

Interoperability of Public Electric Vehicle Charging Infrastructure



INTRODUCTION

This paper is a cooperative effort of the Electric Power Research Institute (EPRI), the Edison Electric Institute (EEI), the Alliance for Transportation Electrification (ATE), the American Public Power Association (APPA), and the National Rural Electric Cooperative Association (NRECA) to identify challenges, create awareness, and provide perspective to achieve greater interoperability and open standards in the burgeoning U.S. electric vehicle (EV) charging market.

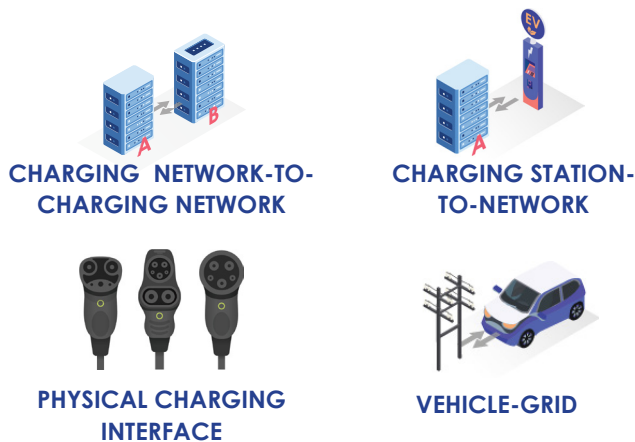
MOTIVATION

The electric vehicle market is rapidly accelerating, as is investment in the charging infrastructure needed to support this growing market. While the vast majority of EV charging now takes place at home and at work, widespread, open-access public charging infrastructure will be essential to support EV drivers beyond early adopters. Visible public infrastructure is a must for more customers to consider EVs as viable for meeting all of their driving needs—from daily commutes to major expeditions—while also supporting drivers who might not have access to workplace or home charging (such as apartment dwellers and other drivers without dedicated residential parking). As a general expectation, public EV charging infrastructure should be convenient and reliable for drivers to use. A recent EEI/Institute for Electric Innovation report¹ projects that, by 2030, nearly one million public charging ports will be needed in the U.S. to support nearly 19 million EVs. Today, fewer than 100,000 such ports are available to U.S. drivers,² and many of these impose limits on their access and use. As infrastructure scales to meet these needs, improved interoperability and standardization will be essential to help enable a multi-stakeholder approach to planning, investment, and operation of public charging.

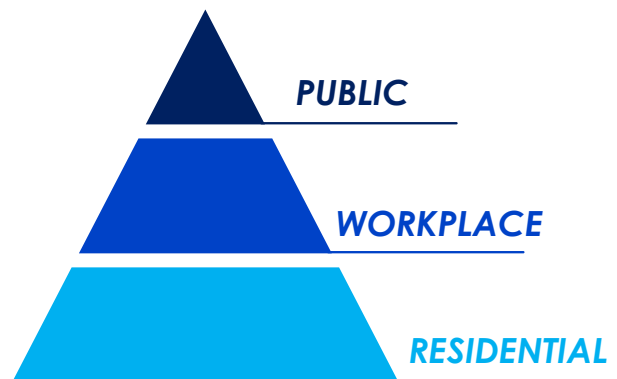
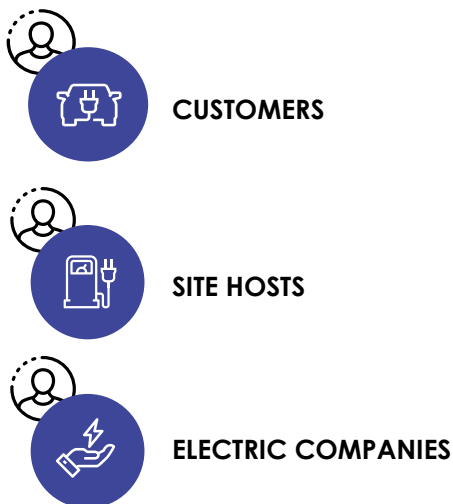
By definition, interoperability is the ability for multiple systems to work together without restriction. With regards to electric vehicle charging infrastructure, interoperability refers to the compatibility of key system components—vehicles, charging stations, charging networks, and the grid—and the software systems that support them, allowing all components to work seamlessly and effectively.

