EVTC

Electric Vehicle Transportation Center

Electric Vehicle Charging Technology Analysis And Standards

Doug Kettles
Florida Solar Energy Center

February 2015

FSEC Report Number: FSEC-CR-1996-15

Sponsored by:
U.S. Department of Transportation's
University Transportation Centers Program
Contract Number: DTRT13-G-UTC51

]

1679 Clearlake Road
Cocoa, FL 32922-5703
Website: evtc.fsec.ucf.edu

University of Central Florida

Table of Contents

Electric Vehicle Charging Technology Analysis and Standards

Doug Kettles
Florida Solar Energy Center
February 2015

1.0 Abstract

This report accesses the technologies and standards associated with Electric Vehicles (EVs), Electric Vehicle Service Equipment (EVSE) and the related infrastructure. A review of infrastructure, highway and vehicle safety standards are included in the paper. The report also evaluates the barriers and challenges of deploying an expanded network of EV charging stations and makes recommendations to help standardize and expedite EVSE infrastructure deployment to support the accelerating growth of EVs. The study focuses on EVSE and the infrastructure for Battery-Electric Vehicles (BEVs) and Plug-In Hybrid Electric Vehicles (PHEVs); collectively known as Plug-In Electric Vehicles (PEVs). The results are restricted to the standards, regulations and deployment of EVSE in the United States.

2.0 Introduction

The infrastructure element that provides the crucial link between an Electric Vehicle (EV) with a depleted battery and the electrical source that will recharge those batteries is the Electric Vehicle Supply Equipment or EVSE. This report provides a review of the current and emerging EVSE technologies and an assessment of the common codes and standards associated with EVSE. The report also evaluates the barriers and challenges of deploying an expanded network of EV charging stations in the U.S. and makes recommendations to mitigate the challenges of deploying the infrastructure required to support the accelerating deployment of EVs.

Although there are many significant barriers to the expansion of the EVSE infrastructure, one of the primary barriers is inadequate communication of the needs and requirements of establishing an easily accessible PEV recharging network. Public officials and private enterprise want to better understand the PEV and infrastructure environment, focused and consistent public awareness campaigns supporting the continued adoption of PEVs and an expanded EVSE infrastructure are needed.

Refueling stations for conventionally fueled vehicles are privately operated, competitive, revenue generating facilities. The PEV population is growing rapidly; however, the current population of PEVs makes it extremely difficult to develop a rational business model that can justify the expense to install, operate and maintain an individual recharging station, much less a large network. Reimbursable governmental incentives tied to the deployment and ROI of the EVSE infrastructure should be explored.

Particular attention needs to be focused on the development of the PEV recharging infrastructure for the urban and multifamily environments. According to the Federal Highway Administration almost 80% of the U.S. population resides in an urban area. [1]

PEVs are ideally suited to the travel requirements of these areas, and the largest positive impacts to the environment and U.S. energy independence will be realized in urban population areas.

PEV owners do not enjoy the benefits of the standardized refueling facilities familiar to the owners of conventionally-powered vehicles. The development of standards to support the expansion of EVSE infrastructure has been slow and frequently interrupted. Combining the lack of physical layer standardization with the proprietary nature of existing PEV recharging networks can make it a real challenge for the average motorist to consider switching to an electric vehicle.

Other standardization and incentives are also needed, including a standardized methodology for establishing off-peak electrical power rate schedules for PEV owners and federal legislation allowing all public EVSE operators to bill by kilowatt hours. Incentives are needed that recognize the PEV's environmental contributions which would allow power companies to establish an attractive tariff level for publically available EVSE. To promote the goal of true Zero Emissions, incentives are also needed that specifically support the inclusion of photovoltaic supplied energy for EVSE installations. Finally, federal tax credits for the installation of public and private EVSE infrastructure need to be restored.

Significant advancements are being made in PEV technologies, and many PEV manufactures have near-term expectations for advanced battery technology that will provide a travel range equal to that of conventionally fueled vehicles. The available model selection of PEVs has expanded quickly and the commitment of major car manufactures continues to intensify. The continued growth and acceptance of PEVs cannot be sustained without an adequate recharging infrastructure; the lack of one may prove to be an extremely difficult negative perception to overcome.

Promising research in wirelessly charging is underway, but more attention is needed to help realize the promise of untethered recharging of EVs. The successful development and deployment of this technology will provide the convenience of pulling into a garage or a parking spot and having the EV recharged without the need to connect and disconnect a cable. There is also the possibility of embedding wireless charging in the roadway as a method of continuously recharging the vehicle while in transit; a system that would allow a dramatic reduction in battery size and extend the travel range of EVs. Wireless Power Transfer (WPT) is a proven technology that also offers the potential of simpler, less expensive infrastructure elements.

PEVs are a fundamental element in recognized plans to increase the United States' energy independence and improve the environment. The continued slow response to the establishment of a reliable, widely available PEV recharging network will negatively impact those plans. There is a serious lack of committed governmental and industry involvement for EVSE infrastructure expansion. To their credit, several PEV manufacturers are taking steps to provide recharging solutions for their customers and a few states have enacted legislative measures that will help support the growth of the recharging infrastructure. Unfortunately, these positive steps are significantly less than what is required to ensure an adequate PEV recharging infrastructure. A comprehensive, coherent strategy that combines public and policy awareness with financial reality is needed to support the continued accelerated adoption of PEVs and the infrastructure needed to support them.

3.0 Electric Vehicle Supply Equipment (EVSE) Technology

EVSE delivers electrical energy from an electricity source to charge a PEV's battery. The EVSE communicates with the PEV to ensure that an appropriate and safe flow of electricity is supplied. EVSE units are commonly referred to as charging stations. [2]

3.1 Basic EVSE Components

EVSE

The equipment, connected to an electrical power source, that provides the alternating current (AC) or the direct current (DC) supply to the electric vehicle that is needed to charge the vehicle's traction batteries. EVSE charging capacity options are an important consideration as they have a direct bearing on how fast the batteries can be recharged. As an example, Level 2 EVSE is available in 20, 30 and 40 amp capacities and higher amperage equates to faster recharge times. However, the PEV's onboard charger must have the ability to match the full output of the EVSE to realize the fastest recharge times.

Electric Vehicle Connector

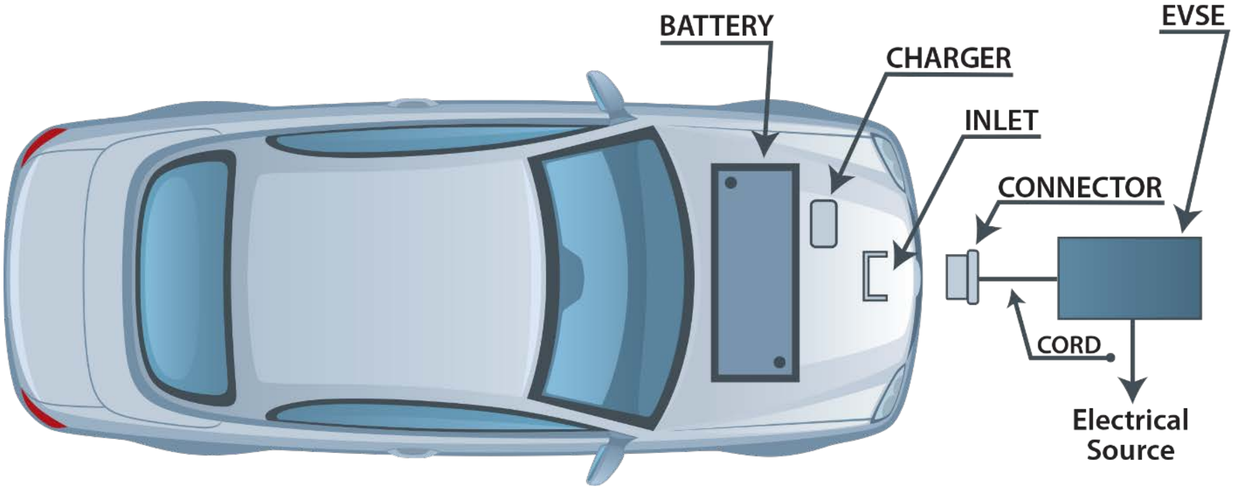
The device attached to the EVSE cable that provides the physical connection between the EVSE and the PEV. There are three predominant connectors in use today: the SAE J1772 based connector (developed by the U.S. auto standards development organization SAE), the CHAdeMO connector (developed by the Japanese auto standards development organization), and the Tesla developed Supercharger connector that is used exclusively for charging Tesla electric automobiles.

Electric Vehicle Inlet

The device on the electric vehicle that provides the physical connection between the PEV and the EVSE connector. Some PEVs have more than one inlet port and locations vary from vehicle to vehicle.

Battery Charger

Level 1 and 2 charging uses the PEV's internal battery charger to convert the EVSE alternating current (AC) supply to the direct current (DC) needed to charge the car's traction batteries. DC Fast Chargers (DCFC) supply high-current DC electricity directly to the PEV's traction batteries; the onboard charger conversion of AC to DC is not required and this function of the on-board charger is by-passed when a DCFC is used. On-board battery charger options are an important consideration when purchasing a PEV as they have a direct bearing on how fast the batteries can be recharged. There are several options available, some of which do not provide an option for DCFC.



3.2 EVSE Charger Classifications

EVSE is normally classified as Level 1, Level 2 or DC Fast Charge (DCFC). In general terms, EVSE classification pertains to the power level that the equipment provides to recharge a PEV's batteries. The use of higher charge levels can significantly reduce the time required to recharge batteries.

Levels 1, 2 and DCFC are the most widely deployed classes of chargers, but there are two other classes of lesser known, high-powered EVSE specifications, AC Level 2 and DC Level 2; information on AC Level 2 and DC Level 2 can be found at: http://standards.sae.org/j2836/2_201109/

Level 1 Charging Cord
Source: Roperld

Level 2 Charging Station
Source: ClipperCreek

DC Fast Charging (DCFC)
Source: Evcaro

AC Level 1 Charging

Level 1 provides charging from a standard residential 120-volt AC outlet, its power consumption is approximately equal to that of a toaster. Most PEV manufacturers include a Level 1 EVSE cord set so that no additional charging equipment is required. As a general rule, Level 1 recharging will add approximately four miles of travel per hour. Level 1 charging is the most common form of battery recharging and can typically recharge a PEV's batteries overnight; however, a completely depleted PEV battery could take up to 20 hours to completely recharge.

AC Level 2 Charging

Level 2 equipment provides charging using 220-volt residential or 208-volt commercial AC electrical service, its power consumption is approximately equal to that of a residential clothes dryer. As a general rule, Level 2 recharging will supply up to approximately 15 miles of travel for one hour of charging to vehicles with a 3.3 kW on-board charger, or 30 miles of travel for one hour of charging for vehicles with a 6.6kWh on-board charger. Level 2 EVSE utilizes equipment specifically designed to provide accelerated recharging and requires professional electrical installation using a dedicated electrical circuit. Level 2 equipment is available for purchase online or from retailers that sell other residential appliances. A completely depleted PEV battery could be recharged in approximately seven hours using a Level 2 charger.

DC Fast Charging (DCFC)

DCFC equipment requires commercial grade 480-volt AC power service and its power requirements are approximately equal to 15 average size residential central air conditioning units. As a general rule, DCFC recharging will add approximately 80-100 miles of travel with 20-30 minutes of charging. The DCFC EVSE converts AC to DC within the EVSE equipment, bypassing the car's charger to provide high-power DC directly to the PEV's traction batteries through the charging inlet on the vehicle. DCFCs are being deployed across the United States, typically in public or commercial settings. While the power supplied to PEVs by all DCFCs is standardized, there is not uniform agreement on the connector that is used to connect the charger to the vehicle. There are two competing standards for the vehicle connectors used with DCFCs; one standard is the SAE J1772 Combo developed by the U.S. auto standards development organization SAE and the other is the CHAdeMO connector developed by a Japanese auto standards organization. As a practical matter, both connectors work very well and many (but not all) PEVs are equipped to utilize either connector. DCFC's high-power capabilities can restore a depleted PEV battery in approximately 30 minutes.

