INSTALLATION GUIDE FOR ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE)

Prepared by: The Massachusetts Department of Energy Resources and Massachusetts Clean Cities Coalition

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This Guide is not intended to be an installation manual or a replacement for approved codes and standards, but rather is intended to create a common knowledge base of EV requirements for stakeholders involved in the development of EV charging infrastructure. EVs have unique requirements that differ from internal combustion engine (ICE) vehicles, and many stakeholders currently are not familiar with these requirements.

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Figure 1: Charging station (free Juice bar) at the Charles Hotel in Cambridge, MA.

Introduction

In the US alone, there are approximately 270 million vehicles, of all kinds and sizes—that circulate on the U.S. transportation system. Of these, 260 million are highway vehicles—approximately one-fifth of the world's passenger vehicles and 40 percent of its trucks and buses.[1,2] The transportation sector accounts for 70.1 percent of total petroleum consumption in the United States. It is the second largest consumer of energy, next to the industrial sector and is the second largest sector generating greenhouse gas emissions, accounting for 26% of the U.S. total.[3]

Massachusetts is a leader in promoting the transformation of our transportation system to alternative fuel vehicles that improve our environment and economic stability. The Commonwealth is committed to a clean environment and EVs will play an important part in our implementation of the 2008 Global Warming Solutions Act and the Green Communities Act. In addition the State has adopted zero emissions vehicle regulations which requires auto manufacturers to sell at least 11 percent of their total vehicle sales "zero emission vehicles" (ZEV), such as electric vehicles with increasing percentages through model year 2018.

[1] US Department of Transportation, Bureau of Transportation Statistics, Table 1-11 Numbers of U.S. Aircraft, Vehicles, Vessels, and Other Conveyances.
[2] US Department of Transportation, Bureau of Transportation Statistics, 2012 and Transportation Statistics Annual Report, p.1-2.
[3] US Department of Transportation, Bureau of Transportation Statistics, 2016 and Transportation Statistics Annual Report, p.176.

In the early years of the automobile industry -- around the turn of the century -- battery-powered electric vehicles (EVs) were quite popular. More than 360 electric recharging stations dotted the landscape in and around Boston alone! Despite the advantages of reduced air pollutants, convenience, and virtually silent driving, electric vehicles fell from favor because of their slow acceleration, low speeds, and limited range between battery 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. The average US driver travels nearly 40 miles per day across 4 trips. Drivers in rural areas averaged 11 more miles in vehicle travel per day than their urban counterparts—48 versus 34 miles.[4] Industry has received over two billion dollars from the federal government and is investing in EVs, which meet commuter and driving needs as well as provide jobs for battery and car production in the U.S.

As the EV industry reemerges in the beginning of the 21st century, the development of an infrastructure for recharging at home, at work, and at public locations is imperative. Generally, EV charging infrastructure consists of three components: (1) electrical service from the local utility, (2) on-site wiring, and (3) charging stations.

Because electrical service is available almost everywhere, the widespread development of EV charging stations is technically feasible. The New England bulk electricity supply system can generally meet the demand for power, and the utilities are involved with us in ensuring that local distribution issues are minimized. For installation of EVSE to occur, EV users will need to learn about the EV equipment and the requirements for proper installation - subjects covered in this guide. Users of EV charging stations can be assured that EVSE 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 EVSE connector.

In most cases, EV owners seek the economy and convenience of home charging and will have to assume responsibility for installing the EVSE. Despite the residential charging expected to occur, further publically accessible, commercial infrastructure is required to allay range fear and enable practical driving patterns.

While the process of installing the EVSE at a home or business is not complicated, important procedures must be followed to ensure safe and efficient charging opportunities. We hope this guide will increase understanding of the battery electric cars and how they work with EVSE, to make planning and installation easier.

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[4] Federal Highway Administration, National Household Travel Survey 2009: Travel Profile of the United States (2012).

1. Technology

A. Electric Vehicle Technology

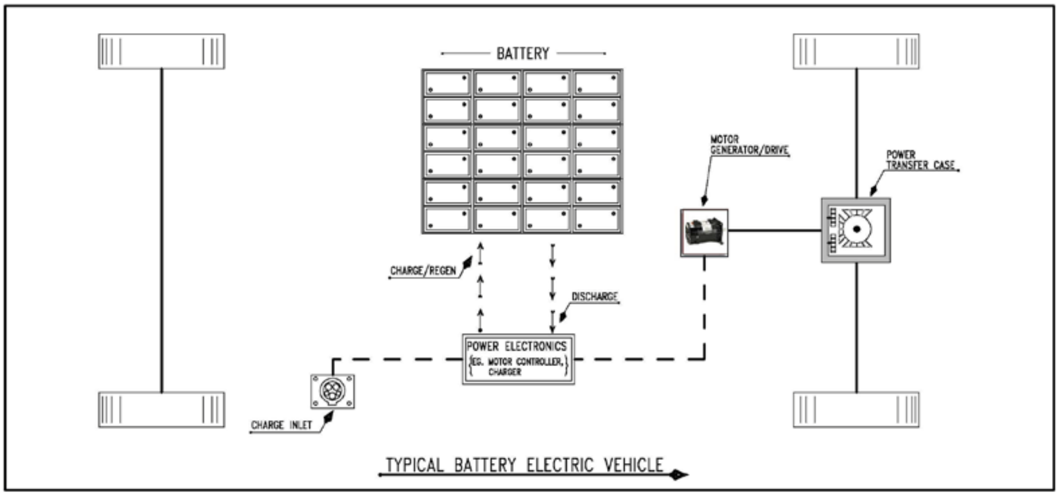
This section describes the basic EV car and light and medium duty truck technologies that are either available in the marketplace or coming to market in the near future. The focus of this section is on street-legal vehicles that incorporate a battery energy storage device that can connect to the electrical grid for the supply of some or all of its fuel energy requirements.

There are two main vehicle configurations and the relative size of their battery packs are discussed in relationship to recommended charging infrastructure.

Battery Electric Vehicles (BEVs)

BEVs are powered 100% by the battery energy storage system available on-board the vehicle. The Nissan LEAF is an example of a BEV. A BEV is refueled by connecting it to the electrical grid through a connector system that is designed specifically for this purpose. Most advanced BEVs have the ability to recapture some of the energy storage utilized through regenerative braking (in simple terms, the propulsion motor acts as a generator during braking). When regenerative braking is applied, BEVs can typically recover 5 to 15 percent of the energy used to propel the vehicle to the vehicle speed prior to braking. Sometimes manufacturers install solar photovoltaic (PV) panels on vehicle roofs. This typically provides a very small amount of energy relative to the requirements of propelling the vehicle, but integrating PV in the roof typically can provide enough power to operate some small accessory loads, such as a radio.