Research and stakeholder engagement over the last decade have shown that interoperable, transparent, open standards-based public EV charging infrastructure can improve the overall customer experience, promote efficient capital investment, enable more optimal EV-grid integration, and support adoption of EVs.

This paper distills, at a high level, four key challenge areas related to interoperability:



And considers their implications for:



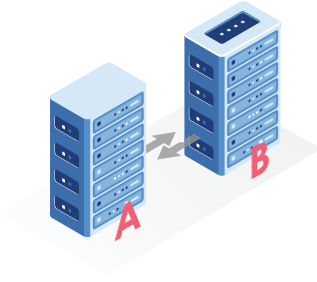
To date, public charging infrastructure in the U.S. has developed through a patchwork of grant funding, settlement funds, private investment, and electric company pilots and programs. The largest portion of public charging is managed by charging network providers, called electric vehicle service providers (EVSPs)—companies that operate charging stations under a variety of business models. Many rely on proprietary software and subscriber service models, resulting in different pricing structures and service offerings for their subscribers versus non-subscribers.

1. *Electric Vehicle Sales Forecast and the Charging Infrastructure Required Through 2030*. Institute for Electric Innovation (IEI) and Edison Electric Institute (EEI), Washington, DC: 2018.
 2. *Plug-In Electric Vehicle Charging Infrastructure Technology Update*. EPRI, Palo Alto, CA: 2018. 3002011592.

INTEROPERABILITY

WHERE TO FOCUS

The four key interoperability-related challenge areas are described below.



Charging network-to-charging network: EVSPs tend to operate their respective networks as islands, lacking communication or integration with other networks. In the current industry vernacular, interoperability most often refers to a vision in which EV drivers can access public charge points from any owner/operator through a common platform and a single network subscription or contract, often called “e-roaming.” Several EVSP networks have signed bilateral agreements to implement roaming partnerships in the past year, marking vital progress towards increased access to networked public charging.

Behind the scenes, this customer-friendly, public charging infrastructure depends on a web of business-to-business (B2B) contracts between network providers, and interoperability among their respective back-end systems. Familiar analogies include the interoperability of financial and banking systems to enable inter-bank and cross-border automated teller machine (ATM) usage and mobile roaming capabilities enabled by interoperability among multiple wireless telecommunication networks.



Charging station-to-network: By definition, networked charging stations must communicate with their supporting networks. Proprietary protocols can create “vendor lock-in” challenges that commit customers (typically the charging station owner) to a single, closed-network provider for the lifetime of the charging

equipment. An open standards-based approach that includes both technical capabilities and contractual rights allows owner-operators to switch between network service providers without having to purchase new charging stations and to install new charging stations without having to change network service providers. This can help stimulate competition in the marketplace and protect infrastructure investments against obsolescence. The Open Charge Point Protocol (OCPP)* is an open networking standard that is widely used in Europe and is growing in acceptance in the U.S. While current versions (OCPP 1.5, 1.6, and 2.0) exhibit some gaps in functionality, their acceptance by most network providers and continued development are important to addressing network interoperability.



Physical charging interface: While a single standard for common AC charging is widely accepted in the U.S. (with Tesla vehicles requiring an adaptor), three different DC charge ports³ are used today. Issues with fragmentation of the early Level 2 AC charging market were mitigated by adoption of the SAE J-1772 standard, which provides automakers and those deploying charging infrastructure with a common system architecture. Meanwhile, the lack of a single accepted standard for DC charging for light duty EVs increases operational complexity and costs, and can lead to customer confusion as public DC fast charging expands.

DC Standard	Connector	Used By
SAE Combined Charging System (CCS)		GM Ford Honda KIA Hyundai BMW Mercedes Porsche Audi VW
CHAdeMO		Nissan Mitsubishi
Tesla Supercharger		Tesla

3. Direct Current Fast Charger System Characterization: Standards, Penetration Potential, Testing, and Performance Evaluation. EPRI, Palo Alto, CA: 2011. 1021743.

* Use of OCPP does not guarantee charging station-to-network interoperability.



Vehicle-grid: Collaboration among EV and charging station manufacturers, network operators, site hosts, and electric companies will be necessary to implement emerging vehicle-grid integration (VGI) technologies.⁴ Vehicle-to-grid charging benefits both the electricity grid and the vehicle owner. At present, electric companies and grid operators are limited in their engagement to support secure, cost-effective, reliable public charging stations at scale by the lack of interoperability among networked systems and limited implementation of open protocols for electric company communications.



