September 21, 2017; 1145 EDT

# INFRASTRUCTURE SYSTEM OVERVIEW: ELECTRIC VEHICLE CHARGING STATIONS

Prepared By: Strategic Infrastructure Analysis Division

## OVERVIEW

**Electric vehicle (EV) usage continues to increase in the United States, along with its supporting infrastructure. As EVs increase in market share, issues like charging speed and battery capacity will drive future development of EV charging technology. As EV demand increases, manufacturers will continue to develop, build, and deploy additional Internet-connected charging stations and new connected technologies to satisfy demand. These Internet connected technologies include enhanced EV supply equipment (EVSE)-to-EV digital communications (advanced control of the charging process), as well as increasingly networked automobiles and charging systems (expanded communications and control for EVs). This research provides a baseline understanding of EV charging technology, as well as what new technology is on the horizon. Analysts should consider the cyber and physical aspects of this technology as it becomes more prevalent.**

SCOPE NOTE: This product provides an overview of EV charging stations and associated equipment, which are important components supporting EVs. It summarizes EV historical background, current standards and regulatory environment, current charging methods, technology and equipment, and future and emerging EV technology. This product does not describe threats, vulnerabilities, or consequences of any aspect of the infrastructure system. This product provides analysts, policy makers, and homeland security professionals a baseline understanding of how EV charging systems work.

The U.S. Department of Homeland Security (DHS)/Office of Cyber and Infrastructure Analysis (OCIA) coordinated this product with the DHS/National Protection and Programs Directorate (NPPD)/Office of Infrastructure Protection/Sector Outreach and Programs Division, DHS/NPPD/Office of Cybersecurity & Communications/Industrial Control Systems Cyber Emergency Response Team, DHS/Transportation Security Administration, and U.S. Department of Transportation/Volpe.

## INTRODUCTION

As of June 2017, fewer than 600,000 EVs[1] exist within an estimated 250 million cars in the United States.[2,3] This number is anticipated to increase to more than 4 million by 2024.[4,5] Improvements in battery technology, availability, and cost have allowed vehicle manufacturers to provide more options for EVs—pure electric models

[1] For this assessment, EVs include plug-in electric vehicles, and plug-in hybrids.
[2] Bhuiyan, J. (2016). "There have now been over 540,000 electric vehicles sold in the U.S." recode. https://www.recode.net/2016/12/21/14041112/electric-vehicles-report-2016. Accessed June 2, 2017.
[3] Hirsh, J. (2014). "253 Million Cars and Trucks on U.S. Roads; average age is 11.4 years." *Los Angeles Times*. http://www.latimes.com/business/autos/la-fi-hy-ihs-automotive-average-age-car-20140609-story.html. Accessed December 30, 2016.
[4] Cobb, J. (2016). "Global Plug-in Car Sales Cruise Past 1.5 Million." Hybrid Cars. http://www.hybridcars.com/global-plug-in-car-sales-cruise-past-1-5-million/. Accessed August 20, 2016.
[5] Murphy, D. (2016). "Report: Daimler Targets Tesla with 6–9 New Electric Vehicles by 2024." *PCMag*. http://www.pcmag.com/news/347601/report-daimler-targets-tesla-with-6-1509-new-electric-veh. Accessed February 8, 2017.

that have a range of more than 200 miles and plug-in hybrid models that have a much longer range on battery power only. With a projected increase in demand and performance, auto manufacturers have announced plans to expand the availability of EVs before 2024, offering unique solutions for hardware, software, and firmware for EV charging.[6,7,8]

EV infrastructure generally includes EV charging stations or EV supply equipment (EVSE). EVSE "includes the electrical conductors and equipment external to the electric vehicle that provide a connection for an electric vehicle to a power source to provide electric vehicle charging."[9]

The need for public and workplace charging stations (figure 1) has risen alongside EV ownership rates. High-speed public charging stations—that use higher voltages and currents—can be found on the street or in shopping centers.[10,11] These public charging stations typically provide heavy duty connectors, which conform to one of three EV charging connector methods, identified as Level 1, Level 2, and Level 3.[12]

