in EVCE installation in single family residential locations. Although there are some unique considerations, this type of installation is not very different from other routine electrical projects. The residential property owner must understand and manage the overall installation process to ensure that it is done safely, effectively, and economically. As with other electrical work requiring a permit, you must obtain the services of a licensed electrician or electrical contractor to perform the EVCE installation.

Because vehicles are routinely parked at single family residences overnight, EVs can be recharged at significant discounts by using off-peak electricity under optional Time-of-Use (TOU) rates. For rate and meter information, check with your local service provider.

A. Vehicle Selection

Depending on the type of EV, EVCE requirements can vary considerably. (See Appendix 1 for EVCE-related information about many of the EVs currently on the market.) Before beginning installation, know the following:

- **Is the EV charged conductively or inductively?**
  These two types of charging methods are incompatible, and there are unique installation requirements for each technology.

- **What type of charging inlet does the vehicle use?**
  Inductive vehicles have adopted a standard "paddle" connector and inlet, while conductive connectors come in several varieties.

- **What charging levels (1, 2, or 3) can the EV accommodate?**
  If it is possible to use both Level 1 and 2, Level 2 is preferred because it charges in half the time. However, because Level 2 might require an electrical service upgrade, installation may be more costly.

- **Is the battery system sealed?**
  If the battery system is not sealed and the charging equipment is in an enclosed area, mechanical ventilation is required for the charging area.

- **What is the recommended operating and charging temperature for the EV battery pack?**
  Refer to the owner's manual or contact the manufacturer for recommended temperatures. This information may affect whether it is better to install the EVCE in a garage or outdoors.

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- **Where is the charge port on the vehicle?**
  Generally, the EVCE should be as close as possible to the charge port location.

- **How much lead-time (before delivery of the EV takes place) is needed for installation of the EVCE?**
  Normally, 7-10 days lead-time is adequate for installation; however, the owner should consult with the electrician about scheduling.

B. Utility Considerations

B.1 Time-of-Use (TOU) Metering for Electrical Service

Depending on the charging schedule and load, the costs of recharging an EV can be greatly reduced by taking advantage of optional Time-of-Use rates (TOU). The rates are generally available when charging during off-peak hours and there is excess regional power plant capacity allowing prices to be relatively lower. The one drawback of TOU rates is that during peak daytime hours (8 a.m. - 6 p.m., generally) the rates are considerably higher than regular residential rates. EV owners should contact their utility company to request a special TOU meter, and ask to be placed on the TOU rate. Depending on which option is least expensive, the owner may decide to:

- Have all household electrical usage, including EV charging, placed on the TOU rate.

- Have all household electrical usage, including EV charging, provided under a standard residential rate.

- Have only the EV charging (and possibly other off-peak uses) served under the TOU rate, and the remaining household needs served on a standard residential rate. This option requires two separate meters, and will result in two separate customer accounts, each of which will have a monthly customer charge.

To determine which option is best, owners should also ask the EV dealer for an estimate of how much electricity will be consumed based on driving requirements. Owners also need to estimate the portion of EV charging that will be done during off-peak hours.

B.2 Electrical Service Upgrades

Most homes have sufficient electric service capacity for either a Level 1 or a Level 2 charging system. All EV battery charging equipment is listed by the National Electrical Code as continuous duty. Level 2 charging systems have a 40A circuit breaker with a 32A load at 240V single phase. (See above B.1 TOU Metering.) Homes that have electric ranges, which use a 40A 240V single-phase circuit, can charge their EV anytime the electric range is not in use.

C. Contact Local Wire Inspector

The process of obtaining a permit for an EVCE installation is fairly straightforward given the adoption of EVCE installation requirements in the Massachusetts Electrical Code. Local codes must meet the MEC requirement; however, they may be more stringent. The electrician or electrical contractor should contact the local inspector to obtain the permit application form to resolve any questions in advance about the process for obtaining a permit and requirements for the post-installation inspection.

D. EVCE Siting Considerations

Some of the key factors affecting EVCE siting are listed below:

D.1 Enclosed Garages

Depending on the EV manufacturer's recommendations concerning ambient charging temperatures and other conditions, it is likely that installing the EVCE in an enclosed garage is best for the EV battery, and also provides the most security. The following considerations should be taken into account:

- **Cables and Cords:** Install the charger where the cable will stretch the shortest distance to the EV charge port without interfering with access to the vehicle, and where the connector can be easily reached. EVCE cords and cables should not interfere with foot traffic.

- **Explosive Material:** Do not install EVCE near explosive material, flammable vapors, liquids and gases, combustible dust or fibers, and materials that ignite spontaneously on contact with air. If these conditions cannot be avoided, MEC Articles 500 to 516 describe the equipment and procedures that must be followed in such locations.

- **Electrical Service:** If the garage is detached and does not have electrical service, install underground conduit or an overhead line to the garage.

D.2 Outside Charging

If installing the EVCE in a garage is not possible, a homeowner may decide to install the EVCE in an outdoor location. Weatherproof charging stations are available. To ensure the security of the installation, fencing or other security measures are advised.

E. Permitting, Installation, and Inspection

With the assistance of a licensed electrician, the owner must apply for an electrical permit within 5 days of commencing work on the installation. A post-installation inspection should also be scheduled.

F. Tax Credits

If the EV and charging equipment are used in a trade or business or for the production of income, the EVCE qualifies for a federal tax deduction of up to $100,000. (See Appendix 3.)

G. Insurance

EV owners should consult their property insurance representative to obtain specific information and insurance company requirements.

Note: The authors contacted several insurance companies and found that none required EVCE to be listed on a rider to the existing insurance policy or to have separate coverage. The installation of EVCE at single family homes had no effect on insurance premiums.