CUSTOMER IMPACT

Improving the overall charging experience means making it easy for EV drivers to find and use charging stations. Increased interoperability and standardization of EV charging infrastructure would streamline the public EV “fueling” experience, which is essential for widespread adoption of EVs.

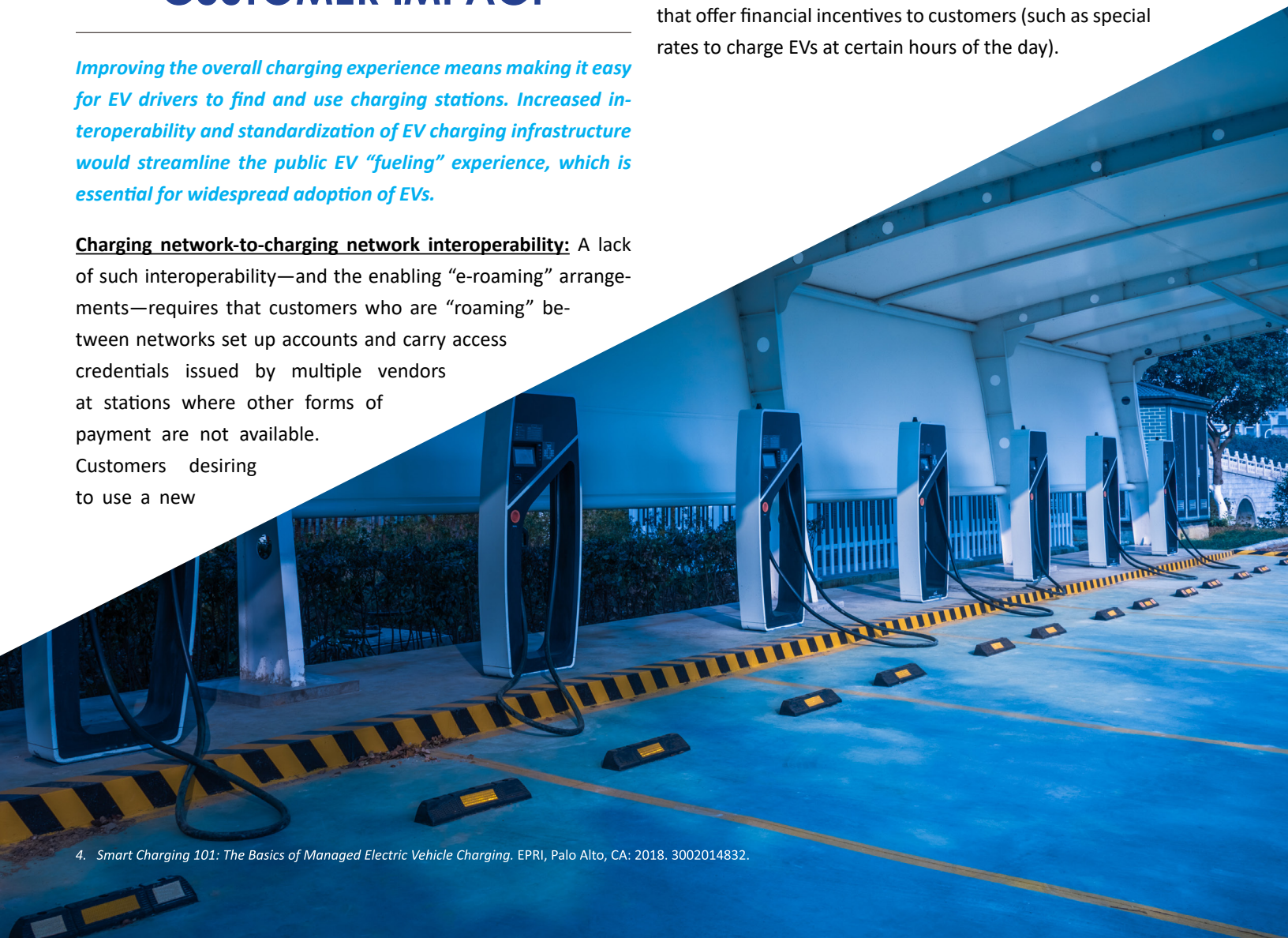
Charging network-to-charging network interoperability: A lack of such interoperability—and the enabling “e-roaming” arrangements—requires that customers who are “roaming” between networks set up accounts and carry access credentials issued by multiple vendors at stations where other forms of payment are not available. Customers desiring to use a new

network must complete a lengthy signup process or use a toll-free phone line to initiate a charge session. “Islanded” charging networks limit the ability to provide customers with charging station maps that include real-time station status data from multiple networks, which is already a concern where EVs are widespread, as drivers must often wait in queue for public charging.