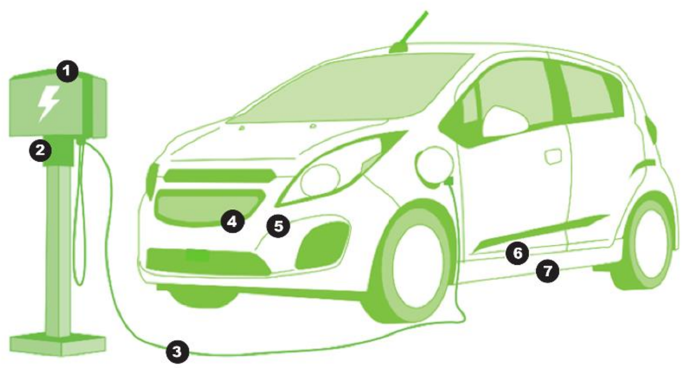


FIGURE 1—PLUG-IN ELECTRIC VEHICLE AND CHARGING STATION WITH PRIMARY COMPONENTS

### Primary Components

1. Cellular Communications: EVSEs use the cellular system to communicate energy transfer and status information to servers.
2. AC Contactor: Electrically controlled switch in the EVSE that closes to allow power to flow from the EVSE to the EV.
3. Cable and Plug: The electrical connection between the EVSE and the EV.
4. CAN (controller area network) Bus: Vehicle communications network used to control actuators and share sensor information (e.g., cruise control, battery charging, anti-lock brakes).
5. Battery: Rechargeable energy storage system that provides DC electrical energy to propel the EV.
6. Battery Management System: Protects battery from damage, maintains battery within operation limits, and maintains battery so it can fulfill its transportation functional requirements.
7. Protection Circuit: Located on the EV to prevent unintended reverse power flow from the EV and plug-in hybrid electric vehicle to the EVSE, power transients, electrical insulation, etc.

---

[6] Murphy, D. (2016). "Report: Daimler Targets Tesla with 6–9 New Electric Vehicles by 2024." *PCMag.* http://www.pcmag.com/news/347601/report-daimler-targets-tesla-with-6-1509-new-electric-veh. Accessed February 8, 2017.

[7] Schaal, E. (2016). "7 Automakers with Major Electric Vehicle Programs in the Works." Fleetcarma. https://www.fleetcarma.com/7-automakers-electric-vehicle-programs/. Accessed February 8, 2017.

[8] Berman, B. (2016). "Carmakers' Commitment to Electric Cars: Brand-by-Brand Review." Plugincars. http://www.plugincars.com/carmakers-commitment-electric-cars-brand-brand-review-130155.html. Accessed February 8, 2017.

[9] NEMA. (2017). "Electric Vehicle Supply Equipment/System." https://www.nema.org/Products/Pages/Electric-Vehicle-Supply-Equipment-System.aspx. Accessed August 14, 2017.

[10] Electric vehicles can be charged in the home (residential), at public charging stations, or at workplace charging stations. U.S. employers use workplace charging stations to provide free charging at their office locations to employees; this is a program encouraged by U.S. Department of Energy. DOE. (2016). "Vehicle Charging." http://energy.gov/eere/eveverywhere/ev-everywhere-vehicle-charging. Accessed December 2, 2016.

[11] Block, D. and Harrison, J. (2014). "Electric Vehicle Sales and Future Projections." University of Central Florida: The Florida Solar Energy Center (FSEC). http://fsec.ucf.edu/en/publications/pdf/fsec-cr-1985-14.pdf, pp. 4–7. Accessed August 20, 2016.

[12] NIST. (2016). "Charging Your Electric Car on the Smart Grid: Three Key Standards." https://www.nist.gov/el/smartgrid/charging-your-electric-car-smart-grid-three-key-standards. Accessed February 7, 2017.

Figure 2 provides a basic flowchart of how the charging process works and discerns between the different charging levels.[13]