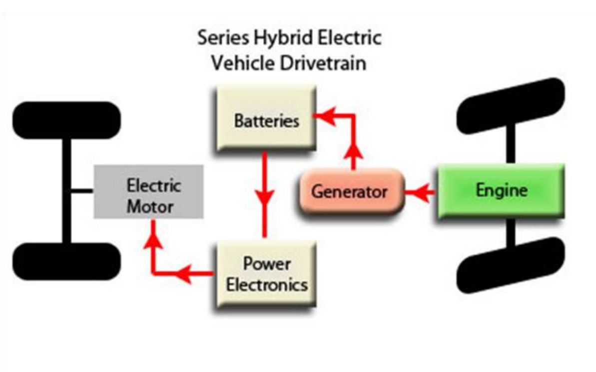
A typical BEV is shown in the block diagram below. Since the BEV has no other significant energy source, a battery must be selected that meets the BEV range and power requirements. BEV batteries are typically an order of magnitude larger than the batteries in hybrid electric vehicles and are generally found in the vehicle's trunk.



Plug–in Hybrid Electric Vehicles (PHEVs)

PHEVs are powered by two energy sources. The typical PHEV configuration utilizes a battery and an internal combustion engine (ICE) powered by either gasoline or diesel. Within the PHEV family, there are two main design configurations, a *Series Hybrid* and a *Parallel Hybrid*.

The Series Hybrid vehicle is propelled solely by the electric drive system, whereas the Parallel Hybrid vehicle is propelled by both the ICE and the electric drive system. As with a BEV, a Series Hybrid will typically require a larger and more powerful battery than a Parallel Hybrid vehicle in order to meet the performance requirements of the vehicle solely based on battery power.



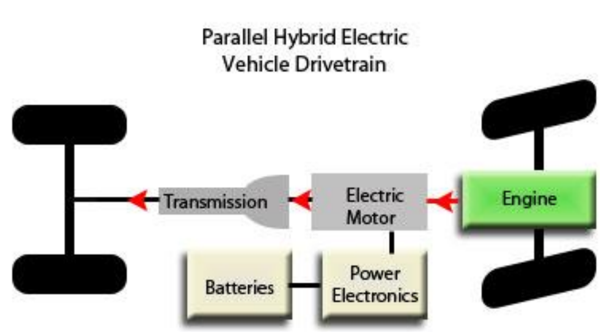
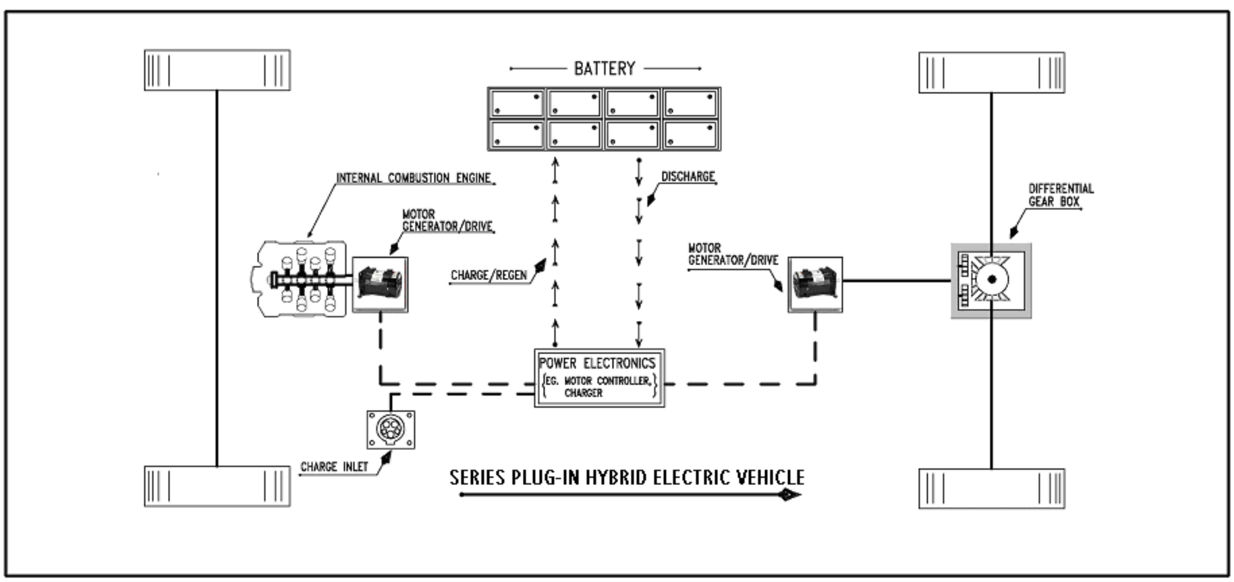


Figure 2: The Chevy Volt Engine.

Manufacturers of PHEVs use different strategies in combining the battery and ICE. For example, the 2017 Chevy Volt utilizes the battery only for the first 53 miles, with the ICE generating electricity for extended range on the vehicle (EREV). Other PHEVs may use the battery power for sustaining motion and the ICE for acceleration or higher-energy demands at highway speeds. Frequently, the vehicles employing the first strategy gain a designation such as "PHEV-20" to indicate that the first 20 miles are battery only. Other terms related to PHEVs may include *Range Extended Electric Vehicle* (REEV) or *Extended Range Electric Vehicle* (EREV).