H. Cost

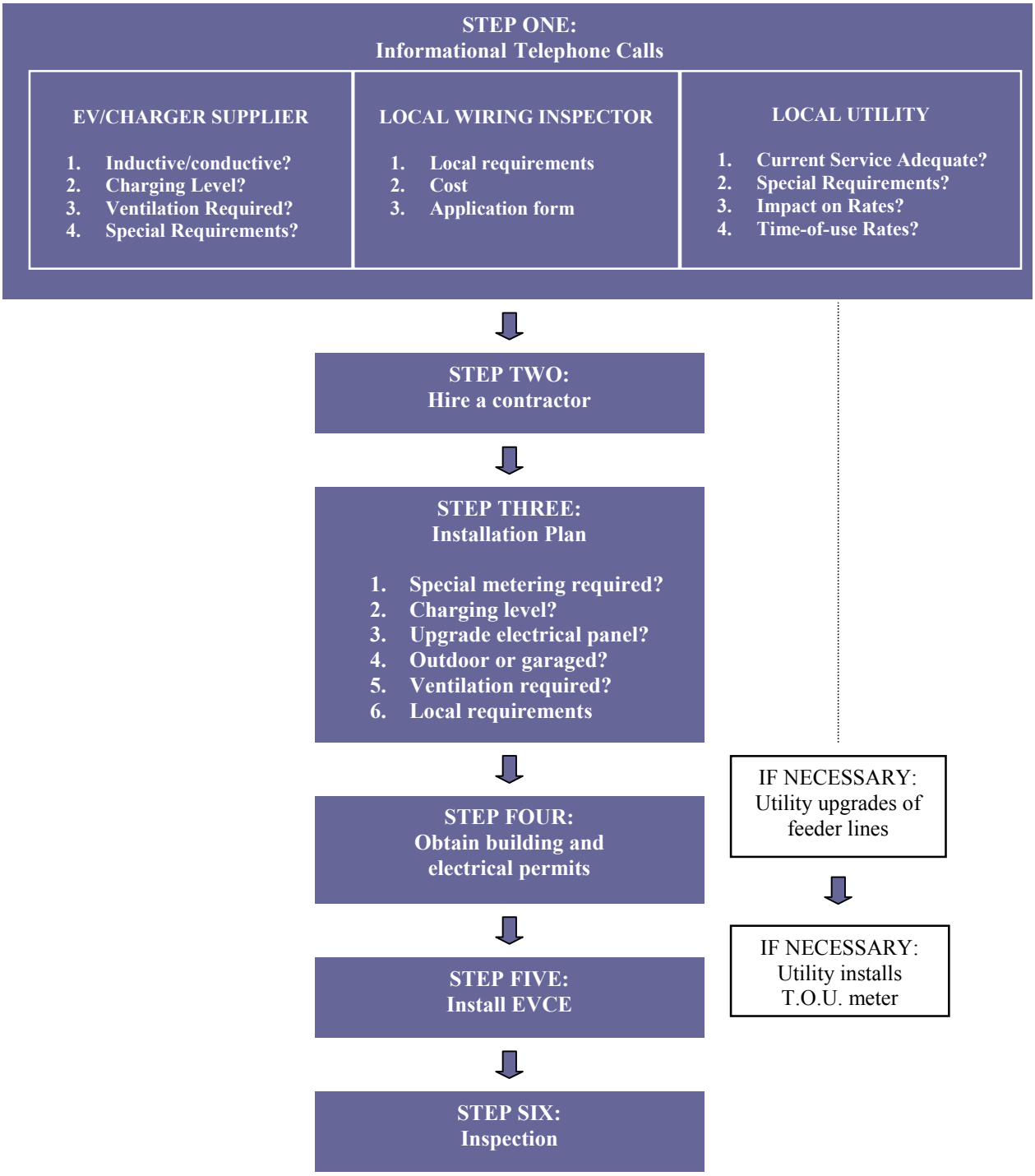
Not including the EVCE itself, EVCE installation can vary greatly from $100 to more than $2,000 depending on:

- The need to upgrade the electrical service panel.
- The type of EVCE (i.e. inductive or conductive).
- Whether the garage is attached or detached.
- The ease of installing necessary wiring.

The significant difference in cost is attributed to the amount of labor required and ease of installation.

EVCE charging equipment can cost from $100 to $3,000. Generally, conductive systems are less expensive than inductive systems, and Level 1 charging is less expensive than Level 2. Consult the EV dealer or charger supplier for specific pricing information.

Figure 5: Residential EVCE Installation Flowchart



Section 5
EV Charging in Multi-family Locations

The installation of EVCE in multi-family locations such as the parking lots and garages of apartment buildings, condominiums, and townhouses generally present the same issues faced in single family residential locations with a few additions. Typically, the tenant, condominium or townhouse owner will need the permission, cooperation and/or financial participation of others before the EVCE can be installed. **This process may require open discussion before installation about respective roles, responsibilities, and collaborative solutions.**

Issues may include:

- *Who pays for and owns the electrical work and circuit from the meter to the EVCE (which a tenant cannot take when moving)? Can the EVCE be moved when the owner moves? If not, who will then own it?*
- *How can the EV owner pay for the electricity if it is not separately metered from the landlord's or community's electricity?*
- *Who is responsible for any increased insurance costs relating to the EVCE?*
- *Where will the EVCE be located? Can all code requirements be met without compromising the appearance of the property?*
- *As more EV charging stations are installed, who will pay to upgrade the electrical panel and other equipment on site to meet the increased load?*

A. Authorization, Cost, and Ownership Issues

Landlords are not required to provide EV charging facilities for tenants. They may deny tenants the authorization to install on-site EVCE even if the tenant agrees to pay the full cost. Condominium and townhouse owners may have to seek the permission of the homeowners association and may have cost and ownership issues. In all likelihood, EV owners in multi-family properties can expect to pay most or all of the installation and equipment costs involved, although federal tax deductions may offset a portion of the cost.