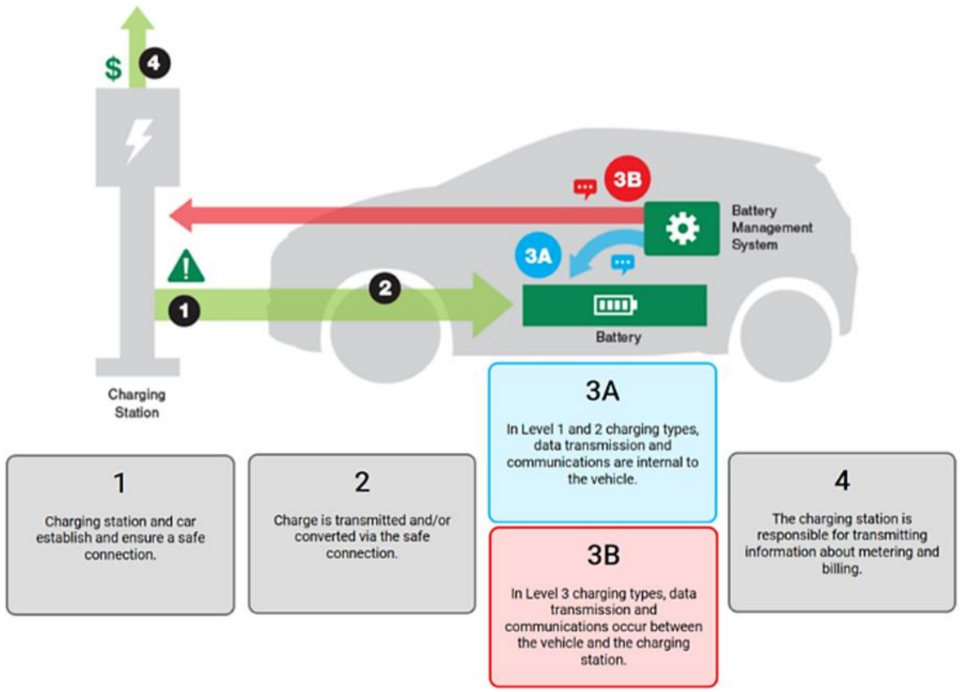


FIGURE 2—FLOWCHART OF ELECTRIC VEHICLE CHARGING EVENTS

## Standards and Regulatory Environment

Standards for EV hardware and software are rapidly evolving. As EVs increase in market share, issues like charging speed and battery capacity will drive future development of EV charging technology. Moreover, the marketplace has yet to set standards for basic EV components and charging methods such as the type of charging connection and the signaling between the EVs and charging stations.

EV charging regulations and codes as of August 2017, encompass fire, building, environmental, and electrical requirements regarding the charging stations and associated equipment.[14] EVSE must comply with Federal, State, and local codes and regulations.[15] Standard development organizations (SDO), such as Society of Automotive Engineers (SAE), Institute of Electrical and Electronics Engineers, Inc. (IEEE), Federal Energy Regulatory Commission (FERC), and National Institute of Standards and Technology (NIST), develop EV charging codes and standards for vehicles, charging (dispensing), and associated infrastructure (figure 3).[16]

As illustrated in figure 3, the Department of Transportation (DOT) and the National Household Travel Survey (NHTS) are the controlling authorities for vehicles. The SDO responsible for writing codes and standards for vehicles, such as fuel cell, hybrid, and storage battery standards is SAE. Local building and fire departments are the controlling authorities on dispensing of electrical power to EVs. IEEE, the National Fire Protection Association (NFPA), and SAE provide codes and regulations for the vehicle charger interface. NFPA also provides standards for the EV charging stations with regard to dispensing power, and Underwriters Laboratory provides dispensing standards for the charging station. The International Code Council provides the standards for general construction

[13] PNNL. (2016). "EV Charging Components." http://rdsx.pnl.gov/ElectricVehicles/. Accessed July 1, 2016.
[14] DOE. (2017). "Plug-In Electric Vehicle Handbook for Fleet Managers." https://www.afdc.energy.gov/pdfs/pev_handbook.pdf, p. 16. Accessed May 22, 2017.
[15] Ibid.
[16] NREL. (2011). "Electric Vehicle and Infrastructure Codes and Standards Chart." https://www.afdc.energy.gov/pdfs/48604.pdf, p. 1. Accessed May 22, 2017.

of these dispensing facilities. Finally, the state and federal energy regulatory commissions are the controlling authorities for all infrastructure required to support EV charging. These include power plant construction and operation standards set by FERC and National Association of Regulatory Utility Commissioners (NARUC), and NIST and North American Electric Reliability Council (NERC) set grid operations standards.[17]