Batteries

a. **Battery Technology:** Recent advancements in battery technologies will allow EVs to compete with ICE vehicles in performance, convenience, and cost. Although lead-acid technology serves many EV applications like forklifts and airport ground support equipment very cost-effectively, the limitations on energy density and repeated cycles of charging and discharging make its application to on-road highway speed EVs less practical. Today, most major car companies utilize nickel-metal-hydride or various lithium-based technologies for their EVs. Lithium provides four times the energy of lead-acid and two times that of nickel-metal-hydride. The materials for lithium-based batteries are generally considered abundant, non-hazardous, and lower cost than nickel-based technologies. The current challenge with lithium-based technologies is increasing battery capacity while maintaining quality and cycle life and lowering production costs. From an infrastructure standpoint, it is important to consider that as battery costs are driven down over time; auto manufacturers will increase the size of the lithium-based battery packs, and thus extend the range of electric vehicles.

b. **Relative Battery Capacity:** Battery size, or *capacity*, is measured in kilowatt hours (kWh). Battery capacity for electric vehicles will range from as little as 3 kWh to as large as 40 kWh or more. Typically, PHEVs will have smaller battery packs because they have more than one fuel source. BEVs rely completely on the storage from their battery pack for both range and acceleration and therefore require a much larger battery pack than a PHEV for the same size vehicle.

c. **Battery Charging Times:** The amount of time to fully charge an EV battery is a function of the battery size (kWh) and the amount of electric power or kilowatts (kW) that a car can accept and an electrical circuit can deliver to the battery. Larger circuits, as measured by voltage and amperage, will deliver larger draws. Despite what can be delivered, it is the EV's on board charger that will determine the ultimate draw in cases where EVSE can dispense at the higher rate.

   The common US wall outlet, 120 volts AC (VAC), 15 amp circuit will deliver at minimum 1.2 kW to a battery. A 240 VAC, 40 amp circuit (similar to the circuit used for household appliances like dryers and ovens) will deliver at minimum 6.5 kW. The classifications of different charging levels is based upon the level at which the equipment can dispense power.

Circuit Size and Power in kW Delivered to Battery					
EV Configuration	Battery Size (kWh)	120 VAC, 15 amp 1.2 kW	120 VAC, 20 amp 1.6 kW	240 VAC, 40 amp 6.5 kW	480 DC, 85 amp 60 kW
PHEV-10	4	3 h 20 m	2 h 30 m	35 m	n/a
PHEV-20	8	6 h 40 m	5 h	1 h 15 m	n/a
PHEV-40	16	13 h 20 m	10 h	2 h 28 m	16 m
BEV	24	20 h	15 h	3 h 41 m	24 m
BEV	35	29 h 10 m	21 h 50 m	5 h 23 m	35 m
PHEV Bus	50	n/a	n/a	7 h 41 m	50 m

B. Electric Vehicle Supply Equipment Technology

This section covers the terminology and general requirements of Electric Vehicle Supply Equipment (EVSE). EVSE provides for the safe transfer of energy between electric utility power and an electric vehicle.

Vehicle Charging Components

Power is delivered to the EV's onboard battery through the *EV inlet* to the onboard *charger*. This charger converts Alternating Current (AC) from the home or site to the Direct Current (DC) required to charge the battery in the vehicle. The onboard charger and EV inlet are considered part of the EV.

A *connector* is a device that, by insertion into an EV inlet, establishes an electrical connection to the EV for the purpose of information exchange and charging. The EV inlet and connector together are referred to as the *coupler*. The EVSE consists of the connector, cord, and interface to utility power. The interface between the EVSE and utility power will be directly "hardwired" to a control device or a plug and receptacle.

During the 1990's, there was no consensus on EV inlet and connector design. Both conductive and inductive types of couplers were designed and in both cases, different designs of each type were provided by automakers. At the present time, however, the Society of Automotive Engineers (SAE) has agreed that all vehicles produced by automakers in the United States will provide an inlet that conforms to a single, specific connector, known as the *J1772 Standard*.

Figure 3: The J1772 Connector.

Figure 4: The J1772 Inlet.

J1772 Coupler

The J1772 Standard EV coupler is designed for 10,000 connections and disconnections with exposure to dust, salt, and water; is able to withstand a vehicle driving over it; and is corrosion resistant. The J1772 Standard and National Electrical Code (NEC) requirements create multiple safety layers for EV components, including:

The EV coupler

- is engineered to prevent inadvertent disconnection.
- has a grounded pole that is the first to make contact and the last to break contact.
- has an interlock device that prevents vehicle startup while connected.
- is unique to EV charging and cannot be used for other purposes.

The EV inlet

- is de-energized until it is attached to the EVSE.
- will de-energize prior to removal of the connector.

Charging Station Levels

In 1991, the Infrastructure Working Council (IWC) was formed by the Electric Power Research Institute (EPRI) to establish consensus on several aspects of EV charging. Charging levels were defined by the IWC, along with the corresponding functionality requirements and safety systems. EPRI published a document in 1994 that describes the consensus items of the IWC4.

Note: For Levels 1 and 2, the conversion of the utility AC power to the DC power required for battery charging occurs in the vehicle's on-board charger. In DC Fast Charging, the conversion from AC to DC power typically occurs off-board, so that DC power is delivered directly to the vehicle.

The build out of charging infrastructure with diverse levels of charging will be necessary to the efficient promotion the widespread adoption of EVs. The levels of charging are as follows:

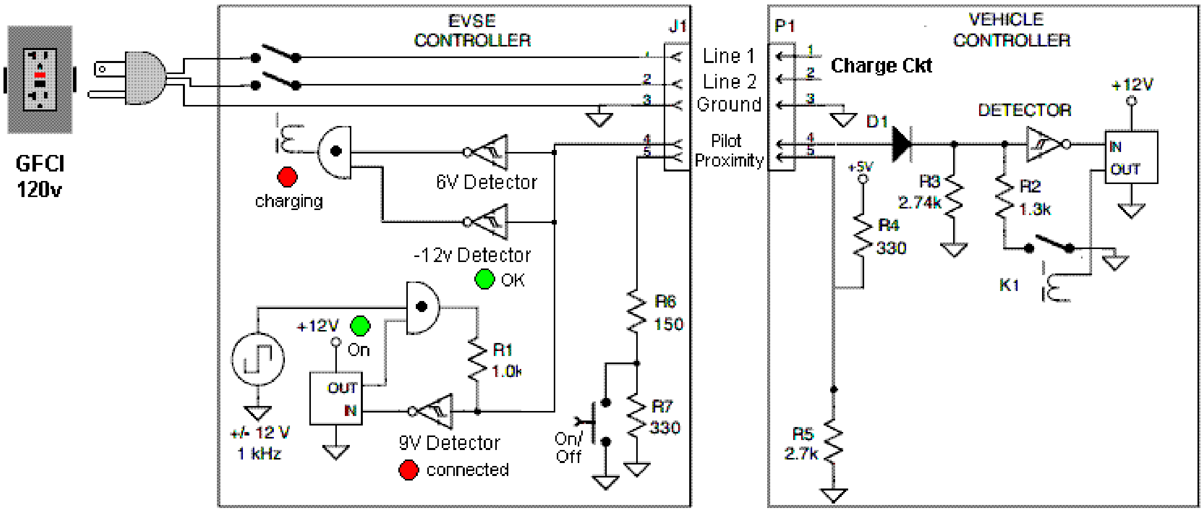
a. **Level 1 – 120 volt AC:** The Level 1 method uses a standard 120 volts AC (VAC) branch circuit, which is the lowest common voltage level found in both residential and commercial buildings. Typical voltage ratings can be from 110 – 120 volts AC. Typical amp ratings for these receptacles are 15 or 20 amps. A 15 amp charge takes twice as long as a 20 amp outlet.

