This page does not get printed – replace it with the Front Cover

Navigating through this document:

- Clicking in the table of contents takes you to the relevant page / section
- Opening the sidebar navigation pane in the pdf file also takes you to navigational links to the individual sections.

Printing the document: Note: **This is a 148-page document.**

Roadmap of Standards and Codes for Electric Vehicles at Scale

By the
ANSI Electric Vehicles Standards Panel (EVSP)

[this page intentionally left blank]

Table of Contents

Acknowledgments

Sincere thanks are extended to all of the individuals and organizations listed below for providing technical input and/or other support associated with the development and promotion of this roadmap. It is because of their involvement and contributions over the last year that this document has been made possible.

The roadmap is based on a consensus of those who actively participated in its development and does not necessarily reflect the views of the individuals or organizations listed below. The employment status and organizational affiliation of participants may have changed during the course of this project.

To be filled in.

Organization	**Name of Individual(s)**

[1] Lead EVs@Scale Lab Consortium, Standards & Codes Pillar
[2] DOE EERE VTO Liaison
[3] EVSP Working Group Co-Chair
Parentheses following a name signify participation also on behalf of another organization.

Executive Summary

In furtherance of the Biden Administration's goal for a clean energy future, the U.S. Department of Energy (DOE) Office of Energy Efficiency & Renewable Energy (EERE) Vehicle Technologies Office (VTO) issued a June 2021 lab call funding opportunity announcement (FOA). The lab call included a pillar on codes and standards with the goal to "identify and address challenges and barriers to the integration of EVs@Scale charging with the grid created by uncoordinated development of codes and standards and the rapid advances in vehicle and charging technologies."

An EVs@Scale lab consortium was formed in response to the FOA with Argonne National Laboratory (ANL) as the lead lab for the codes and standards pillar supported by other national labs. The consortium committed to develop a 2022 roadmap like earlier roadmaps developed by the American National Standards Institute (ANSI) Electric Vehicles Standards Panel (EVSP) in the 2011-14 timeframe. The EVs@Scale effort supports funding initiatives associated with deploying a nationwide EV charging infrastructure, including the National Electric Vehicle Infrastructure (NEVI) Formula Program.

ANSI serves as administrator and coordinator of the U.S. private-sector voluntary standardization system. As a neutral facilitator, the Institute has a successful track record of convening stakeholders from the public and private sectors to define standardization needs for emerging technologies and to address national and global priorities. The ANSI EVSP does not develop standards. Rather, it serves as a forum for facilitating coordination among standards developing organizations (SDOs) and others.

Building on the earlier ANSI EVSP work, this roadmap seeks to describe the current and desired future standardization landscape that will support and facilitate EVs at scale. It identifies key safety, performance, and interoperability issues, notes relevant published and in-development standards, and makes recommendations to address gaps in codes and standards. This includes recommending pre-standardization research and development (R&D) where needed. It also includes identification of prioritized timeframes for when standardization work should occur and SDOs or other organizations that may be able to lead such work.

The roadmap's primary focus is on light duty, on-road plug-in electric vehicles (PEVs) that are recharged via a connection to the electrical grid, as well as the supporting charging infrastructure needed to power them. Medium and heavy-duty EVs are also covered, as is wireless charging. Topics covered include standards to address high power DC charging, storage (i.e., microgrid, distributed energy resource management systems) integrated with DC charging, vehicle grid integration, high power scalable/ interoperable wireless charging, and vehicle-oriented systems. The broad target audience includes vehicle manufacturers, entities that will be installing and operating charging infrastructure, SDOs, U.S. federal, state, and municipal government agencies, electric utilities, and others.

The roadmap has examined a number of issues and identified a total of 30 gaps with corresponding recommendations across the topical areas of vehicle systems, charging infrastructure, grid integration, and cybersecurity. Of that total, 12 gaps/recommendations have been identified as high priority, 16 as medium priority, and 2 as low priority. A "gap" means no *published* standard, code, etc. exists that covers the particular issue in question. In 18 cases, additional R&D is needed.

The hope is that this roadmap will be broadly adopted by the user community and that it will facilitate a more coherent and coordinated approach to the future development of standards for EVs. It is envisioned that the roadmap be widely promoted and that some mechanism be established to assess progress on its implementation.

Summary Table of Gaps and Recommendations

Row	Section	Section Name	Gap #, Title & Description	R&D Needed	Recommendation	Priority	Organization(s)
Chapter 2. Vehicle Systems							
1	2.2	Battery Safety	Gap V1: **Battery safety.** There is an ongoing need to address safety issues related to battery thermal runaway, water immersion, and vibration resistance.	No	Continue to advance battery safety through NHTSA's participation in the development of Phase 2 of Global Technical Regulation No. 20 for Electric Vehicle Safety	High	NHTSA, WP.29
2	2.2.2	Delayed Battery Thermal Events	Gap V2: **Delayed Battery Thermal Events.** The issue of delayed battery thermal events needs to be addressed.	Yes	Address the issue of delayed battery thermal events in future rulemaking and/or revisions of SAE J2929 and J2990.	High	NHTSA, SAE
3	2.4	Battery Storage	Gap V3: **Safe storage of Damaged Lithium-ion Batteries.** No standards or guides have been identified that address the safe storage of damaged (i.e., unknown condition) lithium-ion batteries, whether at warehouses, repair garages, recovered vehicle storage lots, or auto salvage yards.	Yes. On combinations of failure modes.	A standard or guide for the safe storage practices for EV batteries must be developed, addressing damaged batteries and the wide range of storage situations that may exist, including when the batteries have been separated from their host vehicle.	High	SAE, NFPA, ICC, IEC
4	2.5	Battery Packaging, Transport, and Handling	Gap V4: **Packaging and Transport of Lithium-ion Batteries as Cargo on Aircraft.** Standards are being developed on battery package testing and performance-based packaging for lithium batteries as cargo on aircraft.	No	Complete work on SAE standards in development on battery package testing and performance-based packaging for lithium batteries as cargo on aircraft.	High	SAE

Row	Section	Section Name	Gap #, Title & Description	R&D Needed	Recommendation	Priority	Organization(s)
5	2.6	Battery Recycling/Materials Reclamation	Gap V5: **Design for Battery Recyclability/Materials Reclamation.** No standards gap has been identified with respect to battery recycling. However, there is a need for additional R&D on design for recyclability, as batteries are getting less conducive to recycling.	Yes, as noted	Additional R&D is needed by the national labs on design for recyclability of EV (li-on) batteries. This could include addressing the calculation method toward recycling efficiency and recovery rates based on an agreed unit (possibly weight) and/or life-cycle assessment tools, including energy recovery. Recycling is important to reduce the amount of materials to be mined, because the processing of lithium ion produces toxic biproducts.	High	National labs, SAE, ISO
6	2.7	Battery Secondary Uses	Gap V6: **Battery Secondary Uses.** There is a need for standards to address battery second life applications for grid storage and other uses.	Yes, on a ledger or lifetime tracking register, in the cloud or on the device, that shows the history of the battery.	Explore the development of standards for battery secondary uses, addressing such issues as safety and performance testing for intended applications, grid connection/communication interfaces, identification of parts/components that can be removed from the pack without destroying it, etc.	Medium	SAE, UL
Chapter 3. Charging Infrastructure							
7	3.1.2	Megawatt Charging Systems for Medium & Heavy-Duty EVs	Gap C1: **Megawatt Charging Systems (MCS)**. Standards are needed for MCS to support for heavy duty EVs such as trucks and buses.	Yes. Interoperability testing and data collection.	Complete work on SAE J3271.	High	SAE, NREL, DOE
8	3.1.3.1	Static Wireless Power Transfer	Gap C2: **Static Wireless Charging.** Standards for heavy duty/high power static wireless charging are still in development.	No	Complete work on SAE J2954/2 and other in development standards to deal with heavy duty/high power static wireless charging.	High	SAE, UL, IEC/TC 69, ISO TC22/SC37
9	3.1.3.2	Dynamic Wireless Power Transfer	Gap C3: **Dynamic Wireless Charging**. Standards for dynamic wireless charging are still needed.	Yes, Testing, data collection.	Develop standards to address dynamic wireless charging.	Low	SAE, UL, IEC/TC 69, ISO TC22/SC37

Row	Section	Section Name	Gap #, Title & Description	R&D Needed	Recommendation	Priority	Organization(s)
10	3.1.3.3	Communications in Support of Wireless Power Transfer	Gap C4: **Communications in Support of Wireless Power Transfer.** The following issues need to be addressed: • ISO 15118-series – resolution of conflicting requirements in ISO 15118-2 and/or ISO 15118-20 and publication in order to include static WPT • SAE J2847/6 needs to be updated and harmonized with ISO 15118-2and/or ISO 15118-20 so that there are uniform communication requirements for WPT	TBD	Complete work on communication standards in development for static and dynamic wireless charging.	Low	SAE, ISO, IEC
11	3.2.1.2	Charging Station Permitting	Gap C5: **Power Export.** While permitting for EVSE installation is covered by codes, permitting for the actual delivery of power from the vehicle (i.e., power export) is not specified in codes. SAE J3072 specifies the need for a permit but does not describe how to comply. There are terms and conditions for interconnections related to power export. Addressing this gap requires coordination between utilities, AHJs, and code organizations is required.	No	Address power export in relevant codes in cases where the NEC does not apply (e.g., interconnection agreements).	Medium	Code organizations, utilities, AHJs.
12	3.2.1.6	Cable Management	Gap C6: **Cable Management.** Functional management of EV cables in public parking spaces is not specifically addressed by codes or standards.	No	Guidelines or standards relating to EVSE cable management in public parking spaces and how it is documented should be developed.	Medium	UL, NFPA, NIST

Row	Section	Section Name	Gap #, Title & Description	R&D Needed	Recommendation	Priority	Organization(s)
13	3.2.2.1	Residential Charging	Gap C7: **Fire protection in relation to EV parking/charging in/near older buildings.** As mentioned above, there are many conversations around parking and charging EVs in or near older structures, such as multi-family residences with an indoor or underground parking lot. If a fire incident was to occur where many EVs are in the same parking area, issues arise whether the building can withstand the intensity of a lithium battery fire, what that means for any fire protection equipment that should be installed, etc. Development of building codes and fire codes may be needed to address this concern. Note: This is also a concern for parking/charging in or near older commercial buildings as well.	Potentially yes. Research into building materials that can or cannot withstand a lithium fire. Fire protection equipment that should be installed and other fire prevention means may also require research. Note: The 2023 edition of NFPA 88A requires the installation of automatic sprinkler systems in all parking structures in accordance with NFPA 13 and NFPA 13R as applicable. It also requires that automatic sprinkler systems be inspected, tested, and maintained in accordance with NFPA 25.	Develop standards or codes to address the issue of fire protection where EVs are parked/charging in/near older buildings.	Medium	International Code Council (ICC), NECA, NFPA, and the International Association of Electrical Inspectors (IAEI) to address code related issues

Row	Section	Section Name	Gap #, Title & Description	R&D Needed	Recommendation	Priority	Organization(s)
Chapter 4. Grid Integration							
14	4.1.2	Communications Requirements for Various EV Charging & Grid Support Scenarios	**Gap G1: Locating and reserving a public charging station, Obtaining Pricing and Availability Information.** There is a need for standard(s) to permit EV drivers to locate a public charging spot, reserve its use in advance, and obtain pricing information and near real-time availability.	No	Develop a standard(s) to permit EV drivers to universally locate and reserve a public charging spot, and to obtain pricing information and near real-time availability.	Medium	SAE, OCA, EVRoaming Foundation, eMI3, ETSI ITS
15	4.1.3	Communication & Measurement of EV Energy Consumption	**Gap G2: Communication of standardized EV sub-metering data.** Standards are needed for communication of EV sub-metering data between third parties and service providers.	No	Develop a standard to communicate EV sub-metering data between a third party and a billing agent (e.g., utility).	High	OpenADE/NAESB, IEEE, Mesa, SunSpec Alliance, OpenFMB
16	4.1.3	Communication & Measurement of EV Energy Consumption	**Gap G3: Standardization of EV sub-meters.** Standards for EV sub-meters, including embedded sub-meters, are needed to address performance, security/privacy, access, and data aspects.	No	Develop standards or guidelines related to the functionality and measurement characteristics of sub-meters for EVs, including embedded sub-meters in the EVSE or EV. Such standards should address different form factors, capabilities, installation, and certification. Organizations developing standards, guidelines or use cases related to EV sub-metering should coordinate their activities in order to avoid duplication of effort, assure alignment, and maximize efficiency.	High	NEMA, USNWG EVF&S, SEPA, EPRI

Row	Section	Section Name	Gap #, Title & Description	R&D Needed	Recommendation	Priority	Organization(s)
17	4.2.1	Power (electrical) Systems & Safety	Gap G4: **Dynamic Capacity Management (DCM).** DCM relates to managing local distribution capacity constraints and balancing supply and demand on the grid with the requirements of the EV charging station and other loads on the grid. Open Automated Demand Response (OpenADR 2.0) is one way of managing capacity for DCM focusing on energy and demand response, as well as pricing communications. Newer iterations of OpenADR are expected to improve grid coordination. Presently, program guides on OpenADR and IEEE 2030.5 exist. Questions remain though as to clarification of further grid coordination mechanisms to be supported, as well as consumer information to enhance understanding of these standards.	Yes, to determine ways to do DCM	Continue to pursue various ways to do DCM (e.g., within the context of OpenADR) to identify and incorporate advanced grid coordination mechanisms. Determine if existing program guides on OpenADR and IEEE 2030.5 are sufficient or if additional consumer information is needed.	Medium	IEEE, OpenADR Alliance, and others as appropriate

Row	Section	Section Name	Gap #, Title & Description	R&D Needed	Recommendation	Priority	Organization(s)
18	4.2.1	Power (electrical) Systems & Safety	Gap G5: **Safety and Protection of DC architectures are not standardized.** Technology is not well established nor is it currently known how to do a thorough DC protection system design (especially with regard to islanding). Short circuit protection for complex energy sources (e.g., multiple energy sources and bidirectional power flow) is the primary gap. IEEE P2030.12 is a draft guide for microgrid protection systems. The National Electrical Code (NEC) does address DC microgrids, principally driven by photovoltaics and energy storage. There is considerable cross-over with the solar industry within SunSpec and for microgrids within the Emerge Alliance. In Europe, the Open Society (OS) Foundation is working to develop guidelines and transfer them to the International Electrotechnical Commission (IEC) for formal standardization.	Yes	Continue to pursue standardization of safety and protection for DC architectures, especially within the IEEE P2030 suite of standardization activities.	Medium	IEEE

Row	Section	Section Name	Gap #, Title & Description	R&D Needed	Recommendation	Priority	Organization(s)
19	4.2.1	Power (electrical) Systems & Safety	Gap G6: **Fault Current Signatures for AC and DC Architectures under Islanding Conditions.** Identifiable fault currents can be an issue for AC and DC architectures. Specifically, the magnitude and signature of fault currents within AC and DC architectures can be too low to trip protection and provide safety.	Yes	The issue of fault currents is largely covered in UL 1741 and UL 9741. UL 1741 covers AC and DC systems, while UL 9741 covers DC systems and references UL 1741 for AC systems. UL 1741 Supplement SC includes a safety overvoltage protection function in the event the EV exceeds 120 percent of nominal unit voltage. The V2G interconnection criteria will follow national grid interconnection standards. However, coordination in front and behind the meter is needed when systems are islanding, especially within the context of hybrid (AC/DC intertwined) and DC architectures, and non-linear loads. Explore fault currents under islanding conditions and, as appropriate, implement codes and standards development to address safety and grid interconnection performance aspects.	Medium	UL, FERC, NERC
20	4.2.1	Power (electrical) Systems & Safety	Gap G7: **"Ride Through" Requirements for EVSE under Grid Service Conditions.** "Ride Through" requirements encompass how systems/devices will behave when conditions on either side of the point of interconnection (EV Station or grid) are not normal. There is a dichotomy: first, for the distribution network within the EV station itself especially under islanding (i.e., not connected to the grid) conditions, and, second, on the grid side specifically at the systems level with regard to voltage and frequency. When EVSE are supplying power to the grid, "Ride Through" requirements need to be defined under specific conditions. "Ride Through" is not applicable in this context for DC systems.	Yes	Explore "Ride Through" requirements for EVSE under grid service conditions. "Ride Through" requirements are covered under IEEE 1547, with V2G specifically covered under IEEE 1547.1. UL 9741 covers AC coupled output and interconnection, with the latest version addressing vehicle-to-everything (V2X). UL 1741 Supplement SC will address situations where vehicles have onboard AC inverters. As appropriate, implement codes and standards development.	Medium	IEEE, UL

Row	Section	Section Name	Gap #, Title & Description	R&D Needed	Recommendation	Priority	Organization(s)
21	4.2.1	Power (electrical) Systems & Safety	Gap G8: **DC-as-a-Service (DCaaS).** A thorough review of standards is needed for applicability. This includes electrical power standards and any other standards for DC distribution, as well as for fast charging stations and DC microgrids. DCaaS is a business proposition and involves standards, codes, policy development, and coordination to ultimately be successful. Monetization of the business proposition requires an approved DC tariff which does not exist.	No	Pursue a comprehensive review of codes and standards for applicability to DCaaS. Determine which existing codes and standards apply in specific situations and identify any existing gaps. Work with public utility regulators to establish DC tariffs.	Medium	IEEE, NFPA, SunSpec, Emerge Alliance, public utility regulators
22	4.2.2	Communications / Controls	Gap G9: **Structured information and energy services exchange with utilities.** There is a need for structured information and energy services exchange to enable utilities to balance utility-side availability of renewables with EV site requirements, and for EVs to provide grid services. This gap specifically encompasses the need for structured information exchange to enable balance and negotiation, not command and control. This includes how to measure, communicate, and confirm transfer of information. In short, it is an energy services exchange and value proposition gap and incorporates information transfer at the distribution level.	Yes, further development and demonstration	Continue to pursue improved mechanisms for structured information and energy services exchange within the context of IEEE P2030.5 and IEEE P2030.13. Additionally, the North American Energy Standards Board (NAESB) is working on the transmission side, while the US DOE Grid Modernization Laboratory Consortium (GMLC) has looked at this extensively over the last five years.	Medium	IEEE, NAESB, and GMLC

Chapter 5. Cybersecurity							
Row	**Section**	**Section Name**	**Gap #, Title & Description**	**R&D Needed**	**Recommendation**	**Priority**	**Organization(s)**
23	5	Cybersecurity	**Gap S1: Comprehensive review of cybersecurity codes and standards for applicability to the EV charging ecosystem.** Gaps should be identified and prioritized.	No	Conduct a comprehensive inventory and review of standards with regard to cybersecurity applicability across the EV charging ecosystem. Ascertain potential gaps with regard to cybersecurity. In Winter 2023, Southern California Edison proceeded on a project for the California Energy Commission to explore cybersecurity codes and standards gaps with stage 1 focusing on identifying gaps and stage 2 to initiate addressing them.	High	Industry, Government, SDOs
24	5	Cybersecurity	**Gap S2: The lack of an end-to-end secure trust chain and encryption system for the EV charging ecosystem.** This results from the use of different protocols and data transfer mechanisms between EV charging related systems. An entity trust chain is needed across all elements of the EV charging ecosystem incorporating a comprehensive public key infrastructure (PKI).	Yes	Industry consensus and implementation is needed for a comprehensive end-to-end trust chain incorporating a PKI system for the EV charging ecosystem. Consideration could be given to the Cab Authority Browser (CAB) forum as a model to reach consensus. While it appears that in some cases EV-EVSE communications may be fully encrypted, it not clear that other communication channels within the EV ecosystem (e.g., from the charging stations to the EVSPs, and between CNOs) are fully secure. ISO 15118 provides guidance on secure communications, but gaps remain. IEEE P2030.5 indicates there must be end-to-end security but does not provide the means to achieve this. Close coordination should be established with the SAE EV Collaborative Research Project (CRP) which has developed a PKI system and is now shifting to implementation. The European Commission is considering adoption of IEC 62351 and IEC 62443 (both of which reference ISO 15118-2 and 15118-20) to ensure system security, including cybersecurity protection of digital keys. As appropriate, implement codes and standards development to reflect implementation of an industry agreed upon PKI.	High	Industry including equipment and system manufacturers, CNOs, aggregators, PKI infrastructure developers, Government, Associations, and SDOs

Row	Section	Section Name	Gap #, Title & Description	R&D Needed	Recommendation	Priority	Organization(s)
25	5	Cybersecurity	**Gap S3: Cybersecurity and Data Privacy.** Due to the nature of cybersecurity, the interactions of systems, and the emerging threats environment, there is an ongoing need for guidelines and standards to address cybersecurity and data privacy concerns specific to EVs and smart grid communications. Architectures should be designed with cybersecurity in mind.	No	Develop guidelines and standards to address cybersecurity and data privacy concerns specific to EVs and smart grid communications.	High	IEC, IEEE, ISO, NIST, SAE, UL
26	5	Cybersecurity	**Gap S4: Robust "Security-by-Design" is needed for equipment and systems throughout the EV charging ecosystem.**	Yes	Assess cybersecurity requirements in the initial design phases of equipment and systems throughout the EV charging ecosystem. This should be a broad-based assessment examining cybersecurity risks across the EV ecosystem including such areas as mobile apps and platforms. Identify common methods including required and optional features and functions. Establish robust metrics identifying security-by-design; for example, passing vulnerabilities testing. Consider exploration of other industries with similar challenges. Identify gaps and provide recommendations to serve as a model and establish a framework for future codes and standards development. Implement codes and standards, as appropriate, to advance "Security-by-Design" practices.	Medium	Auto OEMs, EVSE manufacturers, CNOs, EVSPs, utilities, Government, and SDOs
27	5	Cybersecurity	**Gap S5: Digital Cybersecurity as Part of Interconnection Standards.** Cybersecurity threats exist at the power system point of interconnection. The digital interconnection could be compromised which may affect the electrical interconnection. Presently, there appears to be no standards requirements nor other guidance for utilities to address digital cybersecurity challenges.	Yes	Assess the need and requirements for cybersecurity as part of power system interconnection standards. Determine cybersecurity challenges facing the digital interface (such as digital entry points) and the hosting capability of existing systems. As part of interconnection agreements, electricity providers should query downstream entities on factors potentially affecting digital cybersecurity such as the number of inverters envisioned to be operating. As appropriate, undertake cybersecurity codes and standards development for power system interconnection.	Medium	Electric utility industry, Government, Aggregators, and SDOs

Row	Section	Section Name	Gap #, Title & Description	R&D Needed	Recommendation	Priority	Organization(s)
28	5	Cybersecurity	Gap S6: **Cybersecurity of Power Management under DER Aggregation Scenarios.** Cybersecurity gaps exist with regard to aggregation of DERs for Grid Services and subsequent power management.	Yes	Assess cybersecurity threats resulting from the aggregation of DERs and subsequent power management within the context of grid services. Identify requirements under multiple use case scenarios, considering broad elements such as the use of telemetry and ability of aggregators to ensure security. Consider IEEE P2030.5 and FERC 2222 as a starting place for guidance. As appropriate, implement codes and standards development to mitigate risks.	Medium	Industry, Government, equipment and system developers, and SDOs
29	5	Cybersecurity	Gap S7: **Cybersecure Firmware Updates.**	Yes	There is a need for secure firmware updates for equipment and systems within the EV charging ecosystem. Signed, authenticated firmware updates are required from trusted sources. Explore industry best practices. Ford is currently developing algorithms to protect firmware updates for vehicles and to provide proof that firmware is safe to upload. Determine needs and requirements, and as appropriate, implement codes and standards development.	Medium	OEMs, EVSE manufacturers, EVSPs, and SDOs
30	5	Cybersecurity	Gap S8: **EVSE Cyber-physical Vulnerabilities.** EVSE have physical vulnerabilities that can serve as threat vectors and cascade to cybersecurity high consequence events.	Yes	Compile a thorough assessment of EVSE physical vulnerabilities and ascertain the principal threat vectors within the overarching physical design. Examples may include such items as debug ports (JTAGs), lockable cabinets, and physical issues of the cable such as broken wire and the potential to wrap and extract information. Prepare recommendations for mitigation. Conduct standards development culminating in a recommended practice addressing EVSE physical vulnerabilities.	Medium	EVSE manufacturers, national laboratories, and SDOs

Breakdown of High, Medium, and Low Priority Gaps

Note: The full text of the gaps can be found in the summary table that precedes this section with additional context regarding relevant standards and codes provided in the text in subsequent chapters. The list below simply follows the sequential order in which the gaps appear in the roadmap chapters; the ordering does not represent a hierarchy within the three priority levels.

Key:

V – Vehicle Systems (chapter 2)
C – Charging Infrastructure (chapter 3)
G – Grid Integration (chapter 4)
S – Cybersecurity (chapter 5)

Total Number of Gaps (30)

High Priority Gaps (12)

- Gap V1: Battery Safety
- Gap V2: Delayed Battery Thermal Events
- Gap V3: Safe storage of damaged lithium-ion batteries
- Gap V4*:* Packaging and transport of lithium-ion batteries as cargo on aircraft
- Gap V5*:* Design for Battery Recyclability/Materials Reclamation
- Gap C1: Megawatt Charging Systems (MCS)
- Gap C2: Static Wireless Charging
- Gap G2: Communication of standardized EV sub-metering data
- Gap G3: Standardization of EV sub-meters
- Gap S1: Comprehensive review of cybersecurity codes and standards for applicability to the EV charging ecosystem
- Gap S2: The lack of an end-to-end secure trust chain and encryption system for the EV charging ecosystem
- Gap S3: Cybersecurity and Data Privacy

Medium Priority Gaps (16)

- Gap V6*:* Battery secondary uses
- Gap C5: Power Export
- Gap C6: Cable management
- Gap C7: Fire protection in relation to EV parking/charging in/near older buildings
- Gap G1: Locating and reserving a public charging station, Obtaining Pricing and Availability
- Gap G4: Dynamic Capacity Management (DCM)
- Gap G5: Safety and Protection of DC architectures are not standardized

- Gap G6: Fault Current Signatures for AC and DC Architectures under Islanding Conditions
- Gap G7: “Ride Through” Requirements for EVSE under Grid Service Conditions
- Gap G8: DC-as-a-Service (DCaaS)
- Gap G9: Structured information and energy services exchange with utilities
- Gap S4: Robust “Security-by-Design” is needed for equipment and systems throughout the EV charging ecosystem.
- Gap S5: Digital Cybersecurity as Part of Interconnection Standards.
- Gap S6: Cybersecurity of Power Management under DER Aggregation Scenarios.
- Gap S7: Cybersecure Firmware Updates.
- Gap S8: EVSE Cyber-physical Vulnerabilities (low-medium)

Low Priority Gaps (2)

- Gap C3: Dynamic Wireless Charging
- Gap C4: Communications in Support of Wireless Power Transfer

1. Introduction

Several factors are spurring keen interest in electric vehicles ("EVs" aka "electric drive vehicles"). The United States federal government increasingly is concerned about energy independence and energy security. It has recognized the potential of EVs to help reduce reliance on fossil fuels with their attendant greenhouse gas emissions that contribute to climate change. Similarly, consumers are wanting to demonstrate their commitment to the environment by purchasing low-emission, fuel-efficient vehicles. There is also a recognition that EVs can contribute to economic growth and jobs creation in the new technologies.

In order for EVs to become ubiquitous, they must be safe, cost competitive, and otherwise satisfy user needs and expectations. A critical need is the establishment of a supporting charging infrastructure to enable vehicle recharging at home, at work, and in public locations. This infrastructure must be reliable and broadly interoperable regardless of the type of EV or charging system utilized. There is also a need for education and training of those supporting the ecosystem such as emergency first responders, vehicle technicians, charging stations installers and inspectors, authorities having jurisdiction, building owners, and consumers.

Standards, codes, and regulations, as well as conformance and training programs, all have a role to play in enabling the large-scale introduction of EVs and associated charging infrastructure.