A.1 Apartments

A tenant seeking EV charging facilities will require the landlord's approval to install EVCE. The landlord's concerns may include safety, cost, and the available capacity of transformers and other equipment. Because the EVCE installation is impermanent, it may make sense for tenants to pay for this equipment and take it with them when they move. The EV circuit (which remains with the property and eventually will be owned by the landlord) is a negotiable item. With the availability of tax deductions for EVCE installations by a business, the landlord may be willing to pay for the EV charging circuit, landscaping, fencing, signage, ventilation, etc., and make an

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appropriate adjustment to the EV user's rent to cover these costs. Additional costs, such as the upgrading of transformers may require consideration; however, these expenses may be borne by the utility company.

A.2 Condominiums and Townhouses

The condominium or townhouse owner will most likely need the permission of the homeowners association before installing the EVCE. The association's concerns might include safety, cost, and electrical capacity of transformers and other equipment. Because the homeowners association and not the homeowner may be eligible for an EVCE tax deduction, the homeowner should discuss the possibility of the association paying for the EVCE installation and recovering the expense through an adjustment in association dues from the EV owner.

B. Utility Service Issues

B.1 Metering

In some situations, it may be possible to run the electrical service from the EV owner's unit to the charging site. In such cases, the owner would be responsible for payment of electric service. As discussed in Section 4.B.1, if Time-of-Use rates (TOU) are offered by the utility, it may be advantageous for the EV owner to install a separate TOU meter. If the EVCE location is not accessible to the EV owner's unit, electrical service and separate metering may be necessary, but may not always be feasible. If the EVCE cannot be separately metered or connected to EV owner's service, this may be another cost-related issue that must be negotiated with the landlord or homeowners association.

B.2 Electrical Capacity

With the rising popularity of large household electrical appliances, many multi-family buildings have very little electrical capacity left to accommodate new, large electrical loads such as EVCE, which equal the average energy use of an entire household. If electrical service is near capacity, the utility may have to upgrade feeder lines and transformers serving the site. Such improvements may delay service and increase costs to the party paying for the installation. The EV owner should consult with the landlord, homeowners association and utility to resolve these issues.

C. Siting Considerations

Owners and managers of multi-family properties have safety and aesthetic concerns that go beyond compliance with electrical and building codes. Issues to address include:

- **Cables and Cords:** To avoid injuries and damage to equipment, cables and cords should not cross walkway areas and should be convenient for the EV user.

- **Wet Areas:** EVCE is designed for safe operation in wet areas, however, for user comfort, EVCE should <u>not</u> be located where water collects or in the spray area of irrigation systems.

- **EVCE Protection:** To prevent inadvertent collision with charging stations by EVs or other vehicles, it is advisable to install curbs, wheel stops, bollards, or other secure barriers that will not impede use of the equipment.

- **Vandalism:** Property owners, managers, and homeowners associations should take steps to reduce the possibility of EVCE being vandalized or tampered with. The parties responsible for the chargers may want to consider installing motion-detector actuated lighting or tamper alarms, locating the space within sight of the manager's office, placing the charger equipment in a locked enclosure, or fencing off the EV parking areas.

- **Disabled Access:** The electrical code requirements for the height of connectors and receptacles reflect access concerns for disabled persons. EV installation can enhance access by including curb cutouts and other access features that aid disabled EV users.

D. Aesthetics

Owners of apartment buildings, condominiums and townhouses are certain to care about the aesthetics of an EVCE installation, as this may affect the appeal of the building to renters or prospective buyers. Aesthetic features however, can add significantly to the cost of the EVCE installation.

Aesthetic considerations include:

- Use of attractive materials and workmanship that complement building design and character.

- Screening of transformers, panels, and other electrical equipment with landscaping (bearing in mind transformer access and other rules in MEC §450-8, 450-13 & 450-41).

E. Signage

The MEC (§625-15) requires that EVCE be marked **For Use with Electric Vehicles**. To ensure that designated charging locations are not used by non-EVs, it is also advisable to place **EV-Only** signage in such locations that warns unauthorized users of being towed at their own expense.