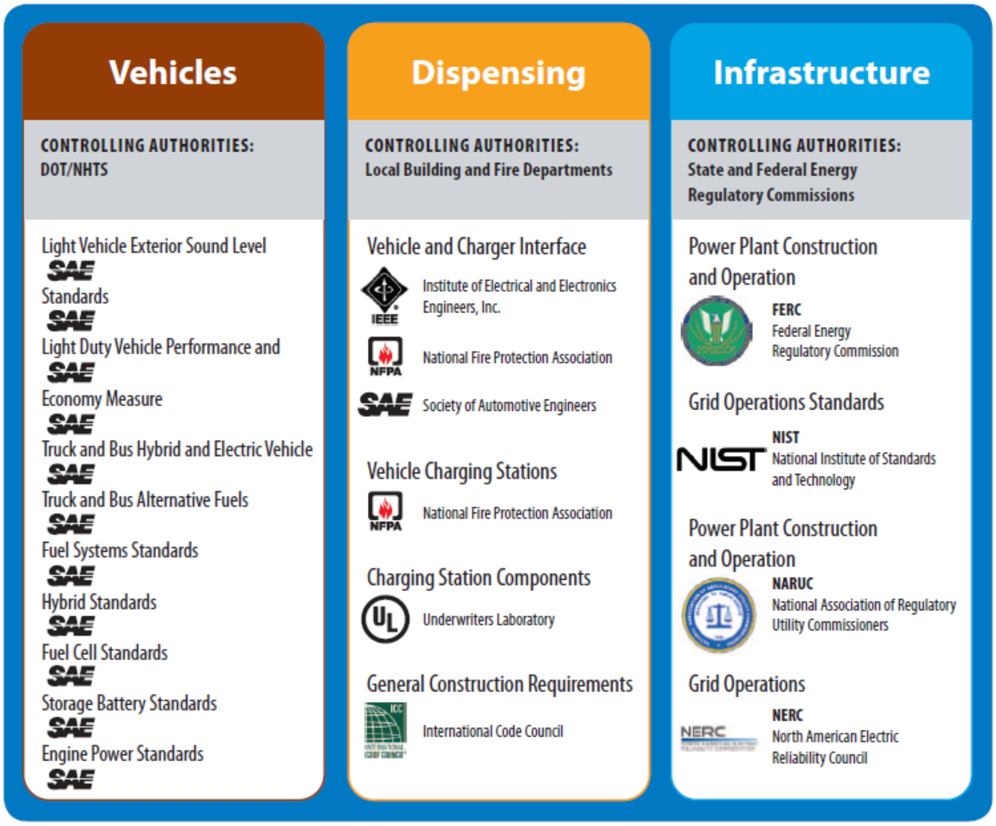


FIGURE 3—ELECTRIC VEHICLE AND INFRASTRUCTURE CODES AND STANDARDS CHART[18]

# ELECTRIC VEHICLE CHARGING: METHODS, TECHNOLOGY, AND EQUIPMENT

## Charging Methods

Manufacturers primarily use three basic EV charging standards that can use the following conductive charging processes (e.g., using a wired AC [electrical connection] between the EV and the EVSE)[19]:

- Charging commences as soon as the EV is plugged into the power supply. This practice is common in most public and many residential charging stations.
- Charging is delayed until an economically or electrically preferential time slot[20] is available. This practice is common in regions with economically preferable time-of-use rates and residential applications.
- Charging commences as soon as the EV is plugged in, but utility-directed load reduction events can reduce or terminate the charging event. Industry refers to this activity as a demand response event. The EV

[17] Ibid.
[18] Ibid.
[19] NIST. (2016). "Charging Your Electric Car on the Smart Grid: Three Key Standards." https://www.nist.gov/el/smartgrid/charging-your-electric-car-smart-grid-three-key-standards. Accessed February 7, 2017.'
[20] Coordinating charging times can improve energy conservation and may allow for less expensive rates for customers if charged during off-peak hours set by local utility companies. Pratt, R. (2014). "Vehicle Communications and Charging Control." https://energy.gov/sites/prod/files/2014/07/f18/vss142_pratt_2014_p.pdf, pp. 4, 5, and 14. Accessed February 8, 2017.

owner is reimbursed for providing this service. The customer contractually enables and uses this charging practice in residential or workplace charging applications.

## CONCEPTUAL CHARGING LEVELS

Automotive industry standards classify charging stations into three levels based on charging power and methods.[21] Charging systems take AC power from the electric grid and transform it to DC power at the correct voltage for charging the vehicle's onboard battery. For plug-in EVs, AC charger components are on board the vehicle. In contrast, DC charging systems operate at higher power levels and therefore split the function and components between the charging station and the EV. The charging station conducts the AC to DC conversion, and the charger uses the CAN bus[22] to communicate with the station while the battery management system controls the voltage and current. Of note, higher power permits faster charger rates.[23,24,25,26]

### Alternating Current Level 1

AC Level 1 (figure 4) charges via a 120 volt (V) AC plug, connected to a cord with a standard three-prong household plug (e.g., NEMA connector), the other end is connected to the SAE J1772 connector. The SAE J1772 connector plugs into the car's J1772 charge port, while the other end, the NEMA connector, plugs into a standard household wall outlet. This level of charging provides vehicles with approximately 2 to 5 miles of range per hour of charging; 8 hours can provide approximately 40 miles of range.[27,28]