1.1 Catalyst for this Roadmap

In furtherance of the Biden Administration's goal for a clean energy future, the U.S. Department of Energy (DOE) Office of Energy Efficiency & Renewable Energy (EERE) Vehicle Technologies Office (VTO) issued a June 2021 lab call funding opportunity announcement (FOA). The lab call included a pillar on codes and standards with the goal to "identify and address challenges and barriers to the integration of EVs@Scale charging with the grid created by uncoordinated development of codes and standards and the rapid advances in vehicle and charging technologies."

The EVs@Scale lab consortium formed in response to the FOA committed to develop a 2022 roadmap like the earlier ANSI EV standards roadmap (see section 1.2 below). Argonne National Laboratory (ANL) is the lead lab for the codes and standards pillar, supported by consortium members National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL), Idaho National Laboratory (INL), and Sandia National Laboratories (SNL).

The EV@Scale initiative supports federal and state funding associated with deploying EV charging infrastructure nationwide. Significantly, the Bipartisan Infrastructure Law (BIL) (i.e., the Infrastructure, Investment and Jobs Act, Public Law 117–58, dated November 15, 2021)[1] included two new programs with a total of $7.5 billion in dedicated funding to help make EV chargers and alternative fueling facilities

[1] Accessed 3/23/2023 https://www.congress.gov/117/plaws/publ58/PLAW-117publ58.pdf

accessible to all Americans. One of these was the National Electric Vehicle Infrastructure (NEVI) Formula Program which provides $5 billion in Federal money to develop a nationwide EV charging infrastructure. Under the BIL, the Federal Highway Administration (FHWA) was directed to release a set of minimum standards and requirements for the implementation of the NEVI program. NEVI Formula Program Guidance was issued in February 10, 2022.[2] In addition, FHWA issued a notice of proposed rulemaking (87 FR 37262) on June 22, 2022. Following disposition of the public comments, the NEVI Final Rule was issued on February 28, 2023.[3] In accordance with the BIL, the NEVI Final Rule addresses six key areas:

(1) Installation, operation, and maintenance by qualified technicians of EV infrastructure.
(2) Interoperability of EV charging infrastructure.
(3) Traffic control devices and on-premise signs acquired, installed, or operated.
(4) Data requested related to EV charging projects subject to this rule, including the content and frequency of submission of such data.
(5) Network connectivity of EV charging infrastructure.
(6) Information on publicly available EV charging infrastructure locations, pricing, real-time availability, and accessibility though mapping applications.

Key definitions and relevant portions of the NEVI Final Rule are interspersed throughout this document. For those seeking complete information, please consult the NEVI Final Rule.

In related activity, DOE's EVGrid Assist Initiative[4] is working to "provide technical assistance and inform research and development on vehicle-grid integration (VGI) to facilitate the rapid deployment of electric vehicles and the associated charging infrastructure by minimizing the impacts to the electric grid and helping electric utilities and regulators make planning and policy decisions." As part of this, DOE is working to develop a vision of the future of vehicle grid integration.

1.2 Background on ANSI EVSP

In order to assess the standards and conformance programs needed to facilitate the safe, mass deployment of EVs and charging infrastructure in the United States, the American National Standards Institute (ANSI) launched the Electric Vehicles Standards Panel ("EVSP") in March 2011. The decision to form the ANSI EVSP was made following a meeting of key stakeholders convened by ANSI in response to suggestions that the U.S. standardization community needed a more coordinated approach to keep pace

---

[2] Federal Highway Administration, National Electric Vehicle Infrastructure (NEVI) Formula Program Guidance, Accessed 3/23/2023 https://www.fhwa.dot.gov/environment/alternative_fuel_corridors/nominations/90d_nevi_formula_program_guidance.pdf

[3] Federal Highway Administration, National Electric Vehicle Infrastructure Standards and Requirements, 88 FR 12724, published 2/28/2023, effective 3/30/2023, accessed 3/5/2023 https://www.federalregister.gov/documents/2023/02/28/2023-03500/national-electric-vehicle-infrastructure-standards-and-requirements.

[4] DOE, EVGrid Assist: Accelerating the Transition, Accessed 3/23/2023 https://www.energy.gov/eere/evgrid-assist-accelerating-transition

with EV initiatives moving forward in other parts of the world. The need for improved coordination was reinforced at an April 2011 ANSI Workshop on *Standards and Codes for Electric Drive Vehicles,* convened on behalf of DOE and INL.

In April 2012, the ANSI EVSP released version 1.0 of its *Standardization Roadmap for Electric Vehicles* ("roadmap"). In May 2013, version 2.0 of the roadmap was released. In November 2014, a progress report was published on efforts to address the earlier roadmap recommendations. The roadmap was widely promoted by ANSI domestically and internationally. Activities included an eMobility standards roundtable with the European standards organizations CEN and CENELEC in Brussels in November 2012, and two technical exchanges in Beijing, China, in July 2012 and June 2015. Such efforts facilitated greater understanding of standards priorities and fostered a healthy dialogue on cooperation, harmonization and alignment of standards and regulations.

The current effort to develop this roadmap was formally launched via webinar on June 15, 2022. Since that time, working groups have been meeting virtually to develop the roadmap content.

As administrator and coordinator of the U.S. private-sector voluntary standardization system, ANSI has a successful track record serving as a neutral facilitator to convene stakeholders from the public and private sectors to define standardization needs in emerging technologies and national and global priority areas. As ANSI itself does not develop standards, the ANSI EVSP is strictly a coordinating body. The actual development of standards to support EVs, charging infrastructure, and related activities is carried about by various standards developing organizations (SDOs).

1.3 Roadmap Goals, Boundaries, and Target Audience

Building on the prior ANSI EVSP efforts, this roadmap seeks to describe the current and desired future standardization landscape that will support and facilitate EVs at scale. It identifies key safety, performance, and interoperability issues, notes relevant published and in-development standards, and makes recommendations to address gaps in codes and standards. This includes recommending pre-standardization research and development (R&D) where needed. It also includes identification of prioritized timeframes for when standardization work should occur and SDOs or other organizations that may be able to lead such work. It seeks to facilitate coordination among SDOs. Standards and conformance activities are emphasized that have direct applicability to the U.S. market for EVs and charging infrastructure. Efforts to harmonize requirements in North America and beyond are noted where relevant.

While there are many types of EVs, this roadmap's primary focus is on light duty, on-road plug-in electric vehicles (PEVs) that are recharged via a connection to the electrical grid, as well as the supporting charging infrastructure needed to power them. Medium and heavy-duty EVs are also covered, as is wireless charging.

Priority topics covered in this roadmap include standards to address high power DC charging, storage (i.e., microgrid, distributed energy resource management systems) integrated with DC charging, vehicle grid integration, high power scalable/interoperable wireless charging, and vehicle-oriented systems.

The roadmap is targeted toward a broad audience including vehicle manufacturers, entities that will be installing and operating charging infrastructure, SDOs, U.S. federal, state, and municipal government agencies, electric utilities, and others. The roadmap may assist:

- SDOs in identifying opportunities to coordinate and collaborate.
- Federal, state, and municipal governments in furthering U.S. EV policy objectives.
- Harmonization of codes and standards efforts among regional and international partners.
- Raising awareness and understanding of the issues around EVs, infrastructure, and related services.
- Stakeholders in focusing standards participation resources.
- Industry with EV technology deployment, identifying commercial opportunities, and reducing safety and economic risks.

1.4 Roadmap Structure

In order to develop this roadmap, three working groups were established to frame activities on: vehicle systems (WG1), charging infrastructure (WG2), and grid integration (WG3). While assigned to WG3, cybersecurity is a cross-cutting issue across all areas and thus has its own chapter. In general, the issues described are highly interrelated and interdependent.

The gap analysis of codes and standards is set forth in Chapters 2-5 of this document. For each topic that is addressed, there is a description of the issue(s), identification of relevant published standards and codes, as well as those in development. A "gap" is defined to mean that no *published* standard, code, regulation, policy, etc. exists that covers the particular issue in question. Where gaps are identified and described, they include an indication whether additional pre-standardization R&D is needed, a recommendation for what should be done to fill the gap, the priority for addressing the gap, and an organization(s) – for example, an SDO or research organization – that potentially could carry out the R&D and/or standards development needed based on its current scope of activity. Where more than one organization is listed, there is no significance to the order in which the organizations are listed.

Each gap is identified as being high, medium, or low priority. In terms of acting to address the priorities, the desired timeframes for having a published standard available are as follows: high priority (0-2 years), medium (2-5 years), and low (5 + years). In arriving at the priority level, consideration is supposed to be given to the criteria described in Table 1 below.

Table 1: Prioritization Matrix

Criteria (Make the C-A-S-E for the Priority Level)	**Scoring Values**
Criticality (Safety/Quality Implications). How important is the project? How urgently is a standard or guidance needed? What would be the consequences if the project were not completed or undertaken? A high score means the project is more critical.	3 - critical 2 - somewhat critical 1 - not critical
Achievability (Time to Complete). Does it make sense to do this project now, especially when considered in relation to other projects? Is the project already underway or is it a new project? A high score means there's a good probability of completing the project soon.	3 - project near completion 2 - project underway 1 - new project
Scope (Investment of Resources). Will the project require a significant investment of time/work/money? Can it be completed with the information/tools/ resources currently available? Is pre-standardization research required? A high score means the project can be completed without a significant additional investment of resources.	3 - low resource requirement 2 - medium resource requirement 1 - resource intensive
Effect (Return on Investment). What impact will the completed project have on the industry? A high score means there are significant gains for the industry by completing the project.	3 - high return 2 - medium return 1 - low return
Score Rankings **High** Priority (a score of 10-12) **Medium** Priority (a score of 7-9) **Low** Priority (a score of 4-6)	

A summary table of the gaps and recommendations and a breakdown of the gaps by priority level appear after the Executive Summary. See the full text in chapters 2-5 for more details.

The final chapter briefly describes next steps.

1.5 List of Organizations Covered in this Roadmap

The following organizations identified in this roadmap have standards, codes, protocols, guidance materials or R&D activities that are supporting EVs at scale.

1	ANSI	American National Standards Institute
2	ANCE	Asociación de Normalización y Certificación, A.C.
3	CSA	Canadian Standards Association
4	CHAdeMO	CHAdeMO Association
5	CharIN	CharIN
6	CTA	Consumer Technology Association
7	DIN	Deutsches Institut für Normung
8	Emerge Alliance	EMerge Alliance
9	eMI³	eMobility ICT Interoperability Innovation Group
10	EPRI	Electric Power Research Institute
11	EPA	Environmental Protection Agency
12	ERTICO	European Road Transport Telematics Implementation Coordination
13	ETSI	European Telecommunications Standards Institute
14	FHWA	Federal Highway Administration
15	Green Button Alliance	Green Button Alliance
16	IAEI	International Association of Electrical Inspectors
17	ICC	International Code Council
18	IEC	International Electrotechnical Commission
19	IEEE	Institute of Electrical and Electronics Engineers
20	ISO	International Organization for Standardization
21	MESA	Modular Energy Systems Architecture Standards Alliance
22	NECA	National Electrical Contractors Association
23	NEMA	National Electrical Manufacturers Association
24	NFPA	National Fire Protection Association
25	NHTSA	National Highway Traffic Safety Administration
26	NIST	National Institute of Standards and Technology
27	NMFTA	National Motor Freight Trucking Administration Inc.
28	NREL	National Renewable Energy Laboratory
29	NAESB	North American Energy Standards Board
30	OSHA	The Occupational Safety and Health Administration
31	OpenADR	OpenADR Alliance
32	OpenADE	OpenADE WG
33	OCA	Open Charge Alliance
34	OpenFMB	OpenFMB User Group
35	PHMSA	Pipeline and Hazardous Materials Safety Administration
36	SAE	SAE International
37	SEPA	Smart Electric Power Alliance
38	SunSpec	SunSpec Alliance
39	UL	UL Solutions; UL Standards & Engagement; UL Research Institutes
40	WP.29	World Forum for Harmonization of Vehicle Regulation

2. Vehicle Systems

The topical area of Vehicle Systems primarily relates to battery energy storage and related subsystems but may also include other energy storage systems, including fuel cells and mechanical energy storage. The most common types of batteries being developed for electric transportation are lithium-ion-based. Topics addressed in this section include: power rating methods; battery safety; battery testing – performance and durability; battery storage; battery packaging, transport and handling; battery recycling; battery secondary uses; and crash tests/safety.

2.1. Power Rating Methods

Power rating methods are important for electric vehicles in order to define test methods and conditions for rating the performance of electric propulsion motors as used in these vehicles, as well as thermal and battery capabilities and limitations.

Published Standards:

The following documents related to this topic have been produced by the SAE Hybrid-EV Committee:

- SAE J2907_201802, Performance Characterization of Electrified Powertrain Motor-Drive Subsystem (2018-02-12). This document was developed to provide a method of obtaining repeatable measurements that accurately reflects the performance of a propulsion electric drive subsystem, whose output is used in an electrified vehicle regardless of complexity or number of energy sources. The purpose is to provide a familiar and easy-to-understand performance rating.
- SAE J2908_202301, Vehicle Power and Rated System Power Test for Electrified Powertrains (2023-01-17). This SAE Information Report provides test methods and determination options for evaluating the maximum wheel power and rated system power of vehicles with electrified vehicle powertrains.

In addition, the following standard has been developed by ISO/TC 22/SC 37, Electrically propelled vehicles:

- ISO 20762:2018, Electrically propelled road vehicles — Determination of power for propulsion of hybrid electric vehicle (2018-08)

No standards gap has been identified with respect to this issue.

2.2. Battery Safety

For electric vehicles to meet their full potential in the marketplace, the public needs to see them as at least as safe as the vehicles they replace. Effective safety standards provide a means to ensure that electric vehicles are safe for occupants, other motorists, children, service technicians, and first responders. Safety standards mainly consist of tests, intended to duplicate real-world events. Compliance to an EV battery safety standard demonstrates that the EV battery meets minimum safety criteria established by that standard. Safety standards not only protect the public – they also help protect manufacturers from legal challenges that may arise. Vehicle manufacturers desire global harmonization of safety standards that are effective without imposing unnecessary costs or limits to innovation.

EV battery safety standards development has been identified as a priority by standards development organizations including IEC, ISO, SAE and UL, the National Highway Traffic Safety Administration (NHTSA) as the U.S. national regulatory body, and the inter-governmental body WP.29 via its EVS-IWG. As a result, a number of electric vehicle battery and related safety standards have been published or are currently under revision or development. A breakdown of this effort by organization is set forth below.

Published Standards:

IEC

Relevant documents produced by IEC TC 21, Secondary cells and batteries, include:

- IEC 62660-2: 2018, Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 2: Reliability and abuse testing (2018-12-12)
- IEC 62660-3:2022, Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 3: Safety requirements (2022-03-01)

ISO

Relevant documents produced by ISO/TC 22/SC 37, Electrically propelled vehicles, include:

- ISO 6469-1:2019[5], Electrically propelled road vehicles — Safety specifications — Part 1: Rechargeable energy storage system (RESS) (2019-04).
- ISO 6469-1:2019/Amd 1:2022, Electrically propelled road vehicles — Safety specifications — Part 1: Rechargeable energy storage system (RESS) — Amendment 1: Safety management of thermal propagation (2022-11)
- ISO 6469-2:2022, Electrically propelled road vehicles — Safety specifications — Part 2: Vehicle operational safety (2022-05)
- ISO 6469-3:2021, Electrically propelled road vehicles — Safety specifications — Part 3: Electrical safety (2021-10)
- ISO 12405-4:2018, Electrically propelled road vehicles —Test specification for lithium-ion traction battery packs and systems — Part 4: Performance testing (2018-07)

[5] Requirements for motorcycles and mopeds are specified in ISO 13063 (Parts 1-3) and ISO 18243.

NHTSA

- FMVSS 305, Electric-powered vehicles: electrolyte spillage and electrical shock protection (49 CFR § 571.305)

SAE

- SAE J1776_201401, Recommended Practice for Electric, Fuel Cell and Hybrid Electric Vehicle Crash Integrity Testing (2014-01-10), developed by the Fuel Cell Standards Committee
- SAE J2464_202108, Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing (2021-08-23), developed by the Battery Safety Standards Committee
- SAE J2929_201302, Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells (2013-02-11), developed by the Battery Safety Standards Committee
- SAE J2990_201907, Hybrid and EV First and Second Responder Recommended Practice (2019-07-29), developed by the Hybrid - EV Committee
- SAE J2990/2_202011, Hybrid and Electric Vehicle Safety Systems Information Report (2020-11-04), developed by the Hybrid - EV Committee
- SAE J3073_201605, Battery Thermal Management (2016-05-10), developed by the Battery Thermal Management Committee

UL

- UL 2580, Edition 3, March 11, 2020, Batteries for Use in Electric Vehicles
- UL 2596, Edition 1, January 27, 2022, Test Method for Thermal and Mechanical Performance of Battery Enclosure Materials

In-Development Standards and Regulations:

NHTSA

According to NHTSA's battery safety initiative, NHTSA chaired the development of the Global Technical Regulation (GTR) for Electric Vehicle Safety (EVS)[6], which was established under the United Nations (UN) World Forum for the Harmonization of Vehicle Regulations (WP.29) in 2018. The GTR contains requirements for in-use operational safety, post-crash electrical safety, and battery fire safety.

NHTSA continues to advance electric vehicle and battery safety by chairing the development of the second phase of work currently underway at the UN. The activity is considering, among other things,

[6] The ECE/TRANS/180/Add.20, Addendum 20: Global Technical Regulation No. 20, "Global Technical Regulation on the Electric Vehicle Safety (EVS)" was established in the Global Registry on 14 March 2018.

safety issues related to battery thermal runaway, water immersion, and vibration resistance.

SAE

- SAE J2929, Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells (2022-03-03)

Gap V1: Battery safety. There is an ongoing need to address safety issues related to battery thermal runaway, water immersion, and vibration resistance.

R&D Needed: No

Recommendation: Continue to advance battery safety through NHTSA's participation in the development of Phase 2 of Global Technical Regulation No. 20 for Electric Vehicle Safety

Priority: High

Organization: NHTSA, WP.29

2.2.1. Functional safety in the charging system

The ISO 26262 series of standards are a set of key automotive umbrella standards developed by ISO/TC 22/SC 32, Electrical and electronic components and general system aspects, that provide a framework for functional safety. They cover safety-related systems that include one or more electrical and/or electronic (E/E) systems and that are installed in series production road vehicles, excluding mopeds. They address possible hazards caused by malfunctioning behavior of safety-related E/E systems, including interaction of these systems. They do not address hazards related to electric shock, fire, smoke, heat, radiation, toxicity, flammability, reactivity, corrosion, release of energy and similar hazards, unless directly caused by malfunctioning behavior of safety-related E/E systems. ISO 26262-10:2018, Road vehicles — Functional safety — Part 10: Guidelines on ISO 26262 (2018-12) is an informative document that provides an overview of the ISO 26262 series.

No standards gap has been identified.

2.2.2. Delayed battery thermal events

All of the current tested failure modes of battery systems can be classed as "real time" with regard to outcome. If a Hazard Severity Level (HSL, defined in SAE J2464) of greater than 2 happens, it is assumed that it happens within minutes or a few hours at most. It is now known that some faults that can create HSL 2 or higher events may not surface for days or even weeks after damage or a defect exists. This possibility introduces a new hazard potential that could surface at a later time unless expediently dealt with in a safe manner. Some of these scenarios are easily recognized and dealt with such as in vehicle accidents and with faulty chargers or battery management systems. Scenarios that are less obvious or detectable are internal partial pack circulating currents that may escalate over time to dangerous thermal states. Stray currents occurring in sub sections of a pack that are intermediate in value between zero and hard shorts can evolve and generate excessive temperatures.

Published Standards:

- SAE J2464_202108, Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing (2021-08-23)
- SAE J2929_201302, Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells (2013-02-11)
- SAE J2990_201907, Hybrid and EV First and Second Responder Recommended Practice (2019-07-29)
- SAE J3073_201605, Battery Thermal Management (2016-05-10)

In Development Standards

- SAE J2929, Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells, revision initiated 2022-03-03, with a planned release of 2024-02-28, which will add additional requirements for risk mitigation during the concept and design phase, with the following objectives:
    - Mitigation of safety (not quality) risk of battery pack within the electric vehicle context
    - The overall safety risk of the failure and defect effect consequences will be described in ISO 26262 terminology (the delay of the thermal events does not result in any significant risk mitigation effect, as the EV location during a thermal event has a higher impact on the severity than the presence of a driver or the moving state of the vehicle, e.g., parked car in integrated parking structure or tunnel)
    - Support the identification of possible failure effects (like "generate excessive temperatures" on pack level), the failure modes (on material, interface, connected system elements, cell level) and root causes
    - Emphasize requirements for battery cell and pack monitoring concepts as part of the EV battery safety concept (the identification of the effect will be too late; the latent failure mode and root cause need to be detected)
    - The testing requirements will also address the resilience of the battery pack in case of a cell defect of EUCAR L4+ to enable a prewarning time which is already requested in existing regulations (see GTR No. 20 and ref. documents)
    - EUCAR will be referenced as a rating scale for battery cell level, while recognizing today's data, which shows: a cell fire (EUCAR L5) in some cases can lead to the same or more severe failure and defect effect consequences than cell rupture (EUCAR L6) integrated in a battery pack.

Gap V2: Delayed battery thermal events. The issue of delayed battery thermal events needs to be addressed.

R&D Needed: Yes

Recommendation: Address the issue of delayed battery thermal events in future rulemaking and/or revisions of SAE J2929 and J2990.

Priority: High

Organization: NHTSA, SAE

2.2.3. Electric Vehicle Emergency Shut Off – High Voltage Batteries, Power Cables, Disconnect Devices; Fire Suppression, Fire Fighting Tactics and Personal Protective Equipment

Emergency responders need to be able to quickly and easily identify high voltage EV batteries and power cables, disable high voltage systems, and otherwise safely manage emergency events involving electric vehicles. Clear safety markings and procedures on how to shut off power to an EV following an incident would help to protect the safety of emergency responders, law enforcement, tow operators, and vehicle occupants from electrical shock hazards during passenger extrication and post-crash vehicle movement and servicing. Best practices for fire suppression, firefighting tactics and personal protective equipment are also necessary to ensure safety.

High voltage cabling in EVs is unlikely to become standardized in terms of location or routing. The routing of EV cables is documented in shop manuals and ERGs. It is important that OEMs specify in their ERGs the location of EV battery and disconnect devices and proper procedures/sequencing to shut off power to the vehicle, and provide the same data to other ERG developers.

The National Fire Protection Association (NFPA) has developed alternative fuel vehicle safety (online) training for first responders.

Published Standards:

- NFPA 1971, Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting (2018 Edition)
- NFPA 1951, Standard on Protective Ensembles for Technical Rescue Incidents (2020 Edition)
- NFPA 1999, Standard on Protective Clothing and Ensembles for Emergency Medical Operations (2018 Edition)
- SAE J2990_201907, Hybrid and EV First and Second Responder Recommended Practice (2019-07-29)
- SAE J3108_201703, xEV Labels to Assist First and Second Responders, and Others (2017-03-02)

No in development standards or standards gap have been identified.

See also section 3.2.1.7 on Labeling of EVSE and Load Management Disconnects for Emergency Situations.

2.2.4. Micromobility and Light Electric Vehicles (LEV)

Micromobility is a transportation alternative receiving increased attention, especially in cities where the use of bikeshare and scooter sharing programs has become more prevalent. The Federal Highway Administration (FHWA) defines micromobility as follows:

> Building upon the Society of Automotive Engineers International's *Taxonomy and Classification of Powered Micromobility Vehicles*, the Federal Highway Administration broadly defines micromobility as any small, low-speed, human- or electric-powered transportation device, including bicycles, scooters, electric-assist bicycles, electric scooters (e-scooters), and other small, lightweight, wheeled conveyances. Other definitions of micromobility focus primarily on powered micromobility devices and characterize these devices as partially or fully motorized, low-speed (typically less than 30 miles [48 kilometers] per hour), and small size (typically less than 500 pounds [230 kilograms] and less than 3 feet [1 meter] wide).[7]

While no standards gap has been identified, the New York Times has reported on fire hazards associated with lithium-ion batteries for e-bikes, scooters, and hoverboards that are charged in apartment buildings that do not have sprinkler systems and that are not certified to industry safety standards.[8] Often, this issue arises with batteries or chargers that are old, damaged, malfunctioning, or mismatched.

In response to these developments, on March 2, 2023, the New York City Council passed legislation that would prohibit the sale of batteries, e-scooters, and e-bikes, if they do not meet industry standards UL 2271 (batteries for LEVs), UL 2272 (personal e-mobility devices), and UL 2849 (electrical systems for e-bikes).[9] More information on these standards can be found below. The legislation will become effective 180 days after it is signed by the NYC mayor.

---

[7] Price, Jeff, et al., Federal Highway Administration. "Micromobility: A Travel Mode Innovation," Spring 2021. Accessed March 5, 2023 https://highways.dot.gov/public-roads/spring-2021/02

[8] The New York Times Newsletter New York Today, "The Scooter Battery Peril Worries the Fire Department," published December 1, 2022. Accessed March 5, 2023 https://www.nytimes.com/2022/12/01/nyregion/lithium-ion-batteries-fires.html

[9] Yobi, Dean. Bicycle Retailer. "NY City Council passes lithium-ion battery safety package," published March 2, 2023. Accessed March 5, 2023 https://www.bicycleretailer.com/industry-news/2023/03/02/ny-city-council-passes-lithium-ion-battery-safety-package#.ZASgA3bMI2x

ANSI/CAN/UL/ULC 2271:2018 defines LEV as follows:

6.22 LIGHT ELECTRIC VEHICLE (LEV) – A light duty on-road or off-road vehicle that uses electricity as its source of energy for motive power. With the exception of motorcycles, an on-road LEV is typically not considered suitable for use on highway systems. The following are considered LEVs:

a) Electric bicycles;
b) Electric scooters and motorcycles;
c) Electric wheel chairs;
d) Golf carts;
e) All-terrain vehicles;
f) Non-ride-on industrial material handling equipment;
g) Ride-on floor care machines and lawnmowers; and
h) Personal mobility devices.

Published Standards:

ANSI/CAN/UL/ULC 2271:2018, Edition 2, Batteries for Use in Light Electric Vehicle (LEV) Applications (September 7, 2018).

1.1 These requirements cover electrical energy storage assemblies (EESAs) such as battery packs and combination battery pack-electrochemical capacitor assemblies and the subassembly/modules that make up these assemblies for use in light electric-powered vehicles (LEVs) as defined in this standard.

1.2 This standard does not evaluate the performance or reliability of these devices.

1.3 This standard does not include requirements for the evaluation of EESAs intended for use in electric vehicles, such as on-road passenger vehicles intended for use on public roadways including highways and heavy-duty off-road vehicles such as battery powered ride-on industrial trucks, which are covered under the Standard for Batteries for Use in Electric Vehicles, UL 2580 / CAN/ULC-S2580.

1.4 This standard does not include requirements for evaluation of EESAs intended for use in light electric rail (LER) applications, which are covered under the Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and LER Applications, UL 1973.

ANSI/CAN/UL 2272:2019, Edition 1, Electrical Systems for Personal E-Mobility Devices (February 25, 2019).

1.1 These requirements cover the electrical drive train system including the battery system, other circuitry and electrical components for electric powered scooters and other devices to be referred to as personal e-mobility devices as defined in this standard.

1.2 This standard is intended for evaluation of the safety of the electrical drive train system and battery and charger combination for energy and electrical shock hazards and does not evaluate the performance or reliability of these devices. In addition, it does not evaluate the physical hazards that may be associated with the use of personal e-mobility devices.

ANSI/UL/CAN 2849:2022A, Edition 1, Electrical Systems for eBikes (June 17, 2022).

1.1 This Standard covers the electrical system of eBikes powered by a lithium-based, rechargeable battery. eBikes include both Electrically Power Assisted Cycle (EPAC – pedal assist) and non-pedal assist eBikes.
1.2 Electrical systems as referenced in 1, may include onboard components and off board components of eBikes. As a minimum, the electrical system consists of the drive unit, battery, battery management system (BMS), interconnecting wiring, and power inlet. Any additional components or systems required to demonstrate compliance are included based on the overall system application and risk.
1.3 Off board components include dedicated chargers for charging batteries that are removed from the eBike during charging or dedicated chargers for charging batteries that are in place on the eBike during charging.
1.4 This Standard does not cover the mechanical structure of the eBike unless specified otherwise.