EVSE General Characteristics (Completely depleted battery)

	Charge Time	Voltage/Amps	Power Equivalent	Installation
Level 1	Up to 20 hrs.	120/15	Toaster	Self
Level 2	Up to 7 hrs.	240/40	Clothes dryer	Professional
DC Fast Charge	Up to 30 min.	480/125	15 Central A.C.	Professional

3.3 PEV Battery Systems

PEVs actually have two battery systems, the larger "traction" batteries that provide propulsion for the vehicle, and a smaller, conventional 12-volt battery that provides auxiliary power for on-board systems such as the entertainment system, dash lights, etc. The traction batteries come in a wide variety of power ratings that are designed to meet the specific needs of the particular model of PEV. Traction batteries are also becoming known by the more technical designation of Rechargeable Energy Storage System (RESS), a reference to their ability to store energy for purposes other than propelling the PEV. Most of today's PEVs use lithium-ion batteries, which are much larger versions of the battery technology used in cell phones and other personal electronics.

3.4 EVSE/PEV Signaling and Communications

EVSE and PEV interaction during the battery recharging process can be an interactive and dynamic process that requires communications between both elements. Multiple, ongoing communications exchanges occur during charging, one of the primary purposes of these communications is to regulate the amount of current provided to charge the vehicle. The EVSE informs the vehicle of the maximum current available, allowing the PEV to manage current flow within the EVSEs service breaker capacity. Additional primary communications and interactions take place that monitor the State-Of-Charge (SOC) of the batteries and also allow the PEV to bypass the on-board charger and use the EVSE charger if a DCFC station is being used.

SAE Recommended Practice SAE J2847/2 establishes requirements and specifications for communication between PEVs and the DC Off-board charger. Where relevant, this SAE document notes, but does not formally specify, interactions between the vehicle and vehicle operator. This document applies to the off-board DC charger for conductive charging, which supplies DC current to the batteries of the electric vehicle through a SAE J1772™ coupler. Communications will be on the J1772 Pilot line for Power Line Communication (PLC). The details of PLC communications are found in SAE J2931/4. The specification supports DC energy transfer via Forward Power Flow (FPF) from source to vehicle.

SAE J2847/2 provides messages for DC energy transfer. The updated version in August, 2012 was aligned with the DIN SPEC 70121 and additions to J1772™ for DC charging, published October, 2012. This revision includes results from implementation and changes not included in the previous version. This revision also includes effects from DC discharging or Reverse Power Flow to off-board equipment that expands on J2847/3 for AC energy flow from the vehicle, and other Distributed Energy Resource functions that are being developed from the use cases in J2836/3™, published January, 2013. [3]

3.5 PEV Battery Charging Frequency

There is a noteworthy similarity between the refueling requirements for conventionally fueled vehicles and the recharging requirements of PEVs. Like their fossil fueled counterparts, how often PEV batteries need to be recharged is generally a function of the distance travelled, the geography, and the driving habits of the individual. Driving fast for long distances, in hilly terrain is going to require more frequent refueling for both types of vehicles.

Worst case charging times can be worrisome to the potential PEV owner, and while it can take a long time to recharge a depleted battery, it doesn't have to be a burdensome endeavor. Most owners simply "top-off" their batteries at home at the end of the day.

3.6 PEV Battery Charging Duration

Several factors influence the amount of time it takes to recharge a PEV's batteries and, taken together, the combination of factors determines the amount of time required to replenish the batteries of a PEV.

<u>State-of-Charge (SOC)</u>

First and foremost is the battery's State-Of-Charge (SOC). SOC refers to the battery charge level at the beginning of the charging cycle. The lower the SOC, the longer it will take to recharge the battery, regardless of what level of charging is applied. A battery that is 50% charged at the beginning of the recharging cycle will take longer to charge at Level 1 than a similar battery recharging from a 75% SOC using the same Level 1 charger. In both instances, the time required to recharge both batteries can be significantly reduced by applying a Level 2 charge, but again the battery with a beginning charge level of 50% will still take more time than the battery at 75% SOC.

<u>Charging Level</u>

Charging level is a measure of the power that is supplied to a battery during recharging and can be represented by a number of different measurements. The most common measurement is maximum current. Level 1 charging provides up to 15 amps of alternating current, Level 2 charging provides up to 40 amps of alternating current and DC Fast Charge will provide up to 125 amps of direct current.

<u>PEV Battery Size</u>

PEV traction battery size requirements increase as the physical size and weight of the PEV increases or if the desired range of travel increases. Larger batteries take longer to recharge, a fact that can be compensated for through the use of the faster charge rates supplied by Level 2 and DC Fast Charge.

PEV Onboard Charger

PEVs are equipped with onboard chargers that regulate the amount of power used during battery recharging at Levels 1 and 2. Standard equipment chargers are typically rated at 3.3 kW; faster 6.6 kW chargers are usually available from the PEV manufacturer, primarily as part of a package of optional equipment.

While all of these factors influence how long it will take to recharge the PEVs batteries, the driving habits of the PEV owner usually determine how frequently and for how long batteries need to be recharged.

3.7 PEV Battery Charging Networks

The vast majority of recharging takes place in the home garage but most PEV owners will eventually use EVSE installed at public charging facilities. Public facilities range from a Level 1 residential type electrical outlet at a local restaurant to a DC Fast Charge facility in a parking garage, they can be free to use or require payment. Deployed EVSE are primarily owned and operated by private network providers, but many local governmental entities have installed chargers at libraries and other public facilities. According to the U.S. Department of Energy's Alternative Fuels Data Center, there are currently over 8,600 PEV recharging stations with over 21,000 charging outlets in the United States.

Finding the location of public charging stations is almost totally dependent on having access to the Internet or a smartphone with a location finder application. Some new PEVs with onboard navigation can display the location of charging stations, but the most up-to-date information will be available on an Internet website or Internet-based smartphone application. Most Internet-based applications are continuously updated and usually provide in-depth information, including: charging station availability, whether there are fees to recharge, station ownership, detailed directions to the location, photos of the location and comments from recent users. Most charging network operators provide Internet based applications to provide information on locating their facilities. Apps for locating charging locations with your smartphone can be found at the appropriate online App Store.

3.8 PEV Battery Charging Expense

The cost to recharge a PEV can be considered from two perspectives. The first is the cost to purchase and install the charging equipment needed for charging the vehicle at home plus the associated cost of the electricity used by that equipment. The second cost can be the expense to recharge using publically available charging stations. The bottom line on the average expense to refuel your electric vehicle is the Miles per Gallon of Gasoline Equivalent (MPGe), which is approximately $1.00 per gallon at $0.12/kWh.

Residential Charging Expense

The PEV owner's equipment cost for EVSE can be very low if they choose to use the Level 1 charging cord that is usually supplied with the vehicle. However, if the owner requires a shorter recharging time, a Level 2 charging station will need to be installed. Level 2 EVSE can be purchased from a variety of retailers or online, the cost range is approximately $450 to $750. Level 2 EVSE should always be installed by a qualified professional electrician. The cost of this installation can be as little as $200, but cost can vary widely based on the physical installation location of the equipment and the customary labor charges in different parts of the country.

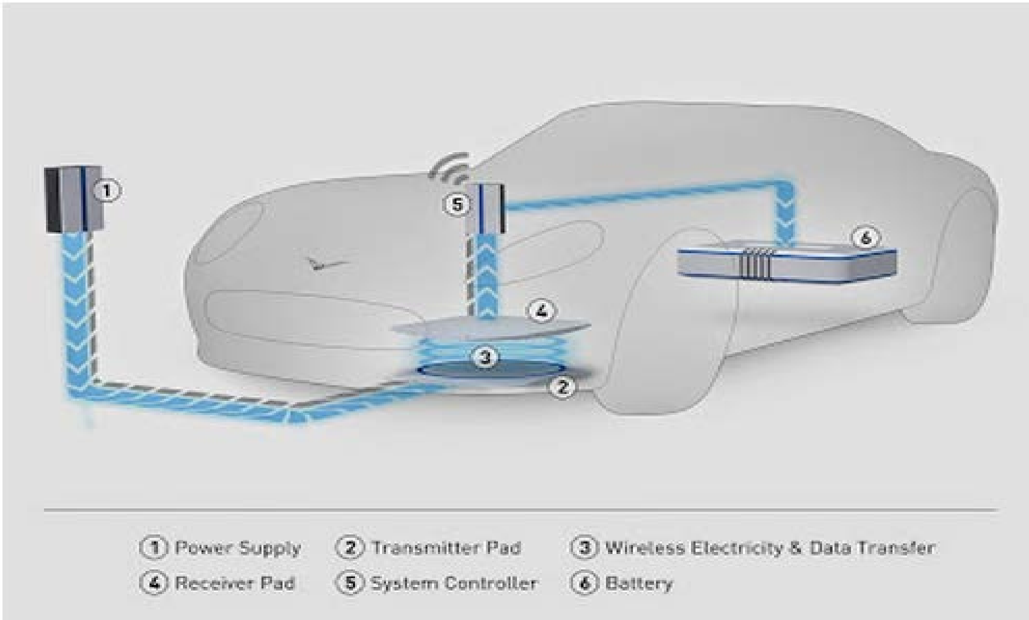
For residential charging, the most basic (and reasonably accurate) calculation is to determine the kilowatt hours/mile (kWh/mi.) used by your vehicle and multiply it by your kWh cost of electricity. For example, a vehicle that uses 0.2 kWh/mi., charged at a residential electrical rate of $0.10/kWh would cost $0.02/mi. (0.2 kWh/mi. x $0.10/kWh = $0.02). In this example, driving 100 miles would cost you about $2.00 to recharge at home.

Heavy residential charging expense can be reduced by enrolling in Time of Use (TOU) plans that are offered by power companies in California, Hawaii and other states. These plans take advantage of the lower "off-peak" demand cost of electricity that occurs late at night and early in the morning. Some PEVs can be plugged in at any time and programmed to automatically begin charging during the off-peak hours.

Public Charging Expense

The expense associated with recharging at a public charging station can be easy to determine, but it also can involve more variables. Generally speaking, calculating the cost to use publically available charging stations is as easy as using only free charging stations or totaling up the charges on your credit card bill. A significant number of public charging stations do not charge for the electrical power used to recharge. These facilities may be provided by a retail establishment or a government agency and the only cost to the PEV owner may be the cost of membership in the charging network program that manages the station for the EVSE owner. Other public stations are owned by charging networks that have various programs that may include some or a combination of the following fee structures: membership fees, rates for amount of time a charger is used or rates for the kilowatt hours used or monthly flat rates for unlimited charging. Charging fees can vary by location because some states allow a charging network to "sell" electricity at a kilowatt/hour rate; other states only allow the charging network to charge for the use of the equipment. Charging fees may also include fees charged by a garage or parking facility, local taxes, service fees, etc. Some PEV manufacturers provide charging stations and/or charging programs at no cost to the owners of their vehicles.

3.9 Wireless Charging



Source: Electric Vehicle News

Inductive and Resonant Technologies

Inductive charging, also known as Wireless Power Transfer (WPT), is an emerging technology that allows PEV recharging without the use of a cabled connection. The most common application uses a charging pad installed on or in the pavement and a receiving pad installed underneath the PEV. Electrical current is passed through the pavement pad, which creates an inductive electrical field that is captured by the PEV's receiving pad to charge the vehicle's batteries.

Induction chargers typically use an induction coil to create an alternating electromagnetic field from within a charging base station, and a second induction coil in the portable device (i.e., PEV) that takes power from the electromagnetic field and converts it back into electrical current to charge the battery. The two induction coils in proximity combine to form an electrical transformer. Greater distances between sender and receiver coils can be achieved when the inductive charging system uses resonant inductive coupling. Recent improvements to this resonant system include using a movable transmission coil, and the use of materials for the receiver coil made of silver plated copper or aluminum. [4]

Wireless Charging Research

A significant effort in research and development is underway by academic, governmental and private industry to help realize the promise of the untethered charging of PEV batteries.

.
The Massachusetts Institute of Technology (MIT) has demonstrated a patented WPT technology that applies magnetic resonance to an inductive electrical field. This technology provides impressive power transfer efficiencies over larger air gaps between the charging transmitter and the PEV's charging receiver. MIT's WPT has been licensed to several large automobile manufacturers. [5]

Utah State University is also involved in wireless charging research and has begun the construction of a new research facility that will include an oval track to test technology for recharging electric vehicles while moving. [6]   Also, the Electric Vehicle Transportation Center (EVTC) at the University of Central Florida is in the process of establishing an EV and Wireless Charging Laboratory.