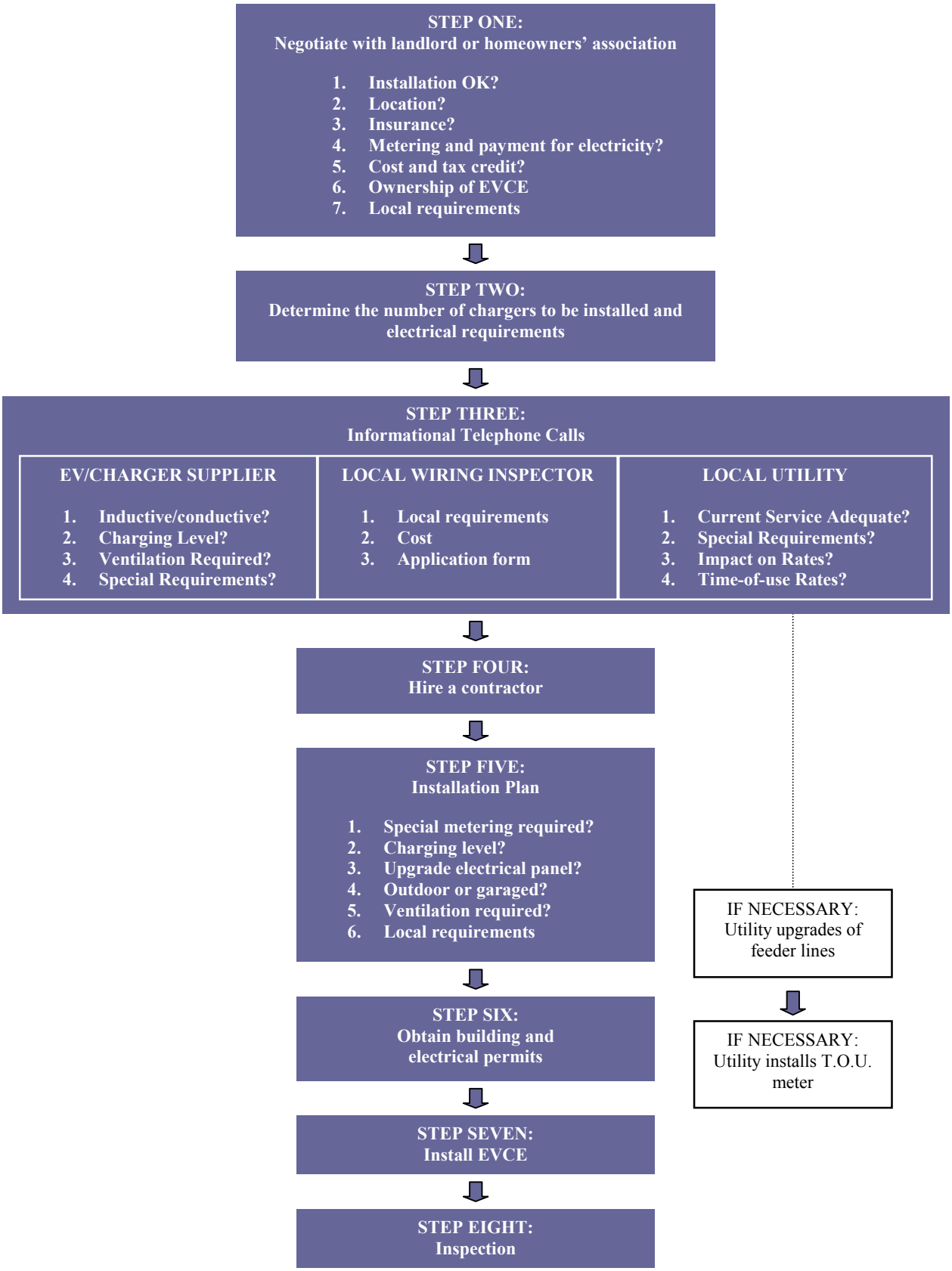
F. Insurance

With the installation of EVCE in multi-family properties, it is possible that the costs of property damage and liability insurance for the landlord or homeowners association may increase. If such an increase can be demonstrated, property managers may seek to pass on such costs to EV users by an appropriate adjustment of rent or association dues. Check with the property's insurance agent for further information.

G. Cost

The cost for multi-family EVCE will depend on a number of factors including the type and number of charging stations, the distance of electrical service from the charging location, whether the facility is indoors or outdoors, security and landscaping costs, and whether ventilation is required. EVCE installation can cost from $100 to more than $2,000. The significant difference in cost is attributed to the amount of labor required and ease of installation. The EVCE itself can cost from $100-$3,000 depending on the charging level and type of equipment.

Figure 6: Multi-family EVCE Installation Flowchart



Section 6
EV Charging in Employee/Fleet Locations

Under the Energy Policy Act (EPAct) of 1992, state and federal government agencies, and alternative fuel providers are required to purchase an increasing percentage of alternative fuel vehicles (AFVs), including battery-powered EVs. EPAct also specifies that by the year 2000, the U.S. Secretary of Energy will determine whether AFV purchase requirements should be extended to other private fleets. This provision has been paused for further evaluation.

EVCE installations for employee and fleet use are subject to the same code requirements as other installation locations. Some concerns specific to fleet managers may include:

A. Siting

- **Developing an EV Recharging Plan:** Generally, it costs less per charging station to provide multiple stations as part of one EVCE installation project. Facility managers should start by estimating EV use for fleet operations and employee commuting in future years. Who are the likely vehicle users and what are their needs? How many vehicles are anticipated? What time of day or night will charging be required? What type of EV charging systems will be required, Level 1, 2 or 3? Inductive or conductive?

- **Location:** EV charging facilities should be located in garages or parking lot areas where they will not interfere with foot traffic or the movement of other vehicles. To increase the attractiveness of EV use for commuters, consider locating charging stations in desirable locations, e.g. high visibility sites, near building entrances, sheltered areas.

- **Cable Considerations:** To prevent injuries, make sure that cords and cables do not cross walkways or vehicle access areas.

- **Ventilation:** Some EV batteries when charged indoors require ventilation, however most do not. If ventilation is required, check the existing ventilation rates in the intended garage location to see if they meet code requirements without costly upgrades, or consider locating the charging station outdoors.

- **Temperature:** Ambient temperatures can affect battery-charging efficiency. Check your vehicle and charging equipment-operating instructions for charging temperature recommendations. In colder climates, indoor facilities may provide better EV charging conditions, but make sure to observe ventilation requirements.

- **Wet Areas:** EVCE is designed to operate safely even in wet conditions. However, to dispel user concerns and enhance comfort, do not locate EVCE in areas prone to puddling, or in the spray area of irrigation systems. Overhangs, though not required, may also enhance user comfort.

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- **Explosive/Flammable Materials:** Do not install EVCE near explosive material, flammable vapors, liquids and gases; combustible dust or fibers; and materials that ignite spontaneously on contact with air. If these conditions cannot be avoided, MEC Articles 500 to 516 describe the equipment and procedures that must be followed in such locations.

- **EVCE Protection:** To prevent inadvertent collision with charging stations by EVs or other vehicles, it is advisable to install curbs, wheel stops, bollards, or other secure barriers that will not impede use of the equipment.

- **Vandalism:** Site managers should take steps to reduce the possibility of EVCE being tampered with or vandalized. Measures include: installing motion-detector actuated lighting or tamper alarms, locating the space within sight of the manager's office, placing the charger equipment in a locked enclosure, or fencing off EV parking areas.

- **Disabled Access:** The electrical code requirements for the height of connectors and receptacles reflect access concerns for disabled persons. EV installations can enhance access by including curb cutouts and other features that aid disabled EV users.