SAE J3194_201911, Taxonomy and Classification of Powered Micromobility Vehicles (2019-11-20)

No in development standards or standards gap have been identified.

2.2.5. Electric Mopeds and Motorcycles

Electric mopeds and motorcycles are called out in some of the standards work.

Published Standards:

- ANSI/CAN/UL/ULC 2271:2018, Edition 2, Batteries for Use in Light Electric Vehicle (LEV) Applications (September 7, 2018).

The following published standards were developed in ISO/TC 22/SC 38, Motorcycles and Mopeds:

- ISO/TR 13062:2015, Electric mopeds and motorcycles – Terminology and classification (2015-11)
- ISO 13063-1:2022, Electrically propelled mopeds and motorcycles — Safety specifications — Part 1: On-board rechargeable energy storage system (RESS) (2022-07)
- ISO 13063-2:2022, Electrically propelled mopeds and motorcycles — Safety specifications — Part 2: Vehicle operational safety (2022-07)
- ISO 13063-3:2022, Electrically propelled mopeds and motorcycles — Safety specifications — Part 3: Electrical safety (2022-07)
- ISO 13064-1:2012, Battery-electric mopeds and motorcycles — Performance — Part 1: Reference energy consumption and range (2012-09) was reaffirmed in 2018.
- ISO 13064-2:2012, Battery-electric mopeds and motorcycles — Performance — Part 2: Road operating characteristics (2012-09) was reaffirmed in 2018.

- ISO 18243:2017, Electrically propelled mopeds and motorcycles — Test specifications and safety requirements for lithium-ion battery systems (2017-04)

No in development standards or standards gap have been identified.

2.3. Battery Testing – Performance and Durability

Battery performance and durability testing incorporates a means to evaluate both the performance and durability of cells, modules and full battery packs, as well as the battery management system.

Published Standards:

IEC

Relevant standards developed by IEC TC 21 – Secondary cells and batteries include:

- IEC 62660-1:2018 – Secondary lithium-ion cells for the propulsion of electric road vehicles – Part 1: Performance testing (2018-12-12)
- IEC 62660-2: 2018 – Secondary lithium-ion cells for the propulsion of electric road vehicles – Part 2: Reliability and abuse testing (2018-12-12)

ISO

Relevant standards developed by ISO/TC 22/SC 37, Electrically propelled vehicles include:

- ISO 12405-4:2018, Electrically propelled road vehicles —Test specification for lithium-ion traction battery packs and systems — Part 4: Performance testing (2018-07)

SAE

Relevant standards developed by the SAE Battery Standards Testing Committee are listed in the table below.

- J1798/1_202008, Recommended Practice for Performance Rating of Lead Acid and Nickel Metal Hydride Electric Vehicle Battery Modules (2020-08-03)
- J1798_201911, Recommended Practice for Performance Rating of Electric Vehicle Battery Modules (2019-11-13)
- J2288_202011, Life Cycle Testing of Electric Vehicle Battery Modules (2020-11-30)
- J2289_202108, Electric-Drive Battery Pack System: Functional Guidelines (2021-08-03)
- J2380_202112, Vibration Testing of Electric Vehicle Batteries (2021-12-21)
- J2758_201812, Determination of the Maximum Available Power from a Rechargeable Energy Storage System on a Hybrid Electric Vehicle (2018-12-10)
- J3220_202301, Lithium-Ion Cell Performance Testing (2023-01-13)

UL

- UL 2580, Edition 3, March 11, 2020, Batteries for Use in Electric Vehicles

In Development Standards

SAE

- J1798/2, Performance Rating of Lithium Ion Electric Vehicle Battery Modules (2019-02-07)
- J3277, Liquid Leak Tightness Evaluation Methodology for EV Battery Packs Informational Report (2022-03-22)
- J3277/1, Liquid Leak Tightness Standards for EV Battery Packs Recommended Practice (2022-03-28)

OEMs have proprietary methods for assessing battery durability and state of health. This is more a warranty issue. No standards gap has been identified.

2.4. Battery Storage

EV Batteries will require storage throughout many stages of their life cycle, namely – prior to market distribution by manufacturers, in import/export locations, logistic centers, in repair workshops as well as garages following accidents, on the street following natural disasters, at recovered vehicle storage lots, at auto salvage yards, and at the end-of-life in recycling facilities. Traceability and life cycle management are important. Differentiation between new and waste batteries (damaged, aged, sent for repair, end-of-life) batteries is also significant. The risk of a stored battery must be evaluated based on several parameters, including, but not limited to, state of charge (SOC), mechanical wholeness, and age of the battery.

Battery storage issues of concern include: high temperature controls, humidity control including adequate air circulation and ventilation to prevent explosive gas atmospheres (especially significant for damaged batteries), hydrogen/oxygen detection, storage of damaged batteries away from other batteries and combustible materials, and fire prevention and extinguishing systems. Research is going on to address these issues.

Battery storage concerns may vary depending on the stage of a battery's lifecycle such as:

- Pre and during new vehicle assembly
- In service battery assembly (the vehicle is in normal use)
- Separated from vehicle for service purpose, e.g., battery pack replaced
- Crash damage where the entire vehicle has to be stored for a period of time

Published Standards, etc.

The following standards, code provisions and regulations relate to safety aspects of battery storage:

- IEC 60068, Environmental testing. Part 1: General and guidance (2013-10-07), provides guidance regarding testing of equipment such as batteries under different environmental conditions, which it expects to be exposed to during storage and operations.
- NFPA 1, Fire Code (2018 Edition), Chapter 52 covers stationary battery installations, which would come into play where batteries are used in a fixed energy storage facility.
- NFPA 13, Standard for the Installation of Sprinkler Systems (2022 Edition), addresses fire protection of storage occupancies.
- NFPA 30A, Standard for Motor Fuel Dispensing Facilities and Repair Garages (2021 Edition), covers fire protection requirements for fueling and service stations including service garages.
- NFPA 70®, the National Electrical Code® (2023 Edition), Article 480, Storage Batteries, covers the installation of electrical conductors, equipment, and raceways; signaling and communications conductors, equipment, and raceways; and optical fiber cables and raceways.
- NFPA 855, Standard for the Installation of Stationary Energy Storage Systems (2023 Edition). This standard applies to the design, construction, installation, commissioning, operation, maintenance, and decommissioning of stationary energy storage systems (ESS), including mobile and portable ESS installed in a stationary situation and the storage of lithium metal or lithium-ion batteries.
- SAE J2950_202006, Recommended Practices for Shipping Transport and Handling of Automotive-type Battery System – Lithium Ion (2020-06-09)
- SAE J2990_201907, Hybrid and EV First and Second Responder Recommended Practice (2019-07-29)
- OSHA 1910.305(j)(7), storage batteries, where provisions shall be made for sufficient diffusion and ventilation of gases from storage batteries to prevent the accumulation of explosive mixtures.
- NFPA's Fire Protection Research Foundation has done research looking at fire suppression techniques related to burning of EV batteries.

In Development Standards

- ICC publishes the International Fire Code® (IFC®) and International Building Code® (IBC®). While the 2021 IFC is generally silent on storage requirements associated with lithium batteries, amendments adopted by ICC for incorporation into the 2024 IFC and IBC will place new storage requirements on lithium batteries.[10]

In-Development Standards:

- SAE J3235 Best-Practice for Storage of Lithium-Ion Batteries (2023-03-20)

[10] PRBA, The Rechargeable Battery Association, "Lithium Batteries and Fire Codes" and George Kerchner Presentation "New Storage Requirements for Lithium Batteries in International Fire Code," Accessed 2/14/2023 https://www.prba.org/areas-of-focus/fire-codes/

<u>Gap V3</u>: Safe storage of lithium-ion batteries. No standards or guides have been identified that address the safe storage of damaged (i.e., unknown condition) lithium-ion batteries, whether at warehouses, repair garages, recovered vehicle storage lots, or auto salvage yards.

<u>R&D Needed</u>: Yes. On combinations of failure modes.

<u>Recommendation</u>: A standard or guide for the safe storage practices for EV batteries must be developed, addressing damaged batteries and the wide range of storage situations that may exist, including when the batteries have been separated from their host vehicle.

<u>Priority</u>: High

<u>Organization</u>: SAE, NFPA, ICC, IEC

2.5. Battery Packaging, Transport, and Handling

Three significant use cases exist with respect to battery packaging, transport and handling:

- Battery packaging and design for the transportation between the battery manufacturer and the vehicle manufacturer;
- Battery packaging and design for battery transportation to workshops; and
- Battery packaging for the transportation of used and damaged batteries.

Transport by ground, air and sea of EV batteries presents a unique risk to their supply chain handlers, as their weight and volume are significantly higher than common consumer batteries. This risk grows further when handling aged and damaged batteries. For example, there may be needed packaging for a damaged or deformed battery to account for possible leakage of materials.

Published Standards, Regulations, etc.

The United Nations (UN) specifically classifies lithium-ion batteries as part of its model regulations on the transport of dangerous goods. Thus, transportation of *new* batteries is covered by the International Air Transport Association (IATA), International Civil Aviation Organization (ICAO), International Maritime Organization (IMO), and local transportation regulations in countries of import/export, based on the appropriate UN number:

- UN3090, Lithium Metal Batteries (including lithium alloy batteries);
- UN3091, Lithium Metal Batteries Contained in Equipment (including lithium alloy batteries) or Lithium Metal Batteries Packed with Equipment (including lithium alloy batteries);
- UN3480, Lithium Ion Batteries (including lithium-ion polymer batteries); and
- UN3481, Lithium Ion Batteries Contained in Equipment (including lithium-ion polymer batteries) or Lithium-ion Batteries Packed with Equipment (including lithium-ion polymer batteries).

UN recommendations (Manual of Tests and Criteria[11], section 38) also cover packaging limitations to ensure proper containment against pressure and temperature changes, mechanical drops, etc. Packaging, storage, and transportation requirements are outlined in 49 CFR § 173.185 - Lithium cells and batteries. With respect to *damaged, defective, or recalled cells or batteries*, it specifies that:

> Lithium cells or batteries that have been damaged or identified by the manufacturer as being defective for safety reasons, that have the potential of producing a dangerous evolution of heat, fire, or short circuit (*e.g.,* those being returned to the manufacturer for safety reasons) may be transported by highway, rail or vessel only. . . ." It goes on to specify packaging requirements in such cases.

The U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) has developed a compliance resource to assist shippers to safely package lithium cells and batteries for transport by all modes.

- HM2150, Lithium battery guide for shippers (September 2021)

Existing consensus standards include the following:

- IEC 62281:2019+AMD1:2021+AMD2:2023 CSV Consolidated Version, Safety of primary and secondary lithium cells and batteries during transport (2023-02-24)
- SAE J1797, Recommended Practice for Packaging of Electric Vehicle Battery Modules (2016-08-02), published in 2008 and stabilized in August 2016. This Recommended Practice provides for common battery designs through the description of dimensions, termination, retention, venting system, and other features required in an electric vehicle application.
- SAE J2950_202006, Recommended Practices for Shipping Transport and Handling of Automotive-type Battery System – Lithium Ion (2020-06-09)
- SAE J2990_201907, Hybrid and EV First and Second Responder Recommended Practice (2019-07-29)
- SAE J3235 Best-Practice for Storage of Lithium-Ion Batteries (2023-03-20) developed by the Battery Transportation Committee

In Development Standards:

Under SAE G27, Lithium Battery Packaging Performance, the following standards are in development:

- AIR6840, Recommendations and Background Material for Battery Package Testing (2020-11-04)

[11] United Nations, "Manual of Tests and Criteria," published revised Edition 7 (2019) and amendment 1 (2021). Accessed March 22, 2023. https://unece.org/sites/default/files/2021-09/ST-SG-AC10-11-Rev7-Amend1e_WEB.pdf

- AS6413, Performance based packaging standard for lithium batteries as cargo on aircraft (2016-03-18)
- AS6413/1, Performance based package standard for lithium batteries as cargo on aircraft - Oven Test (2020-09-01)
- AS6413/2, Performance based package standard for lithium batteries as cargo on aircraft - Direct Flame Test (2020-09-01)

Gap V4: Packaging and transport of lithium-ion batteries. Standards are being developed on battery package testing and performance-based packaging for lithium batteries as cargo on aircraft.

R&D Needed: No

Recommendation: Complete work on SAE standards in development on battery package testing and performance-based packaging for lithium batteries as cargo on aircraft.

Priority: High

Organization: SAE

2.6. Battery Recycling/Materials Reclamation

Battery end-of-life, either through damage beyond repair or full exhaustion following use, requires special consideration from the environmental, geo-political, and economical points of view. As electric vehicle battery manufacturing relies on natural minerals mining, and improper disposal may potentially result in soil, groundwater and air pollution, the need for technology allowing for efficient battery recycling is fast growing. Lead-acid batteries, by comparison, have reached nearly 100% recycling rates worldwide.

Lithium-based batteries are expected to be the main chemistry for the foreseeable future. Positive value for recycling these batteries is likely to be through the nickel and cobalt components, as the lithium itself is a small fraction of the battery, and rather inexpensive. Additional challenges stem from the fact that many battery chemistries exist with different lithium combinations and pack geometries. The challenge has been offset by the value of the recovered materials which is why industry is developing industrial-scale precise recycling processes with high recovery rates and efficiency. Additionally, not all battery chemistries may have a value (e.g., iron phosphate).

Published Standards:

The following standards have been developed by the SAE Battery Standards Recycling Committee:

- SAE J2974_201902, Technical Information Report on Automotive Battery Recycling (2019-02-11)
- SAE J2984_202109, Chemical Identification of Transportation Batteries for Recycling (2021-09-10)

- SAE J3071_201604, Automotive Battery Recycling Identification and Cross Contamination Prevention (2016-04-05)

In-Development Standards:

The following standards are in development by ISO/TC 22/SC 37, Electrically propelled vehicles:

- ISO/AWI 18006-2, Electrically propelled road vehicles — Battery information — Part 2: End of life

Gap V5: Design for Battery Recyclability/Materials Reclamation. No standards gap has been identified with respect to battery recycling. However, there is a need for additional R&D on design for recyclability, as batteries are getting less conducive to recycling. **R&D Needed**: Yes, as noted. **Recommendation**: Additional R&D is needed by the national labs on design for recyclability of EV (li-on) batteries. This could include addressing the calculation method toward recycling efficiency and recovery rates based on an agreed unit (possibly weight) and/or life-cycle assessment tools, including energy recovery. Recycling is important to reduce the amount of materials to be mined, because the processing of lithium ion produces toxic biproducts. **Priority:** High **Organization:** national labs, SAE, ISO

2.7. Battery Secondary Uses

A secondary life for both fixed and removable electric vehicle batteries may include re-use for other vehicular applications and grid and low-power applications. This can include fulfilling different grid functionalities including storing energy and helping to stabilize grids utilizing renewable energy.

Some possible battery second life applications include:

- Re-use or repackaging of modules or packs with testing for compatibility in vehicle applications;
- Re-use for lower power applications especially DC and home to grid and vehicle to grid, etc.;
- Re-use in industrial situations utilizing DC energy for manufacturing with low voltage use and storage;
- Re-use with alternative power in small farm or school type uses, and as battery backup and stable power source;
- Re-use with alternative power in medium factory or building uses, and as battery backup and stable power source;
- Re-use for peak shaving EV charging;
- Re-use for grid support, line balancing and backup stabilization.

The secondary use market for EV batteries has the potential to lower the cost of electro-mobility and enhance environmental protection through materials retention, re-use, and extended battery pack life, leading to value chain enhancements.

In December 2022, the European Parliament approved a "battery passport" regulation. To track provenance and chain of custody, Europe plans to have a label or QR code that will be a unique identifier for each battery and that will be linked to a database. All batteries listed in the European market with a capacity over 2kWh will be required to have this.

The U.S. Department of Energy (DOE) Vehicle Technologies Office will be developing a plan for a similar program in the United States. DOE will likely carry over some but not all of the European requirements. DOE is expected to initiate work on this in the April 2023 timeframe. SAE International is planning to form a group to interface with the DOE activity as it moves forward.

Additionally, California is going to require state-of-health information on the battery. There will also likely be some focus on diagnostics of battery packs.

Published Standards:

- SAE J2950_202006, Recommended Practices for Shipping Transport and Handling of Automotive-Type Battery System - Lithium Ion (2020-06-09)
- UL 1973, Edition 3, February 25, 2022, ANSI/CAN/UL Batteries for Use in Stationary and Motive Auxiliary Power Applications
- UL 1974, Edition 1, October 25, 2018 ANSI/CAN/UL Standard for Evaluation for Repurposing Batteries

In-Development Standards:

- SAE J2997, Standards for Battery secondary use (2012-02-15). This work item in progress, registered in 2012, ran into concerns over liability of using batteries in a non-vehicle context. A white paper internal to the committee at present may eventually be published.

<u>Gap V6</u>: Battery secondary uses. There is a need for standards to address battery second life applications for grid storage and other uses.

<u>R&D Needed</u>: Yes, on a ledger or lifetime tracking register, in the cloud or on the device, that shows the history of the battery.

<u>Recommendation</u>: Explore the development of standards for battery secondary uses, addressing such issues as safety and performance testing for intended applications, grid connection/communication interfaces, identification of parts/components that can be removed from the pack without destroying it, etc.

<u>Priority</u>: Medium

<u>Organization</u>: SAE, UL

2.8. Crash Tests/Safety

To be sold in the U.S., electric vehicles must comply with all applicable Federal Motor Vehicle Safety Standards (FMVSS). These include crash avoidance standards, crashworthiness standards, post-crash safety standards, and others. The FMVSS are enforced by NHTSA, which routinely conducts compliance testing to ensure that the vehicles certified for sale in the U.S. comply with all of the applicable requirements. Vehicles that are noncompliant or vehicles that possess a safety defect are subject to NHTSA's recall and remedy provisions of the Motor Vehicle Safety Act.

<u>FMVSS 305</u>

The only federal motor vehicle safety standard that is unique to electric vehicles is: FMVSS 305, Electric-powered vehicles: electrolyte spillage and electrical shock protection (49 CFR § 571.305). FMVSS 305 is intended to provide manufacturers greater flexibility, requiring them to design electrically-powered vehicles so that, in the event of a crash, the electrical energy storage, conversion, and traction systems are either electrically isolated from the vehicle's chassis or their voltage is below specified levels considered safe from electric shock hazards. The standard was last amended in 2019 to allow high voltage connectors that require the use of a tool to separate from their mating component.

Since the physiological impacts of direct current (DC) are less than those of alternating current (AC), the standard specifies lower electrical isolation requirements for certain DC components (100 ohms/volt) than for AC components (500 ohms/volt). Rulemakings have resulted in the introduction of new definitions, changes to existing definitions, changes to the energy storage/conversion device retention requirements, the introduction of a low voltage option for achieving electrical safety, and a requirement for monitoring the isolation resistance of DC high voltage sources that comply with the 100 ohms/volt electrical isolation requirement. FMVSS 305 applies to passenger cars, multi-purpose vehicles (MPVs), trucks, and buses that have a gross vehicle weight rating (GVWR) of 4,536 kg or less, that use electrical components with working voltages more than 60 volts direct current (VDC) or 30 volts alternating current (VAC), and whose speed attainable over a distance of 1.6 km on a paved level surface is more than 40 km/h.

Published Standards:

The following standard was developed by the SAE Impact and Rollover Test Procedures Standards Committee:

- SAE J3040_202201, Electric Vehicle (E-Vehicle) Crash Test Lab Safety Guidelines (2022-01-20). This SAE Information Report provides guidance on special risks associated with conducting crash tests on E-vehicles from: (1) thermal activity inside the battery (resulting from electrical or mechanical abuse) that may lead to energetic emission of harmful and/or flammable gases, thermal runaway, and potentially fire; and (2) the risk of electrocution.

The following standard was developed by ISO/TC 22/SC 37, Electrically propelled vehicles:

- ISO 6469-4:2015, Electrically propelled road vehicles — Safety specifications — Part 4: Post crash electrical safety (2015-09) was reconfirmed in 2021.

NFPA's Fire Protection Research Foundation has done research looking at questions related to burning of EV batteries and recommendations for suppression efforts. As batteries are getting larger, the out-gassing issue in post-crash scenarios is getting worse.

No in development standards and no standards gap have been identified with respect to this issue.

[this page intentionally left blank]

3. Charging Infrastructure

3.1. Charging Systems

In order to promote the development, acceptance and deployment of EVs, and to discourage the imposition of market barriers, it is imperative that plugs, chargers and EVs be interoperable. EV owners must be able to easily recharge their vehicle at their home or office and when traveling long distances within their own state and across state lines. Harmonized standards that assure the interoperability of EVs with the charging infrastructure will do much to help grow the market for EVs, and thus will be in the best interest of EV and EVSE manufacturers, as well as EV users.

Some though not all of the terms found in section **680.104, Definitions,** of the NEVI Final Rule[12] are reproduced below. The terms selected are ones that are specifically relevant to the discussion that follows in the charging infrastructure and grid interaction sections of the roadmap.

AC Level 2 means a charger that operates on a circuit from 208 volts to 240 volts and transfers alternating-current (AC) electricity to a device in an EV that converts alternating current to direct current to recharge an EV battery.[13]

CHAdeMO means a type of protocol for a charging connector interface between an EV and a charger (see *www.chademo.com*). It specifies the physical, electrical, and communication requirements of the connector and mating vehicle inlet for direct-current (DC) fast charging. It is an abbreviation of "charge de move", equivalent to "charge for moving."

Charger means a device with one or more charging ports and connectors for charging EVs. Also referred to as Electric Vehicle Supply Equipment (EVSE).

Charging Network means a collection of chargers located on one or more property(ies) that are connected via digital communications to manage the facilitation of payment, the facilitation of electrical charging, and any related data requests.

Charging Network Provider means the entity that operates the digital communication network that remotely manages the chargers. Charging network providers may also serve as charging station operators and/or manufacture chargers.

[12] Federal Highway Administration, National Electric Vehicle Infrastructure Standards and Requirements, 88 FR 12724, published 2/28/23, effective 3/30/23, accessed 3/5/23 https://www.federalregister.gov/documents/2023/02/28/2023-03500/national-electric-vehicle-infrastructure-standards-and-requirements.

[13] https://www.federalregister.gov/d/2023-03500/p-328

Charging Port means the system within a charger that charges one EV. A charging port may have multiple connectors, but it can provide power to charge only one EV through one connector at a time.

Charging Station means the area in the immediate vicinity of a group of chargers and includes the chargers, supporting equipment, parking areas adjacent to the chargers, and lanes for vehicle ingress and egress. A charging station could comprise only part of the property on which it is located.

Charging Station Operator means the entity that owns the chargers and supporting equipment and facilities at one or more charging stations. Although this entity may delegate responsibility for certain aspects of charging station operation and maintenance to subcontractors, this entity retains responsibility for operation and maintenance of chargers and supporting equipment and facilities. In some cases, the charging station operator and the charging network provider are the same entity.

Combined Charging System (CCS) means a standard connector interface that allows direct current fast chargers to connect to, communicate with, and charge EVs.

Connector means the device that attaches an EV to a charging port in order to transfer electricity.

Direct Current Fast Charger (DCFC) means a charger that enables rapid charging by delivering direct-current (DC) electricity directly to an EV's battery.

Distributed Energy Resource means small, modular, energy generation and storage technologies that provide electric capacity or energy where it is needed.

Electric Vehicle (EV) means a motor vehicle that is either partially or fully powered on electric power received from an external power source. For the purposes of this regulation, this definition does not include golf carts, electric bicycles, or other micromobility devices.

Electric Vehicle Infrastructure Training Program (EVITP) refers to a comprehensive training program for the installation of electric vehicle supply equipment. For more information, refer to https://evitp.org/.

Electric Vehicle Supply Equipment (EVSE) See definition of a charger.

Open Charge Point Interface (OCPI) means an open-source communication protocol that governs the communication among multiple charging networks, other communication networks, and software applications to provide information and services for EV drivers.

Open Charge Point Protocol (OCPP) means an open-source communication protocol that governs the communication between chargers and the charging networks that remotely manage the chargers.

Plug and Charge means a method of initiating charging, whereby an EV charging customer plugs a connector into their vehicle and their identity is authenticated through digital certificates defined by ISO-15118, a charging session initiates, and a payment is transacted automatically, without any other customer actions required at the point of use.

Power Sharing means dynamically limiting the charging power output of individual charging ports at the same charging station to ensure that the sum total power output to all EVs concurrently charging remains below a maximum power threshold. This is also called automated load management.

Smart Charge Management means controlling the amount of power dispensed by chargers to EVs to meet customers' charging needs while also responding to external power demand or pricing signals to provide load management, resilience, or other benefits to the electric grid.

The following standards also provide definitions of key terms:

- NECA 413-2019, Standard for Installing and Maintaining Electric Vehicle Supply Equipment (EVSE)
- NFPA 70®, National Electrical Code® (NEC®) Current Edition 2023, Article 100
- SAE J1772_201710, Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler (2018-02-12)

3.1.1. DC Fast Charging and AC Level 2 for Light, Medium, and Heavy-Duty EVs

3.1.1.1. Power Quality

Plug-in electric vehicles require both the electric grid and the vehicle charger to be reliable, as the power quality of one depends on the power quality of the other. Coordinating the electric utility grid characteristics and acceptable levels of power quality for vehicles and vehicle chargers allows manufacturers and utilities to ensure that PEV users achieve a reliable and safe charging experience. The increasing number of plug-in electric vehicle chargers has caused concern over their combined effects on the power quality and reliability of electric utility grids.

Published Standards

- SAE J2894/1_201901, Power Quality Requirements for Plug-In Electric Vehicle Chargers (2019-02-23)
- SAE J2894/2_201503, Power Quality Test Procedures for Plug-In Electric Vehicle Chargers (2015-03-17)

In-Development Standards

- SAE J2894/1, Power Quality Requirements for Plug-In Electric Vehicle Chargers (2020-06-08)

- SAE J2894/2, Power Quality Test Procedures for Plug-In Electric Vehicle Chargers (2019-08-27)

No gap has been identified with respect to this issue.

3.1.1.2. EV Charging Levels

Section **680.106, Installation, operation, and maintenance by qualified technicians of electric vehicle charging infrastructure,** of the NEVI Final Rule provides in relevant part:

> (d) *Power Level.* (1) DCFC charging ports must support output voltages between 250 volts DC and 920 volts DC. DCFCs located along and designed to serve users of designated AFCs must have a continuous power delivery rating of at least 150 kilowatt (kW) and supply power according to an EV's power delivery request up to 150 kW, simultaneously from each charging port at a charging station. These corridor-serving DCFC charging stations may conduct power sharing so long as each charging port continues to meet an EV's request for power up to 150 kW.[14]
>
> (2) Each AC Level 2 charging port must have a continuous power delivery rating of at least 6 kW and the charging station must be capable of providing at least 6 kW per port simultaneously across all AC ports. AC Level 2 chargers may conduct power sharing and/or participate in smart charge management programs so long as each charging port continues to meet an EV's demand for power up to 6 kW, unless the EV charging customer consents to accepting a lower power level.

One of the most critical components to electric vehicle adoption is the ease and efficiency by which the vehicle can be recharged, and the availability of charging facilities. AC Level 1 chargers are typically used at residential properties and provide power through a standard 120-volt AC outlet. AC Level 1 chargers require longer periods to charge and equip an EV with enough range (e.g., overnight charging). AC Level 2 chargers are much faster than Level 1 and utilize 208-volt to 240-volt AC outlets. They may be found in a variety of EVSE stations, from residential properties to restaurants, workplaces, schools, healthcare facilities, etc. DCFC are the fastest chargers to date and can deliver up to 480kW, which uniquely requires a 3-phase power to distribute this high magnitude power reliably and safely. DCFC may be found in a variety of EVSE stations which include restaurants, workplaces, and corridors. DCFC may charge in as little as 18 minutes. Therefore, they are the most dependable way to obtain enough range rapidly and efficiently.