### Alternating Current Level 2

Similar to AC Level 1, AC Level 2 (figure 4) charges via 240 V or 208 V, using NEMA and SAE J1772 connectors. The majority of homes are equipped with the 240 V charging capabilities, but AC Level 2 charging stations are also in public charging locations. This level of charging provides approximately 10 to 20 miles of range per hour of charging and can provide a full charge to the battery overnight.[29,30]

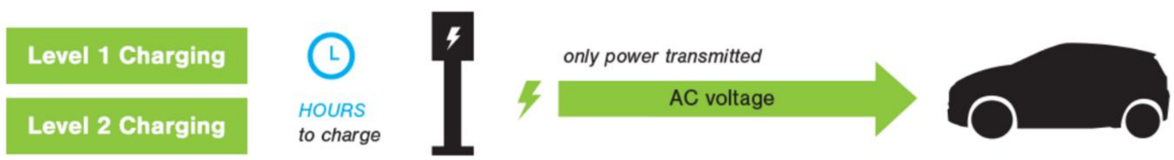


FIGURE 4—LEVELS 1 AND 2 SLOW CHARGING AC

[21] DOE. (2017). "Developing Infrastructure to Charge Plug-In Electric Vehicles: Charging Equipment." https://www.afdc.energy.gov/fuels/electricity_infrastructure.html#level2. Accessed August 7, 2017.
[22] CAN (controller area network) Bus: Vehicle communications network used to control actuators and share sensor information (e.g., cruise control, battery charging, anti-lock brakes).
[23] NIST. (2016). "Charging Your Electric Car on the Smart Grid: Three Key Standards." https://www.nist.gov/el/smartgrid/charging-your-electric-car-smart-grid-three-key-standards. Accessed February 7, 2017.
[24] Bower, G. (2015). "Electric Vehicle Charging Levels Explained." Inside EVs. http://insideevs.com/charging-levels-explained-bower/. Accessed June 15, 2017.
[25] DOE. (2017). "Developing Infrastructure to Charge Plug-In Electric Vehicles: Charging Equipment." https://www.afdc.energy.gov/fuels/electricity_infrastructure.html#level2. Accessed August 7, 2017.
[26] DOE. (2017). "Developing Infrastructure to Charge Plug-In Electric Vehicles: Charging Equipment." https://www.afdc.energy.gov/vehicles/how-do-hybrid-electric-cars-work. Accessed August 9, 2017.
[27] DOE. (2017). "Developing Infrastructure to Charge Plug-In Electric Vehicles: Charging Equipment." https://www.afdc.energy.gov/fuels/electricity_infrastructure.html#level2. Accessed August 7, 2017.
[28] DOE. (2017). "Charging Plug-In Electric Vehicles at Home." Alternative Fuels Data Center. https://www.afdc.energy.gov/fuels/electricity_charging_home.html. Accessed August 7, 2017.
[29] DOE. (2017). "Developing Infrastructure to Charge Plug-In Electric Vehicles: Charging Equipment." https://www.afdc.energy.gov/fuels/electricity_infrastructure.html#level2. Accessed August 7, 2017.
[30] DOE. (2017). "Charging Plug-In Electric Vehicles in Public." https://www.afdc.energy.gov/fuels/electricity_charging_public.html. Accessed August 7, 2017.

**Direct Current Level 3**

DC Level 3 (figure 5) charges via 208 V or 480 V AC three-phase input, using SAE J1772 combo (same as SAE J1772, but with additional two bottom pins), CHAdeMO, or Tesla connectors, depending on the charge port on the vehicle. These charging systems are located only at stations accessible to the public (not in a residence). This level of charging provides approximately 50 to 70 miles of range per 20 minutes of charging.[31,32]


FIGURE 5—LEVEL 3 FAST CHARGING DIRECT CURRENT

## Charging Connector Industry Standards

Two major standards for power connectors are SAE J1772 and CHAdeMO. For standardization within North America, in October 2012, the Society of Automotive Engineers (SAE) completed a new standard connector, SAE J1772 Combo, which combines AC and DC charging capability (figure 6).[33,34] Major Japanese EV manufacturers use CHAdeMO; fast charging stations with these connectors are located throughout the United States and 50 other countries.[35] This standard of electrical connection has an additional charging method that uses the DC pins in the CHAdeMO connector for DC fast charging.[36] Additionally, Tesla, Inc. has a DC charging connector unique to its vehicles and charging stations. These unique connectors can use adaptors, which attach to the connector to charge at SAE J1772-type stations.[37,38] A detailed overview of the charging connectors is in appendix A.