Charge station-to-network interoperability: Open standards-based communications protocols offer service providers and site hosts flexibility in equipment selection that could foster competition and encourage industry innovation by enabling adoption of new technologies, to the benefit of customers.

Physical charging interface interoperability: The existence of multiple interface designs for DC fast charging may add to customer confusion if the charging plaza does not have all the connectors at its stations and limits the portion of installed charging available to any given driver.

Vehicle-grid interoperability: Increased end-to-end interoperability of EV charging infrastructure could streamline communications needed to implement electric company smart charging programs that offer financial incentives to customers (such as special rates to charge EVs at certain hours of the day).



4. Smart Charging 101: The Basics of Managed Electric Vehicle Charging. EPRI, Palo Alto, CA: 2018. 3002014832.

Unlike gas stations, the vast majority of EV charging occurs at home, work, or public locations that the driver frequents—the “fueling” location is infrequently a destination in itself. Electric vehicle charging is an entirely different “refueling” paradigm with a range of cost and convenience advantages, but it is still imperative to ensure that the public charging experience meets or exceeds customers’ expectations set by the baseline “gas station model.”

To highlight customer challenges posed by non-interoperable public charging infrastructure, the table below compares the **public “fueling” experiences of electric vehicle drivers to those of conventional vehicle drivers:**

	Conventional Vehicle Fueling Experience	Public Electric Vehicle Fueling Experience	Ongoing Efforts to Improve Public Charging Experience
Access	Fill up at any gas station; no membership or prior contract required.	Must maintain accounts and access credentials with all networks they wish to utilize.	Many EVSPs are working towards e-roaming.
Payment	Standard forms of payment (credit/debit, cash) accepted at any gas station.	Most public charge points do not accept credit/debit cards; EV drivers must juggle multiple network-specific access cards, apps, and associated accounts to pay for public charging sessions.	Concepts that allow for automatic charging session initiation and payment are being introduced by automotive companies and charging networks.
Pricing	Fuel prices are market-driven and consistently displayed on a \$/gallon basis; drivers can easily compare options.	Many pricing schemes are complex and lack consistency and transparency; may be displayed as \$/kWh, \$/unit time, or \$/session.	Complexity in pricing remains an open issue due to regulation, business models, and bundling with parking/other services or even the purchase of an EV.
Reliability and availability	Navigate to virtually any gas station with the expectation to refuel immediately.	Difficult to find accurate station status, with public charge points often unavailable because they are either in use, out of order, or access is blocked by a non-charging vehicle.	-Each network has its own app with station locations, and this information is also often available through third party apps. -Google Maps recently added charging station locations, and real-time availability info is available for certain networks. -The charging industry is also working on allowing EV drivers to make reservations for public charging.
Vehicle compatibility	Universal expectation that the fuel nozzles at every gas station will fit.	For DC fast charging, drivers must locate chargers compatible with their vehicles; connection types differ by automaker and region.	For non-Tesla DC fast charging stations, site hosts often install both CCS and CHAdeMO connectors.



SITE HOST IMPACT

Chargers are widely available for purchase by commercial landlords as well as network operators. While network operators generally possess the knowledge and experience to make informed decisions about chargers and associated software, commercial and multifamily landlords typically are unaware of the limitations presented by hardware that is restricted from moving between networks. In cases where the charger owner wants to change network providers, for pricing, service, or other reasons, the lack of interoperability typically presents obstacles that often are costly and burdensome.

Charging network-to-charging network interoperability: Network interoperability enables customers to use stations across networks. This can broaden the customer base with access to a particular site host’s charging equipment. It also allows for site inclusion in public charging mapping programs, including those providing real-time status, thus improving equipment utilization.