<u>Wireless Standards</u>

The Society of Automotive Engineers and the International Electrotechnical Commission are currently in the very early stages of standards development for wireless technology and there is limited commercial availability. The standards reference for SAE is SAE J2954; the IEC reference is IEC 61851-1.

The successful development and deployment of wireless technology presents the promise of having the convenience of pulling into your garage or a parking spot and having your car recharge without the need to connect and disconnect a cable. Some researchers are also exploring the possibility of embedding wireless charging in the roadway as a method of continuously recharging the vehicle while in transit; a system that would allow this would dramatically reduce battery size and extend the travel range of PEVs.

3.10 EVSE Power Source

<u>Source Impact on PEV Emissions</u>

The source of power for EVSE has an impact on both ownership expense and the environmental benefits of PEVS. The strict financial expense to refuel an electric vehicle is directly related to the cost of electrical power supplied to the EVSE.

Battery powered automobiles are considered to be "Zero Emissions" vehicles, meaning that they do not produce the Green House Gases (GHG) that are harmful to the environment. However, their environmental benefit can be offset when the method of power generation that provides electricity for the EVSE is considered, especially if coal or petroleum based power generation is used. Hydro-electric, solar and wind energy sources maintain the environmental benefits.

<u>Solar Alternative</u>

Power supplied to EVSE by solar panels maybe a viable alternative and augment to grid supplied electricity. Installing solar can also extend the environmental benefits of owning a PEV by significantly reducing the CO_2 contribution associated with conventional electrical power generation. Factoring the fuel savings of owning a PEV into the solar installation can also help to significantly reduce the return on investment for the homeowner who wishes to install a solar system large enough to provide power to both the home and the EVSE.

Solar augmented PEV charging station at the University of Central Florida

3.11 Vehicle-To-Grid (V2G)

Vehicle to Grid (V2G) is a concept in which an EVSE and EV act together to become a distributed energy resource (DER). The emerging EVSE-EV DER is a new player in the larger DER world of solar PV systems, small wind turbines, stationary storage systems, gas micro-turbines, and other distributed generation since the EV supplies storage that can load level. A device called an inverter must be installed in either the EVSE or the EV to convert DC energy from the EV battery into AC that can be synchronized with the grid. In actual practice the charger and inverter functions would be integrated into a single bidirectional converter, but the device is commonly referred to as an inverter. An EVSE-EV DER can discharge energy from the EV battery into the grid in two ways. The inverter can be located in the EVSE, with only DC power flowing from the EV battery to the EVSE, which from a utility perspective is like a stationary storage DER with an interchangeable battery. Alternatively, the inverter could be located on-board the vehicle. [7]

Most vehicles are parked more than they are driven. Unlike conventionally fueled vehicles, and to their credit, PEVs offer the potential to help electric companies manage their grid resources. PEVs could potentially help keep grid voltages and frequencies stable and provide a source of "spinning reserve" to help meet sudden power demands. A PEV's batteries are also an ideally suited to store the excess energy produced by solar and wind power generation technologies.

V2G requires complex interactions between power companies, PEVs and the infrastructure that supports them. Significant technical challenges in communications and load management are being addressed and the technology exists to realize the potential of V2G applications. The most significant barrier to realizing the contributions of V2G applications are the absence of the infrastructure that would provide an incentive for the increased adoption of PEVs and some resistance of utility companies to use EVs since they do not own them.

The Electric Power Research Institute (EPRI) is working with automakers and utilities to develop and to demonstrate an open platform that would integrate PEVs with smart grid technologies. The open platform will simplify and streamline V2G (Vehicle-to-Grid) communications. The system will allow automobile manufacturers to offer a customer-friendly interface through which PEV drivers can more easily participate in utility PEV programs, such as rates for off-peak or nighttime charging. [8]

4.0 EVSE and Infrastructure Safety Codes and Standards

The primary safety codes and standards applicable to EVSE equipment installation in the U. S., are those established by the National Electrical Code (NEC) and by the Occupational Safety and Health Administration (OSHA) and their network of Nationally Recognized Testing Laboratories (NRTL).

4.1 ANSI

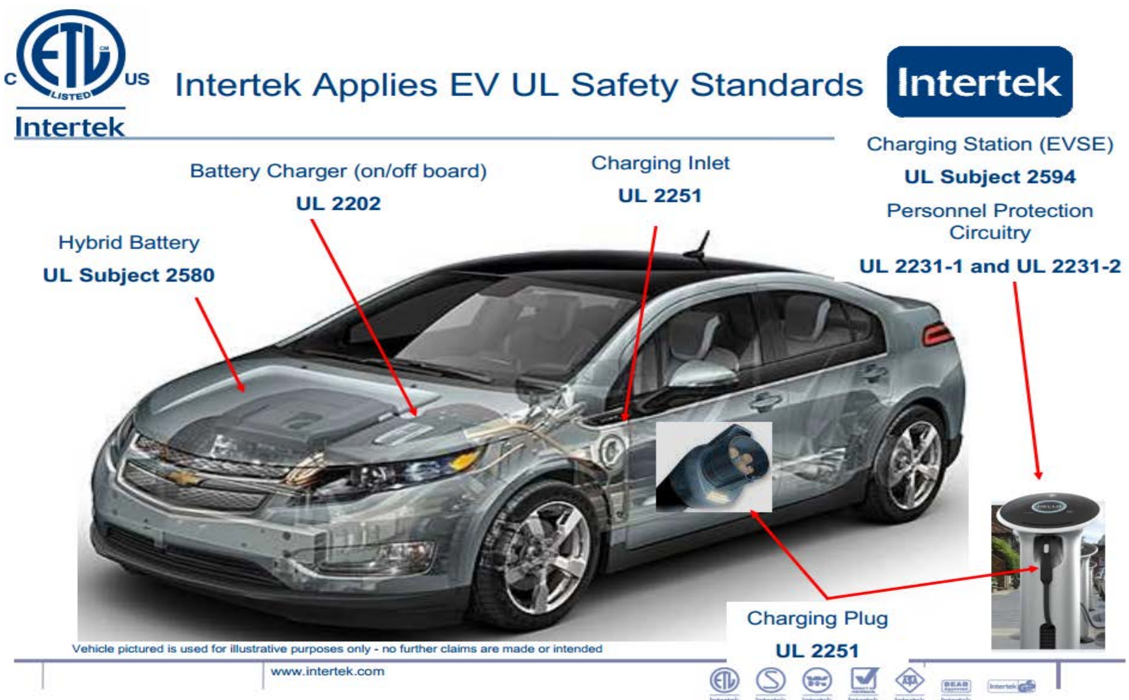
The American National Standards Institute (ANSI) coordinates the U.S. voluntary consensus standards system, providing a neutral forum for the development of policies on standards issues and serves as a watchdog for standards development and conformity assessment programs and processes. They accredit qualified organizations, whose standards development process meets all of their requirements to develop American National Standards. ANSI itself does not develop standards. ANSI also represents U.S. interests in regional and international standardization activities while overseeing conformity assessment activities that promote the global acceptance of U.S. products, services, systems and personnel. [9]

ANSI serves as a coordinator for the development of EVSE and PEV standards by the Society of Automotive Engineers (SAE), the National Highway Traffic Safety Administration (NHTSA) and many others. Their November 2014 Progress Report, “The Standardization Roadmap for Electric Vehicles” is an excellent source of information on standards development for electric vehicles and the associated infrastructure. [10]

4.2 The Occupational Health and Safety Administration (OSHA) and Nationally Recognized Testing Laboratories (NRTL)

OSHA requires NRTL approval for many different types of products; electric equipment is the largest of these product categories. NRTLs are safety consulting and certification companies that provide safety-related certification, validation, testing and inspection services to a wide range of clients including manufacturers, retailers, policymakers, regulators, service companies and consumers.

EVSE Listing Requirement—Compliance with NEC Article 625 includes the requirement that installed charging station equipment must be "Listed." Listed PEV charging systems have been investigated to a comprehensive set of construction and performance requirements designed to reduce the risk of fire, shock and personal injury. The equipment has also been specifically tested and certified for installation in accordance with all of the safety requirements of NEC Article 625. An example of these listings is Underwriters Laboratories' (UL) requirements for charging equipment. Level 1 and 2 chargers require UL category FFWA (EVSE). Equipment providing DCFC must meet the requirements of category FFTG (electric vehicle charging system equipment) (Regulatory Services Department of Underwriters Laboratories Inc. 2010).



Source: Intertek

4.3 Environmental

Recycling—The useful transportation life of PEV batteries is 8-10 years and significant numbers of EVs have only recently been placed into service. As a result, large-scale recycling of PEV lithium-ion batteries hasn't begun. Unlike conventional lead-acid batteries, lithium-ion batteries contain virtually no toxic components and are categorized as non-hazardous waste. The financial viability of recycling the batteries is unclear.

PEV battery recycling can possibly be postponed for years since they are particularly attractive for energy storage after the vehicle is retired or the original batteries are replaced. Several major power utilities are exploring the use of the batteries for storage of the power produced by wind turbines, solar or any distributed power generation stations. Power stored in these batteries would then be used during the off-peak production periods of these renewable power resources. Lithium-ion packs also are being tested as backup power storage systems for retail centers, restaurants and hospitals, as well as for residential solar systems.

4.4 Infrastructure

Infrastructure is defined as structures, machinery, and equipment necessary and integral to support a PEV, including battery charging stations, rapid charging stations, and battery exchange stations. A battery charging station is defined as an electrical component assembly or cluster of component assemblies designed specifically to charge batteries within a PEV. A rapid charging station is defined as an industrial grade electrical outlet that allows for faster recharging of PEV batteries through higher power levels. A battery exchange station is defined as a fully automated facility that will enable a PEV with a swappable battery to enter a drive lane and exchange the depleted battery with a fully charged battery through a fully automated process. Infrastructure must meet or exceed any applicable state building standards, codes, and regulations. [11]

Codes dictate requirements, standards dictate how to meet those requirements and each are codependent. For example, a building code that requires vehicle repair garages have sprinkler protection would need a coexisting standard to specify the requirements for sprinkler protection, and a standard for sprinkler protection would require a code to dictate where it applies. Codes and standards are legally enforceable when jurisdictions adopt them by reference or direct incorporation into their regulations. When jurisdictions adopt codes, they also adopt the standards that dictate how to meet those codes. Codes and standards often become industry norms when industries comply with them even though jurisdictions have not adopted them. [12]

PEVs replenish their battery power using EVSE served by an electric service infrastructure; the interface of both of these elements requires a more demanding adherence to codes and standards than those associated with conventionally fueled vehicles. As an example, although fueling island shutdowns are required, there is no requirement that a gas pump shut down if the supply hose becomes disengaged from the vehicle. PEV refueling requires not only that the fuel source (EVSE) shut down if the supply connector becomes disengaged, it also requires that the PEV drive systems be disabled during the refueling process.

<u>National Electrical Code</u>

The most widely adopted standard governing the installation of EV charging equipment is the National Electrical Code (NEC), specifically Article 625. NEC Article 625 concerns the wiring and equipment external to the PEV that connect the vehicle to a supply of electricity for battery charging. Article 625 details the requirements for the installation of Level 1, 2 and DC fast chargers at both indoor and outdoor sites. Article 625 applies to the installation of both “conductively” cable connected charging equipment and inductive or “wireless” charging equipment.

The NEC, or NFPA 70, is an internationally recognized and regionally adoptable standard for the safe installation of electrical wiring and equipment in the United States. The NEC, while having no legally binding regulation as written, is often adopted by states, municipalities and counties in an effort to standardize their enforcement of safe electrical practices within their respective jurisdiction.

Battery charging safety considerations are addressed by NEC Article 625 and its requirement that all charging equipment be UL listed. PEV battery charging systems are complex, high-voltage electrical systems that contain few if any user serviceable parts. It is important that PEV owners become very familiar with charging procedures specific to their vehicle and the charging systems they routinely use. EVSE users and owners should thoroughly review and adhere to the manufacturer's recommended guidelines. The manufacturer or a qualified professional electrician should always be consulted for answers about the installation or use of PEV charging equipment.

From an infrastructure perspective, the electrical demarcation point for this report is the premise or property threshold. Excluding utility load management, the utility infrastructure interface requirements of the PEV and EVSE look substantially like many other utility service connections. The utility side infrastructure safety requirements of this demarcation are not included in this study, they are a separate infrastructure domain addressed primarily by the National Electric Safety Code (NESC).