Published Standards

The following standards have been published by the SAE Hybrid-EV Committee:

- SAE J1772_201710, Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler (2017-10-13)

[14] https://www.federalregister.gov/d/2023-03500/p-366

The following standards on EV conductive charging systems have been published by IEC TC 69, Electrical power/energy transfer systems for electrically propelled road vehicles and industrial trucks:

- IEC 61851-1:2017 ED3, Electric vehicle conductive charging system - Part 1: General requirements (2017-02-07)
- IEC 61851-21-1:2017 ED1, Electric vehicle conductive charging system - Part 21-1 Electric vehicle on-board charger EMC requirements for conductive connection to AC/DC supply (2017-06-19)
- IEC 61851-21-2:2018 ED1, Electric vehicle conductive charging system - Part 21-2: Electric vehicle requirements for conductive connection to an AC/DC supply - EMC requirements for off board electric vehicle charging systems (2018-04-18)
- IEC 61851-23:2014 ED1, Electric vehicle conductive charging system - Part 23: DC electric vehicle charging station (2014-03-11)
- IEC 61851-23:2014/COR1:2016 ED1, Corrigendum 1 - Electric vehicle conductive charging systems - Part 23: DC electric vehicle charging station (2016-05-18)
- IEC 61851-24:2014 ED1, Electric vehicle conductive charging system - Part 24: Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging (2014-03-07)
- IEC 61851-24:2014/COR1:2015 ED1, Corrigendum 1 - Electric vehicle conductive charging system - Part 24: Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging (2015-06-17)
- IEC 61851-25:2020 ED1, Electric vehicle conductive charging system - Part 25: DC EV supply equipment where protection relies on electrical separation (2020-12-04)

Other SDOs

- IEEE 2030.1.1-2021, IEEE Standard for Technical Specifications of a DC Quick and Bidirectional Charger for Use with Electric Vehicles (Feb, 18, 2022)

In-Development Standards

The following standards on EV conductive charging systems are in development by IEC TC 69, Electrical power/energy transfer systems for electrically propelled road vehicles and industrial trucks:

Project Reference	Initiation Date	Working Group	Forecasted Publ. Date
IEC 61851-1 ED4 Electric vehicle conductive charging system - Part 1: General requirements	2022-01	WG 12	2025-03
IEC TS 61851-3-1 ED1 Electric Vehicles conductive power supply system - Part 3-1: DC EV supply equipment where protection relies on double or reinforced insulation - General rules and requirements for stationary equipment	2013-01	WG 10	2023-08
IEC TS 61851-3-2 ED1 Electric Vehicles conductive power supply system - Part 3-2: DC EV supply equipment where protection relies on double or reinforced insulation - Particular requirements for portable and mobile equipment	2013-01	WG 10	2023-08
IEC TS 61851-3-4 ED1 Electric vehicles conductive charging system - Part 3-4: DC EV supply equipment where protection relies on double or reinforced insulation - General definitions and requirements for CANopen communication	2013-01	WG 10	2023-03
IEC TS 61851-3-5 ED1 Electric vehicles conductive charging system - Part 3-5: DC EV supply equipment where protection relies on double or reinforced insulation - Pre-defined communication parameters and general application objects	2013-01	WG 10	2023-03
IEC TS 61851-3-6 ED1 Electric vehicles conductive charging system - Part 3-6: DC EV supply equipment where protection relies on double or reinforced insulation - Voltage converter unit communication	2013-01	WG 10	2023-03
IEC TS 61851-3-7 ED1 Electric vehicles conductive charging system - Part 3-7: DC EV supply equipment where protection relies on double or reinforced insulation - Battery system communication	2013-01	WG 10	2023-03
IEC 61851-21-1 ED2 Electric vehicle conductive charging system - Part 21-1 Electric vehicle on-board charger EMC requirements for conductive connection to AC/DC supply	2021-05	MT 19	2024-04

IEC 61851-21-2 ED2 Electric vehicle conductive charging system - Part 21-2: Electric vehicle requirements for conductive connection to an AC/DC supply - EMC requirements for off board electric vehicle charging systems	2023-01	MT 19	2025-06
IEC 61851-23 ED2 Electric vehicle conductive charging system - Part 23: DC electric vehicle supply equipment	2015-12	MT 5	2023-10
IEC 61851-23-1 ED1 Electric vehicle conductive charging system - Part 23-1: DC electric vehicle charging station with an automated connection device	2016-04	PT 61851-23-1	2023-11
IEC 61851-24 ED2 Electric vehicle conductive charging system - Part 24: Digital communication between a DC EV charging station and an electric vehicle for control of DC charging	2015-12	MT 5	2023-10
IEC TS 61851-26 ED1 Electric vehicle conductive charging system - Part 26: EV supply equipment with automated connection of a vehicle coupler located at the underbody of an electric vehicle	2020-11	WG 14	2024-02
IEC TS 61851-27 ED1 Electric vehicle conductive charging system - Part 27: EV supply equipment with automated connection of a vehicle coupler according to IEC 62196-2 or IEC 62196-3	2020-11	WG 14	2024-02

No standards gap has been identified.

3.1.1.3. EV Supply Equipment and Charging Systems

Section **680.106, Installation, operation, and maintenance by qualified technicians of electric vehicle charging infrastructure,** of the NEVI Final Rule provides in relevant part:

> (b) Number of Charging Ports. (1) When including DCFCs located along and designed to serve users of designated AFCs, charging stations must have at least four network-connected DCFC charging ports and be capable of simultaneously charging at least four EVs. (2) In other locations, EV charging stations must have at least four network-connected (either DCFC or AC Level 2 or a combination of DCFC and AC Level 2) charging ports and be capable of simultaneously charging at least four EVs. 15

and

[15] https://www.federalregister.gov/d/2023-03500/p-364

(g) *Equipment Certification*. States or other direct recipients must ensure that all chargers are certified by an Occupational Safety and Health Administration Nationally Recognized Testing Laboratory and that all AC Level 2 chargers are ENERGY STAR certified. DCFC and AC Level 2 chargers should be certified to the appropriate Underwriters Laboratories (UL) standards for EV charging system equipment.[16]

As defined in Article 625 of the National Electrical Code®, electric vehicle supply equipment (EVSE) includes off-board charging stations, or portable EV cord sets (also referred to as charge cables) that supply AC power to a vehicle's on-board charger, whereas EV charging system equipment includes off-board chargers that supply DC power to a vehicle in order to charge the on-board storage battery directly. Vehicles may be designed for use with both types of infrastructure equipment. On-board systems and controls are required to maintain the proper charge path such that AC voltages are not applied to the battery and the like.

Infrastructure equipment is provided with a system of protection that is used to monitor ground connections or isolation of the charging circuit from the user. These systems monitor the infrastructure device as well as the vehicle through the conductive connection. The protection systems provide a portion of the control for the charging function and shut down the infrastructure equipment in the event of a loss of the protective elements associated with that system of protection (ground or isolation).

Published Standards

- NFPA 70®, National Electrical Code®, Current Edition 2023. NEC Article 625, Electric Vehicle Power Transfer System, covers the electrical conductors and equipment connecting an electric vehicle to premises wiring for the purposes of charging, power export, or bidirectional current flow.

- UL 2202, Edition 3, December 15, 2022, DC Charging Equipment for Electric Vehicles. These requirements apply to DC conductive charging equipment intended to be supplied with a maximum input voltage of 1000 V ac or 1500 V dc, for recharging the propulsion batteries in over-the-road electric vehicles (EV). This Third Edition of ANSI/UL 2202 dated December 15, 2022 reflects the trinational standard for Canada, Mexico, and the United States.

- UL 2231-1, Edition 2, September 16, 2021, Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 1: General Requirements. These requirements cover devices and systems intended for use in accordance with Annex A, Ref. No. 1, to reduce the risk of electric shock to the user from accessible parts, in grounded or isolated circuits for charging electric vehicles. These circuits are external to or on board the vehicle. This revision of ANSI/UL 2231-1 dated September 16, 2021 is being issued to update the title page to reflect the most recent designation as a Reaffirmed American National Standard (ANS). No technical changes have been

[16] https://www.federalregister.gov/d/2023-03500/p-374

made. As noted in the Commitment for Amendments statement located on the back side of the title page, UL, CSA, and ANCE are committed to updating this harmonized standard jointly. However, the revision pages dated September 16, 2021 will not be jointly issued by UL, CSA, and ANCE as these revision pages only address UL ANSI approval dates.

- UL 2231-2, Edition 2, December 15, 2020, Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: Particular Requirements for Protection Devices for Use in Charging Systems. This Standard is intended to be used in conjunction with the general requirements of Annex A, Ref. No. 1. The requirements of Annex A, Ref. No. 1 apply unless modified by this Standard. This revision to ANSI/UL 2231-2 dated December 15, 2020 includes revising requirements for Isolated Circuit Systems – Capacitor Switching Transient Test and Harmonic Distortion Immunity Test; 24.1.3A, 24.2.1 and 24.9.2.

- UL 2251, Edition 4, December 15, 2022, Plugs, Receptacles, and Couplers for Electric Vehicles. These requirements cover EV plugs, EV receptacles, vehicle inlets, vehicle connectors, and EV breakaway couplings, rated up to 800 amperes and up to 6001000 volts ac or 1500 V dc under conditions of continuous use. This standard applies to the devices which may also be intended for use in charging systems that provide for active cooling or dynamic current control when the device is rated only for DC voltages. These devices are intended for use with conductive electric vehicle supply equipment (EVSE), and are intended to facilitate the conductive connection from the EVSE to the vehicle. These devices are for use in either indoor or outdoor nonhazardous locations in accordance with Annex A, Ref. No. This revision of ANSI/UL 2251 dated December 15, 2022, is being issued to incorporate a number of updates including harmonization of ANCE NMX-J-678/CSA C22.2 No. 282/UL 2251 and IEC thermal cycling tests; 18.3, 18.4, 45.3, Table 45.2, Figure 45.1 and Sections 54A – 54D.

- UL 2594 Edition 3, December 15, 2022, Electric Vehicle Supply Equipment. This Standard applies to conductive electric vehicle (EV) supply equipment with a primary source voltage of 1000 V ac or less, with a frequency of 50 or 60 Hz, and intended to provide ac power to an electric vehicle with an on-board charging unit. This Standard covers electric vehicle supply equipment intended for use where ventilation is not required. This Third Edition of the Standard for Electric Vehicle Supply Equipment, UL 2594 dated December 15, 2022, includes the following revisions: a) Removal of requirement to fasten in place devices rated over 125 V; b) Increase voltage to 1000 V input; c) Revisions due to withdrawal of UL 2744; d) Location of interrupting device for personnel protection systems in EVSE in accordance with the NEC.

In summary, the following are North American standards.

- NMX-J-817-ANCE-2022 / CSA C22.2 No. 346 / UL 2202, DC Charging Equipment for Electric Vehicles
- NMX-J-668/1-ANCE/CSA C22.2 No. 281.1/UL 2231-1 Standard for Safety for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: General Requirements

- NMX-J-668/2-ANCE/CSA C22.2 No. 281.2/UL 2231-2 Standard for Safety for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: Particular Requirements for Protective Devices for Use in Charging Systems
- NMX-J-678-ANCE-2017 / CSA C22.2 No. 282-17 / UL 2251, Plugs, Receptacles and Couplers for Electric Vehicles
- NMX-J-677-ANCE-2022 / CSA C22.2 No. 280-22 / UL 2594, Electric Vehicle Supply Equipment

The IEC 61851 series of standards also address the safety of off-board chargers, off-board charging stations, and portable EV cord sets:

- IEC 61851-1:2017, Ed. 3.0, Electric Vehicle Conductive Charging Systems, Part 1: General Requirements, (2017-02-07)
    - IEC 61851-1 ED4 has an anticipated publication date of March 2025.
- IEC 61851-21-1:2017, Ed 1.0, Electric vehicle conductive charging system - Part 21-1 Electric vehicle on-board charger EMC requirements for conductive connection to AC/DC supply, (2017-06-19)
    - IEC 61851-21-1 ED2 has an anticipated publication date of April 2024.
- IEC 61851-21-2:2018, Ed. 1.0 Electric vehicle conductive charging system - Part 21-2: Electric vehicle requirements for conductive connection to an AC/DC supply - EMC requirements for off board electric vehicle charging systems (2018-04-18)
    - IEC 61851-21-2 ED2 has an anticipated publication date of June 2025.
- IEC 61851-24:2014, Ed. 1.0, Electric vehicle conductive charging system – Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging (2014-03-07)
    - IEC 61851-24 ED2 has an anticipated publication date of June 2025.

- IEC 61851-23:2014, Ed. 1.0, Electric vehicle conductive charging system – D.C. electric vehicle charging station (2014-03-11)
    - IEC 61851-23 ED2 has an anticipated publication date of October 2023.

The IEC 61851-1 standard has many requirements that are similar or identical to what is featured in the North American standards, such as UL 2594 and UL 2202. However, an area of discrepancy exists pertaining to the requirements for personnel protection systems. The IEC documents require a form of protection system that is widely used in Europe but is not used in the U.S., while the National Electrical Code® in the U.S. requires a different system of protection that is not used in Europe. This difference in the standards affects the harmonization of these requirements. In addition, there are differences in the standards used to cover components or subassemblies within the overall equipment, and differences in the evaluation of required environmental ratings for outdoor equipment. From a harmonization perspective, these differences are not as difficult to overcome as the previously discussed personnel protection systems.

Harmonization between the North American safety standards and the IEC 61851 standards is being driven through IEC work and U.S. participation in the appropriate IEC committees. However, no formal program or specific project has been initiated to actually harmonize these standards. Up to this point, the effort has been focused on introducing specific aspects into either the North American standards, or the IEC standards, as opportunity allows. While not a gap per se with respect to the U.S. market, the use of infrastructure equipment and the means to mitigate risks would prove beneficial to manufacturers if harmonization was completed.

Conformance Programs

Various conformance programs exist, with each third-party testing organization having a program in place. Article 625 of the National Electrical Code® requires off-board chargers, off-board charging stations, and portable EV cord sets to be listed. So, conformance programs are essential to listing the product. Although all conformance programs have their own specific parts, for off-board charging stations and portable EV cord sets, all North American conformance programs will be based on the North American standards as shown above.

3.1.1.4. EV Couplers

Section **680.106, Installation, operation, and maintenance by qualified technicians of electric vehicle charging infrastructure,** of the NEVI Final Rule provides in relevant part:

> (c) *Connector type.* All charging connectors must meet applicable industry standards. Each DCFC charging port must be capable of charging any CCS-compliant vehicle and each DCFC charging port must have at least one permanently attached CCS Type 1 connector. In addition, permanently attached CHAdeMO (*www.chademo.com*) connectors can be provided using only FY2022 NEVI funds. Each AC Level 2 charging port must have a permanently attached J1772 connector and must charge any J1772-compliant vehicle. [17]

Safety and Harmonization Efforts

A critical user component required for recharging plug-in electric vehicles is the EV coupler, which consists of a vehicle connector and a vehicle inlet. This vehicle connector and vehicle inlet combination (coupler) provides a conductive path for power from the charging infrastructure equipment to the vehicle, and assists the infrastructure equipment with safety checks, communication, and other aspects associated with safe recharging of the vehicle.

Ideally, electric vehicle operators should be able to use any available charging station to recharge their vehicle. This interoperability is governed by the electric vehicle charging systems including the vehicle

[17] https://www.federalregister.gov/d/2023-03500/p-365

couplers. For these reasons, standardized EV couplers are vitally important in facilitating public adoption of EVs, especially when multiple vehicle models are involved.

The EV coupler is also instrumental in protecting people from the risk of electric shock. This includes the vehicle owner, as well as other people in the area that may contact the electric vehicle or the EV coupler. The EV coupler also protects the vehicle, by guarding against mismatching of the vehicle connector and vehicle inlet and providing for the correct communication and pilot controls via an expected charge protocol. Safety standards provide the minimum requirements necessary to protect the vehicle owner, general public, infrastructure, garage, and charging site, while the vehicle is charging.

With standardized couplers, an EV driver would be familiar with one type of EV connector and would not have to worry about matching a connector to their particular vehicle make and model. Standardization would also reduce attempts to modify equipment, or provide adapters to convert equipment, which could adversely affect the safety of the charging system. Harmonized standards (national, regional, international) would be beneficial, so that all EV couplers and electric vehicles would function in the same manner and provide similar protection.

Today, UL 2251 Plugs, Edition 4, Receptacles and Couplers for Electric Vehicles exists to cover safety for EV couplers. A North American harmonization effort took place based on UL 2251 involving CSA C22.2 No. 282 and similar Mexican documents to cover the safety requirements for vehicle connectors and vehicle inlets with respect to the risk of fire, shock, and injury to persons for both AC and DC rated EV couplers. This tri-national standard is NMX-J-678-ANCE-2017 /CSA C22.2 No. 282-17/UL 2251, Plugs, Receptacles and Couplers for Electric Vehicles.

The IEC 62196 series of standards also address safety of the EV coupler:

- IEC 62196-1:2022, Ed. 4.0, Plugs, Socket-Outlets, Vehicle Connectors and Vehicle Inlets – Conductive Charging of Electric Vehicles – Part 1: General Requirements (2022-05-03)
- IEC 62196-1:2022 CMV, Ed. 4.0, Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 1: General requirements (2022-05-03)
- IEC 62196-2:2022, Ed. 3.0, Plugs, Socket-Outlets, Vehicle Connectors and Vehicle Inlets – Conductive Charging of Electric Vehicles – Part 2: Dimensional Compatibility and Interchangeability Requirements for AC Pin and Contact-Tube Accessories (2022-10-19)
- IEC 62196-3:2022, Ed. 2.0, Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 3: Dimensional compatibility requirements for DC and AC/DC pin and contact-tube vehicle couplers (2022-10-19)
- IEC TS 62196-3-1:2020, Ed. 1.0, Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 3-1: Vehicle connector, vehicle inlet and cable assembly for DC charging intended to be used with a thermal management system (2020-03-26)
- IEC TS 62196-4:2022, Ed. 1.0, Plugs, socket-outlets, vehicle connectors and vehicles inlet - Conductive charging of electric vehicles - Part 4: Dimensional compatibility and

interchangeability requirements for DC pin and contact-tube accessories for class II or class III applications (2022-10-19)

- IEC 62196-6:2022, Ed. 1.0, Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 6: Dimensional compatibility requirements for DC pin and contact-tube vehicle couplers intended to be used for DC EV supply equipment where protection relies on electrical separation (2022-04-22)
- IEC TS 62196-7, Ed. 1.0, Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 7: Vehicle adapter is anticipated to be published in February 2024.

There are some differences between IEC 62196 series standards and the existing North American EV coupler safety standards. These include some construction issues such as acceptance of components and the IEC standards used to certify and test these components, the mandatory use of latching means, and the use of IEC ingress protection (IP) ratings. They also include testing differences such as additional test methods for enclosure strength testing, environmental testing on enclosures (IP ratings), and impact testing on inlets. Harmonization between the North American coupler safety standards and the IEC 62196 standards takes place as opportunities arise through U.S. participation in the appropriate IEC committees.

Conformance Programs

Various conformance programs exist, with each third-party testing organization having a program in place. Article 625 of the National Electrical Code® requires EV couplers, EVSE and EV charging systems to be listed. So, conformance programs are essential to listing the product. Although all conformance programs have their own specific parts, all North American conformance programs will be based on the North American standards as shown above.

Interoperability with EVSE and Harmonization Efforts

SAE J1772™ covers the interface, design, geometry, communication protocol, and pilot controls for electric vehicle infrastructure as it is communicated through the EV connector. Conforming to this SAE document means that any vehicle supplied with an SAE J1772™ inlet on the vehicle can pull up to any SAE J1772™ infrastructure type device (which would be provided with an SAE J1772™ style connector) and be able to charge the vehicle. Such charging interoperability is key to the mass deployment of PEVs. SAE J1772™ is a CCS Type 1 connector as defined in the IEC 62196 standards.

In November, 2022, Tesla announced that it would open its EV connector configuration, which it called the "North American Charging Standard," to charging network operators and vehicle manufacturers.[18] In response, CharIN advocated for the CCS system and encouraged Tesla "to work with CharIN's

[18] The Tesla Team, "Opening the North American Charging Standard," November 11, 2022, Accessed 3/9/2023 https://www.tesla.com/blog/opening-north-american-charging-standard

membership base, the standards organizations, and others to accelerate the adoption of a fully interoperable EV charging solution to transition to electric vehicles more quickly."[19]

Harmonization of EV couplers on a global scale would help to reduce costs for manufacturers of PEVs and charging infrastructure. However, due to market competition, differences in electrical systems, each country's own national rules and regulations, and EV coupler configurations already having been well established in some locations, global harmonization remains a challenge.

Interoperability

Interoperability between PEVs and EVSE an essential component of EVs at scale.

Published Standards

- SAE J2953/1_201310, Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE) (2013-10-07). This SAE Recommended Practice J2953/1 establishes requirements and specification by which a specific Plug-In Electric Vehicle (PEV) and Electric Vehicle Supply Equipment (EVSE) pair can be considered interoperable. The test procedures are further described in J2953/2.

- SAE J2953/2_201401, Test Procedures for the Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE) (2014-01-22). This SAE Recommended Practice SAE J2953/2 establishes the test procedures to ensure the interoperability of Plug-In Vehicles (PEV) and Electric Vehicle Supply Equipment (EVSE) for multiple suppliers.

In Development Standards

- SAE J2953/1, Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE) (2019-03-01) is under its five-year review.

- SAE J2953/2, Test Procedures for the Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE) (2019-03-01) is under its five-year review.

- SAE J2953/3, Test Cases for the Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE) (2016-02-03). This establishes the test cases to ensure the interoperability of PEV and EVSE for multiple suppliers. It defines the test cases for interoperability for AC and DC charging identified in J1772 and J2847/2. The Test Cases complement the interoperability requirements in J2953/1 and test procedures in J2953/2 and

[19] CharIN, "CharIN Response to Tesla Announcement to Open the North America Charging Standard," November 29, 2022, Accessed 3/9/2023 https://www.charin.global/news/charin-response-to-tesla-announcement-to-open-the-north-america-charging-standard/

provide the specific functions, steps and results expected.

No standards gap has been identified.

3.1.1.5. Electromagnetic Compatibility (EMC)

The concept of EMC is to protect both the communications channels and the electrical circuits used in charging and operating the vehicle. The focus is to limit or control electromagnetic emissions by both the vehicle and charging station devices to keep them within tolerable limits for other nearby devices. EMC standards help maintain the integrity of the EV system as a potential emitter and “good citizen” of the electric grid, as well as protecting the vehicle and charging station from other emitters on the grid. This is necessary to maintain the safety and interoperability of the devices within the charging environment.

Published Standards

- IEC 61851-21-1:2017, Ed. 1.0, Electric vehicle conductive charging system - Part 21-1 Electric vehicle on-board charger EMC requirements for conductive connection to AC/DC supply (2017-06-19)

- IEC 61851-21-2:2018, Ed. 1.0, Electric vehicle conductive charging system - Part 21-2: Electric vehicle requirements for conductive connection to an AC/DC supply - EMC requirements for off board electric vehicle charging systems (2018-04-18)

- SAE J551/1_202001, Performance Levels and Methods of Measurement of Electromagnetic Compatibility of Vehicles, Boats (up to 15 m), and Machines (16.6 Hz to 18 GHz) (Stabilized Jan 2020)

- SAE J1113 series covers EMC testing of vehicle components.

- SAE J1772™ includes EMC requirements for the conductive charging interface unit, referring to UL 2231-2 and FCC part 15.

There is an agreement between IEC and ISO regarding EMC as follows: EMC immunity issues relating to vehicles (internal combustion, battery, fuel cell or hybrid powered) while not connected to the power grid are the responsibility of ISO/TC 22 and rf emissions are the responsibility of IEC CISPR/D. EMC issues relating to vehicles while connected to the power grid for charging are the responsibility of IEC/TC 69 with IEC CISPR/B having responsibility for emissions during charging. All of the activities take into account the basic IEC/TC 77 EMC standards (the IEC 61000 series) where appropriate.

In terms of EMC standards for the electric grid, the IEC 61000 series has several parts that cover everything from the general application of the standard (part 1), through discussions of environment, limits, testing and measurement, installation and mitigation, and finally a generic catchall volume (parts 2 through 6 respectively). Propagated by various subcommittees of IEC/TC 77, Electromagnetic compatibility, between electrical equipment including networks, the IEC 61000 series has broad applicability in the infrastructure segment of the EV space.

No standards gap has been identified.

3.1.2. Megawatt Charging Systems for Medium and Heavy-Duty EVs

CharIN is a global association working to promote EV interoperability based on the Combined Charging System (CCS). It has a Megawatt Charing System (MCS) Subgroup working to meet the demand of the truck and bus industry for heavy-duty EV charging. They also developed a white paper[20] of technical and non-technical aspects of the MCS and includes recommended specification for standards development organizations. SAE J3271 is in development to address MCS.

Published Standards

There are no published standards covering MCS. The following documents are related to MCS.

- IEEE P2030.5-2018, IEEE Standard for Smart Energy Profile Application Protocol (2018-06-14)
- ISO 15118 and all its subparts except dash 2 which is superseded by dash 20.
- SAE J1939 series of standards. Additional detail on the J1939 standards is available here.[21]
- SAE J3072_202103, Interconnection Requirements for Onboard, Grid Support Inverter Systems (2021-03-10)
- UL 1741, Edition 3, September 28, 2021, Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources. The standard includes Supplement SA with grid support smart features to be used with IEEE 1547-2003. It also includes Supplement SB with grid support smart features realized in IEEE 1547-2018. The next iteration of the UL 1741 standard will include Supplement SC with V2G-AC support realized in SAE J3072.[22]
- UL 2251, Edition 4, November 20, 2017, Plugs, Receptacles, and Couplers for Electric Vehicles
- UL 9741, Edition 2, May 21, 2021, UL LLC Outline of Investigation for Electric Vehicle Power Export Equipment (EVPE)

---

[20] CharIn. "CharIN Whitepaper Megawatt Charging System (MCS): Recommendations and requirements for MCS related standards bodies and solution suppliers," Version 1.0, 2022-11-24. Accessed 3/9/2034 https://www.charin.global/media/pages/technology/knowledge-base/c708ba3361-1670238823/whitepaper_megawatt_charging_system_1.0.pdf

[21] AutoPi.io, "SAE J1939: The Ultimate Guide (2023)," Accessed 12 February 2023 https://www.autopi.io/blog/j1939-explained/

[22] Interstate Renewable Energy Council (IREC), "Paving the Way: Vehicle-to-Grid Standards for Electric Vehicles," p. 12, Accessed 12 February 2023 https://irecusa.org/resources/paving-the-way-vehicle-to-grid-standards-for-electric-vehicles/

In Development Standards

- IEC 61851-23-3 ED1, Electric vehicle conductive charging system - Part 23-3: DC electric vehicle supply equipment for Megawatt charging systems is anticipated to be published in December 2024.
- SAE J3271, Megawatt Charging System for Electric Vehicles (2021-12-15). CharIN members are participating in the development of J3271.

Gap C1: Megawatt Charging Systems (MCS). Standards are needed for MCS to support for heavy duty EVs such as trucks and buses. **R&D Needed:** Yes. Interoperability testing and data collection. **Recommendation:** Complete work on SAE J3271. **Priority:** High **Organization:** SAE, NREL, DOE

3.1.3. Wireless Power Transfer (WPT)

Wireless charging is a type of charging where energy is transferred to the vehicle in a contactless manner rather than via a physical, conductive electrical connection. Stationary or static wireless charging is where an EV is parked in a garage or charging location and is recharged without being physically plugged in. Dynamic wireless charging takes this one step further and allows a vehicle to be recharged while in motion. Wireless charging is a rapidly developing technology that will lend itself naturally in the promotion and deployment of EVs. It is important to have harmonized standards to ensure a safe, interoperable charging experience.

The principal SDOs working on documents in this space are SAE International, IEC, and ISO. It is important to understand the structural differences between and among them.