## Future Electric Vehicle Chargers Technology Under Development

As EV numbers increase, manufacturers are developing, building, and deploying more Internet-connected charging stations and new connected technologies (especially focusing on decreased charging time and regional power management) to satisfy demand. OCIA has identified the following emerging trends within the industry.

- Manufacturers are enhancing EVSE-to-EV communications via digital communications. This development will form the foundation for more advanced control of the charging process.[39]
- The automotive industry is expanding communications and control capabilities for EVs and charging systems as wireless technologies become widely adopted by auto manufacturers. Moreover, manufacturers are building increasingly networked automobiles and charging systems.[40,41,42]

---

[31] DOE. (2017). "Developing Infrastructure to Charge Plug-In Electric Vehicles: Charging Equipment." https://www.afdc.energy.gov/fuels/electricity_infrastructure.html#level2. Accessed August 7, 2017.
[32] DOE. (2017). "Charging Plug-In Electric Vehicles in Public." https://www.afdc.energy.gov/fuels/electricity_charging_public.html. Accessed August 7, 2017.
[33] SAE. (2012). "SAE International Releases New Fast-Charging Combo Coupler Standard (SAE J1772) for Plug-In Electric and Electric Vehicles." http://www.sae.org/servlets/pressRoom?OBJECT_TYPE=PressReleases&PAGE=showRelease&RELEASE_ID=1897. Accessed July 11, 2017.
[34] REMA EV. (2012). "DC Fast Charge: SAE J1772TM Fast Charge Connector (CSS 1.0)." http://rema-ev.com/dc-fast-charge/. Accessed October 1, 2016.
[35] CHAdeMo. (2017). "North American Map; Fast Charger Map (US)." https://www.chademo.com/about-us/fast-charger-maps/north-american-map/. Accessed February 2, 2017.
[36] Blink. (2016). "Blink DC Fast Charger." http://www.blinknetwork.com/chargers-commercial-dc-fast.html. Accessed October 1, 2016.
[37] Tesla. (2017). "Charging: Overview." Tesla. https://www.tesla.com/charging. Accessed May 26, 2017.
[38] Tesla. (2017). "Charging: Charge at Home." Tesla. https://www.tesla.com/charge-at-home. Accessed May 26, 2017.
[39] SAE. (2016). "Security for Plug-in Electric Vehicle Communications." SAE. http://standards.sae.org/wip/j2931/7/. Accessed June 1, 2016.
[40] Ibid.
[41] Shahan, C. (2017). "Nissan, BMW, and EVgo Expand DC Fast Charging Across US." CleanTechnica. https://cleantechnica.com/2017/01/26/nissan-bmw-evgo-expand-dc-fast-charging-across-u-s/. Accessed February 6, 2017.
[42] Businesswire.com. (2017). "NRG Launches Nation's First Privately Funded, Comprehensive Electric Vehicle Charging Ecosystem." http://www.businesswire.com/news/home/20101118005462/en/NRG-Launches-Nation%E2%80%99s-Privately-Funded-Comprehensive-Electric. Accessed February 6, 2017.

- Industry is integrating increased connectivity and Internet of Things smart capability into charging stations and is closely synchronizing with the power industry to increase efficiency and lower costs. Industry has developed EVSE that adjusts charging rates based on demands upon the electrical grid and is optimized for off-peak conditions, reducing costs.[43,44]
- Other charging practices in research and development include inductive charging in which the EV and EVSE make no physical electrical connection. Instead, the design uses electromagnetic fields to couple energy between the EVSE and the EV.[45]
- The SAE J3068 standard is under development for three-phase power, providing higher rates of AC charging. "Components of the standard will be adapted from the European three-phase charging standards and specified for North American AC grid voltages and requirements. In the United States, the common three-phase voltages are typically 208/120 V, 480/277 V. The standard will target power levels between 6 kW and 130 kW."[46]
- In early 2017, dynamic EV charging was unveiled during a demonstration, which allows for dynamic charging of an EV while being driven at highway speeds. If the technology is successful and implemented, EVs could charge while on the road and may never require a charging station. Multiple companies are pursuing similar variations of this charging technology.[47]