The National Electrical Safety Code (NESC) is sometimes confused with the National Electrical Code (NEC). To provide clarification, utility employees, who provide electrical services up to the premise edge, follow the National Electrical Safety Code (NESC). Electricians, working with premises' wiring and utilization equipment, use the National Electrical Code (NEC). There are situations when the installation of a charging station or other equipment may require both NEC and NESC considerations, particularly in an outdoor or public environment; these and other specialized installations should be addressed on an individual basis. This report is restricted to the environment governed by the NEC.

Signage Requirements

Signage for plug-in electric vehicle (PEV) charging stations is an important consideration at workplaces, public charging stations, parking garages, and multi-unit residential complexes that offer access to electric vehicle supply equipment (EVSE).

Appropriate charging station signage can:

- Help PEV drivers navigate to and identify charging stations
- Optimize use of EVSE by helping all drivers understand that parking spaces at charging stations are for PEVs only
- Provide information about regulations—such as access, time limits, and hours of use—and facilitate enforcement

- Facilitate deployment of plug-in vehicles by providing visibility for charging infrastructure to prospective PEV drivers.

Signage for charging stations falls into two categories: way-finding signage and station signage. Way-finding signage helps EV and PHEV drivers navigate to charging stations from other locations, such as a freeway exit. Station signage helps EV and PHEV drivers identify charging stations. It also helps charging station hosts communicate and enforce regulations related to the use of the EVSE and associated parking spaces.

The Federal Highway Administration (FHWA) defines the minimum standards for signage, which it publishes in the Manual on Uniform Traffic Control Devices (MUTCD). The standards in the MUTCD apply to all signage on public highways, streets, bikeways, and private roads open to the public, such as at shopping centers and airports. FHWA has approved the following interim designs for charging station signs:

D9-11bp

D9-11b

FHWA refers to the signs above as D9-11bp (written description) and D9-11b (symbol). For way-finding purposes, these designs can be combined with directional arrows and mileage.

To be enforceable, any signs posted in a public right of way must be supported by local ordinances that specify any time limits, penalties, and definitions. Any signs posted in the public right of way must meet MUTCD requirements. Private parking areas that are not open to the public (such as employee parking areas at workplaces) are not required to meet MUTCD signage requirements. But organizations that provide charging in private areas may find that consistency with the standards helps all drivers understand and recognize charging station signage.

Pavement markings, painted on the surface of a parking space, can be used to reinforce signage for charging stations. Notably, most jurisdictions deem pavement markings unenforceable on their own. For general information about pavement markings, see Chapter 3B of the MUTCD. [13]

Americans with Disabilities Act

Most public EVSE installations must include access for persons with disabilities and comply with the Americans with Disabilities Act (ADA). ADA requires nondiscriminatory access to places that accommodate the general public. Commercial facilities that do not directly serve the public – like office facilities and warehouses – also must meet ADA requirements for new construction and alterations. [14]

Federal statutes and National standards that guide accessibility requirements include:

- 2003 International Building Code
- 2009 ANSI A117.1
- U.S. Americans with Disabilities Act – 28 CFR Part 36 (ADA)

Key elements of providing access at charging stations for persons with disabilities include:

- Adequate space to move a wheelchair or other equipment in and out of the vehicle
- Placing operable parts of the charging equipment within unobstructed reach from a wheelchair
- Space for turning around a wheelchair near the charging equipment on the vehicle
- Charging stations on accessible paths and near the destination for which the parking was developed [15]

4.5 Vehicle Design

Several organizations work in close cooperation to develop safety and testing standards for PEVs and the systems found in those vehicles. The most prominent standards organizations in the U.S. and the interaction of their standards are illustrated below.

Source: Robert Galyen, SAE International

There is some overlap in standards, but all of the organizations involved work to "harmonize" their standards to avoid serious conflicts. A significant level of standardization of EVSE has been achieved, but there remains an open debate in the United States about the standardization of the DC Fast Charge (DCFC) device that is used to connect the charging station to the vehicle. Some PEV manufacturers prefer the CHAdeMO connector standard, and several other manufacturers have chosen the SAE J1772 Combo T2 standard. Several vehicles have the ability to accommodate both types of recharging connectors. CHAdeMO connectors have been the most widely-deployed fast charge connector; the newer 1772 Combo has the flexibility to be used for both Level 2 and DCFC. Both connectors meet all safety standards and are very similar in how they are used, individual vehicle manufacturer connector selection is based primarily on technical preferences. The most notable considerations are that the

CHAdeMO is significantly larger and is limited to 62.5 kW, while the smaller 1772 Combo is rated at 100kW.

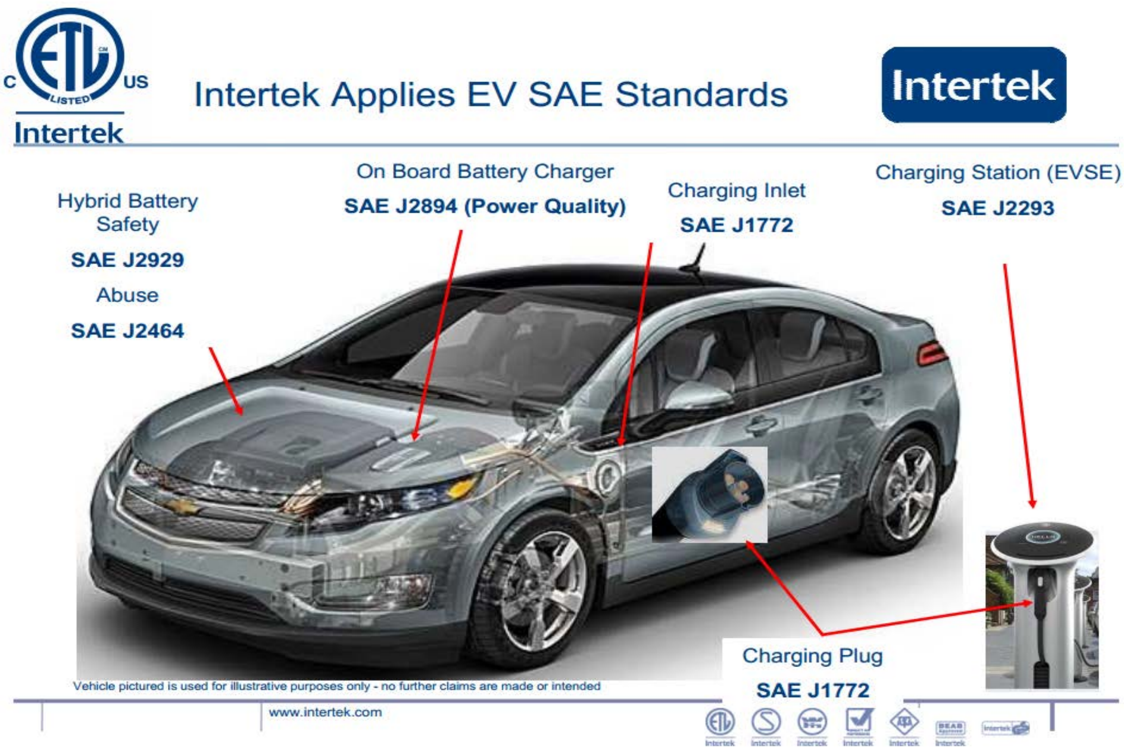
Source: WordPress

SAE—SAE International, initially established as the Society of Automotive Engineers, is a U.S.-based, professional association and standards development organization for engineering professionals in various industries. SAE's primary interest is on transport industries such as automotive, aerospace, and commercial vehicles. SAE International coordinates the development of technical standards based on best practices identified and described by SAE committees and task forces.

SAE is involved in the development of standards used in the U.S. auto industry, and by extension, those applied to the manufacture of PEVs and the supporting infrastructure. The extent of their standards development can be appreciated by reviewing the following list of PEV standards that are either completed or being developed. More information can be found on at their website: http://www.sae.org/automotive/

SAE—PEV/EVSE Related Standards [16]

Document Number	Title – Works in Progress
J1772 (v5)	SAE Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler
J2836/3	Use Cases for Communication between Plug-in Vehicles and the Utility Grid for Reverse Power Flow
J2836/4	Use Cases for Diagnostic Communication for Plug-in Vehicles
J2836/5	Use Cases for Communication between Plug-in Vehicles and their customers.
J2836/6	Use Cases for Wireless Charging Communication between Plug-in Electric Vehicles and the Utility Grid
J2847/1	Communication between Plug-in Vehicles and the Utility Grid
J2847/2	Communication Between Plug-in Vehicles and Off-Board DC Chargers
J2847/3	Communication between Plug-in Vehicles and the Utility Grid for Reverse Power Flow
J2847/4	Diagnostic Communication for Plug-in Vehicles
J2847/5	Communication between Plug-in Vehicles and their customers
J2847/6	Wireless Charging Communication between Plug-in Electric Vehicles and the Utility Grid
J2894/2	Power Quality Requirements for Plug In Vehicle Chargers - Part 2: Test Methods
J2931/1	Digital Communications for Plug-in Electric Vehicles
J2931/4	Broadband PLC Communication for Plug-in Electric Vehicles
J2931/5	Telematics Smart Grid Communications between Customers, Plug-In Electric Vehicles (PEV), Energy Service Providers (ESP) and Home Area Networks (HAN)
J2931/6	Digital Communication for Wireless Charging Plug-in Electric Vehicles
J2931/7	Security for Plug-in Electric Vehicle Communications
J2953	Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)
J2954	Wireless Charging of Electric and Plug-in Hybrid Vehicles
J2990	Hybrid and EV First and Second Responder Recommended Practice
J3009	Trapped Energy- Reporting and Extraction from Vehicle Electrical Energy Storage System



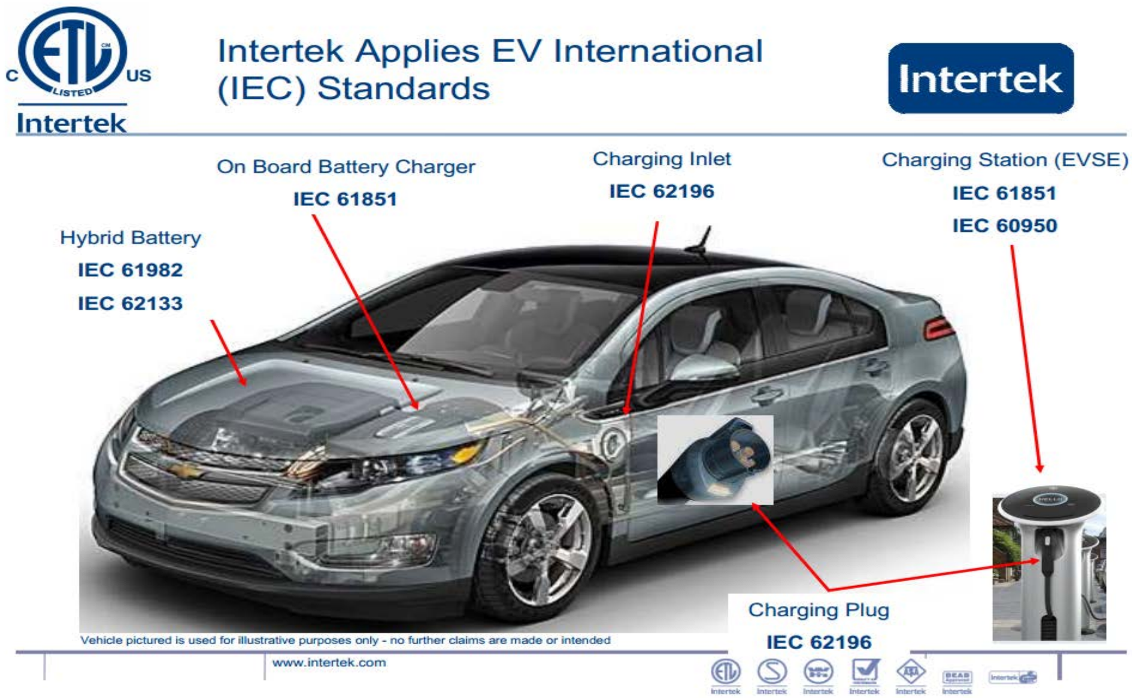
Source: Intertek

International Organization for Standardization—ISO is an independent, non-governmental membership organization and the world's largest developer of voluntary International Standards. Based in Geneva, Switzerland, its members are the national standards bodies for 163 member countries around the world. ISO has published more than 19,500 International Standards covering almost every industry, from technology, to food safety, to agriculture and healthcare.