SAE, with regard to wireless charging, covers the entire system, both the offboard components and the onboard (on the vehicle) components, as well as the system communication requirements, in a single document.

IEC and ISO, by agreement, split the systems with IEC covering the offboard portion of the systems and ISO covering the onboard portion of the systems. Also, by agreement in this application space, the communication aspects of system operation are specified in either an IEC or an ISO document and adopted and referenced by the related document on the other side (the communications aspects are dealt with separately below). The division between ISO and IEC applies to both Static Wireless Power Transfer (Static WPT) and Dynamic Wireless Power Transfer (DWPT).

3.1.3.1. Static Wireless Power Transfer

Standards development activity in this space has been ongoing for many years. By mutual agreement, the relevant groups in SAE, IEC, and ISO have considered the documents being developed in the other organizations in an attempt to understand and minimize differences in requirements where appropriate, so that the results are largely harmonized and automotive OEMs do not have to deal with fundamental differences and can work towards compliance with all the relevant documents.

Published Standards

- IEC 61980-1:2020, Ed. 2.0, Electric vehicle wireless power transfer (WPT) systems - Part 1: General requirements (2020-11-19)
- IEC 61980-3:2022, Ed 1.0, Electric vehicle wireless power transfer (WPT) systems - Part 3: Specific requirements for magnetic field wireless power transfer systems (2022-11-23)
- ISO 19363:2020, Electrically propelled road vehicles — Magnetic field wireless power transfer — Safety and interoperability requirements (2020-04)
- SAE J2954_202208, Wireless Power Transfer for Light-Duty Plug-in/Electric Vehicles and Alignment Methodology (2022-08-26)
- SAE J2954/2_202212, Wireless Power Transfer for Heavy-Duty Electric Vehicles (2022-12-16) This document covers Static wireless charging and has some Dynamic wireless charging information as well.
- UL 2750, Edition 1, March 13, 2020, UL LLC Outline of Investigation for Wireless Power Transfer Equipment for Electric Vehicles

In Development Standards

- IEC 61980-4 ED1, Interoperability and safety of high-power wireless power transfer (H-WPT) for electric vehicles is anticipated to be published in December 20234. IEC 61980-3 covers WPT up to 11 kVA input, but this document will continue up to 500 KW input.
- ISO/AWI 5474-4, Electrically propelled road vehicles — Functional requirements and safety requirements for power transfer — Part 4: Magnetic field wireless power transfer — Safety and interoperability requirements (ISO TC22/SC37/WG5). This is based on ISO 19363 but will go further. It will supersede ISO 19363 and ISO 6469-3 when published.

It should be noted that in the case of static low power (SAE J2954, IEC 61980-2, IEC 61980-3, ISO 19363, and perhaps portions of IEC 61980-4), there is an expectation of interoperability at an acceptable level of power transfer and efficiency (described in the documents) across all vehicles and systems covered.

For high power/heavy duty, a concept of Application Class is added (e.g., bus routes vs. highway tractors (that pull trailers) vs. refrigerator trailers), and interoperability is primarily targeted within the application class. In effect, IEC 61980-3 and ISO 19363, which were designed to work together, make up an application class that might be called "light duty vehicles."

None of the above include the Chinese GB standards. There are some similarities to the SAE and ISO/IEC documents as well as some differences. Full harmonization seems to be unlikely, so there is probably not going to be "one solution" worldwide.

Gap C2: Static Wireless Charging. Standards for heavy duty/high power static wireless charging are still in development.

R&D Needed: No

Recommendation: Complete work on SAE J2954/2 and other in development standards to deal with heavy duty/high power static wireless charging.

Priority: High

Organization: SAE, UL, IEC/TC 69, ISO TC22/SC37

3.1.3.2. Dynamic Wireless Power Transfer

According to the Office of Energy Efficiency & Renewable Energy (EERE) Vehicle Technologies Office[23], high-power dynamic wireless power transfer (dWPT) technologies enable electric vehicles (EVs) to be charged as they are driven at highway speeds. These technologies hold significant potential to bolster consumer confidence and reduce onboard EV energy storage requirements. This capability will especially benefit medium- and heavy-duty applications. However, lab-developed, high-power dWPT technologies have not yet been tested under real-world road conditions to understand the practical installation, operation, performance, and maintenance challenges to deployment. In practice, a lack of practical and verified methods of integrating dWPT hardware into different types of roadways without compromising performance and safety and comprehensive data on performance impacts under rigorous operating conditions will need to be addressed to better understand key system and component-level challenges.

Published Standards

- SAE J2954/2_202212, Wireless Power Transfer for Heavy-Duty Electric Vehicles (2022-12-16)

In Development Standards

- IEC 63243 ED1, Interoperability and safety of dynamic wireless power transfer (WPT) for electric vehicles is anticipated to be published in December 2023. This is planned to become IEC 61980-5 after issuance of the first CD.

[23] Electric Vehicles at Scale Consortium, Office of Energy Efficiency & Renewable Energy, "Dynamic Wireless Power Transfer," Accessed February 22, 2023 https://www.energy.gov/eere/vehicles/electric-vehicles-scale-consortium-dynamic-wireless-power-transfer

- ISO/AWI 5474-6, Electrically propelled road vehicles — Interoperability and safety of dynamic wireless power transfer (D-WPT) for electric
- SAE Hybrid - EV Committee plans to develop J2954/3, a recommended practice for light-duty and heavy-duty dynamic wireless power transfer.

Gap C3: Dynamic Wireless Charging. Standards for dynamic wireless charging are still needed.

R&D Needed: Yes. Testing, data collection.

Recommendation: Develop standards to address dynamic wireless charging.

Priority: Low

Organization: SAE, UL, IEC/TC 69, ISO TC22/SC37

3.1.3.3. Communications in Support of Wireless Power Transfer

Standards activities for communications to support both static and dynamic WPT is underway however efforts harmonize or resolve conflicting requirements across available standards would be beneficial. IEC, ISO and SAE address WPT communications between the EV and infrastructure/grid, signaling, physical versus data link layers, etc. as follows:

Published Standards

- IEC TS 61980-2:2019, Ed. 1.0, Electric vehicle wireless power transfer (WPT) systems - Part 2: Specific requirements for communication between electric road vehicle (EV) and infrastructure (2019-06-13) applies to static wireless charging.
- ISO 15118-2:2014 Road vehicles — Vehicle-to-Grid Communication Interface — Part 2: Network and application protocol requirements (reapproved in 2020)
- ISO 15118-8:2020, Ed. 2.0, Road vehicles - Vehicle to grid communication interface - Part 8: Physical layer and data link layer requirements for wireless communication (2020-09)
- ISO 15118-9:2022, Ed. 1.0 Road vehicles - Vehicle to grid communication interface - Part 9: Physical and data link layer conformance test for wireless communication (2022-11)
- ISO 15118-20:2022, Road vehicles — Vehicle to grid communication interface — Part 20: 2nd generation network layer and application layer requirements (2022-04)
- SAE J2836/6_202104, Use Cases for Wireless Charging Communication for Plug-in Electric Vehicles (2021-04-09) applies to static PWT.
- SAE J2847/6_202009, Communication for Wireless Power Transfer Between Light-Duty Plug-in Electric Vehicles and Wireless EV Charging Stations (2020-09-29) applies to static PWT.
- SAE J2931/6_202208, Signaling Communication for Wirelessly Charged Electric Vehicles (2022-08-26)

In Development Standards

- IEC 61980-2 ED1, Electric vehicle wireless power transfer (WPT) systems - Part 2: Specific requirements for MF-WPT system communication and activities is anticipated to be published in June 2023 and will replace IEC TS 61980-2:2019 ED1.
- IEC 63381 ED1, Communication requirements of dynamic wireless power transfer (D-WPT) for electric vehicles is anticipated to be published in December 2023. This is planned to become IEC 61980-6 after issuance of the first CD.
- ISO/DIS 15118-2 Road vehicles — Vehicle-to-grid communication interface — Part 2: Network and application protocol requirements is a revision to ISO 15118-2:2014.

Gap C4: Communications in Support of Wireless Power Transfer. The following issues need to be addressed:

- ISO 15118-series – resolution of conflicting requirements in ISO 15118-2 and/or ISO 15118-20 and publication in order to include static WPT
- SAE J2847/6 needs to be updated and harmonized with ISO 15118-2and/or ISO 15118-20 so that there are uniform communication requirements for WPT

R&D Needed: TBD

Recommendation: Complete work on communication standards in development for static and dynamic wireless charging.

Priority: Low

Organization: SAE, ISO, IEC

3.2. Station / Site Architecture

Electric vehicle charging stations and respective site architectures will have some unique considerations, different from what a fueling station would require for example. Traditional fueling stations are also retrofitting their sites to include EV charging. With regards to location of the EV and the EVSE, NFPA 30A will incorporate requirements to accommodate these modifications, whereas charging capacity determinations may rely on the National Electric Code (NEC), published by NFPA. Several factors will need to be considered, including broad installation requirements and specific charging scenarios anticipated, as described in 3.2.1 and 3.2.2.

3.2.1. General Infrastructure Installation Considerations

Installing electric vehicle infrastructure can be a unique challenge for communities. Appropriate codes and standards to guide infrastructure installation will enable safe and effective deployment. Several key areas described in this section must be addressed to streamline and more effectively deploy EV infrastructure including:

- site assessment / power capacity assessment
- charging station permitting
- electrical inspections
- environmental and use conditions
- ventilation – multiple charging vehicles
- cable management
- labeling of EVSE and load management disconnects for emergency situations
- EV charging – signage and parking
- physical security of EVSE
- accessibility for persons with disabilities to EVSE

The following published standards provide guidance for installation of EVSE:

- NECA 413-2019, Standard for Installing and Maintaining Electric Vehicle Supply Equipment (EVSE). This standard describes the procedures for installing and maintaining AC Level 1, AC Level 2 and fast charging DC EVSE. It includes a review of the various types of EVSE and applicable rules in the NEC as well as applicable installation guidelines and checklists to assist contractors, installers and inspectors.
- NECA 416-2016, Recommended Practice for Installing Energy Storage Systems (ESS). This standard describes general and electrical installation requirements, battery systems safety, installation, cleaning, start-up and commissioning as well as smart charger V2G application considerations.

3.2.1.1. Site Assessment / Power Capacity Assessment

Electric vehicle supply equipment (EVSE) for vehicle charging places an additional demand on the electrical system where the capacity to supply the load must be verified and provided. A site assessment is typically performed by an electrical contractor to verify capacity and ensure the existing service or system will not be overloaded.

The National Electrical Code® (NEC®) provides minimum requirements for performing site assessments, specifically NEC® Articles 210, 215, 220, and 750 contain rules that relate to calculations and loading of services, feeders, and branch circuits in all occupancies. AC Level 1 and AC Level 2 EVSE are considered continuous loads with the maximum current expected to continue for 3 hours or more. If an automatic load management system is used, the maximum electric vehicle supply equipment load on a service or feeder shall be the maximum load permitted by the automatic load management system. If there is no load management, then they must be sized for 125% of the maximum current. Fast-charging EV supply equipment operates for less than three hours but is calculated at 125% of the nameplate current rating. Section 625.41 of the NEC® contains additional provisions related to the load calculations for EVSE.

In conducting a site/power capacity assessment for existing facilities (residential, commercial, and industrial), the following, among other things, needs to occur:

- Conduct site visit;
- Inventory electrical equipment;
- Interview the facility occupants to determine the cyclical daily and seasonal loading of the facility in order to project total capacity (existing and new capacity loading);
- When available, review a minimum of 12 months of electric utility bills to determine the maximum demand for incorporation into load calculations; and
- Verify by calculation the existing loads on the service or system. For commercial installations, consideration for future expansion and multiple EVSE should be included in load calculations. Involve electrical utility planners early in the process when planning EVSE for fleet applications.

Site Assessment Verifies Locations and Other NEC® Requirements

A site assessment is required to verify acceptable location(s) of the EVSE and requirements to conform with the NEC® and other applicable codes such as the International Residential Code® for One- and Two-Family Dwellings (IRC®), International Building Code® (IBC®), Americans with Disabilities Act (ADA) requirements (ICC/ANSI A117), and other state or local zoning regulations.

Section 406.2.7 of the 2021 IBC® provides that EV charging systems must be installed in accordance with the NEC®, that EV charging system equipment must be listed and labeled in accordance with UL 2202, that EVSE must be listed and labeled in accordance with UL 2594, and that accessibility to EV charging stations must be provided in accordance with IBC® Section 1107.[24]

Local codes and regulations may be more restrictive than national codes and must be verified with the applicable jurisdiction. This can be determined during the permitting process for installation.

Other NEC® Rules and Installation Standards

The NEC® also provides the minimum requirements for service equipment, overcurrent protection, grounding and bonding, appropriate wiring methods, and locations or occupancy types that are often determined as part of a site assessment. Branch circuit or feeder wiring method can vary depending on the EVSE installation location. A National Electrical Installation Standard (NEIS) NECA 413, Standard for Installing and Maintaining Electric Vehicle Supply Equipment (EVSE), provides site selection, preparation, pre-installation and inspection guidelines (Section 5 and Annex B) and information about installation of EVSE in new and existing electrical systems (Section 6). NECA 413 covers the following related to performing effective site assessments:

Supply Equipment/Charging Power Selection: AC Level 1, AC Level 2, Fast Charging;

[24] IBC®, Accessed 3/18/2023 https://codes.iccsafe.org/content/IBC2021P2/chapter-4-special-detailed-requirements-based-on-occupancy-and-use#IBC2021P2_Ch04_Sec406.2.7

- Charging Equipment (Type): Conductive, Inductive, WPT;
- Service or Power Capacity (load on new and existing systems or services);
- Electrical Load Calculations;
- Site Selection and Preparation;
- Sites for Fleet Charging Installations;
- Energy Code Requirements;
- Mechanical Ventilation (where required);
- Electric Utility Interconnection Installation Requirements;
- Utility Interactive EVSE Installation;
- Special Metering or Special Metering Equipment Installation; and
- Load control strategies (Time of Use or Off-Peak charging).

Some specific installations under the exclusive control of an electric utility are excluded from the scope of the National Electrical Code® (NEC®) and fall under the scope of ANSI C2, the National Electrical Safety Code® (NESC®). These are generally locations where the utility-owned installations are on legally established easements or rights-of-way. The NESC® is a code that is primarily used for generation, transmission, distribution, and metering of electrical energy. However, the National Electrical Code® (NEC®) applies to some installations that are owned by electric utilities including utility owned office buildings and garages. The addition of electric vehicles may necessitate the need for a utility infrastructure upgrade to achieve an adequate power supply.

The site/power capacity requirements for EVSE connected to an electric service or other power source are already well covered in the NEC®. The permit process usually captures any issues related to the site as far as zoning or suitable locations for EVSE.

NEC® Section 625.41 on overcurrent protection continues to address the ratings of electric vehicle supply equipment and that the load profile is that of a continuous duty load for the purposes of Article 625. Article 625.42 applies to energy management and automatic load management systems. Where an automatic load management system is used, the maximum load on a feeder or service shall be the maximum load permitted by the automatic load management system. The significance of this is that an alternative exists to use automatic load management systems to keep a service or feeder from being overloaded, rather than have the installation of EVSE force a service upgrade. The concept is similar to that of recognizing non-coincidental loads connected to the same service or feeder.

Specifically, NEC Section 625.42(A) provides in relevant part: "Where an Energy Management System (EMS) in accordance with 750.30 provides load management of EVSE, the maximum equipment load on a service and feeder shall be the maximum load permitted by the EMS. The EMS shall be permitted to be integral to one piece of equipment or integral to a listed system consisting of more than one piece of equipment. When one or more pieces of equipment are provided with an integral load management control, the system shall be marked to indicate this control is provided."

No gaps have been identified at this time with respect to this issue.

Harmonization Efforts

A harmonization assessment was conducted examining NEC® Article 625, the Canadian Electrical Code, and IEC 60364 to identify parallel sections which have already been harmonized and those which may still need to be. In concept, they are similar but they are not fully harmonized.

3.2.1.2. Charging Station Permitting

To enable the widespread acceptance of electric vehicles, it is important that charging station installations be safe and meet electrical and building code requirements. These requirements help assure that personal injuries, fires, and other hazards are avoided through proper installations and are managed through existing building plan approval and inspection processes. The existing safety system relies on product safety standards and certification, installation and building codes and standards, and permits and inspections – all three of which are essential to the safe functioning of the system. See also section 3.2.1.3 below on electrical inspections.

Normally the installation of EVSE is governed under a construction permitting process of the applicable authority having jurisdiction, which could be a state, city, county, town, or other municipality. Often the local jurisdiction has knowledge of additional permits necessary and advises this during the initial permitting application process.

Another condition that may necessitate additional permits for installing EVSE is when the equipment is located in public right-of-ways. In these cases, a state, county, or city may require a right-of-way work permit and inspection. There may also be right-of-way specifications by the permit-issuing entity. Airports, train stations, bus stations, and other public transit depots may have specific owner permits that are required, in addition to the city, county, or state permit required for installation safety.

Residential Permitting: Permitting and inspection of a residential charging station is likely the only time a jurisdiction has the opportunity to determine that the charging system is correctly installed to ensure life safety for residents and to minimize fire or other risks to the property. Before approving a residential installation, jurisdictions may require information on the system being installed, the method of installation and any standards or product requirements relating to installation. Information on the licensing or qualifications of the installer may also be required. There may be differences in permitting requirements for single- and multi-family dwellings depending upon the jurisdiction.

The primary purpose of the permitting process is to ensure an installation that is safe from shock and fire hazards, as well as the potential for physical damage. EVSE installations are a significant continuous duty load. Older homes may not have the capacity to safely supply the load. Even some more modern homes with electric heating or air conditioning may be near their capacity limit. The permitting process involves a review of the plans and an on-site inspection to ensure compliance with the requirements of the National Electrical Code® (NEC®). The NEC® is widely adopted, and is also referenced in the International Residential Code® for One- and Two-Family Dwellings (IRC®), published by ICC, that is used as the basis for regulation of residential buildings in all 50 states, at the state or local level. Provisions exist in the 2023 NEC® to cover EV charging systems and their installation. The DOE Clean Cities 25 program has published information which may be used as a starting point for jurisdictions looking to establish permitting procedures for EVSE.[26]

Commercial/Public Permitting: The permitting and inspection of a commercial or public charging station has greater potential to impact a larger population than a residential installation, but the jurisdiction will likely have greater opportunity to monitor the system through common annual building inspections conducted to assure compliance with the local fire code. As with residential installations, jurisdictions may require product, installation, and installer information to ensure safety.

The permitting process is also important for nonresidential installations. Capacity of the electrical system is also a concern in these occupancies, particularly where there are multiple EVSE that may be in use. Fire and shock hazards are a concern. There is also a higher risk of vehicle damage and the potential for exposure to other hazards.

The permitting process will verify electrical system capacity and compliance with the requirements of the NEC®. The NEC® is referenced in the International Building Code® (IBC®), published by ICC, which is used as the basis for regulation of buildings of four stories or greater in most states, at the state or local level. As noted, provisions exist in the NEC® to cover EV charging systems and their installation.

There are some ongoing challenges associated with the permitting process. These include: varying costs of permits by jurisdiction, length of the permitting process, and achieving widespread adoption of the DOE template (for example, some state laws preclude its use and inspection processes may vary from the template). These issues continue to be the subject of discussion among affected stakeholders.

Power Export: Power export is addressed by the NEC Section 90.2(c)6 and Section 625.60. If the EV is connected to the premises wiring, the NEC rules apply. If the EV is not connected to the premises wiring, and is used for isolated or separate EV power export, the NEC does not apply. UL 9741, Edition 2, May 21, 2021, UL LLC Outline of Investigation for Electric Vehicle Power Export Equipment (EVPE) covers anything that does power export with batteries. NFPA 855, Standard for the Installation of Stationary Energy Storage Systems 2023 Edition, section 15.11, describes situations where the EV is being used to provide temporary power to a dwelling.

[25] "Clean Cities Coalition Network," Office of Energy Efficiency & Renewable Energy, U.S. Department of Energy, https://cleancities.energy.gov/ (Accessed February 23, 2023).
[26] "Electric Vehicles," Alternative Fuels Data Center, Office of Energy Efficiency & Renewable Energy, http://www.afdc.energy.gov/vehicles/electric_deployment.html (Accessed February 23, 2023).

Gap C5: Power Export. While permitting for EVSE installation is covered by codes, permitting for the actual delivery of power from the vehicle (i.e., power export) is not specified in codes. SAE J3072 specifies the need for a permit but does not describe how to comply. There are terms and conditions for interconnections related to power export. Addressing this gap requires coordination between utilities, authorities having jurisdiction (AHJs), and code organizations is required.

R&D Needed: No

Recommendation: Address power export in relevant codes in cases where the NEC does not apply (e.g., interconnection agreements).

Priority: Medium

Organization: Code organizations, utilities, AHJs.

Harmonization Efforts

Permitting is a local issue and as such does not really lend itself to harmonization.

Conformance Programs

In the U.S., conformance with electrical and building codes relies on three inter-related mechanisms: applicable installation codes and standards, product safety standards and certifications, and plan approval and inspection. Each of the three components is considered critical to electrical and building safety, and the system is compromised if one of the three is missing. While there may be some variations in policies and procedures among jurisdictions, the three elements described are common to most jurisdictions and have been largely successful in achieving safe buildings. While checklists can be of assistance to jurisdictions in helping to assess conformance with common requirements, they should be considered a starting point so that jurisdictions can address specific or unique concerns in their inspection regimens.

NIST Handbook 44 Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices outlines the basic performance requirements for certification. Other documents complement it by providing type and field test procedures. After installation, once certification is obtained, weights and measures inspectors will perform a metrological performance field test and an inspection on signage and such before certifying that the station is approved for use.

3.2.1.3. Personnel Involved in Installing, Maintaining, and Operating EV Charging Infrastructure

Section **680.106, Installation, operation, and maintenance by qualified technicians of electric vehicle charging infrastructure,** of the NEVI Final Rule provides in relevant part:

(j) *Qualified Technician*. States or other direct recipients shall ensure that the workforce installing, maintaining, and operating chargers has appropriate licenses, certifications, and training to ensure that the installation and maintenance of chargers is performed safely by a qualified and increasingly diverse workforce of licensed technicians and other laborers.[27] Further:

(1) Except as provided in paragraph (j)(2) of this section, all electricians installing, operating, or maintaining EVSE must meet one of the following requirements:

(i) Certification from the EVITP.

(ii) Graduation or a continuing education certificate from a registered apprenticeship program for electricians that includes charger-specific training and is developed as a part of a national guideline standard approved by the Department of Labor in consultation with the Department of Transportation.

(2) For projects requiring more than one electrician, at least one electrician must meet the requirements above, and at least one electrician must be enrolled in an electrical registered apprenticeship program.

(3) All other onsite, non-electrical workers directly involved in the installation, operation, and maintenance of chargers must have graduated from a registered apprenticeship program or have appropriate licenses, certifications, and training as required by the State.

Below is additional information about organizations and key documents relevant to this topic.

National Fire Protection Association (NFPA)

The National Fire Protection Association (NFPA) has published important documents related to electrical inspections and professional qualifications of electrical inspectors. These documents are designated and titled as follows:

- NFPA 73-2021 Standard for Electrical Inspections for Existing Dwellings
- NFPA 78-2020 Guide on Electrical Inspections
- NFPA 1078-2020 Standard for Electrical Inspector Professional Qualifications

These are included in the ANSI EVSP Roadmap of Codes and Standards as they relate to important processes that are implemented (many by law) in Code adopting jurisdictions in North America. As growth of the charging infrastructure progresses, the need for consistent conformance assessment processes increases.

NFPA 73-2021 Standard for Electrical Inspections for Existing Dwellings

[27] https://www.federalregister.gov/d/2023-03500/p-379

It is important to inspect existing buildings into which new EVSE installations will be integrated. NFPA 73 assists users to identify the readiness and appropriateness for EVSE installations. It provides inspectors guidance including but not limited to the following:

- Examination of install equipment
- Services, outside feeders and branch circuits
- Panelboards and distribution equipment
- Overcurrent protective devices
- Cables, their assemblies and conductors
- Boxes and enclosures
- Appliances and special equipment

This document provides criteria to identify hazardous conditions and evaluate safety of installed electrical systems (e.g., fire, shock, overheating, deterioration, noncompliance) for one-, two-, and multifamily dwellings.

NFPA 78-2020 Guide on Electrical Inspections

From shocks and burns to fires and explosions, there are myriad hazards arising from the use of electricity. NFPA 78 offers a complete overview and instruction in cutting-edge electrical inspection best practices. This vital document for helping to protect people and property is designed to deliver a systematic framework by which effective electrical inspections can be accomplished.

Intended primarily for use by code enforcing authorities such as public sector employees and insurance field inspectors, NFPA 78 outlines and describes procedures for administration, plans review, and field inspection tasks and responsibilities, defined as follows:

- Electrical Inspection Administration: The practice of establishing and managing the electrical inspection processes or activities
- Plans review: An assessment of construction documents to verify that the design and layout of electrical systems comply with requirements
- Field inspection: An on-site assessment to confirm that the methods, materials, and equipment used in the installation and maintenance of electrical systems are compliant with requirements

This document covers minimum criteria to aid in organizing and conducting electrical inspections, which include administration, plan review, and field inspection for new installations and modifications to existing installations in accordance with requirements of the authority having jurisdiction.

This guide is designed to help facilitate a systematic working framework or outline by which effective electrical inspection and electrical plan review can be accomplished. It contains specific procedures for conducting electrical inspections which have been developed from the NFPA consensus process which when used effectively can improve the probability of protecting persons and property from hazards arising from the use of electricity.

Each electrical inspection has uniqueness and is different from another. This guide is not designed to encompass all aspects of every electrical installation. Particular characteristics of the installation sites, such as occupancy use, construction type, structure designs, and other related factors should be considered as part of the inspection processes.

This guide applies to electrical inspections conducted to verify minimum compliance with applicable codes and standards and to meet AHJ requirements such as local electrical code rules or local inspection and plan review administrative procedures.

NFPA 1078-2020 Standard for Electrical Inspector Professional Qualifications

Performing electrical inspections is a responsibility that has a significant impact on public safety. NFPA 1078 was created to improve the quality of electrical inspections by establishing minimum qualifications of electrical inspectors. Based on the recommendations of NFPA 78, the debut 2020 edition of NFPA 1078 introduces minimum job performance requirements (JPRs) to validate that personnel serving as electrical inspectors possess the necessary skills and experience.

This document is intended primarily for use by credentialing organizations as the basis for examinations designed to identify qualified electrical inspectors. Applicants and inspectors-in-training can use the standard to learn about work expectations, while employers may reference it in creating job descriptions and identifying proficient candidates.

NFPA 1078 identifies various duties of electrical inspectors, with content covering these areas:

- Electrical inspector administration, plans review, and field inspection qualifications and requirements
- Referenced publications from NFPA and other sources, including references for extracts in mandatory sections
- General and NFPA official definitions relating to electrical inspections and inspector qualifications
- Additional explanatory materials, including explanations and an overview of standards and concepts of JPRs for electrical inspectors, sample job definitions, and informational references

International Code Council (ICC)

The International Code Council (ICC) published two Codes that contain requirements directly related to electric vehicle supply equipment installations. These two codes are frequently adopted and used by authorities having jurisdiction, in addition to the National Electrical Code (NEC) published by NFPA.

The two codes are as follows:

- International Green Construction Code® (IgCC®) – Section R202
- International Residential Code (IRC) – Section N1101.6

No gap has been identified with respect to personnel involved in installing, maintaining, and operating EV charging infrastructure.

3.2.1.4. Impact of Environmental and Use Conditions on EVSE

EVSE may be affected by a wide variety of conditions. Environmental factors that may affect the safety, durability, performance or life of the EVSE include ambient temperature, precipitation, humidity, corrosive agents, and altitude.