B. High Voltage Charging Systems

In multiple vehicle charging locations, particularly during off-peak hours, facility managers may find it advantageous to install Level 3 charging equipment (480 volt, three phase). EVCE technology now being tested will allow a single charger to connect with several vehicles and charge them automatically in sequence. Depending on the cost of the equipment and the extent to which it maximizes the use of off-peak electricity, this choice may be cost effective for fleet applications.

C. Electrical Service

EV charging installations at fleet locations may require upgraded electrical service, including new feeder lines and on-site equipment such as service panels, sub-panels, and transformers. Some factors that determine the need for electrical service upgrades include:

- **Number and Type of Charging Units:** This depends on the anticipated number of vehicles for the location, vehicle usage schedules, the desired charging level, and the possible use of new technologies that allow multiple vehicles to charge simultaneously.

- **Load Management Considerations:** Time-of-Use and peak demand considerations can affect electric utility charges. Before installation, check with the local service provider for information on rates, meters and any applicable charges.

- **Electrical Capacity Considerations:** Some sites may be at or near their electrical load capacity. Before installation, the fleet and/or facility manager should have an electrician or the local service provider assess the electrical needs of the EVCE device and the capabilities of the current electrical service.

D. Aesthetics

Fleet operators and facility managers should pay close attention to the aesthetics of EVCE installation as well as code and other requirements. However, aesthetic features can add significantly to the cost of the EVCE installation.

Aesthetic considerations include:

- Use of attractive materials and workmanship that complement building design and character.

- Screening of transformers, panels, and other electrical equipment with landscaping (bearing in mind transformer access and other rules in MEC §450-8, 450-13 & 450-41).

E. Signage

The MEC (§625-15) requires that EVCE be marked **For Use with Electric Vehicles**. To ensure that designated charging locations are not used by non-EVs, it is also a good idea to place **EV-Only** signage in such locations to warn unauthorized users of possible fines, penalties or towing.

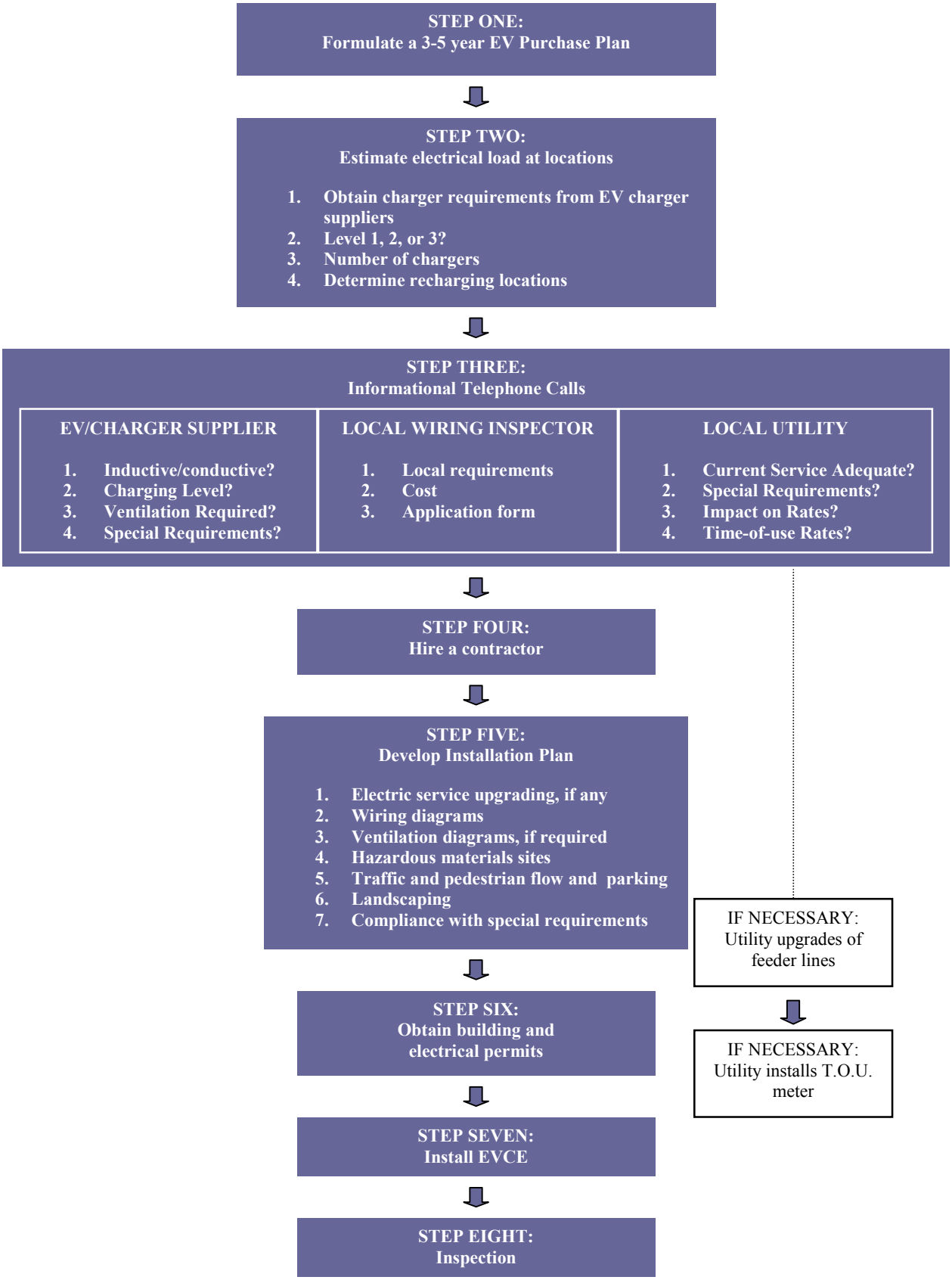
F. Insurance

With the installation of EVCE in fleet locations, it is possible that the cost of property damage and liability insurance may increase and additional coverage may be required. Check with the facility's insurance agent for further information.