   EV suppliers provide a Level 1 Cord Set (120 VAC, 15 or 20 amps) with the vehicle. The Cord Set uses a standard 3-prong plug (NEMA 5-15P/20P) with a charge current interrupting device (CCID) located in the power supply cable within 12 inches of the plug. The vehicle connector at the other end of the cord will be the design identified in the J1772 Standard. This connector mates properly with the vehicle inlet, also approved by J1772.

   Because charge times can be very long at Level 1, many EV owners will be more interested in Level 2 charging at home and in publicly available locations. Some EV manufacturers suggest their Level 1 Cord Set should be used only during unusual circumstances when Level 2 EVSE is not available, such as when parked overnight at a non-owner's home.

   Several companies provide kits to convert ICE and hybrid vehicles to plug-in vehicles. Many of these conversions use a standard 3-prong electrical plug and outlet to provide Level 1 charging to their vehicles. With the standardization of EVs on the

J1772 Standard and the higher level of safety afforded by a J1772-compliant charging station, existing vehicles will need to be retrofitted to accommodate a J1772 inlet in order to take advantage of the deployment of EVSE infrastructure.



b. Level 2 – 240 volt AC: Level 2 is typically described as the "primary" and "standard" method for the EVSE for both private and publicly available facilities. This method specifies a single-phase branch circuit with typical voltage ratings from 220 – 240 volts AC. The J1772-approved connector allows current as high as 80 amps AC (100 amp rated circuit). However, current levels that high are rare, and a more typical rating would be 40 amps AC, which allows a maximum current of 32 amps. This provides approximately 7.7 kW with a 240 VAC circuit.

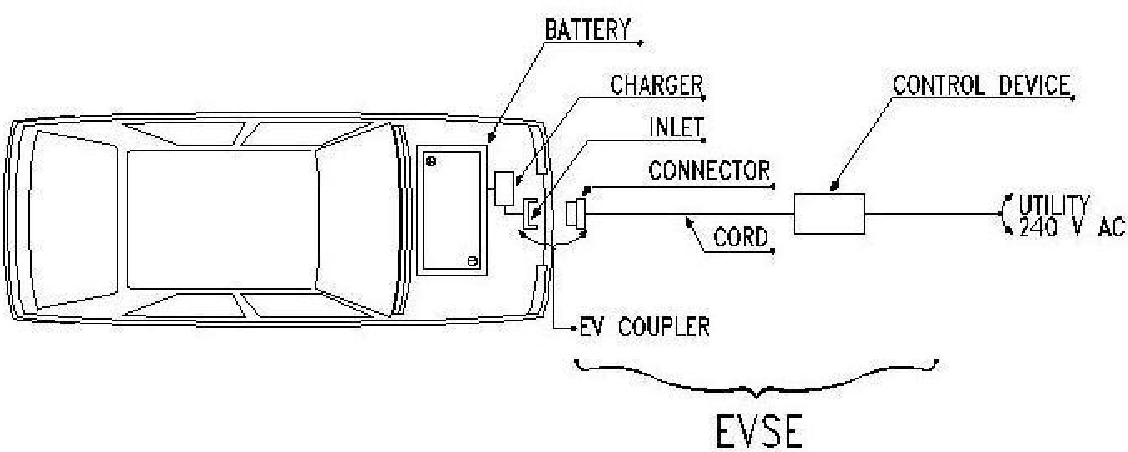


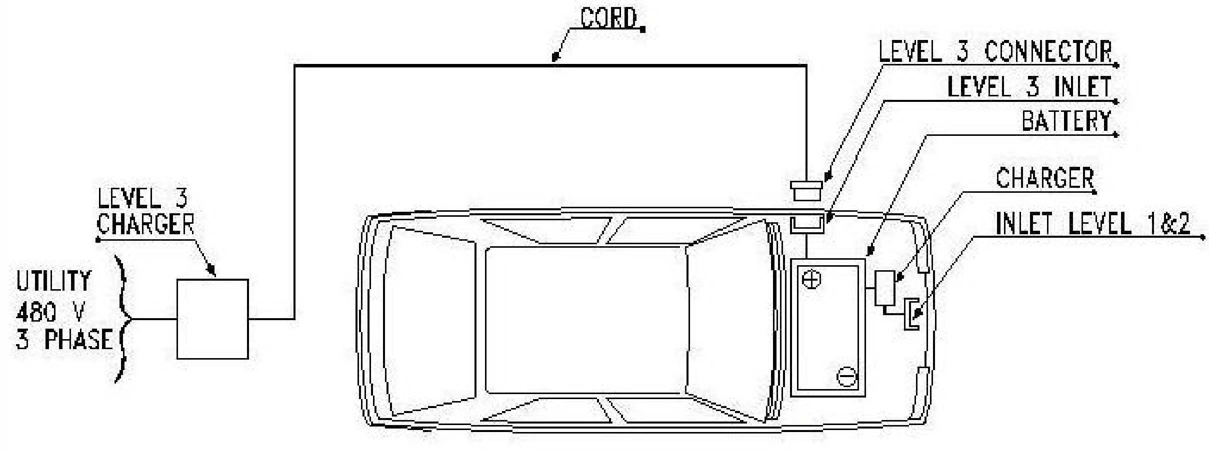
Figure 5: A Nissan Leaf using Level 2 charging.