Temperature range, including consideration of extremes of hot and cold exposure, may affect the ability of the EVSE to function in the expected manner. Precipitation or other contaminants such as dust may degrade the insulation or performance of equipment. Where applicable, the equipment's ability to withstand the effects of icing and/or de-icing may be important. High humidity conditions may also affect equipment insulation or performance. Another consideration is whether the equipment will be exposed to potentially corrosive agents such as salts, through installation in proximity to bodies of salt water or through exposure to anti-icing salts applied to roads.

Hazardous or classified locations (i.e. locations that are classified as hazardous because of the type of material or exposure in that environment) are terms used to identify installations where fire or explosion hazards may exist because of the presence of flammable or combustible gases or vapors, or other potential sources or likely causes of fire and/or explosion hazards. These may be relevant to EVs both with respect to the existing presence of such hazards from outside sources (for example, at a fuel station), and for the generation of such hazards through the electric vehicle charging process, if applicable, based upon the battery technology that is employed.

Product standards such as UL 2594, Standard for Electric Vehicle Supply Equipment, generally anticipate maximum ambient temperatures of 40C, although higher limits may be declared by manufacturers and validated in the testing. This is consistent with widespread use of a 40C default ambient threshold for industrial and similar equipment. Product testing generally includes consideration for lower ambient levels, such as -30C, for particular test conditions.

Exposure to the elements is generally addressed by established test methods, such as the NEMA 250 Enclosures for Electrical Equipment defines enclosure type designations and related testing. Environmental considerations, as well as related testing, are also addressed in UL 50E, Enclosures for Electrical Equipment, Environmental Considerations.

Exposure to corrosive agents for EV infrastructure equipment is addressed in various ways by product standards, generally in consideration of the degrading effects of exposure to the elements, anticipated fumes or solvents, and/or anticipated compounds such as gasoline fuels that may be present in vehicular locations.

Use of equipment, including electric vehicle supply equipment, in hazardous (classified) locations is addressed by well-established requirements. These requirements mitigate the potential fire or explosion hazards by various strategies to minimize the risk of an electrical circuit from serving as a source of ignition for the potentially hazardous gases, vapors, or other sources. The established requirements include numerous product standards relevant to the use of the equipment in particular classified locations, and installation requirements in Chapter 5 of the National Electrical Code®.

Electric vehicles will be exposed to many of the same hazards as conventionally powered vehicles. The principal difference is that EVs are a source, as well as a user, of large amounts of electrical energy. EVSE installation must consider all of the potential environmental and occupancy exposures. For example, in a parking garage, there may be more potential for exposure to vehicle impact damage. Considerations should be made for bollards or other protective measures. Parking garages may be required to comply with NFPA 88A, Standard for Parking Structures (updated in 2023), or with Section 406 of the International Building Code® (IBC®), Motor Vehicle Related Occupancies. Which code or standard applies depends on which code or standard the particular jurisdiction has adopted.

Another example is that EVs are likely to use automotive service stations. Parts of these stations are considered to be hazardous locations in accordance with Article 514 of the National Electrical Code®, and Section 307 of the International Building Code® (IBC®). Exposure to this type of hazard will require the compliance with additional requirements in Articles 500, 501, and 514 of the NEC® to ensure that EVSE does not become an explosion hazard.

Other applicable hazards also need to be considered. Location of the EVSE installation away from hazards is the primary means to minimize risk.

3.2.1.5. Ventilation – Multiple Charging Vehicles

During normal operations, there is not a major concern with ventilation associated with EV charging. Ventilation concerns arise if charging stations are installed in enclosed areas such as parking garages located in or under older commercial buildings or multi-family residential dwellings, where many vehicles are charging at the same time. In such cases, there exists the possibility of heat generation and fire risk during charging operations, both of which may affect ventilation standards or codes. See section 3.2.2.1 on Residential Charging. Vehicle charging locations may be designated in, or only permitted for, ventilated areas of enclosed buildings.

NEC® Code Provisions Section 625.52 of the NEC 2023 specifies ventilation requirements for charging an EV in an indoor, enclosed space.

> **(A) Ventilation Not Required.** Where electric vehicle storage batteries are used or where the equipment is listed for charging electric vehicles indoors without ventilation, mechanical ventilation shall not be required.

> **(B) Ventilation Required.** Where the equipment is listed for charging electric vehicles that require ventilation for indoor charging, mechanical ventilation, such as a fan, shall be provided. The ventilation shall include both supply and exhaust equipment and shall be permanently installed and

> located to intake from, and vent directly to, the outdoors. Positive-pressure ventilation systems shall be permitted only in vehicle charging buildings or areas that have been specifically designed and approved for that application.

It goes on to specify the requirements for mechanical ventilation.

Conformance Programs

Most jurisdictions currently issue permits and inspect parking garages through building code enforcement permitting and inspection processes that are well-established and well understood. No gaps have been identified at this time with respect to this issue.

3.2.1.6. Cable Management

Cord connected EVSE poses several challenges with regard to safety and theft especially within the public arena. Safety aspects include possible tripping hazards and concerns about vehicle drive-aways while still plugged in. Copper cables within EVSE offer tempting theft opportunities with resulting safety implications.

EVSE standards, including ANSI/UL 2251, the Standard for Safety for Plugs, Receptacles and Couplers for Electric Vehicles, and the National Electrical Code®, contain requirements for breakaway protection of cables.

ANSI/UL 355, the Standard for Safety of Cord Reels, covers cord reels for general use, as well as special-use cord reels intended to be mounted on or in electrical utilization equipment such as appliances or similar equipment.

Security of EVSE cables, including means to discourage theft of copper cables from EVSE, is not specifically addressed at this time. Attempted theft of EVSE cables may also lead to potential safety hazards.

A definition of the term Cable Management System is found in the NEC® Article 100 on Definitions as follows:

> *Cable Management System. An apparatus designed to control and organize lengths of cable or cord.*

The term cable management system, which is used in Section 625.17(C), generally limits the usable cable length to 7.5 m (25 feet). If a cable management system is part of listed electric vehicle supply equipment, longer output lengths are permitted and are governed under the listing of the EVSE.

A related provision in NEC® Section 625.50 provides height limitations for storing the means of coupling, unless specifically listed and marked for the location. For indoor locations it shall be stored at a height of not less than 450 mm (18 inches) above the floor level and for outdoor locations at a height of not less than 600 mm (24 inches) above the grade level. This requirement does not apply to portable EVSE constructed in accordance with 625.44(A).

Two definitions in NEC® Article 100 differentiate what constitutes an output cable to the electric vehicle from a power supply cord for the electric vehicle supply equipment. Below are the two definitions:

Output Cable to the Electric Vehicle. An assembly consisting of a length of flexible EV cable and an electric vehicle connector (supplying power to the electric vehicle).

Power-Supply Cord. An assembly consisting of an attachment plug and a length of flexible cord connected to utilization equipment.

Requirements for the output cable and power supply cord are found in NEC Section 625.17.

NIST HB 44, UR.1.2 Connection Cord-Length, provides that *an adequate means for cord management shall be in use when the cord exceeds 25 ft in length.*

Gap C6: Cable management. Functional management of EV cables in public parking spaces is not specifically addressed by codes or standards.

R&D Needed: No

Recommendation:

Priority: Medium

Organization: UL, NFPA, NIST

3.2.1.7. Labeling of EVSE and Load Management Disconnects for Emergency Situations

General safety labeling of EVSE is important to protect those operating the equipment. In addition, during emergencies involving EVs that are connected to charging stations, either in public or private locations, emergency responders need to understand how to shut down and disconnect the equipment. Labeling, especially graphics, would aid in quickly identifying devices and disconnect locations.

General safety labeling of residential/commercial/public EVSE is covered under UL 2594 and UL 2202. However, the standards do not specifically address disconnecting the devices in emergency situations when a vehicle is connected to the EVSE and where a load management system is involved.

Under NEC Section 625.43, if the disconnecting means is installed remote from the equipment, a plaque shall be installed on the equipment denoting the location of the disconnecting means.

No standards gap has been identified. See also section 2.2.3. Electric Vehicle Emergency Shut Off – High Voltage Batteries, Power Cables, Disconnect Devices; Fire Suppression, Fire Fighting Tactics and Personal Protective Equipment.

3.2.1.8. EV Charging – Signage and Parking

Consistent and abundant public signage regarding the availability of electric vehicle charging facilities will enable current EV drivers to easily recharge their vehicles. The prevalence of such signage may also serve as an incentive that will help to attract new buyers to the EV market.

In order to accommodate increased numbers of electric vehicles in urban settings, considerations are needed with regard to facilities' charging and parking provisions. As parking requirements are sometimes established by standards, codes, and/or regulations for various building types, insights for EVs may be gleaned therein and potentially incorporated as part of revised versions. Traditionally determined locally, enforcement of parking space use is more complex, involving considerations of whether parking is for electric vehicles generally or only for charging and, if so, for what duration.

Public Signage

The Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways contains federal regulations that govern the design and usage of traffic control devices. These are minimum standards for use which means that states and local agencies can establish standards above the MUTCD minimums. The most current version is the MUTCD 2009 Edition with Revision Numbers 1, 2, and 3, dated July 2022. In April 2011, the U.S. Department of Transportation (DOT) Federal Highway Administration issued an interim approval for the optional use of a General Service symbol sign that provides road users direction to electric vehicle charging facilities that are open to the public.[28] The Federal Highway Administration (FHWA) is in the process of updating the MUTCD. In December 2020, a Notice of Proposed Amendments (NPA) to issue a new edition of the MUTCD was published in the Federal Register for public comment.[29] FHWA proposes a new Guidance statement to incorporate provisions for Electric Vehicle parking. The proposed language is based on FHWA's Memorandum on Regulatory Signs for Electric Vehicle Charging and Parking Facilities.[30] The Infrastructure Investment and Jobs Act directs DOT to update the MUTCD by no later than May 15, 2023, and at least every four years thereafter.[31]

Section **680.110, Traffic control devices or on-premises signs acquired, installed, or operated,** of the NEVI Final Rule provides in relevant part:

---

[28] Federal Highway Administration (FHWA), Manual on Uniform Traffic Control Devices (MUTCD), "Interim Approval for Optional Use of an Alternative Electric Vehicle Charging General Service Symbol Sign (IA-13)," Accessed 2/14/2023 http://mutcd.fhwa.dot.gov/resources/interim_approval/ia13/

[29] FHWA, "National Standards for Traffic Control Devices; the Manual on Uniform Traffic Control Devices for Streets and Highways; Revision," 85 FR 80898, December 14, 2020, Accessed 2/14/2023 https://www.federalregister.gov/documents/2020/12/14/2020-26789/national-standards-for-traffic-control-devices-the-manual-on-uniform-traffic-control-devices-for

[30] FHWA, MUTCD, "Regulatory Signs for Electric Vehicle Charging and Parking Facilities," Accessed 2/14/2023 https://mutcd.fhwa.dot.gov/resources/policy/rsevcpfmemo/

[31] FHWA, MUTCD, Status of Rulemaking for the Eleventh Edition of the MUTCD, March 2, 2022, Accessed 2/14/2023 https://mutcd.fhwa.dot.gov/mutcd11status.htm

(a) *Manual on Uniform Traffic Control Devices for Streets and Highways*. All traffic control devices must comply with part 655 of this subchapter.[32]

(b) *On-Premises Signs*. On-property or on-premise advertising signs must comply with part 750 of this chapter.

No gaps have been identified at this time with respect to this issue.

Parking Space Allocation

The 2021 International Green Construction Code™ (IgCC™), section 501.3.7.3, has a provision requiring electric vehicle charging spaces.[33] The state of California has a law that governs electric vehicle charging station parking. See also the discussion below on accessibility for persons with disabilities to EVSE.

No gaps have been identified at this time with respect to this issue.

Harmonization Efforts

As urban planning is a localized activity, harmonization is generally not a relevant issue.

Conformance Programs

Most jurisdictions in the United States regulate parking issues at the local level without reference to national standards. This is accomplished through ordinances and accompanying regulations including various means of enforcement (mechanical and electronic), as well as civil and criminal requirements and penalties. No gaps have been identified at this time.

3.2.1.9. Physical Security of EVSE

Physical security of EVSE is an important issue. Appropriate guarding of EVSE will enhance protection for users, facilitate safe charging experiences, and lower risks in situations of vehicular collisions.

Section **680.106, Installation, operation, and maintenance by qualified technicians of electric vehicle charging infrastructure,** of the NEVI Final Rule provides in relevant part:

(h) *Security*. States or other direct recipients must implement physical and cybersecurity strategies consistent with their respective State EV Infrastructure Deployment Plans to ensure charging station operations protect consumer data and protect against the risk of harm to, or disruption of, charging infrastructure and the grid.[34]

---

[32] https://www.federalregister.gov/d/2023-03500/p-398
[33] International Code Council, IGCC, Accessed 2/14/2023 https://codes.iccsafe.org/content/IGCC2021P2/chapter-5-site-sustainability#IGCC2021P2_Ch05_Sec501.3.7
[34] https://www.federalregister.gov/d/2023-03500/p-375

(1) Physical security strategies may include topics such as lighting; siting and station design to ensure visibility from onlookers; driver and vehicle safety; video surveillance; emergency call boxes; fire prevention; charger locks; and strategies to prevent tampering and illegal surveillance of payment devices.

In general, available information with regard to guarding of EVSE is limited. Section 110 of the (NEC®) addresses protection of electrical equipment generally. In addition, NFPA 730, Guide to Premises Security (approved in 2023), addresses security in all occupancies from residential dwellings to large industrial complexes. Provisions describe construction, protection, and occupancy features and practices intended to reduce security risks to life and property. Annex E is an informative annex which discusses the placement/design of barriers, bollards, and other security features. Another issue is when to design for physical protection as opposed to designing for a breakaway scenario if a vehicle from a nearby roadway collides with the EVSE. See also Gap S8: EVSE Cyber-physical Vulnerabilities in chapter 5.

3.2.1.10. Accessibility for Persons with Disabilities to EVSE

Design and location considerations for EVSE must also take into account accessibility requirements in design standards, building codes, as well as state and federal accessibility regulations including the Americans with Disabilities Act and the Fair Housing Act.

Section **680.106, Installation, operation, and maintenance by qualified technicians of electric vehicle charging infrastructure,** of the NEVI Final Rule provides in relevant part:

(e) *Availability*. Charging stations located along and designed to serve users of designated Alternative Fuel Corridors must be available for use and sited at locations physically accessible to the public 24 hours per day, 7 days per week, year-round. Charging stations not located along or not designed to serve users of designated Alternative Fuel Corridors must be available for use and accessible to the public at least as frequently as the business operating hours of the site host. This section does not prohibit isolated or temporary interruptions in service or access because of maintenance or repairs or due to the exclusions outlined in § 680.116(b)(3).[35]

(f) *Payment Methods.* Unless charging is permanently provided free of charge to customers, charging stations must:

(1) Provide for secure payment methods, accessible to persons with disabilities, which at a minimum shall include a contactless payment method that accepts major debit and credit cards, and either an automated toll-free phone number or a short message/messaging system (SMS) that provides the EV charging customer with the option to initiate a charging session and submit payment;

(2) Not require a membership for use;

[35] https://www.federalregister.gov/d/2023-03500/p-368

(3) Not delay, limit, or curtail power flow to vehicles on the basis of payment method or membership; and

(4) Provide access for users that are limited English proficient and accessibility for people with disabilities. Automated toll-free phone numbers and SMS payment options must clearly identify payment access for these populations.

and

(k) *Customer Service*. States or other direct recipients must ensure that EV charging customers have mechanisms to report outages, malfunctions, and other issues with charging infrastructure. Charging station operators must enable access to accessible platforms that provide multilingual services. States or other direct recipients must comply with the American with Disabilities Act of 1990 requirements and multilingual access when creating reporting mechanisms.[36]

In addition, section **680.118, Other Federal requirements,** of the NEVI Final Rule provides in relevant part that:

(c) The American with Disabilities Act of 1990 (ADA), and implementing regulations, apply to EV charging stations by prohibiting discrimination on the basis of disability by public and private entities. EV charging stations must comply with applicable accessibility standards adopted by the Department of Transportation into its ADA regulations (49 CFR part 37) in 2006, and adopted by the Department of Justice into its ADA regulations (28 CFR parts 35 and 36) in 2010.[37]

The U.S. Access Board, an independent federal agency that issues accessibility guidelines under the Americans with Disabilities Act (ADA), Architectural Barriers Act (ABA), Rehabilitation Act of 1973, and other laws, has provided a technical assistance document "Design Recommendations for Accessible Electric Vehicle Charging Stations"[38] to assist in the design and construction of electric vehicle (EV) charging stations that are accessible to and usable by people with disabilities. In the Fall 2022 Unified Agenda and at recent Board Meetings, the Access Board announced that it anticipates a Notice of Proposed Rulemaking (NPRM) for EVSE towards the end of the summer of 2023. Noting the expected continuing expansion and use of EV charging stations, the Board noted in relevant part that:

[T]here are no federal regulations specifying accessibility requirements for EV charging stations to ensure that they are accessible to and useable by persons with disabilities. The Access Board thus intends to publish a notice of proposed rulemaking to supplement its Accessibility Guidelines under

[36] https://www.federalregister.gov/d/2023-03500/p-385
[37] https://www.federalregister.gov/d/2023-03500/p-465
[38] The Access Board, "Design Recommendations for Accessible Electric Vehicle Charging Stations" last updated 7/21/2022, Accessed 3/13/2023 https://www.access-board.gov/tad/ev/

the Americans with Disabilities Act (ADA) and Architectural Barriers Act (ABA) with scoping and technical requirements for electric vehicle charging stations.[39]

The DOE Clean Cities Coalition Network provides best practices for installing ADA-compliant EV charging stations.[40]

In addition, the California Division of the State Architect has developed accessibility requirements for EV charging which are part of the California Building Code.[41]

The 2021 International Building Code® (IBC®), section 1107, provides that no less than 5% of vehicle spaces at an EV charging site, and not fewer than one space for each type of EV charging system, shall be accessible.[42] This is not required for R-2, R-3, and R-4 occupancies.

In terms of standards activity, ICC A117.1—2017 Accessible And Usable Buildings And Facilities, section 502.11, provides requirements that EV charging stations comply with requirements for operable parts (card readers) and are free of obstructions between the charging station and the adjacent parking space.[43]

As noted, there is some policy activity anticipated. At this time, no codes and standards gap has been identified.

3.2.2. Specific Installation Considerations for Different Charging Scenarios

3.2.2.1. Residential Charging

Residential charging has been in the field since 2008. This technology is well established for charging products with a rating of 240 V ac, 32 A or less. Advancements in charging technology that may implement new functions or use cases, or new methods of transferring power, are being developed, but that development has been slower than the initial development for residential charging. Today, residential equipment may be conductive or wireless in nature. There is consideration of DC residential charging, and bi-directional current flow to allow for charging and for power export from the vehicle. Energy Management Systems have been implemented which allow circuits and systems to perform

---

[39] The Access Board, "Accessibility Guidelines for Electric Vehicle Charging Stations," RIN: 3014-AA48, Fall 2022, Accessed 2/13/2023 https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=202210&RIN=3014-AA48

[40] U.S. Department of Energy, Alternative Fuels Data Center, "Installing Electric Vehicle Charging in Compliance with the Americans with Disabilities Act Requirements," Accessed 2/14/2023 https://afdc.energy.gov/fuels/electricity_infrastructure_ada_compliance.html

[41] State of California, Division of the State Architect, "Electric Vehicle Charging Station Accessibility," Accessed 2/14/2023 https://www.dgs.ca.gov/DSA/Resources/Page-Content/Resources-List-Folder/Access-Compliance-Reference-Materials?search=Electric%20Vehicle%20Charging

[42] International Code Council, IBC, Accessed 2/14/2023 https://codes.iccsafe.org/content/IBC2021P2/chapter-11-accessibility#IBC2021P2_Ch11_Sec1107.2

[43] International Code Council, A117.1, Accessed 2/14/2023 https://codes.iccsafe.org/content/icca117-12017P4/chapter-5-general-site-and-building-elements#ICCA117.12017P4_Ch05_Sec502.11

rationing and prioritization of EV chargers as part of the home or dwelling infrastructure power consumption. To drive the adoption of EVs, and to prepare for a resilient grid when more EVs are on the road, there are developments in building codes and electrical codes to address preparedness.

The increase in residential charging has also been a driver for discussions around firefighting concerns related to a large number of EVs charging or parking near or under older apartment buildings that did not anticipate EVs. Some of these areas are already addressed by existing standards and some of them are not. Although this is not the area of greatest innovation, it does have some gaps in standardization that are required to be filled in order to safely adopt new technologies and continue to use existing technologies in a manner that is safe and user friendly, all while supporting the health of the grid.

Published Standards:

Published standards and codes include the following:

- ICC, 2021 International Green Construction Code (IgCC)
- ICC, 2021 International Residential Code (IRC)
- NECA 413-2019, Standard for Installing and Maintaining Electric Vehicle Supply Equipment (EVSE)
- NFPA 13, Standard for the Installation of Sprinkler Systems, Current Edition 2022
- NFPA 13R, Standard for the Installation of Sprinkler Systems in Low-Rise Residential Occupancies, Current Edition 2022
- NFPA 25, Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems, Current Edition 2023
- NFPA 70®, National Electrical Code®, Current Edition 2023 (Article 625)
- NFPA 88A, Standard for Parking Structures, Current Edition 2023
- UL 916, Edition 5, October 22, 2015, Energy Management Systems[1]
- UL 1741, Edition 3, September 28, 2021, Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources
- NMX-J-817-ANCE-2022 / CSA C22.2 No. 346 / UL 2202, DC Charging Equipment for Electric Vehicles[2]
- NMX-J-678-ANCE-2017 / CSA C22.2 No. 282-17 / UL 2251, Plugs, Receptacles and Couplers for Electric Vehicles[2]
- NMX-J-677-ANCE-2022 / CSA C22.2 No. 280-22 / UL 2594, Electric Vehicle Supply Equipment[2]
- UL 2750, Edition 1, March 13, 2020, Wireless Power Transfer Equipment for Electric Vehicles
- UL 9540, Edition 2, February 27, 2020, Energy Storage Systems and Equipment
- UL 9540A, Edition 4, November 12, 2019, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
- UL 9741, Edition 2, May 21, 2021, / CSA C22.2 No. 348 – Electric Vehicle Power Export Equipment (EVPE)[3]
- UL 60730-1, Edition 5, October 18, 2021, Automatic Electrical Controls – Part 1: General Requirements[4]

- CAN/CSA E60730-1, Automatic Electrical Controls - Part 1: General Requirements[4] (5th Edition)
- SAE J1772, ™ Electric Vehicle and Plug-in Hybrid Electric Vehicle Conductive Charge Coupler (2017-10-13)
- SAE J2954, Wireless Power Transfer for Light-Duty Plug-In/Electric Vehicles and Alignment Methodology (2022-08-26)

Note 1: In addition to the specifics about these residential charging equipment installations, the NECA standard addresses quality and performance and workmanship issues and goes beyond minimum safety requirements. It includes valuable information about performing site assessments to determine required capacity needs in addition to comprehensive inspection and plan review information to address those processes.

Note 2: Outside of North America, additional standards may apply. These include IEC 62752, IEC 61851-1, and IEC 62196 series for conductive charging and the IEC 61980 series for wireless power transfer charging.

[1] Right now UL 916 points directly to UL 60730-1 for EV Charger Energy Management Systems.

[2] These standards are tri-nationally harmonized between the US (UL), Canada (CSA) and Mexico (ANCE).

[3] This standard will be bi-nationally harmonized between the US (UL) and Canada (CSA) by the time this roadmap is published.

[4] This standard is not binational as minor differences exist between US (UL) and Canada (CSA); both are based on the international IEC 60730-1. Even though the 60730-1 standard does not directly reference "EV," it has suitable/potential requirements for EV Charger Energy Management Systems (local and remote).

In-Development Standards. None identified

Gap C7: Fire protection in relation to EV parking/charging in/near older buildings. As mentioned above, there are many conversations around parking and charging EVs in or near older structures, such as multi-family residences with an indoor or underground parking lot. If a fire incident was to occur where many EVs are in the same parking area, issues arise whether the building can withstand the intensity of a lithium battery fire, what that means for any fire protection equipment that should be installed, etc. Development of building codes and fire codes may be needed to address this concern. Note: This is also a concern for parking/charging in or near older commercial buildings as well.

R&D Needed: Potentially yes. Research into building materials that can or cannot withstand a lithium fire. Fire protection equipment that should be installed and other fire prevention means may also require research. Note: The 2023 edition of NFPA 88A requires the installation of automatic sprinkler systems in all parking structures in accordance with NFPA 13 and NFPA 13R as applicable. It also requires that automatic sprinkler systems be inspected, tested, and maintained in accordance with NFPA 25.

Recommendation: Develop standards or codes to address the issue of fire protection where EVs are parked/charging in/near older buildings.

Priority: Medium

Organization(s): International Code Council (ICC), NECA, NFPA, and the International Association of Electrical Inspectors (IAEI) to address code related issues

3.2.2.2. Commercial / Workplace Charging

In January 2023, the U.S. Department of Energy (DOE) published a fact sheet titled "Connecting Electric Vehicle Charging Infrastructure to Commercial Buildings."[44] DOE also held a webinar covering this topic on March 1, 2023.[45] These materials cover, among other things, the different EV charger types, which are suitable for different building types, and potential building infrastructure upgrades to accommodate EV charging. For commercial enterprises and short-term charging scenarios, ACL2 or DCFC are generally the appropriate chargers. It is recommended that "a thorough review of the building's existing electrical hardware, power, and energy consumption" be done prior to installing an EV charging station. Relevant standards to be considered include NEC Article 625 and SAE J1772. Electrical requirements include dedicated circuitry, correct sizing of components, and sufficient capacity. Other considerations include installation costs, joining an EV charging network, issues associated with metering and utilities, and charging equipment ownership options.

---

[44] Accessed 3/9/2023 https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Connecting%20Electric%20Vehicle%20Charging%20Infrastructure%20to%20Commercial%20Buildings.pdf

[45] Recording and slides accessed 3/9/2023 https://betterbuildingssolutioncenter.energy.gov/webinars/selecting-and-connecting-ev-chargers-commercial-buildings

During discussions to develop this roadmap, a specific code issue was identified with respect to setbacks from commercial buildings. This relates to some EV charger manufacturers that are developing fast chargers that have batteries included in the equipment enclosure. NFPA 855, Standard for the Installation of Stationary Energy Storage Systems, covers any energy storage system greater than 20kWh. For some of these EVSE coupled with ESS, they are not obtaining the appropriate listing for the ESS components in accordance with UL9540. NREL developed guidance clarifying the listing requirements.

As to the separation distance, the 2021 International Fire Code (IFC), section 1207.8.3,[46] and NFPA 855, section 9.5.2.6.1, include the same language:

> ***9.5.2.6.1 Clearance to Exposures.***
> *ESS located outdoors shall be separated by a minimum 10 ft (3 m) from the following exposures:*
> *(1) Lot lines*
> *(2) Public ways*
> *(3) Buildings*
> *(4) Stored combustible materials*
> *(5) Hazardous materials*
> *(6) High-piled stock*
> *(7) Other exposure hazards not associated with electrical grid infrastructure*

Both codes have a few exceptions allowing reduction to 3' where 1 to 2 hr. fire barriers are provided, or if results of large-scale fire testing under UL9540A determine that is a safe distance. For EVSE coupled with ESS, 3' should be an acceptable distance for most charging applications.

3.2.2.3. Highway / Corridor Charging

According to the aforementioned DOE fact sheet, DCFC is "most suitable for long-distance interstate EV travel and for vehicles with high battery storage capacity like electric long-haul trucks and buses charged at the commercial buildings along highway corridors or truck depots."

Many of the relevant provisions of the NEVI Final Rule[47] are interspersed throughout this roadmap. Some though not all additional provisions not covered elsewhere in this roadmap regarding highway/corridor charging follow. Please refer to the NEVI Final Rule for complete information. The NEVI Final Rule:

complements the February 10, 2022, NEVI Formula Program Guidance, which encouraged EV chargers to be spaced a maximum distance of 50 miles apart along designated Alternate Fuel

[46] IFC, Accessed 3/19/2023 https://codes.iccsafe.org/content/IFC2021P2/chapter-12-energy-systems#IFC2021P2_Pt03_Ch12_Sec1207
[47] Accessed 2/26/2023 https://www.fhwa.dot.gov/environment/nevi/resources/ev_charging_min_std_rule_fr.pdf

Corridors (AFCs), by requiring minimum standards for the development of each station to achieve fully built out status.