G. Cost

The cost for EVCE depends on a number of factors including the type and number of charging stations, the distance of electrical service from the charging location, whether the facility is indoors or outdoors, security and landscaping costs, and whether ventilation is required. EVCE installation per vehicle can cost from $100 to more than $2,000. The significant difference in the cost is attributed to the amount of labor required and ease of installation. The EVCE itself can cost another $100 to $3,000 depending on the charging level and type of equipment.

Figure 7: Commercial/Fleet EVCE Installation Flowchart



Section 7
EV Charging in Public Access Locations

Public access locations differ in some important ways from other EV installations including:

A. Billing Systems

Operators of EV charging stations require a means of measuring and charging customers for usage. Currently a number of point-of-sale payment systems are being evaluated across the country including credit cards, debit cards, pre-paid fuel cards, and parking meter-type units. When a commercially feasible system is adopted, it is likely that EVCE suppliers will bundle the payment system with the EVCE.

B. Conductive and Inductive Chargers

There are currently two competing technologies for EV charging in the marketplace: conductive and inductive. Therefore, a public access charging facility should attempt to offer both technologies. A standard connector for **inductively** charged vehicles has emerged – the so-called **paddle**. However, there are several competing **conductive** connector types in use including AVCON, Yazaki, and ODU. It is anticipated that over time a single standard will emerge for conductive charging connectors.

C. Charging Levels

Level 1 EV charging requires 8-14 hours and is impractical for public access charging locations where vehicles need to charge during short stays such as shopping trips or a restaurant meal.

Level 2 charging offers the possibility of a full recharge in 3-6 hours and a partial recharge in less time.

Level 3 fast charge technology provides more than half a battery's capacity in 10-15 minutes. Still under development, it may become the preferred charging method for public access locations depending on acquisition and operating costs. However, such conductive systems are not yet UL approved and are not commercially available.

D. Siting

- **Location:** EV charging facilities should be located in garage or parking lot areas where they will not interfere with foot traffic or the movement of other vehicles. To increase the attractiveness of EVs for commuters, locate charging stations in desirable locations (i.e. locations with high visibility, near building entrances, in sheltered areas).

- **Cable Considerations:** To prevent injuries, make sure that cords and cables do not cross walkways or vehicle access areas. Use cable retractors when possible.

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- **Ventilation:** Some EV batteries, when charging indoors, require ventilation but most do not. If ventilation is required, check the existing ventilation rates in the intended garage location to see if they meet code requirements without undertaking costly upgrades. If not, consider locating the charging station outdoors.

- **Temperature:** Ambient temperatures can affect battery-charging efficiency. Check your vehicle and charging equipment-operating instructions for charging temperature recommendations. In colder climates, indoor facilities may provide better EV charging conditions, **but make sure to observe ventilation requirements**.

- **Wet Areas:** EVCE is designed to operate safely even in wet conditions. However, to allay user concerns and enhance comfort, do not locate EVCE in areas prone to puddling, or in the spray area of irrigation systems. Overhangs, though not required, may also enhance user comfort.

- **Explosive Material:** Do not install EVCE near explosive material; flammable vapors, liquids and gases; combustible dust or fibers; and materials that ignite spontaneously on contact with air. If these conditions cannot be avoided, MEC Articles 500-516 describe the equipment and procedures that must be followed in such locations.

- **EVCE Protection:** To prevent inadvertent collision with charging stations by EVs or other vehicles, install curbs, wheel stops, bollards, or other secure barriers that will not impede use of the equipment.

- **Vandalism:** Facility operators should take steps to reduce the possibility of EVCE being tampered with or vandalized. Operators may want to consider installing motion-detector actuated lighting or tamper alarms; locating the charging equipment within sight of the manager's office; and making EVCE areas more secure with fencing or other enclosures.

- **Disabled Access:** The electrical code requirements for the height of connectors and receptacles reflect access concerns for disabled persons. In addition, EV installations can enhance access by including curb cutouts and other features that aid disabled EV users.

E. Electrical Service

EV charging installations at public access locations may require upgraded electrical service including new feeder lines and on-site equipment such as service panels, sub-panels, and transformers. Some factors that determine the need for electrical service upgrades include:

- **The number and type of charging units:** This depends on the anticipated number of vehicles, usage schedules, charging level, and the possible use of new technologies that allow multiple vehicles to charge simultaneously using a single charging station.

- **Load management considerations:** Time-of-Use and peak demand considerations can greatly affect electric utility charges. The manner in which the EVCE installation addresses these rate issues may influence the need for electrical service upgrades.

F. Aesthetics

Site managers must pay close attention to the aesthetics of EVCE installation as well as code and other requirements. However, aesthetic features can add significantly to the cost of the EVCE installation.

Aesthetic considerations include:

- Use of attractive materials and workmanship that complement building design and character.
- Screening of transformers, panels, and other electrical equipment with landscaping (bearing in mind transformer access and other rules in MEC §450-8, 450-13 & 450-41).
- Providing adequate lighting to ensure that the station is a safe and secure location to stop and charge a vehicle. Light should provide proper illumination for the user to read instructions and signage, but not be overly harsh or glaring. Care should be taken to prevent light spillage into neighboring areas.