The higher voltage of Level 2 allows a much faster battery charge. Because of the higher voltage, Level 2 has a higher level of safety requirements than Level 1 under the NEC, including the requirement that the connector and cord be hardwired to the control device and premises wiring.

c. **DC Fast Charging:** This type of charging connection can raise the rate of charge to approximately 75% to 80% in as little as 20 to 30 minutes, depending on battery size. This type of EVSE uses an off-board charger that transforms AC power to DC and bypasses the on-board charger. Generally, 208V three-phase or 480V service is required for this type of charging and may not be commonly available. In many cases, a new separate service will need to be installed by the local utility.

d. **Inductive Charging:** Although not utilized widely in the U.S., inductive charging uses an electromagnetic field to transfer electricity to a PEV without the use of a cord at levels similar to that of level 2 AC. In other countries this technology is used at higher power levels in mass transit operations.

e. **Future Technologies:** An additional AC charging standard is under development using three phase power at 208/120V, 480/277V with a target power level between 6 and 130 kW.



SAE Standards for Fast Charging

The original version of J1772™ defined AC Level 1 and AC Level 2 charge levels and specified a conductive charge coupler and electrical interfaces for AC Level 1 and AC Level 2 charging. The new revision incorporates DC charging where DC Level 1 and DC Level 2 charge levels charge coupler and electrical interfaces are defined. The standard was developed in cooperation with the European automotive experts who also adopted and endorsed a combo strategy in their approach.

SAE Charging Configurations and Ratings Terminology

SAE International

	**AC level 1** (SAE J1772™) PEV includes on-board charger 120V, 1.4 kW @ 12 amp 120V, 1.9 kW @ 16 amp Est. charge time: PHEV: 7hrs (SOC* - 0% to full) BEV: 17hrs (SOC – 20% to full)		**DC Level 1** (SAE J1772™) EVSE includes an off-board charger 200-500 V DC, up to 40 kW (80 A) Est. charge time (20 kW off-board charger): PHEV: 22 min. (SOC* - 0% to 80%) BEV: 1.2 hrs. (SOC – 20% to 100%)
	AC level 2 (SAE J1772™) PEV includes on-board charger (see below for different types) 240 V, up to 19.2 kW (80 A) Est. charge time for 3.3 kW on-board charger PEV: 3 hrs (SOC* - 0% to full) BEV: 7 hrs (SOC – 20% to full) Est. charge time for 7 kW on-board charger PEV: 1.5 hrs (SOC* - 0% to full) BEV: 3.5 hrs (SOC – 20% to full) Est. charge time for 20 kW on-board charger PEV: 22 min. (SOC* - 0% to full) BEV: 1.2 hrs (SOC – 20% to full)		**DC Level 2** (SAE J1772™) EVSE includes an off-board charger 200-500 V DC, up to 100 kW (200 A) Est. charge time (45 kW off-board charger): PHEV: 10 min. (SOC - 0% to 80%) BEV: 20 min. (SOC – 20% to 80%)

Voltages are nominal configuration voltages, not coupler ratings
Rated Power is at nominal configuration operating voltage and coupler rated current
Ideal charge times assume 90% efficient chargers, 150W to 12V loads and no balancing of Traction Battery Pack

Notes:
1) BEV (25 kWh usable pack size) charging always starts at 20% SOC, faster than a 1C rate (total capacity charged in one hour) will also stop at 80% SOC instead of 100%
2) PHEV can start from 0% SOC since the hybrid mode is available.
ver. 100312

Despite this standardization, there are two other Fast Charge couplers being used. Tesla has a proprietary coupler that works only with their cars. They have their stations that uniquely serve their customers alone and are currently deploying them. Also available and utilized internationally, is CHAdeMO. Certain upgraded Nissan LEAFs are equipped to handle this connector. Some stations may have both the J1772 Combo as well as the CHAdeMO. There is also the possibility of co-locating more than one model at the same charging site in some places.

Figure 6: The CHAdeMO connector.

2. Planning

Despite the differences among residential, commercial and municipal charging scenarios, they all require planning, and face similar issues.

In single-family homes, decision-making is simplified. The equipment generally ties into existing electrical service and usage is simply rolled into the bill for the account. The alternative may be separately metered service, the argument for which would be to take advantage of eventual time varying rates (TVRs) or EV tariffs.[5] These options are currently limited in Massachusetts but are being investigated for potential instatement.

Multi-family dwellings often face unique issues with dedicated parking and compensation for electricity. Charging stations in such a setting may require access control.

Workplace charging may tie into existing service paid for by the business owner or possibly building owner. Alternatively, workplace charging may require or desire separately metered service. This issue has to be addressed when the EVSE owner and the property owner are not the same.

[5] Time Varying Rates (TVRs), as implied by the name, change according to the time of day during which electricity is consumed. On peak use, as defined by the individual utility, is generally charged at a higher level than non TVRs would be, but at a significant discount during off peak hours.

Building owners, large business owners, and fleet managers can sometimes face a TVR option, and need to evaluate carefully due to the nature of when employees will most likely want to charge. Typical business hours often coincide with the various utilities' defined peak hours.[6] Another issue, sometimes faced by large utility customers, is the demand charge. Demand charges are levied based upon peak draw from the grid. EVSE equipment used during on peak hours will increase a customer's demand, thereby increasing their bill by far more than the typically small amount increased by additional kWh usage.

Municipalities may face issues similar to those discussed above, depending upon their intended use EVSE.

A. Determination of Equipment Needs

Appropriate Charging Level

Given the time element involved in charging an EV at various levels of charging, the appropriate location of infrastructure will not mirror that of gas stations in most cases. Before the specific hardware is chosen, it is important to look at the way you expect your stations to be utilized.

In commercial applications such as restaurants or malls, users may be expected to spend anywhere from an hour to a few hours. At a location such as these, Level 2 chargers are the most appropriate because of the typically required charging time. However, at airports or park and rides, where people may often leave their vehicles for much longer time periods, level 1 may be more desirable. Many sites, such as workplaces and college campuses, may be able to utilize a mix of both.

[6] Off peak, or over-night charging, is often appropriate for residential or fleet charging. Commercial EVSE owners and municipalities should carefully assess projected usage if given a choice of rates.

Fast Charging is more appropriate for situations in which drivers need to charge up quickly. This level of charging is considered 'pathway' infrastructure as it enables drivers to recharge quickly in situations where the time element of recharging would be a concern, such as on long trips. It requires far more extensive planning and utility involvement than do the installations of the other levels of charging.

Figure 7: Assorted charging stations.

Software Requirements

Basic EVSE

Different models of EVSE have different levels of networking capabilities. Basic models, sometimes called "dumb chargers," communicate only with the vehicle as the "handshake" begins the charging session and ends when the vehicle's charger completes the session or the charge is interrupted by the EVSE or uncoupling.