ISO standards address considerations in the design of systems associated with PEVs, taking into account that the standards that will apply in more than 163 countries. ISO 6469 helps manufacturers design fail-safe electrically propelled vehicles and provides a framework for the information they need to make available to safety personnel and emergency responders dealing with accidents. [17]

International Electrotechnical Commission

IEC is a non-profit, non-governmental international standards organization that prepares and publishes International Standards for electrical, electronic and related technologies. IEC 62196 is an international standard for a set of electrical connectors and charging modes for electric vehicles which have been the basis for a number of standards associated with PEV charging. Safety features that immobilize the PEV during charging and that de-energize the charger in the event of an accidental disconnection are significant contributions of this standard. [18]



Source: Intertek

National Highway Traffic Safety Administration (NHTSA)

The NHTSA oversees the safety performance standards for motor vehicles and motor vehicle equipment commercially available in the United States. Electric drive vehicles must meet the same federal motor vehicle safety standards and undergo the same rigorous safety testing as conventional vehicles. These Federal safety standards are regulations written in terms of minimum safety performance requirements for motor vehicles or items of motor vehicle equipment. Requirements are specified in such a manner "that the public is protected against unreasonable risk of crashes occurring as a result of the design, construction, or performance of motor vehicles and is also protected against unreasonable risk of death or injury in the event crashes do occur". [19]

The National Highway Traffic Safety Administration has a legislative mandate under Title 49 of the United States Code, Chapter 301, Motor Vehicle Safety, to issue Federal Motor Vehicle Safety Standards (FMVSS) and Regulations to which manufacturers of motor vehicle and equipment items must conform and certify compliance. New standards and amendments to existing standards are published in the Federal Register.

PEV/Battery Survivability

PEVs in general, routinely receive the highest ratings crash safety ratings available from NHSTA and others. Safety standards and codes are in a perpetual state of review and refinement, however the most convincing testament to the safety of the PEV and its associated infrastructure has to be the continued and growing deployment of the vehicle. Investigations by the NHTSA into events involving the Chevy Volt and Tesla Model S found no latent safety defects, but improvements were designed into future models to reduce the likelihood of the problems reoccurring. The PEV population has been has been able to grow exponentially without a significant safety issue since first introduced.

PEVs traction battery systems are encased in sealed shells and meet NHTSA and other testing standards that subject the batteries to conditions such as overcharge, vibration, extreme temperatures, short circuit, humidity, fire, collision, and water immersion. Manufacturers design these vehicles with well insulated high-voltage lines and safety features that deactivate the electrical system when a collision or short circuit is detected. PEV traction battery systems routinely exceed 350 volts and their high-voltage electrical systems warrant specific considerations in situations that involve a crash, fire or flooding. While these considerations are unique to PEVs, experts agree that PEV batteries are safe and that PEVs are safer in rear-end collisions than gas propelled cars with a gas tank located at the back of the car.

PEV/Battery Accident Recovery

The high-voltage battery systems in PEVs sometimes present uncommon problems if a vehicle accident occurs. Special consideration must be given to disabling the battery system and the avoidance of fires and fumes resulting from rapid battery discharge. Several components within the system may remain energized after the traction battery has been disabled. The NHSTA recommends the following general safety considerations.

Considerations in the event of damage, fire, or flooding involving an electric vehicle (EV) or hybrid-electric vehicle (HEV):

- Always assume that the high voltage (HV) battery and associated components are energized and fully charged.
- Exposed electrical components, wires and HV batteries present potential HV shock hazard.
- Venting and/or the off-gassing of HV battery vapors are potentially toxic and flammable.
- Physical damage to the vehicle or the HV battery may result in an immediate or delayed fire, and/or the release of toxic and flammable gases.
- An HV battery in a flooded vehicle may have high voltage and short circuits that can cause shocks and fires.

Post-Incident considerations involving the damage, fire, or flooding of an electric vehicle (EV) or hybrid-electric vehicle (HEV):

- Always assume the HV battery and associated components are energized and fully charged.
- Ensure that the passenger and cargo compartments remain ventilated (i.e., open window, door, or trunk).
- Notify an authorized service center or vehicle manufacturer representative as soon as possible, there may be additional steps that should be taken to secure and discharge the HV battery.
- Do not store a severely damaged vehicle with a lithium-ion battery inside a structure, or within 50 feet of any structure, vehicle or combustibles.
- Call the fire department if leaking fluids, sparks, smoke or flames are observed, or if bubbling from the HV battery is heard.

Additional important guidance is available at:
http://www.evsafetytraining.org/~/media/Electric%20Vehicle/Files/PDFs/NHTSA%20Interim_Guidance_ELECTRIC%20and%20HYBRID%20VEHICLES.pdf

First Responders Training

First Responder training addressing the special considerations associated with PEV traffic accidents is offered by several organizations. First Responders should be trained in the technology and standards of PEV manufacturing and understand the vehicle's safety features. PEV high-voltage wiring and battery systems warrant special consideration when victim extraction is attempted. DOE's Clean Cities program offers training in co-operation with National Alternative Fuels Train Consortium, more information can be found at:
http://naftc.wvu.edu/course_workshop_information/first_responders/first-responder-safety-training-cclp

5.0 EVSE Infrastructure Development

The EV Project

The existing EVSE infrastructure owes much of its existence to funding provided by the Department of Energy's (DOE), EV Project. The EV Project, officially launched in October of 2009, was the largest electric vehicle infrastructure demonstration project in the world, equally funded by the United States Department of Energy through the American Recovery and Reinvestment Act and private sector partners. The EV Project deployed over 12,000 EVSE charging stations for residential and commercial use, as well as over 100 dual-port direct current fast chargers (DCFCs).

The EV Project ended in December of 2013. Usage data collected from approximately 8,300 Nissan LEAF™, Chevrolet Volts and other electric drive vehicles totaled almost 125 million miles and 4 million charging events. [20]

EV Project Overview Report

Project to date through December 2013

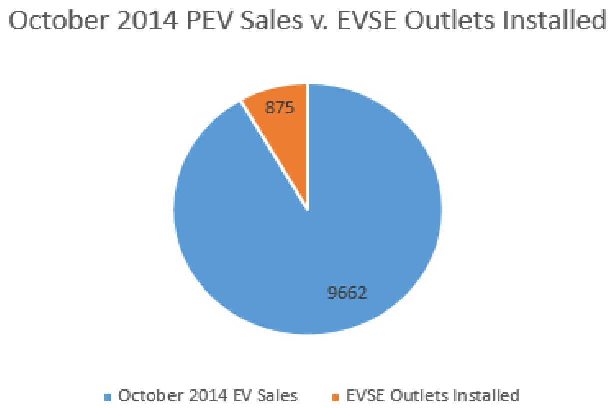
Charging Infrastructure Region[1]	Number of EV Project Charging Units Installed To Date	Number of Charging Events Performed	Electricity Consumed (AC MWh)
Phoenix, AZ Metropolitan Area	957	238,877	1,785.58
Tucson, AZ Metropolitan Area	196	53,782	367.16
Los Angeles, CA Metropolitan Area	1,176	379,399	3,085.61
San Diego, CA Metropolitan Area	1,485	633,063	5,607.06
San Francisco, CA Metropolitan Area	2,071	828,305	7,734.02
Washington, D.C. Metropolitan Area	378	159,135	1,066.16
Oregon	1,195	403,313	3,086.58
Chattanooga, TN Metropolitan Area	165	40,399	319.07
Knoxville, TN Metropolitan Area	409	75,116	611.03
Memphis, TN Metropolitan Area	135	38,926	278.63
Nashville, TN Metropolitan Area	1,064	342,136	2,832.25
Dallas/Ft. Worth, TX Metropolitan Area	585	130,458	845.75
Houston, TX Metropolitan Area	295	52,353	341.26
Washington State	1,517	617,990	4,836.34
Chicago, IL Metropolitan Area	184	64,507	426.70
Atlanta, GA Metropolitan Area	384	87,006	715.18
Philadelphia, PA Metropolitan Area	160	29,168	212.90
Total	12,356	4,173,933	34,151.28

Source: Idaho National Labs

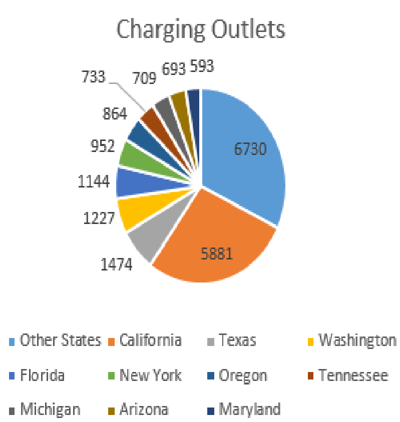
5.1 Current EVSE Deployment Metrics

There were over 8600 public EV charging stations in the U.S at the end of October 2014. A significant number of the existing stations were installed as part of the Department of Energy's EV Project, and the installation of new charging stations continues but at a much slower pace. [22] In October of 2014 a total of 9,662 PEVs were sold. [23] A review of locations identified by the DOE's Alternative Fuel Data Center (AFDC) revealed that approximately 145 new stations with 875 outlets were installed during the same period. Note that in 2011, DOE began counting public EVSE by the plug-in outlets rather than by the geographical location. Thus, a single EVSE location with two charging cables is now counted as two charging locations.

Conventional fueling locations are counted as one geographic location, not by the number of fueling hoses they have. Better equality of charging infrastructure to vehicle sales is needed to support future the accelerating deployment of PEVs.



California leads all other states in the total number of publically accessible charging stations by a significant margin. The top ten states for public EVSE deployment, as of November of 2014, are:



1.	California	5881
2.	Texas	1474
3.	Washington	1227
4.	Florida	1144
5.	New York	925
6.	Oregon	864
7.	Tennessee	733
8.	Michigan	709
9.	Arizona	693
10.	Maryland	593

The data also shows that Hawaii has 365 and Alabama has 46. [23]

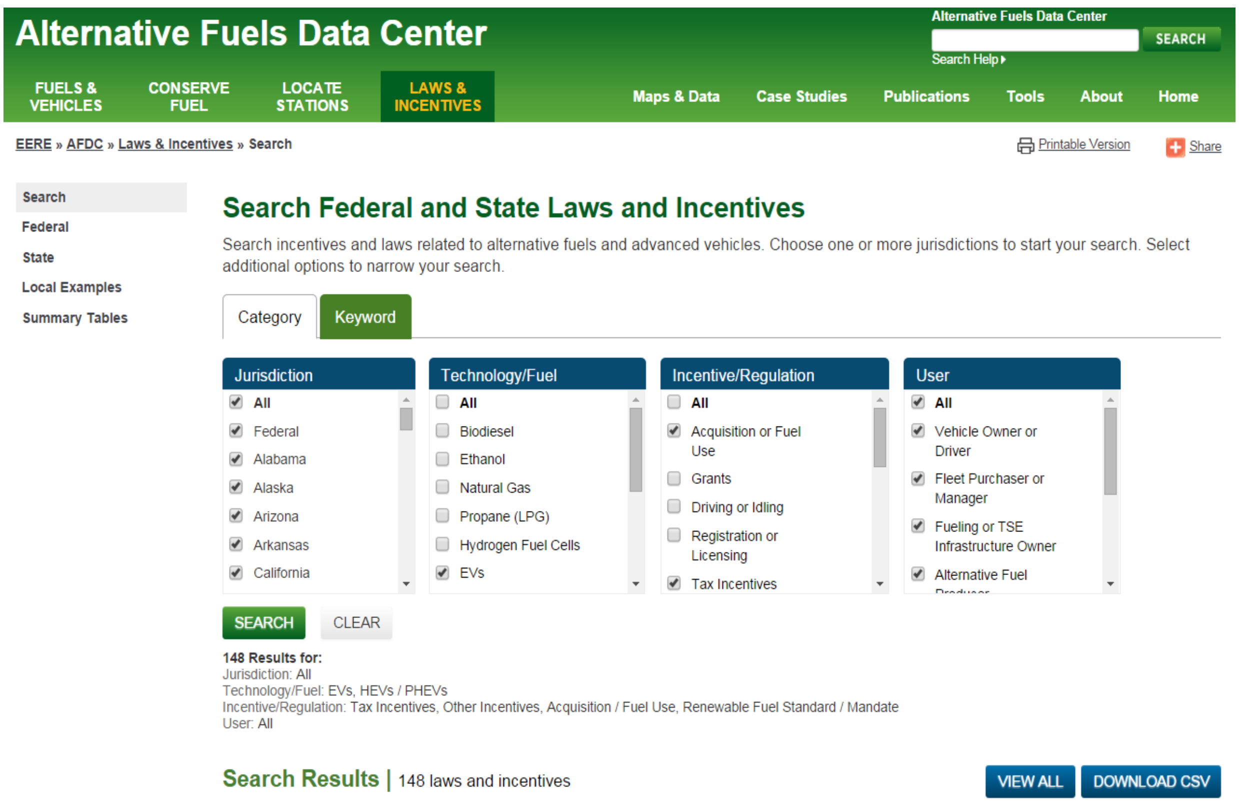
5.2 Governmental EVSE Deployment Programs and Resources