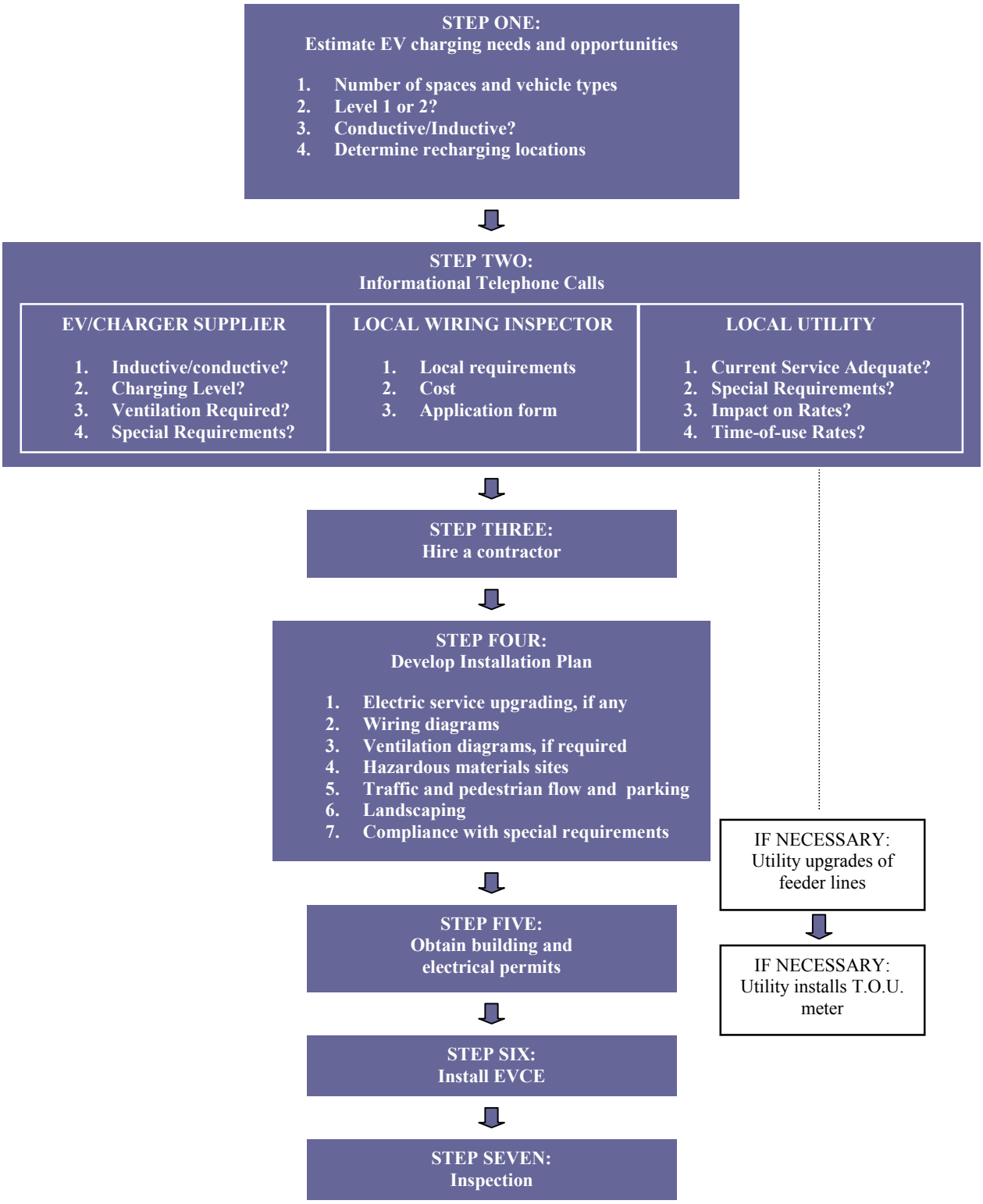
G. Insurance

It is possible that the cost of property damage and liability insurance may increase and additional coverage may have to be obtained for public charging facilities. Check with your insurance agent for further information.

H. Cost

The cost for public access will depend on a number of factors including the type and number of charging stations, the distance of electrical service from the charging location, whether the facility is indoors or outdoors, security and landscaping expenses, and whether ventilation is required. EVCE installation per vehicle can cost from $100 to more than $2,000. The significant difference in the installation cost is attributed to the amount of labor required and ease of installation. The EVCE will cost another $100-$3,000, depending on the charging level and type of equipment chosen.

Figure 8: Public Access EVCE Installation Flowchart



Appendix 1: **Charging System Requirements of EVs on the Market**

Electric Vehicle Make/Model [Availability Date in MA]	**Battery Type**	**Charger Type**	**Charging Levels Accepted**	**Connector Type**	**Recharge Time (at Level 2)**	**Ventilation Required**	**Installation Assistance Available**
Chevy S-10 [available now]	Lead Acid	Inductive; Off-board	Level 1 &2	Inductive Paddle	2.5 hours	No	Yes
Chrysler EPIC Minivan [no available date]	Lead Acid	Conductive; On-board	Level 2	ODU	8 hour	No	No
Ford Ranger [available now]	Lead Acid	Conductive; On-board	Level 2	AVCON	3-8 hours	No	No
GM EV1 [no available date]	Lead Acid	Inductive; Off-board	Level 1 &2	Inductive Paddle	2-3 hours	No	Yes
Honda EV Plus [limited availability]	NiMH	Conductive; On-board	Level 1 & 2	AVCON	6-8 hours	No	Yes
Nissan Prairie Joy [no available date]	Li-Ion	Inductive; Off-board	Level 1 & 2	Inductive paddle	2-3 hours	No	No
Solectria Force (Level 1 Model) [available now]	Lead Acid	Conductive 1.6kW; Onboard	Level 1	NEMA 5-20P	6-8 hours	No	No

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Electric Vehicle Make/Model [Availability Date in MA]	Battery Type	Charger Type	Charging Levels Accepted	Connector Type	Recharge Time (at Level 2)	Ventilation Required	Installation Assistance Available
Solectria Force (Level 1&2 Model) [available now]	Lead Acid (standard) Ni-Cad (opt.) NiMH (opt.)	Conductive, 3.3kW (standard) 6.6 kW (optional); Onboard (Inductive on request at additional cost)	Level 1 & 2	NEMA 6-20P (std) or NEMA type 50 amp plug; AVCON (optional - will become standard)	3.5 hour full recharge (lead acid) Ni-Cad & NiMH: 8 hrs at 3.3 kW; 4 hours at 6.6kW	No	No
Solectria Citivan [available now]	Lead Acid	Conductive 3.3kW (standard), 6.6 kW (optional); onboard	Level 2	NEMA-type 50 amp plug (standard) AVCON (optional; will become standard)	10 hours for 3.3kW 5 hours for 6.6kW	No	No
[available now]	NiMH	Conductive On-board (Inductive on request at additional cost)	Level 2	AVCON (std) Inductive Paddle (opt)	6-8 hours	No	Yes