Smart EVSE

Smart EVSE are offered in Levels 1, 2, and Fast Chargers. Commercial duty qualities are generally more expensive than basic chargers. They offer differing levels of communication with the user, site host, utility grid, and the Internet, depending on model and manufacturer. They also offer the option of collecting fees for the charging session and a high level of reporting capabilities.

Depending on model and manufacturer, smart chargers offer a high degree of information for the user, often by computer or smart phone. Commonly available features are: verification of the user by means of a radio-frequency identification (RFID) card, point of sale using credit cards, display of fee rates, rate of charging, cell phone or email notification of a completed session, plug-out notification, Internet location of EVSE with rates, in-use status, and reservation capabilities. Reporting capabilities commonly include: date, location, electricity used for each charging session, monthly reports, and fee totals. The site host can also communicate with smart EVSE to establish rates, determine usage, verify user identity, trouble shoot errors, and gather kWh consumption data.

Depending on the business model being used by the manufacturer, smart EVSE usually involve on-going monthly or annual fees for the user, site host, or both.

B. Site Assessment

See the Appendix in Section 4 for a checklist identifying other factors in the site assessment process.

Power Source Proximity

One of the major cost variables of an EVSE installation is the immediate proximity of adequate power. A site assessment looks at the available space within the power panel. Dedicated circuits are required. In general, the closer the power source is to the potential site, the less expensive the installation will be.

Potential trenching

A site assessment takes full account of the surroundings of a potential site. Trenching and landscaping can significantly increase costs of installation. This leads to outdoor installations typically being more costly than indoor garage projects.

Cord Management

The placement of EVSE takes account of how the car will be connected to the station. Safety has to be considered and running a cord across a walkway is problematic. Placing the EVSE at a curbside or utilizing a cord management system is recommended.

Lighting

Possible sites should be examined for lighting and security for the safety and convenience of EV drivers.

C. Site Selection

See the Appendix in Section 4 for a checklist identifying other factors in the site selection process.

Cost

The project cost can be determined after site assessments by combining the cost of installation and equipment. The cost of any installation is site specific and averages are not to be trusted. The site assessments will allow cost comparison of various sites and less costly will most likely be chosen over more expensive ones. Sometimes site assessments can rule out cost prohibitive projects.

The appropriate station choice among potential locations will partly be determined by the choice of site. The cost of equipment will vary primarily depending upon the level of equipment chosen and software package included. Keep in mind that level one charging can come directly from a 110 volt wall outlet. Each EV will come with a cord, which plugs into the wall like an extension cord on one end and a J1772 connector on the other.

Visibility

Many commercial and municipal EVSE owners will want to choose a site with high visibility to make it easy for drivers to locate as well as to promote their 'greening' efforts. While this is ideal, many times the most visible site is not affordable. This can be addressed with proper signage. If the station has communication software then the drivers will be able to get the address on an app. However, while the address is given, the exact location at that address is not. Proper and adequate signage is strongly recommended.

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.

D. EVSE Signage

Providing proper EV signage enables EV drivers to find charging stations and can communicate all station related site regulations. EV signage comes in the form of Station signage and Wayfinding signage. Station signage is meant to help drivers identify the stations and its policies, while wayfinding signs guide the drivers to the stations from other places, like a freeway or through a parking garage.

Station Signage

Currently, the Manual for Uniform Traffic Control Devices (MUTCD) has approved the symbol shown in Figure 8 to denote EV charging stations.[7] In addition to letting drivers know of the station, some sites use signs to communicate relevant EVSE and parking regulations. For example, sites may communicate time limits or that the space is reserved for EVs only. It is important to note that signs posted at charging stations in the public right of way must be supported by ordinances under the local jurisdiction, and that the signs must adhere to MUTCD requirements.

Figure 8: The MUTCD approved sign for EV charging stations.

Wayfinding Signage

The same signage approved by the MUTCD to denote EVSE can be combined with directional arrows or and mileage to direct drivers to the charging station. Although many EV owners locate charging stations on their smartphone, placing directional signs towards the EVSE in

[7] The current edition of the MUTCD can be found here: https://mutcd.fhwa.dot.gov/kno_2009r1r2.htm

areas with inconsistent cell service and complex parking structures can help drivers locate a station.[8]

3. Safe Implementation

A. Installation of EVSE code and UL information

EVSE level 2 models selected must be:

- UL certified.
- Installed by a Massachusetts licensed electrician.
- Installed in compliance with NFPA 70, National Electric Code article 625 and applicable Massachusetts electrical code adopted and enforced within the jurisdiction of installation.

It is suggested that the utility supplying power to the installation site be contacted to ensure adequate power supply to the site. This may become standard procedure as more EVSEs are installed in a neighborhood or in district with heavy power demands.

Installation is generally straightforward and under state permitting laws each City or Town is required to issue a permit to install a device within 5 days from request and then upon completion of the work the Town or City must inspect the completed job within 5 days.

Always use a licensed electrician. When appropriate, be sure to contact Dig Safe, the laws and rules for which can be found at http://www.digsafe.com/laws_rules.php.

B. NEC 625 code information

The NEC, National Electric Code, is part of the National Fire Code and is mandated by most state or local law in the USA. The code covers all wiring in and around structures.

The NEC article 625 covers the wires and equipment used to supply electricity for charging an electric vehicle. The 2008 version does not cover motorcycles, industrial trucks, or golf carts. It covers the charging process to the end of the connector that plugs into the vehicle. It does not cover whatever happens with that power once it enters the vehicle.

1999 was the first edition of NFPA 70 the National Electric Code (published by the National Fire Protection Association) to include article 625 about Electric Vehicle Charging. Coincidently, this is the first edition after the introduction of the GM EV1 vehicles. Minor changes have been made over the years. The following notes are based on the 2008 edition.

[8] Signage information from https://www.afdc.energy.gov/fuels/electricity_charging_station_signage.html

If the charging power source is 120 volts and is powered by a 15 or 20 amp standard ground fault protected outlet, NEC article 625 has no other requirements. The 120 volt power and lower is safer and allows emergency charging anyplace. The switch for the outlet is an extra level of safety. The switch for the outlet is turned off when not in use, before the extension cord is connected to the vehicle and before the extension cord is disconnected from the vehicle. It improves safety in a potentially wet environment.

If the voltage or current exceeds 120 volts or 20 amps, the other requirements of NEC article 625 apply.