Charge station-to-network interoperability: Many commercial charging equipment providers bundle their charging hardware with software so that the hardware is incompatible with other networks. When the lack of open standards is compounded by contractual restrictions for charging station control systems, a host desiring to change network service providers will likely need to purchase and install entirely new charging hardware. By installing a networked charging station, site hosts are often tied to the original network provider for the hardware’s lifetime, limiting customer mobility and competition.

Information barriers resulting from networked chargers' proprietary communications protocols present challenges to the site hosts, hardware owners, and other stakeholders responsible for their long-term operation and maintenance. Open standards-based approaches would mitigate these integration challenges, while improving site hosts' ability to monitor the condition of their charging stations in real time to ensure timely maintenance.

Physical charging interface interoperability: Site hosts are forced to decide which of the three prevalent DC fast charging standards they will support. Supporting multiple formats adds equipment complexity and cost and may increase the footprint required to serve a given number of vehicles.

Vehicle-grid interoperability: The inability to manage the vehicle-grid interaction may hamper the site host's ability to manage on-site charging in ways that reduce electricity costs for the site host.

may select one network as the turnkey operator after issuing an RFP. Others electric companies may engage multiple vendors and operating systems to operate in their service territories – integrating their IT and management systems with the vendors' systems and associated data (which is generated, controlled, and managed by the EVSPs).

Charging network-to-charging network interoperability: Enabling customers to use stations across networks broadens the customer base for installed equipment, increasing utilization of the charging infrastructure.

Charge station-to-network interoperability: Like site hosts, some electric companies install, own, and operate public EV charging infrastructure through third-party networks, meaning resulting charging points are not open-access. To access these (often rate-based) public infrastructure investments, customers must first subscribe to a proprietary network as a member.

Due to proprietary back-end software and the charge station hardware locked to it, the electric company owner-operators of networked public charging risk stranding assets, potentially rendering these investments unusable if the selected network provider curtails or ceases operations.

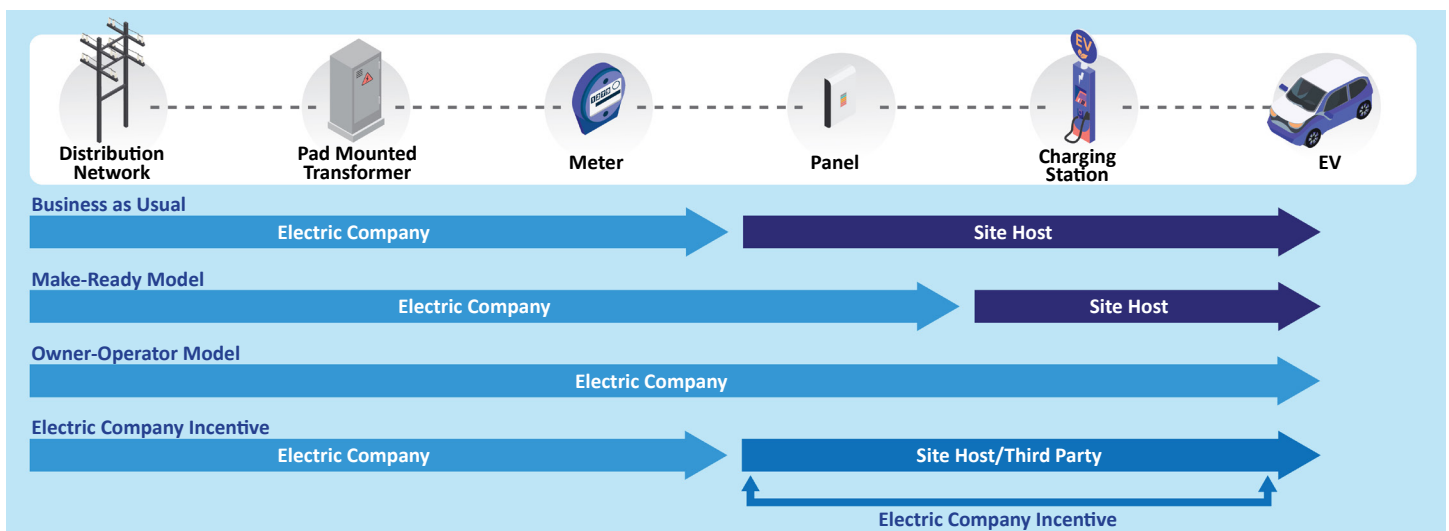
When charging assets are deployed with bundled hardware and proprietary software, utility owner-operators may be tied to the same lifetime vendor commitment (and associated challenges) faced by site hosts, but on a much larger scale. They may face restrictions in negotiating the most cost-effective solution for customers.