There are currently a variety of programs offered by various federal government entities, individual states and PEV manufacturers. Some states have passed legislation to either mandate or encourage the continued expansion of the EVSE infrastructure. For complete information on state incentives, go to http://www.afdc.energy.gov/data/10366. The most notable recent example is California's recent passage of legislation (Assembly Bill No. 2565) requiring rental property owner's to allow the installation of EVSE. [24]

There are no longer any federal programs that support the continued deployment of EVSE infrastructure to the degree that the EV Project did. Several federal financial incentives for EVSE were not renewed by Congress at the end of 2013. Homeowners were eligible to receive a tax credit of up to $1,000 for the purchase of a 240-volt Level 2 EV charging station, and multi-family residential developers and other businesses were eligible for a tax credit of up to 30 percent or $30,000 toward the purchase of EVSE. [25]

Department of Energy, Alternative Fuels Data Center

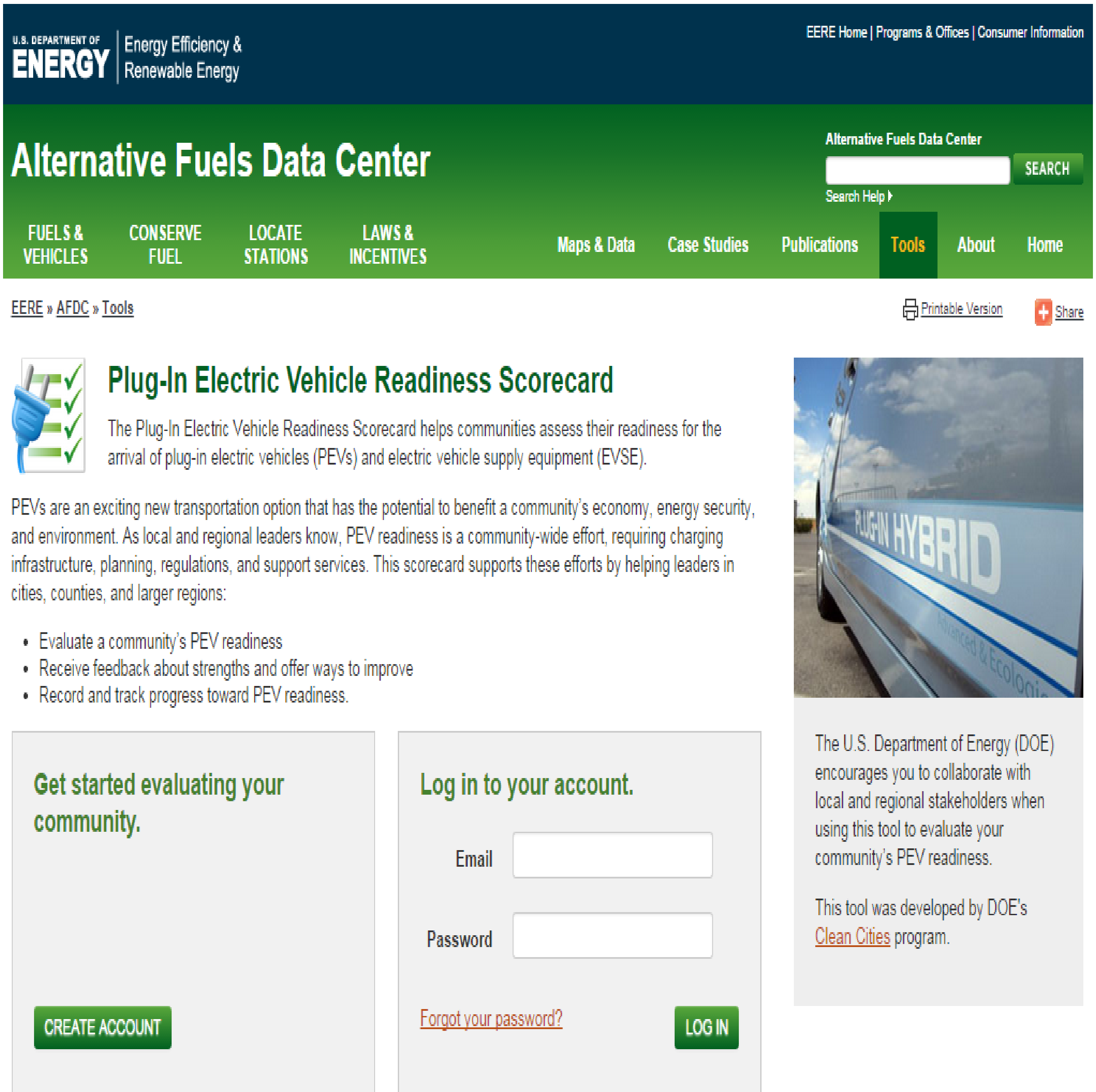
Federal and state incentives and requirements that impact the EVSE infrastructure and information on programs can be found on the U.S. Department of Energy's Alternative Fuels Data Center website under the "Laws and Incentives" tab.



Source: http://www.afdc.energy.gov/laws/search

Alternative Fuels Data Center, Plug-In Electric Vehicle Readiness Scorecard

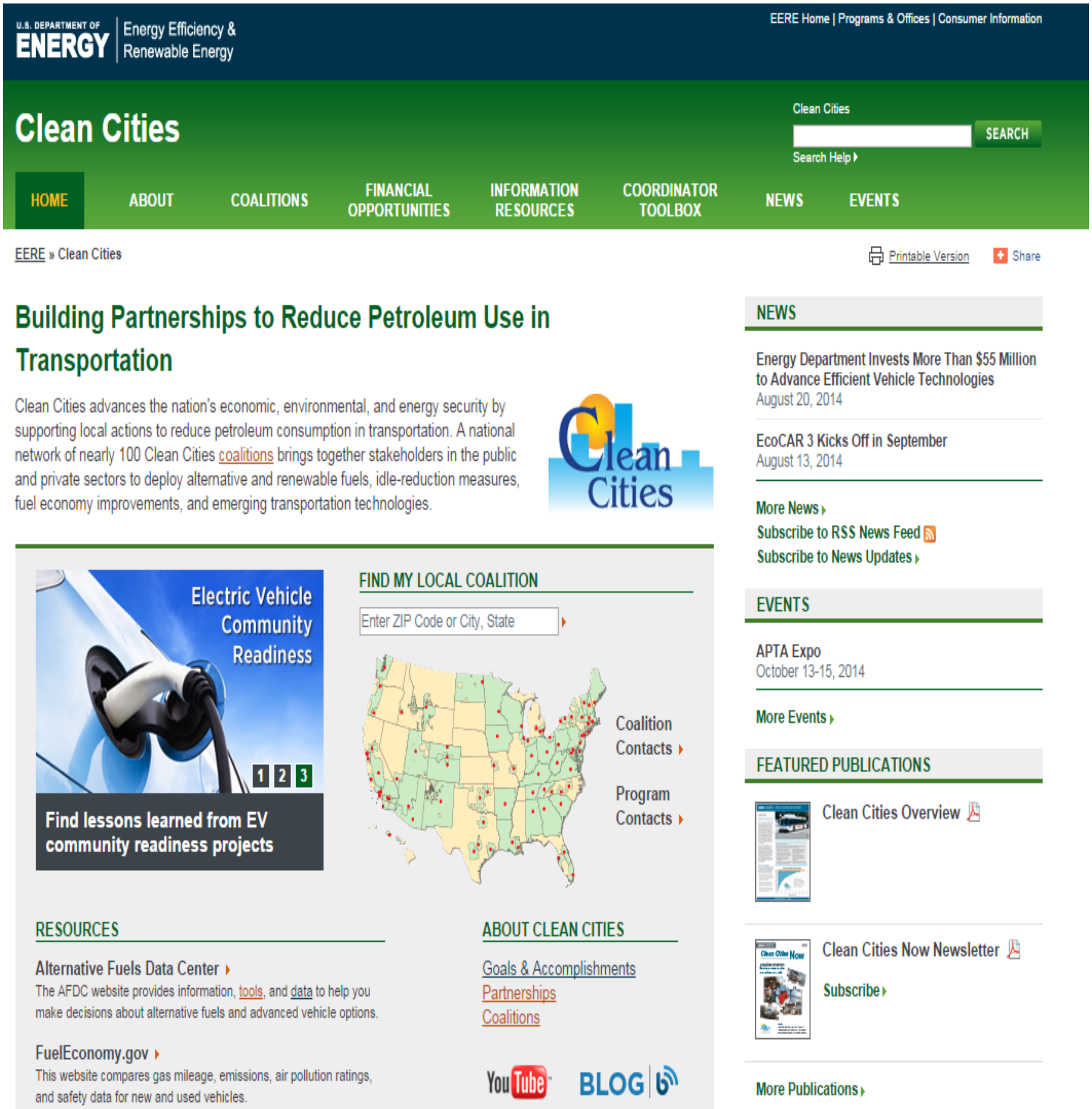
The Plug-In Electric Vehicle Readiness Scorecard is available on the DOE's Alternative Fuels Data Center website; the Scorecard helps communities assess their readiness for the arrival of plug-in electric vehicles (PEVs) and electric vehicle supply equipment (EVSE). The scorecard will help evaluate a community's PEV readiness by providing feedback about strengths and offering ways to improve readiness; it will also help record and track progress toward PEV readiness.