Areas of concern within the EV and EV charging industry include the increased demand for electricity on residential and commercial electrical grids and potential increases in cyber related vulnerabilities to the EV the EVSE or the billing components related to charging. These concerns may increase as EVs become more widely used, but as of 2017, there are limited to no examples of these being widespread or significant problems. [48,49]

---

43 eMotorWerks. (2016). "Juicebox EV Charging Stations." https://emotorwerks.com/products/juicebox. Accessed December 1, 2016.
44 St. John, J. (2015). "Can EV Chargers Earn Enough Money on Grid Services to Give Them Away for Free?" GreenTechMedia. http://www.greentechmedia.com/articles/read/emotorwerks-mines-for-data-gold-in-the-ev-charging-field. Accessed October 1, 2016.
45 Energy.gov. (2016). "Wireless Electric Charging: The Future of Plug-In Electric Vehicles Going Cordless." https://energy.gov/eere/articles/wireless-electric-charging-future-plug-electric-vehicles-going-cordless. Accessed February 6, 2017.
46 DOE. (2017). "Developing Infrastructure to Charge Plug-In Electric Vehicles." https://www.afdc.energy.gov/fuels/electricity_infrastructure.html. Accessed May 22, 2017.
47 Ward, A. (2017). "Qualcomm Unveils Dynamic Electric Vehicle Charging Tech." AndroidHeadlines. https://www.androidheadlines.com/2017/05/qualcomm-unveils-dynamic-electric-vehicle-charging-tech.html. Accessed May 25, 2017.
48 International Energy Agency. (2017). "Global EV Outlook 2017: Two Million and Counting." https://www.iea.org/publications/freepublications/publication/GlobalEVOutlook2017.pdf. pp. 41-42. Accessed September 13, 2017.
49 DHS. (2017). "OCIA - Limited Consequences of Cyber Attacks on Electric Vehicles Charging Stations." http://nppd-sp.dhs.gov/IATF-HITRAC/_layouts/listform.aspx?PageType=4&ListId={01776638-6EAC-423F-A616-3B78650D1F13}&ID=2322&ContentTypeID=0x010033EBEDA74BA2E941A2A4705A8F58F3B2. pp. 1-2. Accessed September 13, 2017.

# APPENDIX A

## OVERVIEW OF CHARGING CONNECTORS

SAE J1772 is a North American standard for an electrical connector and signaling scheme, connecting charger stations to EVs (figure 6).[50] All charger levels use the same connector. The plug-in EV and EVSE charging cable has five pins: AC Line 1, AC Line 2, ground, proximity, detect, and control pilot.[51] The control pilot pin coordinates the charging level between the plug-in EV and EVSE on all SAE J1772 charging stations using the pulse width of a 1 kHz/±12 V signal. Institute of Electrical and Electronics Engineers 1901 standard plans for the control pilot were to carry high-speed power line communications, allowing digital communications among the vehicle, charging station, and the smart grid.[52] Communications will be Internet Protocol-based, providing the basic network functionality for Smart Energy Profile 2.0 and ISO/IEC 15118, standards that define the communication interface and interactions among vehicle, charging station, and smart grid.[53] The SAE J1772 Combo (figure 7) allows Levels 1, 2, and DC fast, because it has the additional DC fast charge connector pins added to the traditional J1772 charge port.[54]

FIGURE 6—SAE J1772 CHARGING CONNECTOR[55]

FIGURE 7—SAE J1772 COMBO CHARGING CONNECTOR[56]

CHAdeMO is a DC Level 3 "fast charger," delivering up to 62.5 kW over Japan Automobile Research Institute DC fast charge connector (figure 8). Manufacturers designed it as a current source: the system holds the current constant, while the voltage is highly controlled between 50 V and 500 V through the CAN bus, the vehicle charger tells the charging station, the battery capacity, and at what level to set the voltage. Every 0.1 second, the vehicle tells the charging station how much current to deliver, according to a specific circuit current and constant voltage charging curve profile defined in the CHAdeMO specification, and tells it when to stop. Safety interlocks are also