There are requirements for the connector:

- It must be polarized.
- It cannot be interchanged with any standard connector.
- It must be touch safe when in use and not in use.
- It must have a latch to prevent unintentional disconnection.
- It must have a grounding connection that makes first and brakes last.
- All of these requirements are covered by using a SAE J1772 compliant connector and communications.

The charging equipment must be:

- Marked with the intended use (electric vehicle charging) and if the location has ventilation required for some battery types.
- The cable used between the equipment and vehicle can only be one of several types. specifically designed for EV charging, all types have the first two letters in the wire type as EV.
- There will be an interlock that only supplies power to an electric vehicle.
- Power will automatically disconnect if the cable is disconnected.
- Power will automatically disconnect if the cable pulled on (tension) before it separates or fails.
- There will be over current protection.
- Ground fault protection is required.
- There are requirements about storing the cable between used 18-48 inches above the floor.
- There are other requirements for very high power charging systems and interactive system beyond the scope of these notes.
- For indoor sites, there are requirements for batteries that could produce flammable gasses (flooded lead acid) and require ventilation that is beyond the scope of these notes.

- Outdoor charging is permitted.

C. 2008 NEC Codes

The 2008 NEC items required for the installation of EVSE are below. Please check your most recent edition of the NEC for updates.

NEC ITEM Chapter or Article	**Items required in the 2008 NEC Codes for the installation of EVSE.**
Chapter 2 and 3	**Branch Circuit** A new electrical box added on a branch circuit shall comply with NFPA 70 National Electrical Code® Chapter 2 Wiring and Protection and Chapter 3 Wiring Methods and Materials and all administrative requirements of the NEC or the electrical code in effect in the jurisdiction.
625.4	**VOLTAGES** Unless other Voltages are specified, the nominal ac system voltages of 120, 120/240, 208Y/120, 240, 480Y/277, 480, 600Y/347, and 600 Volts shall be used to supply equipment
625.5	**LISTED OR LABELED** All electrical materials, devices, fittings, and associated equipment shall be listed or labeled.
625.9	The electric vehicle coupler shall comply with 625.9(A) through (F). (A) Polarization. The electric vehicle coupler shall be polarized unless part of a system identified and listed as suitable for the purpose. (B) No interchangeability. The electric vehicle coupler shall have a configuration that is no interchangeable with wiring devices in other electrical systems. No grounding -type electric vehicle couplers shall not be interchangeable with grounding-type electric vehicle couplers. (C) Construction and Installation. The electric vehicle coupler shall be constructed and installed so as to guard against inadvertent contact by persons with parts Made live from the electric vehicle supply equipment or the electric vehicle battery. (D) Unintentional Disconnection. The electric vehicle coupler shall be provided with a positive means to prevent unintentional disconnection. (E) Grounding Pole. The electric vehicle coupler shall be provided with a grounding pole, unless part of a system identified and listed as suitable for the purpose in Accordance with Article 250. (F) Grounding Pole Requirements. If a grounding pole is provided, the electric vehicle coupler shall be so designed that the grounding pole connection is the first to Make and the last to break contact.
625.13	**ELECTRIC VEHICLE SUPPLY EQUIPMENT** Electric vehicle supply equipment rated at 125 volts, single phase, 15 or 20 amperes or part of a system identified and listed as suitable for the purpose and Meeting the requirements of 625.18, 625.19, and 625.29 shall be permitted to be cord-and-plug-connected. All other electric vehicle supply equipment shall be Permanently connected and fastened in place. This equipment shall have no exposed live parts
625.14	**Rating** Electric vehicle supply equipment shall have sufficient rating to supply the load served. For the purposes of this article, electric vehicle charging loads shall be Considered to be continuous loads.
625.15	**Markings** The electric vehicle supply equipment shall comply with 625.15(A) through (C). (A) General. All electric vehicle supply equipment shall be marked by the manufacturer as follows: FOR USE WITH ELECTRIC VEHICLES (B) Ventilation Not Required. Where marking is required by 625.29(C), the electric vehicle supply equipment shall be clearly marked by the manufacturer as follows: VENTILATION NOT REQUIRED The marking shall be located so as to be clearly visible after installation.

	(C) Ventilation Required. Where marking is required by 625.29(D), the electric vehicle supply equipment shall be clearly marked by the manufacturer, "Ventilation Required." The marking shall be located so as to be clearly visible after installation.
625.16	**Means of Coupling** The means of coupling to the electric vehicle shall be either conductive or inductive. Attachment plugs, electric vehicle connectors, and electric vehicle inlets shall Be listed or labeled for the purpose.
625.17	**Cable** The electric vehicle supply equipment cable shall be Type EV, EVJ, EVE, EVJE, EVT, or EVJT flexible cable as specified in Article 400 and Table 400.4. Ampacities shall be as specified in Table 400.5(A) for 10 AWG and smaller, and in Table 400.5(B) for 8 AWG and larger. The overall length of the cable shall not Exceed 7.5 m (25 ft) unless equipped with a cable management system that is listed as suitable for the purpose. Other cable types and assemblies listed as being Suitable for the purpose, including optional hybrid communications, signal, and optical fiber cables, shall be permitted.
625.18	**Interlock** Electric vehicle supply equipment shall be provided with an interlock that de-energizes the electric vehicle connector and its cable whenever the electrical connector Is uncoupled from the electric vehicle. An interlock shall not be required for portable cord-and-plug-connected electric vehicle supply equipment intended for Connection to receptacle outlets rated at 125 volts, single phase, 15 and 20 amperes.
625.19	**Automatic De-Energization of Cable** The electric vehicle supply equipment or the cable-connector combination of the equipment shall be provided with an automatic means to de-energize the cable conductors and electric vehicle connector upon exposure to strain that could result in either cable rupture or separation of the cable from the electric connector and Exposure of live parts. Automatic means to de-energize the cable conductors and electric vehicle connector shall not be required for portable cord-and-plug connected Electric vehicle supply equipment intended for connection to receptacle outlets rated at 125 volts, single phase, 15 and 20 amperes.
625.21	**Over current Protection** Over current protection for feeders and branch circuits supplying electric vehicle supply equipment shall be sized for continuous duty and shall have a rating of not Less than 125 percent of the maximum load of the electric vehicle supply equipment. Where noncontiguous loads are supplied from the same feeder or branch Circuit, the over current device shall have a rating of not less than the sum of the noncontiguous loads plus 125 percent of the continuous loads.
625.22	**Personnel Protection System** The electric vehicle supply equipment shall have a listed system of protection against electric shock of personnel. The personnel protection system shall be Composed of listed personnel protection devices and constructional features. Where cord-and-plug-connected electric vehicle supply equipment is used, the interrupting device of a listed personnel protection system shall be provided and shall be an integral part of the attachment plug or shall be located in the power Supply cable not more than 300 mm (12 in.) from the attachment plugs.
625.23	**Disconnecting Means** For electric vehicle supply equipment rated more than 60 amperes or more than 150 volts to ground, the disconnecting means shall be provided and installed in a Readily accessible location. The disconnecting means shall be capable of being locked in the open position. The provision for locking or adding a lock to the disconnecting means shall be installed on or at the switch or circuit breaker used as the disconnecting means and shall remain in place with or without the lock Installed. Portable means for adding a lock to the switch or circuit breaker shall not be permitted.
625.25	**Loss of Primary Source** Means shall be provided such that, upon loss of voltage from the utility or other electrical system(s), energy cannot be back fed through the electric vehicle and the Supply equipment to the premises wiring system unless permitted by 625.26.
625.26	**Interactive Systems** Electric vehicle supply equipment and other parts of a system, either on-board or off-board the vehicle, that are identified for and intended to be interconnected to a