Source: https://www.afdc.energy.gov/pev-readiness

Department of Energy, Clean Cities

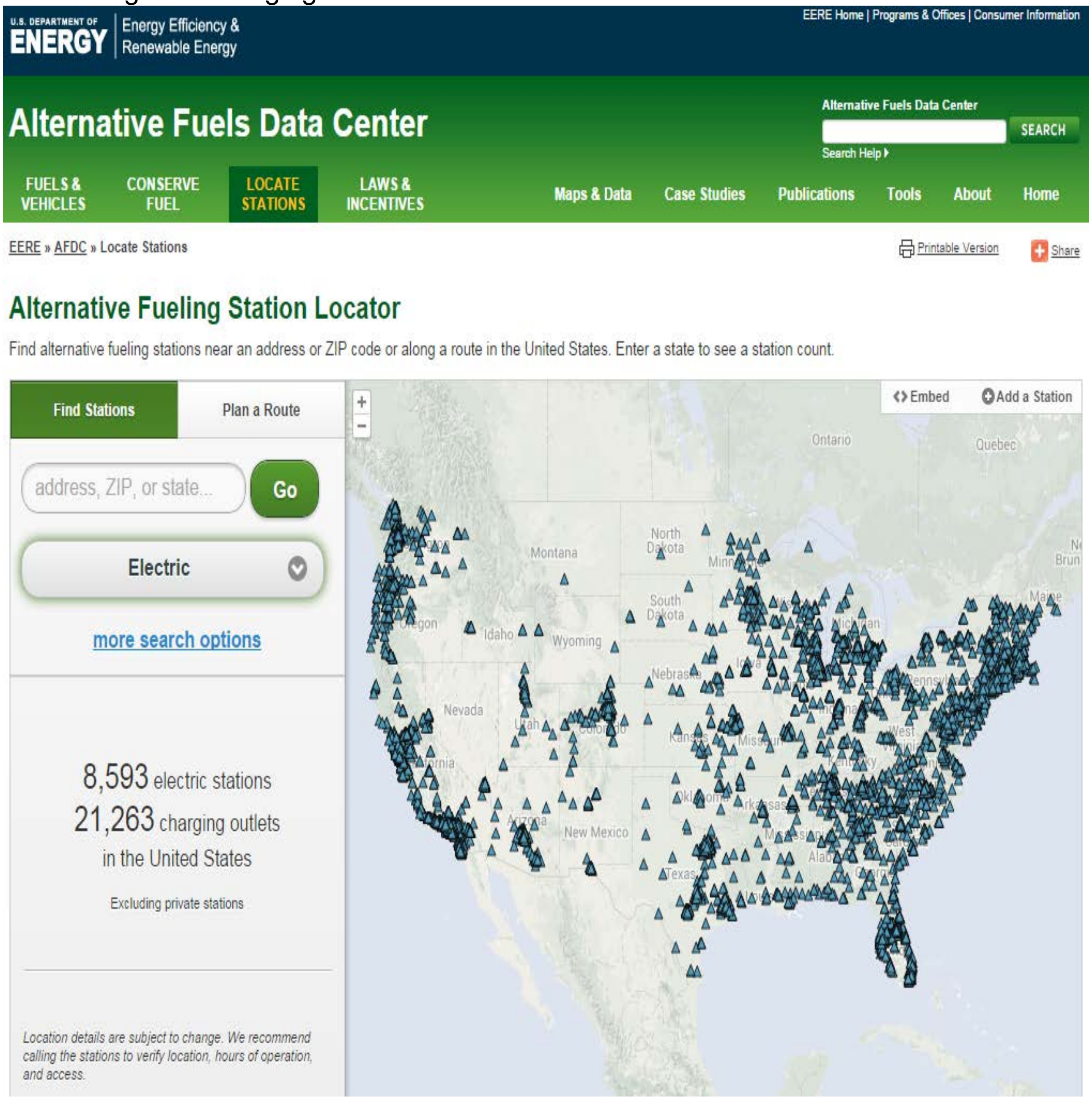
The U.S. Department of Energy's (DOE) Clean Cities program supports local actions to cut petroleum use in all modes of transportation. The program supports the adoption of PEVs and the expansion of the associated infrastructure. A national network of nearly 100 Clean Cities coalitions brings together stakeholders from the public and private sectors to deploy alternative and renewable fuels, implement idle-reduction measures, encourage fuel economy improvements, and promote emerging transportation technologies.



Source: http://www1.eere.energy.gov/cleancities/

Department of Energy, Clean Cities—Charging Station Locator

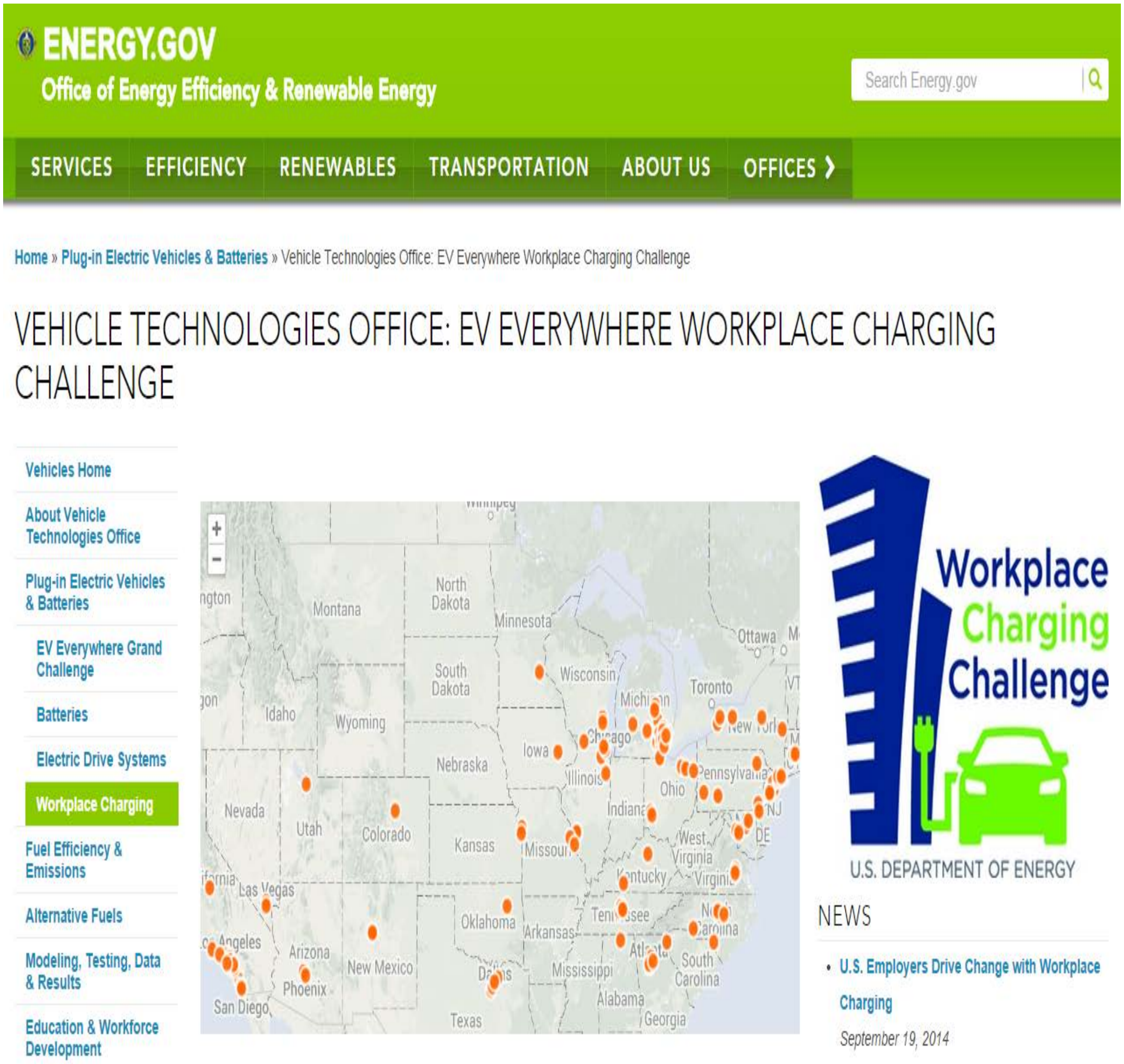
Clean Cities also maintains and updates the DOE's Alternative Fuels Data Center site for locating PEV charging stations.



Source:
http://www.afdc.energy.gov/locator/stations/results?utf8=%E2%9C%93&location=&filtered=true&fuel=ELEC&owner=all&payment=all&ev_level1=true&ev_level2=true&ev_dc_fast=true&radius_miles=5

Department of Energy, “Workplace Charging Challenge”

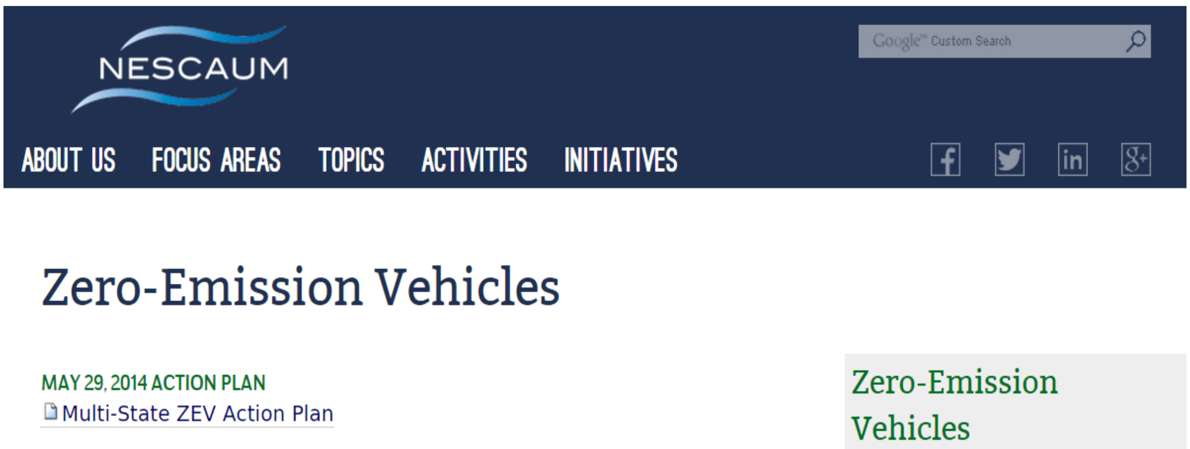
The DOE’s “Workplace Charging Challenge” offers employers guidance on providing PEV charging at the workplace. To support the deployment of this infrastructure, DOE has launched the Workplace Charging Challenge, with the goal of achieving a tenfold increase in the number of U.S. employers offering workplace charging.



Source: http://energy.gov/eere/vehicles/vehicle-technologies-office-ev-everywhere-workplace-charging-challenge

Zero Emissions Vehicles Action Plan

In October of 2013, the governors of eight states signed a memorandum of understanding supporting a multi-state cooperative effort to enhance the deployment of Zero Emissions Vehicles (ZEVs) and the infrastructure to support them. The partner states are California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island and Vermont. Together they comprise about a quarter of the nation's new car sales. Details on the ZEV action plan, including Action #6, "Promote ZEV infrastructure planning and investment by public and private entities" can be found at: http://www.nescaum.org/topics/zero-emission-vehicles



5.3 Commercial and Public EVSE Deployment

PEV Charging Networks

The vast majority of recharging takes place in the home garage but most PEV owners will eventually use EVSE installed at public charging facilities. Public facilities range from a Level 1 residential type electrical outlet at a local restaurant to a DC Fast Charge facility in a parking garage, they can be free to use or require payment. Deployed EVSE are primarily owned and operated by private network providers, but many local governmental entities have installed chargers at libraries and other public facilities.

According to the U.S. Department of Energy's Alternative Fuels Data Center, there are currently over 8,600 PEV recharging stations with over 21,000 charging outlets in the United States. Finding the location of public charging stations is almost totally dependent on having access to the Internet or a smartphone with a location finder application. Some new PEVs with onboard navigation can display the location of charging stations, but the most up-to-date information will be available on an Internet website or Internet-based smartphone application. Most Internet-based applications are continuously updated and usually provide in-depth information, including: charging station availability, whether there are fees to recharge, station ownership, detailed directions to the location, photos of the location and comments from recent users. Most charging network operators provide Internet based applications to provide information on locating their facilities. Apps for locating charging locations with your smartphone can be found at the appropriate online App Store.

While there are standards for the manufacturing, installation and operation of charging stations, there is limited standardization of the charging networks used by the public. Charging stations can be installed and owned by local governments, electric utilities, retail merchants or private nationwide companies that manage their own charging networks and also provide management services for charging stations installed by others. The proprietary nature of recharging networks can be challenging, as each have different conditions for use. Fees can vary from charging station to charging station, and network membership is usually required to charge your car. Efforts are underway to standardize several elements of charging networks and the Open Charge Alliance has proposed communications protocols to standardize back-office, billing and other network-to-network communications between charging providers. The Open Charge Point Protocol (OCPP) uniform communications between charging stations and management systems. [26]

An excellent introductory review of the major PEV charging networks has been published by PluginCars.com, it can be found at: http://www.plugincars.com/ultimate-guide-electric-car-charging-networks-126530.html

EV Manufacturer's EVSE Initiatives

Several automobile dealers are actively engage in the deployment of EVSE or have programs that support deployment.

Tesla Motors probably has the most visible EVSE deployment with over 122 stations installed along well traveled highways. Tesla's network of Superchargers allow Model S owners to charge for free between cities in North America. Superchargers provide a full charge in as little as 20 minutes and are strategically placed to allow owners to drive from station to station with minimal stops. Tesla's charging network is reserved for the exclusive use of Tesla owners, and is projected to be available in 98% of the US population areas by the end of 2015.

BMW recently announced their program to deploy 50 DC Fast Chargers at NRG eVgo Freedom Stations throughout California by the end of 2014 and 100 by the end of 2015. BMW's program will provide buyers of the 2014 BMW i3 EV with free DC fast charging at NRG eVgo network charging equipped with BMW's new i DC Combo Fast Charger through the end of 2015. The BMW ChargeNow DC Fast program allows i3 drivers unlimited access to participating stations, the chargers are capable of restoring the battery to 80 percent capacity in about 30 minutes.