Section **680.106, Installation, operation, and maintenance by qualified technicians of electric vehicle charging infrastructure,** of the NEVI Final Rule provides in relevant part:

> (e) *Availability*. Charging stations located along and designed to serve users of designated Alternative Fuel Corridors must be available for use and sited at locations physically accessible to the public 24 hours per day, 7 days per week, year-round. Charging stations not located along or not designed to serve users of designated Alternative Fuel Corridors must be available for use and accessible to the public at least as frequently as the business operating hours of the site host. This section does not prohibit isolated or temporary interruptions in service or access because of maintenance or repairs or due to the exclusions outlined in § 680.116(b)(3).[48]

and

> (i) *Long-Term Stewardship*. States or other direct recipients must ensure that chargers are maintained in compliance with this part for a period of not less than 5 years from the initial date of operation.[49]

A point of clarification made in the NEVI Final Rule, regarding section 680.106.(b), is that "States would have additional flexibility to determine the type and location of any additional EV charging infrastructure after the Secretary of Transportation has certified that the State's AFCs for EVs are fully built out."[50]

[48] https://www.federalregister.gov/d/2023-03500/p-368
[49] https://www.federalregister.gov/d/2023-03500/p-378
[50] https://www.federalregister.gov/d/2023-03500/p-128

4. Grid Integration

4.1. Communications/Controls

The charging of EVs creates both risks and opportunities for service providers and consumers. At a minimum, consumers want access to a ubiquitous charging infrastructure that enables them to charge their EVs safely and quickly at the cheapest possible rate and to know what that rate will be, in advance. Energy Service Providers want to be able to incentivize charging to off-peak hours to improve grid efficiency and potentially to protect grid assets. In certain regulatory environments and/or grid situations, utilities want to use EV inverter-based functions for V2G discharging, frequency support, and voltage support.

Additionally, EVs can provide value-added services such as demand response load control, pricing, locating and reserving charging stations, reverse energy flow, charge/discharge management, and "EV as DER" distribution grid support services for further benefits to consumers and the grid. To advance a truly smart grid that can accommodate EVs, it is necessary that communication among the various entities involved be enabled to maximize the services offered and the benefits that EVs can deliver. Put another way, the vehicles, charging network providers and utilities must be able to interact with one another seamlessly. While standards are a critical part of this, business models are also needed to support the infrastructure for these interactions.

The first part of this chapter is focused on communications/controls generally between EVs and charging stations, between charging network providers, and between charging network providers and the grid. This section is broken down into: communications architecture for EV charging; communications requirements for various EV charging and grid support scenarios; communication and measurement of EV energy consumption; and telematics smart grid communications). The second part of this chapter deals with power distribution/distributed energy resource (DER) integration, and fast charging stations/microgrids. This includes a discussion of: power (electrical) systems and safety and communications/controls.

4.1.1. Communications Architecture for EV Charging

The actors and communication methods involved in EV charging may vary, depending on criteria such as the location of charging; the EV-related infrastructure (communications-capable or not); the type of charging (AC/DC/wireless); the charging provider (utility, corporation, municipality, EV Services Provider, etc.); and the requirements for authentication, authorization, accounting, and billing of the charging session.

An actor is an entity that serves as one end point of communications. For example, when an EV communicates with a charger aka electric vehicle supply equipment (EVSE), the two actors are the EV and the EVSE. The primary actors involved in EV-related communication are expected to be the: (1) EV, (2) EV driver / operator, (3) EVSE, (4) Energy Service Provider (ESP), (5) Energy Management System

(EMS), (6) Energy Service Interface (ESI), (7) End Use Measurement Device (EUMD), and (8) EV Services Provider (EVSP) e.g., EV charging network operator. For purposes of this document, these actors are defined below.

An Energy Service Provider (ESP) is an entity that generates, transmits, and distributes electrical power (e.g., a utility) though it could also encompass an energy retailer that sells electricity and related services such as customer service and billing, but is not involved in electrical power generation, transmission and distribution.

An Energy Management System (EMS) is a logical entity that manages energy consumption in a home/building/premises. This may be controlled by a consumer (e.g., homeowner, premises owner) or an Energy Service Provider (e.g., a utility).

An Energy Service Interface (ESI) is defined in IEEE 2030.5-2018, Standard for Smart Energy Profile Application Protocol, as a "device, with multiple network interfaces, which is a member of both the home smart energy network and a service provider's private network. This is the primary mechanism for the service provider to contribute data and directives into the smart energy network and to receive responses from smart energy devices."

An End Use Measurement Device (EUMD) is a revenue-grade meter responsible for directly measuring energy delivered to an EV. The physical form, location and ownership of the EUMD may be unique for different applications.

An EV Services Provider (EVSP) aka charging service provider (CSP) is an entity that provides some services related to EV charging such as a utility, municipality or company. Subcategories include:

- A charging station operator (CSO) aka charge point operator (CPO) that is in charge of the physical charging station.
- A charging network operator (CNO) aka e-mobility service provider (eMSP) that is in charge of the transaction between the EV and the charging station operator.

In the U.S. charging network operators typically also are charging station operators, whereas in Europe there are many more companies that only fulfill the role of one or the other.

EV charging infrastructure is a subset of the electric grid or smart grid. For simplicity, the generation, transport and distribution parts of the grid can be bundled up and referred to as the utility or Energy Service Provider (ESP).

Broadly speaking, EV charging infrastructure downstream from the utility may be subdivided into home (residential) charging, commercial (workplace) charging, and public charging.

In all these scenarios, the utility, the EV, and in most cases the EVSE are the constants.

Home (Residential) Charging

For home charging, the utility may communicate directly with the smart meter(s) installed at the home. These meters send consumption data to the utility, and the costs can be calculated according to the tariff schedules. This scenario only requires communication between the smart meter (operated by the utility) and the utility. This could happen over the Advanced Measuring Infrastructure (AMI) network deployed by the utility.

In a more advanced scenario, the EV may use the Original Equipment Manufacturer's (OEM) telematics network to download demand response (DR) information and tariff rates, and schedule charging accordingly.

In cases where a jurisdiction (such as a public utilities commission) has mandated that sub-metering be opened up to third party agents, a sub-meter that resides in the EVSE, EV, or outside of them needs to communicate its metering data to the third party, and the third party needs to then forward that data (as-is or in an aggregated format) to the utility.

Home charging communication may use the customer's internet connection, or it may use its own cellular data connection.

Commercial (Workplace) Charging

In scenarios where EVSEs are restricted to authorized access only EVs or EV drivers, then communication is required for authentication purposes, e.g., using an RFID card, credit card, QR code, smartphone application, etc.

The commercial charging scenario includes entities such as corporations, supermarkets, universities, hospitals, commercial fleets at depots, etc. A commercial entity may offer different levels of service to different customers. For instance, a supermarket may provide benefits to customers who charge at their EVSEs. Hospitals and corporations may restrict EV charging to their employees only, in certain spaces. In other cases, charging may be allowed for everyone.

The commercial charging scenario could also include multi-dwelling units (MDUs) such as apartment complexes. If a small number of EVSEs are shared amongst all the EV driving residents of an MDU, then the MDU operator may want to restrict access to those residents who sign up for a charging plan. Similar to home charging, MDUs most likely would be using ACL2 charging.

Public Charging

As EVs proliferate, there may be a large number of EV owners who do not have the luxury of charging at home because they have to park their EVs on the street or they have to travel long distances.

Public charging may require the AAA (Authentication, Authorization and Accounting) function to be able to bill the appropriate consumer, i.e., the consumer must be unambiguously identified such that the proper service can be provided, and the service (electricity delivered to the EV) must be metered accurately and securely, so that the consumer can be billed for their EV charging.

Also, since EVSEs are not ubiquitous, there needs to be a means for a driver to locate them, view information (such as pricing and availability), and possibly reserve their use.

Variety of Use Cases and Bi-lateral Communication

There are many variations for EV communication. These include:

- Multiple application contexts
- Multiple possible coordination approaches
- Multiple phases (authentication, authorization, operation, billing, and more)

These all create differences in which entities are involved and who talks with whom.

For example, in one use case, EV charging is attached to a residence or a small commercial building, with dynamic prices (e.g., hourly), and with the possibility of dynamic capacity management[51] of the customer site as a whole. In such case, the grid coordinates with the customer as a unitary entity rather than with the EV directly and alone. Today, the needed price information can be carried over the Open Automated Demand Response (OpenADR) protocol, IEEE P2030.5, and CTA-2045.

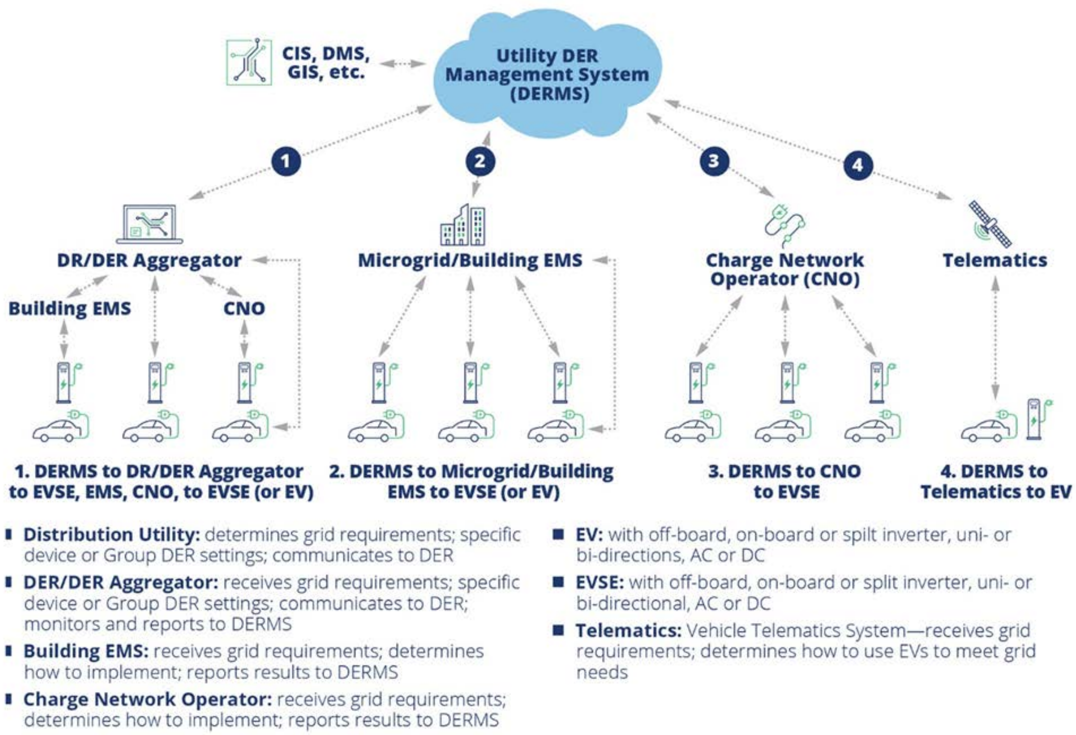
A list of use cases and the bi-lateral communication involved might include, for example, the following:

- Price communication from grid to EVSE (or EV)
- Price communication from grid to building central device
- Price communication from building central device to EVSE (or EV)
- Dynamic capacity coordination between grid and customer (central entity device)
- Capacity modulation signal from customer central device to EVSE (or EV)

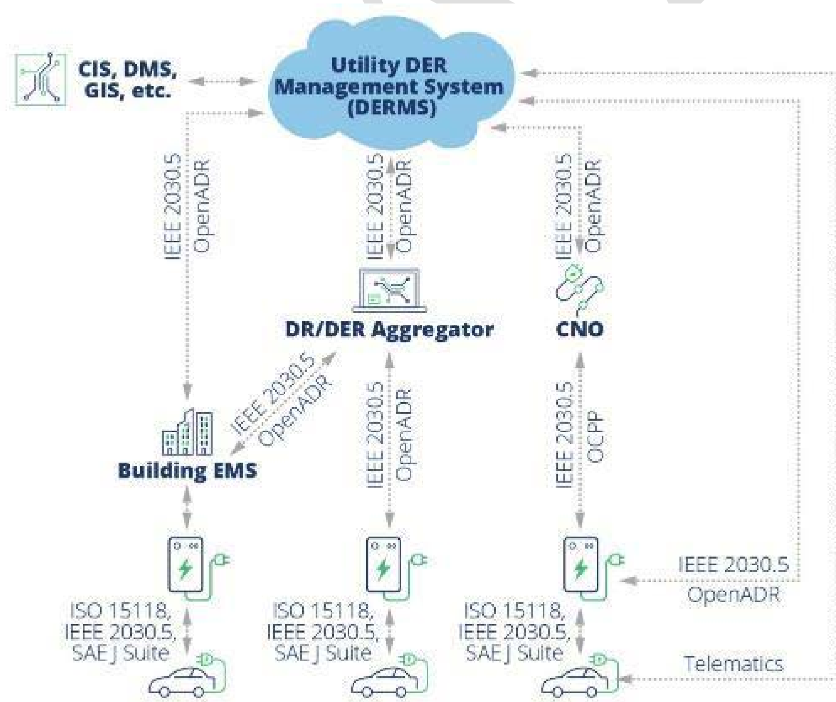
Sample High Level Communications Architecture, Standards, and Protocols

With the aforementioned caveats, below are some graphics and additional context on the ways and means by which charging can occur and relevant standards and protocols.

[51] Bruce Nordman, with contributions from Jim Zuber, "Dynamic Capacity Management (DCM), August 2022, Accessed 2/20/2023 https://docs.google.com/document/d/1yGTTATHXMu1k8gTFH_rDNu7im4wGP7TYV6TlxK5_MOE/edit



Source: Smart Electric Power Alliance, 2020.



Source: Smart Electric Power Alliance, 2020.

Figures above taken from *Guidelines for Selecting a Communications Protocol for Vehicle-Grid Integration* (August 2020, pp. 15 & 20). Used with Permission of Smart Electric Power Alliance.

Typically, there is an entity that manages the energy flow within each location and acts as an interface between the Energy Service Provider and the various charging locations.

In a home, an Energy Management System (EMS) could act as an analog of a building EMS and control all the energy loads in the home, including EVs. While the external communication with the Energy Service Provider uses an Energy Services Interface (ESI), communication between the EMS and the internal charging infrastructure could take place via a Home Area Network (HAN), though that is rarely used. Optionally, an EV Services Provider may manage the EV portion of the load, leaving the EMS to handle the remaining loads such as air-conditioning. Home charging is often managed by customer phone apps. In such cases, communications use the cellular phone network.

In the case of a commercial/industrial building, an EMS may be the entity managing the energy flow. It communicates with the ESP via a standard ESI, and with the building's charging infrastructure via some internal communications mechanism (e.g., BACnet).

For public charging stations, an EV Services Provider manages a network of EVSEs and provides charging availability to EV drivers. The EVSP communicates with the ESP using a standard protocol such as the OpenADR 2.0b or the Open Charge Point Protocol (OCPP), and may act as an aggregator, providing a single communication point with the ESP for all the EVSEs in its purview. Creating a single application programming interface (API) specific to public charging communication is desirable in order to provide services such as finding and reserving charging stations, providing information on charging reliability, etc.

Most of the completed and ongoing standardization related to communications for EV charging infrastructure has taken place within SAE International and the ISO/TC 22/SC 31 – IEC/TC 69 Joint Working Group (JWG) which developed the ISO 15118 standards (see complete list below). Other standards such as the Smart Energy Profile 2.0 (SEP 2.0, now IEEE P2030.5), and OpenADR incorporate EV charging-related communications.

Charging-related communication between the EV and EVSE for conductive charging has been standardized in SAE J1772™ (and in the IEC 61851 series). This communication is used to signal the readiness of the EV to accept energy and of the EVSE to supply energy. It also allows the EVSE to signal the ampacity (maximum allowable current) that the EV should consume. Verification of the connection, equipment grounding continuity, and proximity detection are also provided.

SAE has undertaken to develop standards for EV communication that go beyond SAE J1772™ and define communications functions including utility communications, DC charging, reverse power flow, diagnostics, and wireless charging (see complete list below). These documents have various slash sheets to keep the functions separated and concise, and yet build on each other depending on the functions desired. SAE J2836™ includes the use cases and general information for each function. SAE J2847 includes the corresponding slash sheets that use the requirements defined in SAE J2836™ and adds messages, sequence diagrams, and other details. SAE J2931 includes the communication protocol for various mediums including power line communication (PLC), telematics, and dedicated short range communication (DSRC) for use in the messages of J2847. Security is included specifically in J2931/7. SAE J2953 identifies the interoperability criteria for the various mediums (PLC, telematics, DSRC, etc.) and associated communications protocols identified in J2931. SAE J3072 establishes requirements for a grid support inverter system function integrated into a plug-in electric vehicle (PEV).

The ISO/TC 22/SC 31 – IEC/TC 69 Joint Working Group (JWG) has undertaken to develop EV communication standards concurrently with SAE. The ISO 15118 EV communications standards are related to the SAE documents as follows: ISO 15118 part 1 identifies use cases, part 2 network and application protocol requirements, and part 3 physical and data link communications layers. ISO 15118-1 corresponds to SAE J2836™, while 15118-2 and 15118-3 correspond to various documents under the SAE J2847 and SAE J2931 series. The full list of ISO/IEC JWG EV communication standards follows below.

Section **680.108, Interoperability of electric vehicle charging infrastructure,** of the NEVI Final Rule[52] provides in relevant part:

> (a) *Charger-to-EV communication.* Chargers must conform to ISO 15118-3 and must have hardware capable of implementing both ISO 15118-2 and ISO 15118-20. By February 28, 2024, charger software must conform to ISO 15118-2 and be capable of Plug and Charge. Conformance testing for charger software and hardware should follow ISO 15118-4 and ISO 15118-5, respectively.[53]

SAE Hybrid EV Committee Documents

Overarching Documents

Published Standards:

- SAE J2836_201807, Instructions for Using Plug-In Electric Vehicle (PEV) Communications, Interoperability and Security Documents (2018-07-18)

Use Case Documents

Published Standards:

- SAE J2836/1_201907, Use Cases for Communication Between Plug-in Vehicles and the Utility Grid (2019-07-15)
- SAE J2836/2_201109, Use Cases for Communication between Plug-in Vehicles and Off-Board DC Charger (2011-09-15)

[52] Federal Highway Administration, National Electric Vehicle Infrastructure Standards and Requirements, 88 FR 12724, published 2/28/23, effective 3/30/23, accessed 3/5/23 https://www.federalregister.gov/documents/2023/02/28/2023-03500/national-electric-vehicle-infrastructure-standards-and-requirements.
[53] https://www.federalregister.gov/d/2023-03500/p-394

- SAE J2836/3_201701, Use Cases for Plug-In Vehicle Communication as a Distributed Energy Resource (2017-01-18)
- SAE J2836/4_202106, Use Cases for Diagnostic Communication for Plug-in Electric Vehicles (2021-06-10)
- SAE J2836/5_202112, Use Cases for Customer Communication for Plug-in Electric Vehicles (2021-12-16)
- SAE J2836/6_202104, Use Cases for Wireless Charging Communication for Plug-in Electric Vehicles (2021-04-09)

In-development Standards:

- SAE J2836/2, Use Cases for Communication between Plug-in Vehicles and Off-Board DC Charger (2022-11-02)
- SAE J2836/3, Use Cases for Plug-In Vehicle Communication as a Distributed Energy Resource (2020-01-03)

Signal/Message Documents

Published Standards:

- SAE J2847/1_201908, Communication for Smart Charging of Plug-in Electric Vehicles Using Smart Energy Profile 2.0 (2019-08-20)
- SAE J2847/2_201504, Communication Between Plug-In Vehicles and Off-Board DC Chargers (2015-04-09)
- SAE J2847/3_202103, Communication for Plug-in Vehicles as a Distributed Energy Source (2021-03-23)
- SAE J2847/6_202009, Communication for Wireless Power Transfer Between Light-Duty Plug-in Electric Vehicles and Wireless EV Charging Stations (2020-09-29)

In-development Standards:

- SAE J2847/2, Communication Between Plug-In Vehicles and Off-Board DC Chargers (2020-12-01)
- SAE J2847/3, Communication for Plug-in Vehicles as a Distributed Energy Source (2022-04-19)
- SAE J2847/5, Communication between Plug-in Vehicles and Customers (2022-04-04)
- SAE J2847/6, Communication for Wireless Power Transfer Between Light-Duty Plug-in Electric Vehicles and Wireless EV Charging Stations (2022-10-09)

Requirements and Protocol Documents

Published Standards:

- SAE J2931/1_201412, Digital Communications for Plug-in Electric Vehicles (2014-12-11)
- SAE J2931/4_201410, Broadband PLC Communication for Plug-in Electric Vehicles (2014-10-21)

- SAE J2931/6_202208, Signaling Communication for Wirelessly Charged Electric Vehicles (2022-08-26)
- SAE J2931/7_201802, Security for Plug-In Electric Vehicle Communications (2018-02-15)

In-development Standards:

- SAE J2931/1, Digital Communications for Plug-in Electric Vehicles (2022-11-01)
- SAE J2931/4, Broadband PLC Communication for Plug-in Electric Vehicles (2022-11-01)

Interoperability Documents

Published Standards:

- SAE J2953/1_201310, Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE) (2013-10-07)
- SAE J2953/2_201401, Test Procedures for the Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE) (2014-01-22)
- SAE J2953/4_202106, Plug-in Electrical Vehicle Charge Rate Reporting and Test Procedures (2021-06-10)

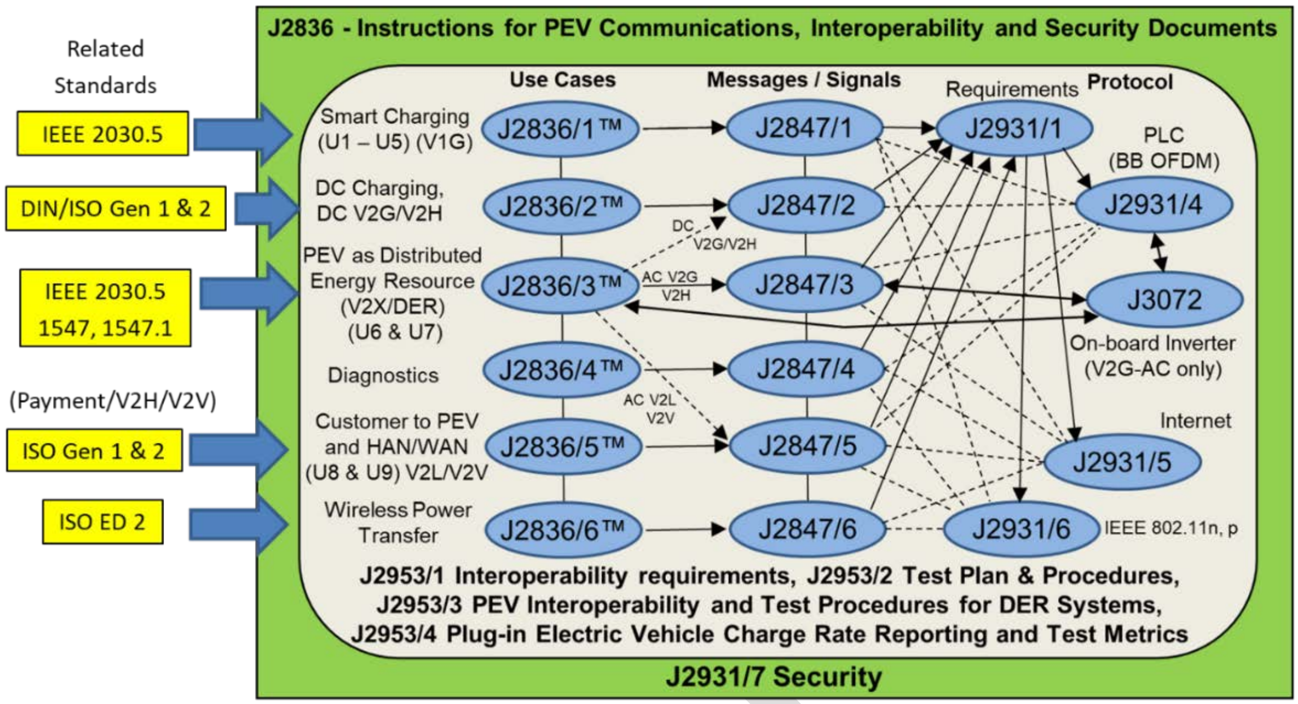
In-development Standards:

- SAE J2953/1, Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE) (2022-11-01)
- SAE J2953/2, Test Procedures for the Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE) (2022-11-01)
- SAE J2953/3, Test Cases for the Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE) (2016-02-03)
- SAE J2953/4, Plug-in Electrical Vehicle Charge Rate Reporting and Test Procedures (2021-06-28)

Requirements and Testing Documents

Published Standards:

- ISO/TC 22/SC 31 – IEC/TC 69 Joint Working Group (JWG) ISO 15118 Documents
- SAE J3072_202103, Interconnection Requirements for Onboard, Grid Support Inverter Systems (2021-03-10)



Published Standards:

- ISO 15118-1:2019, Edition 2.0, Road vehicles - Vehicle to grid communication interface - Part 1: General information and use case definition (2019-04-02)
- ISO 15118-2:2014, Edition 1.0, Road vehicles -- Vehicle-to-Grid Communication Interface -- Part 2: Network and application protocol requirements (2014-03-31)
- ISO 15118-3:2015, Edition 1.0, Road vehicles -- Vehicle to grid communication interface -- Part 3: Physical and data link layer requirements (2015-05-26)
- ISO 15118-4:2018, Edition 1.0, Road vehicles - Vehicle to grid communication interface - Part 4: Network and application protocol conformance test (2018-03-07)
- ISO 15118-5:2018, Edition 1.0, Road vehicles - Vehicles to grid communication interface - Part 5: Physical and data link layer conformance tests (2018-03-07)
- ISO 15118-8:2020, Edition 2.0, Road vehicles - Vehicle to grid communication interface - Part 8: Physical layer and data link layer requirements for wireless communication (2020-09-21)
- ISO 15118-9:2022, Edition 1.0, Road vehicles - Vehicle to grid communication interface - Part 9: Physical and data link layer conformance test for wireless communication (2022-11-24)
- ISO 15118-20:2022, Edition 1.0, Road vehicles - Vehicle to grid communication interface - Part 20: Network and application protocol requirements (2022-04-26)

In-development Standards:

- ISO 15118-2 ED2, Road vehicles -- Vehicle-to-Grid Communication Interface -- Part 2: Network and application protocol requirements (Fcst. Publ. Date: 2024-01)
- ISO 15118-4 ED2, Road vehicles - Vehicle to grid communication interface - Part 4: Network and application protocol conformance test (Fcst. Publ. Date: 2024-01)

4.1.2. Communications Requirements for Various EV Charging and Grid Support Scenarios

There are various communication requirements for charging of EVs under different use cases (home, commercial, public) and metering options, each with different levels of complexities.

Basic charging at home does not require communications. However, additional benefits become available if smart charging capabilities exist, such as if sub-metering, charge management and/or demand response are implemented. Further communication complexities come into play if the EV is to be used as a supply source providing reverse power flow to the home or grid.

Commercial / industry applications (e.g., fleets) often involve multiple vehicle charging scenarios with load balancing and sequencing in order to meet business application requirements and minimize costs. Accurate, real time coupling of state of charge (SOC) assessment, business application requirements, and service provider demand response load control is essential.

Public charging communication requirements include the need to quickly and easily locate, price compare, and reserve charging stations on the fly. Additional complexities are also introduced due to the need to authenticate, authorize, and bill the user, especially when crossing over different service territories.

The following briefly describes a number of the requirements for information/communication exchange, not all of which are germane to each use case.