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Appendix 2: EV Charging Equipment Resource Directory

	EVCE Product(s)	Inductive/ Conductive		Charger/ Power Station	Outdoor Use	Recommended by EV Seller	Distributor for Massachusetts Area
Electric Vehicle Infrastructure, Inc. 11839 Industrial Court Auburn, CA 95603 530/823-8077	MCS-100	Cond.	L1/ L2	PS	Yes		Edison EV 515 S. Figueroa St., Suite 950 Los Angeles, CA 90071 888/ 890-GOEV
	ICS-200	Cond.	L2	PS	Yes	• Honda EV Plus • Ford Ranger	
Magne Charge **Delco Electronics Corporation** **Power Control Systems** P.O. Box 2923 Torrance, CA 90509-2923 800/282-8250	WM200	Induct.	L2	CH	No	• GM EV1 • Chevy S10 EV	Boston Edison 800 Boylston Street Boston, MA 02199 800/368-2288
	FM200	Induct.	L2	CH	Yes		
Norvik Technologies, Inc. 2486 Dunwin Drive Mississauga, Ontario, L5L 1J9 905/828-7700	25 AFE (25kW)	Cond.	L3	CH	Yes		Direct Sale Only
	150 AFE (150 kW)						
SCI Systems Inc. 8600 South Memorial Parkway Huntsville, AL 35807 205/882-4800	Stylized Wall Mount	Cond.	L2	PS	Yes	• Ford Ranger EV	Boston Edison 800 Boylston Street Boston, MA 02199 800/368-2288
	Pedestal						
	Industrial Wall Mount						
	Level 1 Charging Station		L1				

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Appendix 3: Tax Incentives to Assist in Developing EV Charging Installations

To assist individuals, businesses and other organizations with the purchase of EVs and the development of EVCE infrastructure, the federal government established tax incentives. State and local governments, as well as regional planning agencies may also offer various types of assistance, financial and otherwise.

Federal EV Tax Incentives

Purchasers of **EVs** may be eligible for a federal tax credit on the vehicle whether it is used for personal or business purposes. The federal tax credit for **EVCE** is limited to cases where the vehicle or equipment is used in a trade or business, or for the production of income. Additional information about tax credits is described below.

- **Electric Vehicle Credit**
  Under the Energy Policy Act of 1992 (EPAct), the federal government allows a credit of 10% of the price of the EV, up to $4,000 whether the vehicle is used personally, in a trade or business. Individuals and business users can claim the credit on Form 8834. IRS publication 535 "Business Expenses" has further information on filing the form. The maximum credit will drop to $3,000 in 2002; $2,000 in 2003; and $1,000 in 2004.

- **Charging Equipment**
  Charging equipment used for business purposes qualifies as "clean fuel" vehicle refueling property and is eligible for up to $100,000 in federal tax deductions per location. IRS Publication 535 "Business Expenses" details the procedures for claiming this deduction.

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Appendix 4: Massachusetts Utility Rate Considerations for EV Charging System Operators

At present, Massachusetts's electric utilities do not offer special EV charging rates. However, all of the Massachusetts electric utilities do offer optional Time-of-Use rates that vary based on when and how much electricity is used. The differences in price can be quite significant.

It is anticipated that as competition grows in the electric retail marketplace, there will still be significant price advantages for customers with off-peak load requirements. Thus, to the extent that EVCE uses off-peak electricity for charging, the EVCE operator may be able to obtain substantial discounts on EV electrical usage.

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Appendix 5: Glossary of Terms

ampere - a common unit of electric current representing a flow of one coulomb per second, or $6.2x10^{18}$.

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, designed to meet the voltage and layout requirements of a vehicle.

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

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

charge - conversion of electrical energy into chemical potential energy within a cell by the passage of a direct current.

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 (i.e. metal-to-metal contact) to the vehicle circuit.

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 (i.e., a mating vehicle inlet and connector set).

continuous duty - operation at a substantially constant load for an indefinite period of time.

continuous load - an electrical load for which the maximum current is expected to continue for three hours or more.

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.

current - the rate of flow of electrons in a circuit measured in amperes (A).

diode - has two electrodes or terminals used especially as a rectifier.

electric vehicle (EV) - a vehicle (such as passenger automobiles, buses, trucks, vans) for highway use, 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, etc. are not discussed in this guide.

Electric Vehicle Charging Equipment (EVCE) – ungrounded and grounded conductors, equipment grounding conductors, 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.

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 that 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.

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

inverter - converts DC to AC.

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 (Reference) 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 with **charger** input power at 480 volts, 400 amps, and three-phase power. This energy transfer method uses 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 the energy from an off-board power supply.

non-continuous load - an electrical load where the maximum current is not expected to continue more than three hours.

off-board charger - a charger (usually inductive) that is not located on the vehicle.

on-board charger - a charger (usually conductive) that is located on the vehicle.

rectifier - converts AC to DC.

overcurrent - current exceeding the rated current of equipment or the ampacity of a conductor.

Time-of-Use (TOU) rates - electricity pricing established by utilities to encourage use of electricity during off-peak hours. Rates vary based on when and how much electricity the customer uses.

transformer - transforms AC voltage up or down; changes AC system Delta to Y or Y to Delta 3 Phase or Single Phase. Works only on AC; will not work on DC.

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.

voltage - the force that moves electrons in an electric circuit.

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