Nissan is developing EVSE infrastructure by partnering with local governments and third party organizations and corporations and installing charging stations at Nissan dealer outlets throughout the country. Nissan provides a program that allows new purchasers of its Leaf EV to charge for free for up to two years. Nissan's program is available in 25 markets that represent 80% of the EV sales. The program provides access to four different nationwide charging networks. [27]

6.0 Barriers to EVSE Infrastructure Expansion

PEV sales in the United States continue to grow very rapidly, with a 28% growth in 2014 from 2013. One of the most commonly cited barriers to the continued adoption of PEVs is limited access to the recharging facilities, and while direct equality of infrastructure growth to PEV sales is not required, the continued accelerated deployment of PEVs must have the support of accessible and reliable recharging facilities.

Public and Governmental Awareness

Although there are many significant barriers to the expansion of the EVSE infrastructure, the primary barrier is inadequate communication of the needs and requirements of establishing an easily accessible PEV recharging network. A January 2014 report by the Department of Energy's Clean Cities program identifies 16 barriers to charging station installation, 50% of the barriers are categorized under "Information and coordination". [28] Among the barriers cited are uncertainty among public planners and private investors about the intensity and demand for public charging stations, and best practices for planning parking sites with public charging stations. The report also points out that lack of communication and coordination between stakeholders hinders the installation of EVSE infrastructure.

The Clean Cities report also highlights some of the financial and policy barriers that impede the installation of charging stations, including the, "Difficulty establishing a profitable business case for charging stations" and the, "Expensive, complex, protracted, and/or non-uniform permitting and inspection procedures for residential and workplace charging station installation."

Financial Incentives

EVSE technology is relatively new and much work is being done to bring standardization to all of the infrastructure elements. The deployment of a readily available charging infrastructure will be delayed until substantial work is completed on standards such as PEV/EVSE/ grid communications and management.

The lack of financial incentives to support the deployment of a readily accessible charging infrastructure to support environmental and national energy independence are a substantial barrier. The development of infrastructure standards will not be very useful if there is no money to build charging stations.

Standards

PEV owners do not enjoy the benefits of the standardized refueling facilities familiar to the owners of conventionally-powered vehicles. Existing PEVs and recharging facilities are safe and effective, to get to the required level of EVSE availability and convenience requires a significant increase in commitment, effort and standardization. The development of standards to support the expansion of EVSE infrastructure has been slow and frequently interrupted. Combining the lack of physical layer standardization and reliability with the proprietary nature of existing PEV recharging networks can make it a real challenge for the average motorist to consider switching to an electric vehicle.

Cumulatively, all of the barriers point to a lack of any coherent strategy for expanding EVSE infrastructure; economics, forecasting, planning and a concern for stated national strategic goals need to be considered jointly.

7.0 Recommendations for Accelerated EVSE Infrastructure Expansion

The following recommendations are made in an effort to focus attention on some of the key elements needed to stabilize and accelerate the establishment of a nationwide PEV re-charging infrastructure.

1. Policy and decision-maker involvement and support for the expansion of EVSE infrastructure, including:

   a) Overall EVSE network expansion strategy
   b) Governmental incentives tied to the deployment and ROI of the EVSE infrastructure to support a deployment business model
   c) The development of the PEV recharging infrastructure for the urban and multi-family environments needs specific attention
   d) Requirements establishing an EVSE network within the federal highway system
   e) Adoption of infrastructure reliability and performance standards similar to those required of conventional refueling stations
   f) State and local strategies for the deployment of EVSE in primary travel corridors, airports and significant public gathering places
   g) Research and development of wirelessly charging EVs
   h) Intensified research and development of Vehicle-To-Grid (V2G) applications
   i) Public awareness campaigns for PEV and EVSE
   j) Standardized methodology for establishing off-peak electrical power rate schedules for PEV owners
   k) Standardized billing methodology allowing all public EVSE operators in all states to charge by kilowatt hours
   l) Incentives recognizing PEV environmental contributions that allow power companies to establish a tariff level for publically available EVSE
   m) Incentives for the installation of photovoltaic supplied energy for public EVSE
   n) Restoration of tax credits for the installation of public and private EVSE

2. Industry support groups and stakeholders:

    a) EVSE network expansion strategy
    b) Public awareness campaigns for PEV and EVSE
    c) Strategies for the deployment of EVSE in primary travel corridors, airports and significant public gathering places
    d) Non-Internet based recharge station location capabilities for PEV owners who lack Internet access or Smartphones
    e) Models for the strategic deployment of EVSE and ROI
    f) Improved coordination among stakeholder groups in promoting the expansion of EVSE infrastructure

3. EVSE/Network/Auto Industry Standards — Uninterrupted commitment to the development and adoption of standards for:

    a) Payment processes and back-office communications and interfaces
    b) Public EVSE network-to-network communications
    c) EVSE V2G communications
    d) Performance measurements of station reliability and availability

8.0 Conclusions

PEVs are a fundamental element in recognized plans to increase the United States' energy independence and improve the environment. The continued slow response to the establishment of a reliable, widely available PEV recharging network will negatively impact those plans.

PEV owners do not enjoy the benefits of the standardized refueling facilities familiar to the owners of conventionally-powered vehicles, and there is limited consensus on how to standardize and expand the EVSE infrastructure. Existing PEVs and recharging facilities are safe and effective to get to the next level of EVSE availability and convenience requires a significant increase in commitment, effort and standardization. The physical infrastructure required to provide ubiquitous recharging of PEVs is slowly being built and much of the technology and standards are new and unique. Like any new technology, the establishment of this infrastructure contains a significant element of the "learn as you build" experience and many regulatory guidelines and standards are being refined and developed as the population of PEVs grows and the infrastructure expands. Unfortunately there is no coherent strategy by either industry or government on how to expand and support an EVSE infrastructure and problems continue to plague the necessary expansion.

Refueling stations for conventionally fueled vehicles are privately operated, competitive, revenue generating facilities. The PEV population is growing rapidly; however, the current population of PEVs makes it extremely difficult to develop a rational business model that can justify the expense to install, operate and maintain a recharging station, much less a large network. Ironically, several areas in California with high PEV populations have overwhelmed the existing recharging infrastructure with the rapid growth of their PEV population.

The development of standards to support the expansion of EVSE infrastructure has been slow and frequently interrupted. There are several different power levels for recharging batteries, different equipment connectors for different recharging levels (in one case, different connectors for the same charging level), and a variety of onboard chargers for PEVs. Some charging networks are also plagued by equipment that fails to operate reliably and have unacceptably long periods of downtime. These are not "bells and whistles" options for the purchaser of a PEV, they have very real, permanent consequences that affect the day-to-day use and lifestyle of the PEV owner. Combining the lack of physical layer standardization and reliability with the proprietary nature of existing PEV recharging networks can make it a real challenge for the average motorist to consider switching to an electric vehicle.

Restricting the ability to locate recharging stations to those able to acquire and master the fundamentals of Internet access, and requiring the ownership of electronic devices to do so, significantly reduces the potential market for PEVs.

There is currently a serious lack of governmental and industry involvement for EVSE infrastructure expansion. To their credit, several PEV manufacturers are taking steps to provide recharging solutions for their customers and a few states have enacted legislative measures that will help support the growth of the recharging infrastructure. Unfortunately, these positive steps are significantly less than what is required to ensure an adequate PEV recharging infrastructure.

The available model selection of PEVs has expanded quickly and the commitment of major car manufactures continues to intensify. The continued growth of PEV sales cannot be sustained without an adequate recharging infrastructure, and the lack of one may prove to be an extremely difficult negative perception to overcome. A comprehensive strategy that combines public and policy awareness with financial reality is needed to support the continued, accelerated adoption of PEVs and the infrastructure needed to support them.

This report is not meant to be an exhaustive investigation into the standards, products and operations that apply in the EVSE environment; there are a multitude of standards and considerations that influence the operation and design of EVSE and the infrastructure that supports it. Much of the subject matter in this report is evolving and inherently detailed and complex; the agencies and organizations responsible for standards, regulations and manufacture should always be consulted for the latest authoritative answers to specific questions.

9.0 References

1. United States Census Bureau FAQ
   https://ask.census.gov/faq.php?id=5000&faqId=5971
2. Clean Cities Publications, Plug-In Electric Vehicle Handbook, August 2013
   http://www.afdc.energy.gov/uploads/publication/pev_workplace_charging_hosts.pdf
3. SAE International, Communication Between Plug-in Vehicles and Off-Board DC Chargers
   http://standards.sae.org/wip/j2847/2/
4. Wikipedia, Inductive Charging
   http://en.wikipedia.org/wiki/Inductive_charging
5. WiTricity Automotive
   http://witricity.com/applications/ automotive/
6. USTAR Advance Transportation Institute
   http://www.innovationutah.com/innovation-research/research-teams/advanced-transportation/
7. ANSI, Progress Report, Standardization Roadmap For Electric Vehicles, Version 2.0
   http://publicaa.ansi.org/sites/apdl/evsp/ANSI_EVSP_Progress_Report_Nov_2014.pdf
8. Electric Power Research Institute Press Release, July 29, 2014
   http://www.epri.com/Press-Releases/Pages/EPRI,-Utilities,-Auto-Manufacturers-to-Create-an-Open-Grid-Integration-Platform.aspx
9. American National Standards Institute, FAQ
   http://www.ansi.org/about_ansi/faqs/faqs.aspx?menuid=1
10. ANSI, Progress Report, Standardization Roadmap For Electric Vehicles, Version 2.0
    http://publicaa.ansi.org/sites/apdl/evsp/ANSI_EVSP_Progress_Report_Nov_2014.pdf
11. Alternative Fuels Data Center, Laws and Incentives, Electric Vehicle Infrastructure Definitions
    http://www.afdc.energy.gov/laws/6534
12. Alternative Fuels Data Center, Codes and Standards Basics
    http://www.afdc.energy.gov/codes_standards_basics.html
13. Alternative Fuels Data Center, Signage For Plug-In Electric Vehicle Charging Stations
    http://www.afdc.energy.gov/fuels/electricity_charging_station_signage.html
14. ADA.gov, Information and Technical Assistance On The Americans With Disabilities Act, Standards For Accessible Design
    http://www.ada.gov/2010ADAstandards_index.htm
15. Virginia Clean Cities, Electric Vehicle Charging For Persons With Disabilities Version 1.0, David Mayfield, February 2012
    http://www.vacleancities.org/wp-content/uploads/EV-Charging-ADA-Version-1.0s.pdf
16. Argonne National Laboratory, Codes And Standards Support For Vehicle Electrification, Theodore Bohn, May 2013
    http://energy.gov/sites/prod/files/2014/03/f13/vss053_bohn_2013_o.pdf

17. International Organization For Standards
http://www.iso.org/iso/home/about.htm
18. International Electrotechnical Commission
http://www.iec.ch/
19. National Highway Traffic Safety Administration, Federal Motor Vehicle Standards And Regulations
http://www.nhtsa.gov/cars/rules/import/FMVSS/
20. Idaho National Labs, Observations From The EV Project In Q4 2013, February, 2014
http://avt.inel.gov/pdf/EVProj/EVProjectSummaryReportQ42013FINAL.pdf
21. Alternative Fuels Data Center, Alternative Fueling Station Locator, Electric
http://www.afdc.energy.gov/locator/stations/results?utf8=%E2%9C%93&location=&filtered=true&fuel=ELEC&owner=all&payment=all&ev_levels%5B%5D=1&ev_levels%5B%5D=2&ev_levels%5B%5D=dc_fast&radius_miles=5
22. Inside EVs, Monthly Plug-In Sales Scorecard
http://insideevs.com/monthly-plug-in-sales-scorecard/
23. Alternative Fuels Data Center, Electric Charging Station Locations By State
http://www.afdc.energy.gov/data/10366
24. California Legislative Information, Assembly Bill 2565
http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB2565
25. Cornell University Law School, Legal Information Institute, U.S. Code Title 26, Alternative Fuel Vehicle Refueling Property Credit
http://www.law.cornell.edu/uscode/text/26/30C
26. Open Charge Alliance
http://www.openchargealliance.org/
27. NissanNews.com, April 16, 2014
http://nissannews.com/en-US/nissan/usa/releases/nissan-launches-programs-to-make-leaf-charging-free-and-ez
28. A Guide to the Lessons Learned From the Clean Cities Community Electric Vehicle Readiness Projects
http://www.afdc.energy.gov/uploads/publication/guide_ev_projects.pdf