[50] SAE International. (2017). "SAE Electric Vehicle and Plug Hybrid Electric Vehicle Conductive Charge Coupler." http://standards.sae.org/j1772_201602/. Accessed February 6, 2017.
[51] EV-Institute. (2017). "Plug-In Around the EV World." http://www.ev-institute.com/images/Plug_World_map_v5.pdf, p. 1. Accessed February 7, 2017.
[52] IEEE. (2017). "1901-2010 - IEEE Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications." http://standards.ieee.org/findstds/standard/1901-2010.html. Accessed February 7, 2017.
[53] Saksena, M. (2011). "Smart Energy Profile (SEP) 2.0 Uncovered." *EE Times*. http://www.eetimes.com/document.asp?doc_id=1279156. Accessed February 7, 2017.
[54] DOE. (2017). "Developing Infrastructure to Charge Plug-In Electric Vehicles: Charging Equipment." https://www.afdc.energy.gov/fuels/electricity_infrastructure.html#level2. Accessed May 26, 2017.
[55] Zero Emission Motoring. (2011). "SAE and IEE call for new J1772 Charging Standard." http://www.zemotoring.com/news/2011/08/sae-and-ieee-call-for-new-j1772-charging-standard. Accessed August 10, 2017.
[56] Gordon-Bloomfield, N. (2012). "SAE Finalizes New Electric Car Fast Charging 'Combo Connector'.Green Car Reports. http://www.greencarreports.com/news/1079858_sae-finalizes-new-electric-car-fast-charging-combo-connector. Accessed July 11, 2017.

managed through the CAN bus, which tests the charger circuit and the battery for any fault conditions (short circuits, high-leakage currents, overheating) before the charging station can apply power to the connector, preventing it from being energized before it is safe. In this way, the vehicle essentially controls the charging process.[57,58]


FIGURE 8— CHAdeMO CHARGING CONNECTOR[59]

The Tesla Combo (figure 9) is a unique charging connector for Tesla vehicles, which works with all their charging options: home, destination, and supercharger.[60,61] Home charging and destination charging options provide approximately 29 miles per hour of charging either through a wall connector installed at the location (e.g., house, hotel, shopping center) or through a mobile connector used with or without an adaptor. The mobile connector and adaptor plug into any standard outlet, but they provide a more efficient and faster charge in a 240 V outlet. Using an adaptor on the standard Tesla connector allows for use at public charging stations, which use the SAE J1772 connection.[62] The supercharger charging option is available only at Tesla-specific public charging stations that allow 120 kW in DC through multiple parallel chargers controlled by the vehicle's computer, charging the vehicle to 80 percent capacity, which is equivalent to approximately 170 miles, in 30 minutes.[63]

FIGURE 9—TESLA COMBO CHARGING CONNECTOR[64]

The Office of Cyber and Infrastructure Analysis (OCIA) provides innovative analysis to support public and private-sector stakeholders' operational activities and effectiveness and to inform key decisions affecting the security and resilience of the Nation's critical infrastructure. All OCIA products are visible to authorized users at HSIN-CI and Intelink. For more information, contact OCIA@hq.dhs.gov, or visit http://www.dhs.gov/office-cyber-infrastructure-analysis.

PDM17127

57 Herron, D. (2015). "EV DC Fast Charging Standards – CHAdeMO, CCS, SAE Combo, Tesla Supercharger, etc." Green Transportation Info. https://greentransportation.info/ev-charging/range-confidence/chap8-tech/ev-dc-fast-charging-standards-chademo-ccs-sae-combo-tesla-supercharger-etc.html. Accessed February 7, 2017.
58 CHAdeMO. (2016). "FAQ – CHAdeMO." http://www.chademo.com/wp/blog/category/faq-chademo/. Accessed November 28, 2016.
59 Herron, D. (2017). "Range Confidence: Charge Fast, Drive Far, with Your Electric Car; EV DC Fast Charging Standards – CHAdeMO, CCS, SAE Combo, Tesla Supercharger, etc." https://greentransportation.info/ev-charging/range-confidence/chap8-tech/ev-dc-fast-charging-standards-chademo-ccs-sae-combo-tesla-supercharger-etc.html. Accessed August 10, 2017.
60 DOE. (2017). "Developing Infrastructure to Charge Plug-In Electric Vehicles: Charging Equipment." https://www.afdc.energy.gov/fuels/electricity_infrastructure.html#level2. Accessed May 26, 2017.
61 Tesla. (2017). "Charging: Overview." https://www.tesla.com/charging. Accessed May 26, 2017.
62 Tesla. (2017). "Charging: Charge at Home." https://www.tesla.com/charge-at-home. Accessed May 26, 2017.
63 Tesla. (2017). "Charging: Supercharger." https://www.tesla.com/supercharger. Accessed May 26, 2017.
64 Kane, M. (2014). "What Are The Actual Power Limits of Available DC Quick Charging Standards?" Insideevs. http://insideevs.com/what-are-the-power-limits-of-available-dc-quick-charging-standards/. Accessed July 11, 2017.