	vehicle and also serve as an optional standby system or an electric power production source or provide for bi-directional power feed shall be listed as suitable for That purpose. When used as an optional standby system, the requirements of Article 702 shall apply, and when used as an electric power production source, the Requirements of Article 705 shall apply.
625.28	**Hazardous (Classified) Locations** Where electric vehicle supply equipment or wiring is installed in a hazardous (classified) location, the requirements of Articles 500 through 516 shall apply.
625.29	**Indoor Sites** Indoor sites shall include, but not be limited to, integral, attached, and detached residential garages; enclosed and underground parking structures; repair and nonrepair commercial garages; and agricultural buildings. (A) Location. The electric vehicle supply equipment shall be located to permit direct connection to the electric vehicle. (B) Height. Unless specifically listed for the purpose and location, the coupling means of the electric vehicle supply equipment shall be stored or located at a height of not less than 450 mm (18 in.) and not more than 1.2 m (4 ft) above the floor level. (C) Ventilation Not Required. Where electric vehicle nonvented storage batteries are used or where the electric vehicle supply equipment is listed or labeled as Suitable for charging electric vehicles indoors without ventilation and marked in accordance with 625.15(B), mechanical ventilation shall not be required. (D) Ventilation Required. Where the electric vehicle supply equipment is listed or labeled as suitable for charging electric vehicles that require ventilation for indoor Charging, and is marked in accordance with 625.15(C), mechanical ventilation, such as a fan, shall be provided. The ventilation shall include both supply and Exhaust equipment and shall be permanently installed and located to intake from, and vent directly to, the outdoors. Positive pressure ventilation systems shall be Permitted only in buildings or areas that have been specifically designed and approved for that application. Mechanical ventilation requirements shall be determined By one of the methods specified in 625.29(D) (1) through (D) (4). (1) Table Values. For supply voltages and currents specified in Table 625.29(D)(1) or Table 625.29(D)(2), the minimum ventilation requirements shall be as Specified in Table 625.29(D) (1) or Table 625.29(D) (2) for each of the total number of electric vehicles that can be charged at one time. (2) Other Values. For supply voltages and currents other than specified in Table 625.29(D)(1) or Table 625.29(D)(2), the minimum ventilation requirements shall be **Indoor sites(con't)** Calculated by means of general formulas stated in article 625.39(D) (2). (3) Engineered Systems. For an electric vehicle supply equipment ventilation system designed by a person qualified to perform such calculations as an integral part Of a building's total ventilation system, the minimum ventilation requirements shall be permitted to be determined per calculations specified in the engineering study. (4) Supply Circuits. The supply circuit to the mechanical ventilation equipment shall be electrically interlocked with the electric vehicle supply equipment and shall Remain energized during the entire electric vehicle charging cycle. Electric vehicle supply equipment shall be marked in accordance with 625.15. Electric vehicle supply equipment receptacles rated at 125 volts, single phase, 15 and 20 amperes shall be marked in accordance with 625.15(C) and shall be switched, and the Mechanical ventilation system shall be electrically interlocked through the switch supply power to the receptacle.
625.30	**Outdoor Sites** Outdoor sites shall include but not be limited to residential carports and driveways, curbside, open parking structures, parking lots, and commercial charging Facilities. (A) Location. The electric vehicle supply equipment shall be located to permit direct connection to the electric vehicle. (B) Height. Unless specifically listed for the purpose and location, the coupling means of electric vehicle supply equipment shall be stored or located at a height of not less than 600 mm (24 in.) and not more than 1.2 m (4 ft) above the parking surface.

4. Resources

www.mass.gov/energy/cleancities
http://evseready.org/
http://www.pluginamerica.org/accessories/aerovironment-evse-rs
http://www.afdc.energy.gov/fuels/electricity_infrastructure.html
https://www.afdc.energy.gov/fuels/electricity_charging_station_signage.html
http://www.evconnect.com/tag/evse-infrastructure/
http://www.transportationandclimate.org/content/northeast-electric-vehicle-network
http://www.georgetownclimate.org/
https://mutcd.fhwa.dot.gov/kno_2009r1r2.htm

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Appendix:
Site Selection and Site Assessment Checklists

The following checklists are not meant to serve as a standalone guide, but are a non-exhaustive list of considerations intended to assist with the initial stages of the site selection and site assessment process for EVSE infrastructure installation.

Site Selection Checklist

- ☐ Identify non-premium parking spots to reduce conflict with ICE vehicles
- ☐ Check for walkways that may cause cords to become a tripping hazard for pedestrians
- ☐ Consider the accessibility and distance to the charging unit handle
- ☐ Identify potential conflict with snow and snow banks
- ☐ Determine the expected charging duration and the expected number of cars
- ☐ Consider the potential for future expansion of EVSE
- ☐ Determine what policies will be associated with site use and what relevant signs will be posted

Site Assessment Checklist

- ☐ Identify EVSE circuit requirements
- ☐ Identify all potential power sources
- ☐ Determine existing load capacity of panels and transformers
- ☐ Determine requirements to plan for additional stations
- ☐ Determine cellular signal availability (if station uses cell network)
- ☐ Determine the necessary physical protections (Curbs, wheel stops, bollards, etc.)