Physical charging interface interoperability: Depending on local and site-specific infrastructure, new DC fast charging installations may require distribution upgrades. As the fast charging market expands and as vehicles capable of higher-powered charging en-



ELECTRIC COMPANY IMPACT

Some electric companies install, own, maintain, and operate public EV charging infrastructure as utility owner-operators, while others focus on providing the conduit, wiring, and other necessary on-site infrastructure. To meet customer needs, electric companies are engaged in various ways with EVSPs, site hosts, and others in the early stages of charging infrastructure development. Electric companies serving as the owner-operator



ter the market, the frequency and extent of required upgrades to the grid will likely increase. The existence of multiple disparate, non-interoperable DC fast charging standards could limit the efficiency of these charging infrastructure investments.

Vehicle-grid interoperability: The lack of networked charging system transparency and interoperability inhibits the ability of electric companies to manage public charging infrastructure securely, cost-effectively, and reliably, while also planning for future public charging growth. For electric company owner-operators, this creates inefficiencies in the operation and maintenance of public charging. Secure, integrated communication between the grid and downstream components of EV charging infrastructure is required for optimal EV-grid integration, but is impeded by a lack of open standards, interoperability, and transparency in the current model.

CONCLUSION

Without broadly addressing interoperability issues, U.S. public charging infrastructure will continue to scale along fragmented and inefficient paths, potentially resulting in higher costs, less than optimum customer experience, and stranded investments. Sustainable, effective infrastructure development requires a shared focus on interoperability, transparency, and open-standards to streamline system integration and improve the customer experience. From the customer's perspective, the goal should be more than a system that "just works" – and one that offers convenience, confidence, and security.

COLLABORATIVE AREAS OF FOCUS

Charging network-to-charging network interoperability: Implementation of a standard protocol for B2B connectivity that facilitates customer roaming between charging networks.

Charge station-to-network interoperability: Implementation of open, nonproprietary protocols enabling interchangeable services and operations between charge stations and networks.

Physical charging interface interoperability: The adoption, through appropriate standards-setting organizations, of a DC charging protocol and interface, or alternative solutions to facilitate interoperability, for light duty EVs to improve charging access and scale infrastructure efficiently.

Vehicle-grid interoperability: Development and implementation of open standards for grid-condition based charging management.

By working together, all stakeholders in public EV infrastructure—including EVSPs, electric companies, EV supply equipment OEMs, and automakers—can help advance both technical and best practice solutions to interoperability-related challenges. This includes collaborative efforts to inform and support standards development and implementation through industry forums such as [The National Electric Transportation Infrastructure Working Council \(IWC\)](#).





GLOSSARY OF TERMS

AC, DC: **alternating current, direct current.** The U.S. electricity grid operates on AC. A typical household outlet is 110–120 VAC (volts alternating current). Large home appliances use 240 VAC. Electric car batteries operate on DC.

Charging Level: The terms, AC Level 1, AC Level 2, and DC Fast describe how energy is transferred from the electrical supply to the car’s battery. Level 1 is the slowest charging speed. DC Fast is the fastest. Charging rate varies within each charging level, depending on a variety of factors including the electrical supply and the car’s capability.

CHAdeMO: An abbreviation of “CHArge de MOve”, A DC fast charging standard co-developed by Tokyo Electric Power Company (TEPCO) and Japanese automakers.

CCS: Stands for “Combined Charging System.” A charging standard developed by the Society of Automotive Engineers (SAE) and the European Automobile Manufacturers Association that supports both AC and DC charging, combined in a single plug design.

Connector: The plug that connects the electricity supply to charge the car’s battery. J-1772 is the standard connector used for Level 1 and Level 2 charging. CCS or “Combo” connectors are used for DC Fast charging on most American and European cars. CHAde-MO is the connector used to DC Fast charge some Japanese model cars.

EVSE: Electric vehicle supply equipment. An industry term for the charging appliance. Most people say chargers or charging stations. Charging station once referred to just the appliance but now is also being used to describe a location with multiple chargers (think: gas station).

EVSP: Electric vehicle service providers. Companies that deploy and operate charging station networks.