Locating and Using Public Charging Stations (EVSE):

EV drivers charging outside their home need to easily find and optionally reserve an available, compatible charging station. In-vehicle dashboard systems, portable navigation devices, smartphones, and personal computers need to communicate with entities that can provide these services.

Public charging stations are already available and in use; however, there is no standardized method to identify the location and capabilities of a charging station. Such a capability is available for a subset of stations via Google Maps, websites of EVSPs, smartphone applications, or navigation applications/

devices. Notably, DOE provides an Alternative Fueling Station Locator database which includes EV charging station information.[54]

A well-known registry of public charging stations combined with a standardized querying method would enable the broadest public awareness and utilization. It is likely some information about a charging station will be static (e.g., location, type) and can be queried from a global registry, but other information (availability, pricing) will be dynamic and must be queried from the station or the managing entity.

Some work has been done to standardize locating and reserving charging stations, on the inter-provider protocols required for various aspects of EV roaming, and between charging stations and the back office software systems that manage them. Efforts include those listed below.

The National Electrical Manufacturers Association (NEMA) has published EVSE 1.1-2018 Charging Network Interoperability Standard—A Contactless RFID Credential for Authentication (UR Interface).

The Open Charge Alliance (OCA) is a global consortium of public and private electric vehicle infrastructure leaders that have come together to promote open standards through the adoption of the Open Charge Point Protocol (OCPP) and the Open Smart Charging Protocol (OSCP).

OCPP is aimed at providing interoperability between EVSEs and charging networks from different vendors and to reduce the effort required to support multiple EVSEs and/or networks. OSCP facilitates communication of grid capacity to charging station operators. Charging protocols need to continually evolve to fill gaps not served by OCPP or other communication protocols.[55]

Section **680.108, Interoperability of electric vehicle charging infrastructure,** of the NEVI Final Rule provides in relevant part:

> (b) *Charger-to-Charger-Network Communication.* Chargers must conform to Open Charge Point Protocol (OCPP) 1.6J or higher. By February 28, 2024, chargers must conform to OCPP 2.0.1.[56]

In addition, section **680.114, Charging network connectivity of electric vehicle charging infrastructure,** of the NEVI Final Rule provides in relevant part:

> (a) *Charger-to-charger-network communication.*[57]

---

[54] U.S. Department of Energy, Alternative Fuels Data Center, Accessed 3/12/2023 http://www.afdc.energy.gov/afdc/locator/stations/
[55] Driivz, "EV Charging Industry Protocols and Standards," Accessed 3/12/2023 https://driivz.com/blog/ev-charging-standards-and-protocols/
[56] https://www.federalregister.gov/d/2023-03500/p-395
[57] https://www.federalregister.gov/d/2023-03500/p-420

(1) Chargers must communicate with a charging network via a secure communication method. See § 680.108 for more information about OCPP requirements.

(2) Chargers must have the ability to receive and implement secure, remote software updates and conduct real-time protocol translation, encryption and decryption, authentication, and authorization in their communication with charging networks.

(3) Charging networks must perform and chargers must support remote charger monitoring, diagnostics, control, and smart charge management.

(4) Chargers and charging networks must securely measure, communicate, store, and report energy and power dispensed, real-time charging-port status, real-time price to the customer, and historical charging-port uptime.

(b) *Interoperability.* See § 680.108 for interoperability requirements.

In Europe, under the umbrella of ERTICO – ITS Europe, the eMobility ICT Interoperability Innovation, eMI³, is an open group of significant actors from the global EV market who joined forces to harmonize the ICT data definitions, formats, interfaces, and exchange mechanisms in order to enable a common language among all ICT platforms for Electric Vehicles.

Also in Europe, the ETSI Intelligent Transport Systems (ITS) supports the development and implementation of ITS service provision across the network, for transport networks, vehicles and transport users, including interface aspects, multiple modes of transport and interoperability between systems.

Reserving Charging Stations (EVSE and Obtaining Pricing Information):

Due to the relatively long duration of EV charging, the ability to reserve a charging station in advance will be useful to EV drivers. Standardization of the messaging required to reserve a charging station would allow a driver to use a variety of methods (smartphone application, website, etc.) to reserve a station.

Charging Related Information Retrieval: EV drivers need to retrieve information about the current SOC of their EV and an estimate of how long charging may take. Based on this information, the driver can make an informed decision about where to charge, relieving range anxiety. This information is available in the EV and needs to be communicated to the driver via standard mechanisms.

Pre-Charging Information Exchange: In order for charging to take place, an EV must be physically associated with an EVSE. At that point, charging parameters such as direction of energy flow, start and end time of charging, price, and EV/driver authentication information need to be communicated between the EV, EVSE, and grid.

During a Charging Session: For billing purposes, it is critical to accurately measure the energy being provided to the EV and communicate this to the EVSP/ESP, optimally in real time. Charge management including battery SOC is important. Energy Service Providers may need to act in real time during peak demand situations by providing incentives to EVs to reduce the amount of energy consumed (demand response load control).

Notifications: The EV driver may optionally opt-in to receive notifications when charging is completed or ends due to a fault. Such information needs to be communicated from the EV/EVSE to the driver.

Post-Charging: At the end of a charging session, the EV driver/owner must be billed. This may involve communications with a credit card processor, communication between an EVSP and an ESP, or communication between two EVSPs (e.g., when roaming).

In order to successfully communicate the information required in the above scenarios, multiple actors, protocols, and communication media may be involved. Each primary actor may be capable of communicating via multiple methods. For example, an EV may be able to communicate with an EVSE using power line communication (PLC) over the physical link between them. The EV may also be able to communicate with an EV telematics provider using telematics communication over wireless cellular radio.

Due to the number of actors involved and services being offered, as well as the plethora of communications technologies in service, it is critical to standardize these communications as much as possible to provide ease of entry into the market while also allowing widespread and consistent charging capabilities to drivers without adversely impacting the grid. Communications interoperability is a critical component of a smart grid.

Section **680.116, Information on publicly available electric vehicle charging infrastructure locations, pricing, real time availability, and accessibility through mapping**, of the NEVI Final Rule provides in relevant part**:**

> (a) *Communication of price.* (1) The price for charging must be displayed prior to initiating a charging transaction and be based on the price for electricity to charge in $/kWh. If the price for charging is not currently based on the price for electricity to charge an Electric Vehicle in $/kWh, the requirements of this subparagraph must be satisfied within one year from February 28, 2023.[58]
>
> (2) The price for charging displayed and communicated via the charging network must be the real-time price (i.e., price at that moment in time). The price at the start of the session cannot change during the session.
>
> (3) Price structure including any other fees in addition to the price for electricity to charge must be clearly displayed and explained.

[58] https://www.federalregister.gov/d/2023-03500/p-428

(b) *Minimum Uptime*. States or other direct recipients must ensure that each charging port has an average annual uptime of greater than 97%.

(1) A charging port is considered "up" when its hardware and software are both online and available for use, or in use, and the charging port successfully dispenses electricity in accordance with requirements for minimum power level (see § 680.106(d)).

(2) Charging port uptime must be calculated on a monthly basis for the previous twelve months.

(3) Charging port uptime percentage must be calculated using the following equation:

$\mu = ((525{,}600 - (T_{outage} - T_{excluded}))/525{,}600) \times 100$ where:

μ = port uptime percentage,

T_{outage} = total minutes of outage in previous year, and

$T_{excluded}$ = total minutes of outage in previous year caused by the following reasons outside the charging station operator's control, provided that the charging station operator can demonstrate that the charging port would otherwise be operational: electric utility service interruptions, failure to charge or meet the EV charging customer's expectation for power delivery due to the fault of the vehicle, scheduled maintenance, vandalism, or natural disasters. Also excluded are hours outside of the identified hours of operation of the charging station.

(c) *Third-Party Data Sharing*. States or other direct recipients must ensure that the following data fields are made available, free of charge, to third-party software developers, via application programming interface:

(1) Unique charging station name or identifier;

(2) Address (street address, city, State, and zip code) of the property where the charging station is located;

(3) Geographic coordinates in decimal degrees of exact charging station location;

(4) Charging station operator name;

(5) Charging network provider name;

(6) Charging station status (operational, under construction, planned, or decommissioned);

(7) Charging station access information:

(i) Charging station access type (public or limited to commercial vehicles);

(ii) Charging station access days/times (hours of operation for the charging station);

(8) Charging port information:

(i) Number of charging ports;

(ii) Unique port identifier;

(iii) Connector types available by port;

(iv) Charging level by port (DCFC, AC Level 2, etc.);

(v) Power delivery rating in kilowatts by port;

(vi) Accessibility by vehicle with trailer (pull-through stall) by port (yes/no);

(vii) Real-time status by port in terms defined by Open Charge Point Interface 2.2.1;

(9) Pricing and payment information:

(i) Pricing structure;

(ii) Real-time price to charge at each charging port, in terms defined by Open Charge Point Interface 2.2.1; and

(iii) Payment methods accepted at charging station.

Roaming:

Public charging stations may be owned by hosts and managed by EVSPs. EV drivers may subscribe to a charging plan offered by an EVSP (the Home EVSP). Roaming, in the context of EV charging, is the ability to charge at a charging station managed by a different EVSP (Visited EVSP), using the subscription to the Home EVSP.

Communication related to roaming scenarios may take place directly between two EVSPs. Alternatively, a third-party financial clearinghouse may be required to act as an intermediary between the Home EVSP and Visited EVSP(s). In order to support roaming scenarios, standardization is required for authentication of the EV/driver, authorization of the EV/driver for a certain quality of service, relaying of accounting records related to the charging session, and settlement of billing.

Owner/operators need to define a business plan to facilitate roaming EVs to charge at spots affiliated with a different EVSP (i.e., to address implementation challenges).

The objective of the EVRoaming Foundation[59] is to facilitate roaming services for charging electric vehicles and provide transparent information to consumers about charging locations and prices, by use of the open and independent Open Charge Point Interface (OCPI) protocol. OCPI "supports connections between eMobility Service Providers who have EV drivers as customers, and Charge Point Operators who manage charge stations. This protocol is free to use and independent. It can work both bilateral as well as in combination with roaming hubs."[60]

Section **680.108, Interoperability of electric vehicle charging infrastructure,** of the NEVI Final Rule provides in relevant part:

---

[59] EVRoaming Foundation, Home page, Accessed 2/21/2023 https://evroaming.org/
[60] OCPI Background, Accessed 2/21/2023 https://evroaming.org/ocpi-background/

> (c) *Charging-Network-to-Charging-Network Communication.* By February 28, 2024, charging networks must be capable of communicating with other charging networks in accordance with Open Charge Point Interface (OCPI) 2.2.1.[61]

> (d) *Network Switching Capability.* Chargers must be designed to securely switch charging network providers without any changes to hardware.

In addition, section **680.114, Charging network connectivity of electric vehicle charging infrastructure,** of the NEVI Final Rule provides in relevant part:

> (c) *Charging-Network-to-Charging-Network Communication.* A charging network must be capable of communicating with other charging networks to enable an EV driver to use a single method of identification to charge at Charging Stations that are a part of multiple charging networks. See § 680.108 for more information about OCPI requirements.[62]

> (d) *Charging-Network-to-Grid Communication.* Charging networks must be capable of secure communication with electric utilities, other energy providers, or local energy management systems.

> (e) *Disrupted Network Connectivity*. Chargers must remain functional if communication with the charging network is temporarily disrupted, such that they initiate and complete charging sessions, providing the minimum required power level defined in § 680.106(d).

Gap G1: Locating and reserving a public charging station, Obtaining Pricing and Availability Information. There is a need for standard(s) to permit EV drivers to locate a public charging spot, reserve its use in advance, and obtain pricing information and near real-time availability.

R&D Needed: No

Recommendation: Develop a standard(s) to permit EV drivers to universally locate and reserve a public charging spot, and to obtain pricing information and near real-time availability.

Priority: Medium

Organization(s): SAE, OCA, EVRoaming Foundation, eMI[3], ETSI ITS

Other Initiatives

Other recent initiatives related to the integration of EV charging stations with the grid include:

---

[61] https://www.federalregister.gov/d/2023-03500/p-396

[62] https://www.federalregister.gov/d/2023-03500/p-425

- A new NIST publication, IEC 61850 Profile for Distributed Energy Resources Supporting IEEE 1547, that maps functional requirements for DER interconnection in IEEE 1547 to the communication and data requirements in IEC 61850-7-420.[63]

- Smart Electric Power Alliance (SEPA) Interoperability Profile for Electric Vehicle Fleet Managed Charging. This document relates to fleet managed charging and covers information exchange between EV charging station management systems and grid distribution system operators. It uses IEEE 2030.5 and its communications and information model requirements.[64]

4.1.3. Communication and Measurement of EV Energy Consumption

Residential Charging (Single-Family Homes)

Though not required for charging purposes, the measurement of EV energy consumption is deemed necessary to provide customers certain value-added services related to EV energy usage information and control. Along with demand response (DR) programs, discrete measurement of an EV allows for time of use (TOU) tariffs to encourage charging during off-peak times, thereby lowering customer costs and addressing issues related to the integration of renewables.

Regulatory issues and business cases will determine how metering of EVs is implemented. This includes whether End Use Measurement Devices (EUMDs) need to be revenue grade in order to be used for customer billing; who is allowed to own the EUMDs; who bills the customer; and how they communicate. EUMDs can be separate meters (and therefore most likely to utilize existing metering communication such as utility Advanced Metering Infrastructure (AMI) systems), probably necessitating a second panel and service account. EUMDs could also be sub-meters, installed on a branch circuit of the premises meter and necessitating a subtractive billing process to apply special rates. Sub-meters could be located anywhere from the branch circuit to within the EVSE or EV itself.

Overview of Sub-metering

Sub-metering, whereby the EUMD is located on a branch circuit from the premises meter, measures specific end use loads that are physically and electrically downstream of the meter used to collect the premises usage (master meter). Unlike separate (parallel) metering, where there are effectively two separate instances of usage data being collected and billed, in sub-metering the master meter is recording the same usage that is being recorded by the sub-meter. Therefore, the sub-meter usage must be subtracted from the master meter in order to apply special device specific time of use (TOU) rates. It

[63] "NIST Develops Interoperability Profile for Distributed Energy Resources and Grid Integration," July 1, 2022, Accessed 2/20/2023, https://www.nist.gov/news-events/news/2022/07/nist-develops-interoperability-profile-distributed-energy-resources-and

[64] "NIST, SEPA Develop Interoperability Profile for Integrating Electric Vehicle Charging with Grid," July 1, 2022, Accessed 2/20/2023, https://www.nist.gov/news-events/news/2022/07/nist-sepa-develop-interoperability-profile-integrating-electric-vehicle

is possible for the master meter and sub-meter to be on two different rates. Where used for billing, because of volume, complexity, and existing capabilities, a manual process is usually used to collect, subtract, and bill sub-metering customers.

Third Party Sub-Metering Use Cases

The method through which sub-metering occurs depends on regulatory and business policies, how the meter is set up, and the communication capabilities of the system infrastructure. If the sub-meter is utility provided, then most likely a meter similar to the master meter will be used, and existing Advanced Metering Infrastructure (AMI) or meter reading systems could be used to communicate directly to back office systems or through the premises meter.

A sub-meter option explored by the California Public Utilities Commission (CPUC) is to allow third party or customer ownership of the sub-meter and for third parties to provide the bundled services directly to the customer. The sub-meters could therefore be located anywhere downstream of the master meter including on a smart plug, on the EVSE, or even in the PEV. In August 2022, California became the first state in the U.S. to allow for the measurement of an EV's energy consumption from sub-metering, via a decision of the CPUC.[65]

The simplest use case is where a customer acquires a stationary fixed sub-meter and has it installed downstream of the master meter. They then contract with a sub-meter data management agent (DMA), who could also be the meter provider, to collect the data. The communication between the sub-meter and the third party could be proprietary or could be based on an existing metering communication standard (e.g., ANSI C12 developed by NEMA (ASC/C12), IEEE P2030.5). The DMA, who has previously established a relationship with the billing agent, then provides them with the customer PEV consumption data (in a standardized format) so they can subtract the usage from the premise's usage, apply tariffs, and complete the billing processes. Additional complications arise based on the location of the sub-meter (EVSE, smart plug, PEV, mobile cord set), number of sub-meters and sub-meter DMAs, regulatory structures (e.g., certification), system requirements (e.g., transfer timing), and communication capabilities (e.g., data format).

These types of metering and use cases create additional complexity including sub-meter measurement (accuracy), access, performance, security/privacy, and communications. An example is mobile sub-metering which refers to sub-meters within EVs or combined with 110V or 220V cord sets that can be transported and exchanged. Pre-authorization would be required if an EV consumed energy at a visited premise but was to be billed to the owner's home account. This pre-authorization would have to be on file with the utility to subtract the energy used by the EV from the bill of the visited premises.

---

[65] California Public Utilities Commission (CPUC). "CPUC Decision Makes California First State in the Nation To Allow Submetering of Electric Vehicles," August 4, 2022. Accessed March 7, 2023 https://www.cpuc.ca.gov/news-and-updates/all-news/cpuc-decision-makes-california-first-state-in-the-nation-to-allow-submetering-of-electric-vehicles

Additionally, the vehicle must associate with that premises and both the vehicle's ID and premises meter or account ID must be communicated with the utility. This would involve local association (e.g., PLC or HAN technology). If the vehicle is travelling outside of the territory for which it has an associated service account, utilities will most likely have to share customer and consumption information. Similar to premises meters, mobile metrology could be collected using either a proprietary or standardized communication method (e.g., telematics, AMI, or IEEE P2030.5 for utilities), depending on regulatory and utility policies.

Standardization Activities

One area of standardization related to sub-metering is the communications format necessary between the third-party DMA and the billing agent. The CPUC activities have identified the Energy Services Provider Interface (ESPI) as a national standard that can be used for this interface. "Green Button *Connect My Data* (CMD) is the energy-industry standard (formally, the "NAESB REQ.21 - Energy Services Provider Interface Model Business Practices" standard) for enabling easy access to, and secure sharing of, utility-customer energy- and water-usage data."[66] The Open Automated Data Exchange (OpenADE) Task Force "is a group of smart-energy-management vendors, utilities, and government interests developing recommendations toward building interoperable data exchanges that allow customer authorization and sharing of utility consumption information with third-party service providers. It is the *open-to-anyone* technical arm of the Green Button Alliance for the promotion of the Green Button ecosystem."[67]

Gap G2: **Communication of standardized EV sub-metering data**. Standards are needed for communication of EV sub-metering data between third parties and service providers.

R&D Needed: No

Recommendation: Develop a standard to communicate EV sub-metering data between a third party and a billing agent (e.g., utility).

Priority: High

Organization(s): OpenADE/NAESB, IEEE, Mesa, SunSpec Alliance, OpenFMB

Besides the utility interface standard, is the issue of requirements and guidelines related to the standardization of third-party sub meters. The National Electrical Manufacturers Association (NEMA) sponsors the C12 series of standards including ANSI C12.1-2022, Electric Meters - Code For Electricity Metering (Incorporates ANSI C12.20-2015). **"**This Code establishes acceptable performance criteria for new types of AC watthour meters, demand meters, demand registers, pulse devices, and auxiliary devices. It describes acceptable in-service performance levels for meters and devices used in revenue

[66] Green Button® Connect My Data® (CMD), Accessed 2/21/2023 https://gba.memberclicks.net/about-cmd
[67] The OpenADE Task Force, Accessed 2/21/2023 https://gba.memberclicks.net/technical-committee

metering. It also includes information on related subjects, such as recommended measurements, installation requirements, test methods, and test schedules. This Code for Electricity Metering is designed as a reference for those concerned with the art of electricity metering, such as utilities, manufacturers, and regulatory bodies."

NIST's U.S. National Work Group on Measuring Systems for Electric Vehicle Fueling and Sub-metering

The U.S. National Work Group (USNWG) formed in August 2012, to develop proposed requirements for commercial electricity-measuring devices (including those used in sub-metering electricity at residential and business locations and those used to measure and sell electricity dispensed as a vehicle fuel) and to ensure that the prescribed methodologies and standards facilitate measurements that are traceable to the International System of Units (SI). This work is not intended to address utility metering in the home or business where the electricity metered is consumed by the end purchaser and that falls under the authority of entities such as the local utility commission.[68]

The USNWG will review and propose changes as needed to:

1. Draft requirements for equipment used to measure and sell electricity in commercial applications for possible inclusion in NIST Handbook 44 (HB 44), ''Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices''; and

2. Draft procedures for type evaluation, laboratory, and field testing of equipment for possible inclusion in NIST Examination Procedure Outlines and other procedure documents.

Included among the topics to be discussed by the USNWG for current and emerging device technologies used in commercial electric measuring systems are: (1) Method-of-sale requirements; (2) metrology laboratory standards and test procedures; (3) uncertainties; (4) measurement traceability; (5) tolerances and other technical requirements for commercial measuring systems; (6) existing standards for testing equipment; (7) field implementation; (8) data analysis; (9) field test and type evaluation procedures; (10) field enforcement issues; (11) training at all levels; and (12) other relevant issues identified by the USNWG.

The USNWG's technical output may result in the revision of current standards or the development of new standards for testing equipment, including documents such as the NIST Handbook 105 Series: *Specifications and Tolerances for Reference Standards and Field Standard Weights and Measures* available on the NIST OWM/Publication website; NIST HB 44: *Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices*, and NIST Examination Procedure Outlines (EPO), as well as proposed changes to requirements and testing procedures for commercial devices and systems used to assess charges to consumers for electric vehicle fuel.

[68] "Electric Vehicle Fueling and Submetering: U.S. National Work Group on Measuring Systems," Accessed 2/21/2023 https://www.nist.gov/pml/owm/legal-metrology-devices/electric-vehicle-fueling-and-submetering

<u>Gap G3</u>: Standardization of EV sub-meters. Standards for EV sub-meters, including embedded sub-meters, are needed to address performance, security/privacy, access, and data aspects.

<u>R&D Needed</u>: No

<u>Recommendation</u>: Develop standards or guidelines related to the functionality and measurement characteristics of sub-meters for EVs, including embedded sub-meters in the EVSE or EV. Such standards should address different form factors, capabilities, installation, and certification. Organizations developing standards, guidelines or use cases related to EV sub-metering should coordinate their activities in order to avoid duplication of effort, assure alignment, and maximize efficiency.

<u>Priority</u>: High

<u>Organization(s)</u>: NEMA, USNWG EVF&S, SEPA, EPRI

4.1.4. Telematics Smart Grid Communications

Telematics is the process for long-distance transmission of computer-based information and can provide the capability to directly facilitate PEV smart grid load management communications with utilities, other Energy Service Providers (ESPs), Independent System Operators and Regional Transmission Organizations (ISOs/RTOs), aggregators, and Electric Vehicle Services Providers (EVSPs). Telematics has the versatility to further interact with Home Area Networks (HAN) and facility Energy Management Systems (EMS) either through a gateway, the customer internet, or the PEV.

Telematics as a concept can also be used to support the development of applications focused on monitoring the operational health of the smart grid to confirm that the grid supporting the charging of EVs is operating properly and that its connections to other upstream elements (e.g., power delivery and distribution) are active.

Published Standards:

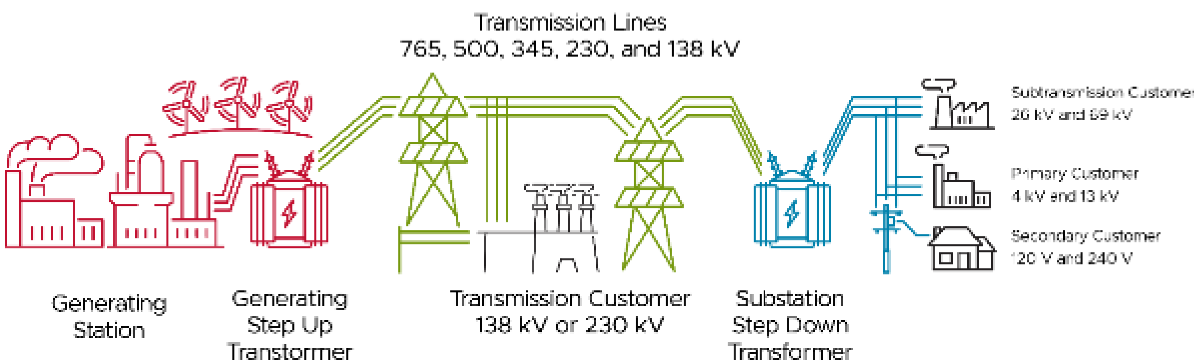
- SAE J2836/1_201907, Use Cases for Communication Between Plug-in Vehicles and the Utility Grid
  SAE J2836/3_201701, Use Cases for Plug-In Vehicle Communication as a Distributed Energy Resource
- SAE J2836/5_202112, Use Cases for Customer Communication for Plug-in Electric Vehicles
- OpenADR 2.0

No standards gap has been identified.

4.2. Power Distribution / DER Integration and Fast Charging Stations / Microgrids

Power Distribution / DER Integration:

The electrical grid is a tightly coupled system that manages and delivers power from where and how it is generated to where – and how – it is consumed. Because electricity is perishable, most power is delivered at the time it is generated. The supply, transmission, distribution, and consumption of electricity are therefore closely coupled, and must be actively coordinated. Significant changes in the consumption, such as large-scale electrification of transportation, can impact this coordination and require new infrastructure or operating methods. Elements associated with this coordination, such as communications infrastructure and cyber secure operation of the electric grid components, also become significant drivers. Even under these shifting conditions, the electric grid is divided into three main domains: generation, transmission, and distribution as shown below:



Source: Pacific Northwest National Laboratory 2021

Electricity generation is the process of creating electricity from other forms of energy and is the first process in delivering electricity to customers. As the primary electricity supply for the electrical grid, the Generation, including distributed energy resources (DERs), is electrically connected to the Transmission and Distribution domains. The scalability and modularity of modern generating technologies alters the physical relationship and points of coupling between generation assets and the grid, as well as the distribution of generation assets. Furthermore, many of these distributed generator assets are owned by the end customer, not the utility. Accordingly, this domain has been updated to reflect direct electrical interconnection with the distribution system that smaller scale and distributed generation assets may utilize. The generation mix may include more solar and wind, often interfaced through power electronic inverters.

Transmission is the bulk transfer of electrical power from generation sources to distribution through multiple substations. A transmission electrical substation uses transformers to step up or step-down voltage across the electrical supply chain. Substations contain switching, protection, and control equipment and may also connect two or more transmission lines. The distribution system is the electrical interconnection between the transmission system and end-use consumers. It includes all points from substation that step-down voltage from the transmission system to the grid-edge and consumer. As with the generation system, distribution may contain DER, such as electrical storage, peaking generation units that supply electricity during times of high demand, and other assets such as community solar installations. The reliability of the distribution system varies depending upon its structure, the types of configuration and control devices that are implemented, and the degree to which those devices communicate with each other and with entities in other domains. Grid modernization efforts are enabling customers to have more choice and control in their systems. Due to the change from traditional power delivery, distribution systems often require more significant upgrades and operational changes. Furthermore, operational considerations like cybersecurity are more relevant in the modern distribution system.

Distributed energy resources are smaller-scale generation sources or controllable loads that are distributed through the power system. These are typically connected at the distribution level, with an increasing shift toward them being consumer-owned devices like rooftop solar and EVs, as well as traditional appliances or onsite battery energy storage. DERs have the capability to provide services to the electric grid, via producing power for the grid, or being able to reduce or shift load to help stabilize the power grid. The deployment of DERs often increases measurement points and communications further into the distribution system, which enables better visibility into what is traditionally a “simple black box system,” but also introduces considerations such as cybersecurity and information privacy.

Typically, electricity suppliers provide electricity to customers in the form of alternating current (AC) at various levels of medium voltage ranging from 4-69 kV. Sub-transmission customers may receive electricity at 26 and 69 kV, primary customers (at 4 and 13kV), and secondary customers at 120 and 240V via the distribution system. DC-as-a-Service (DCaaS) relates to providing direct current (DC) electricity to the site or point-of-use, as opposed to AC electricity. Advantages for EV charging sites include potentially higher efficiencies resulting from not having to convert from AC to DC within the charging site, potentially lower cost and management ease, and easy integration with battery energy storage and renewables.

DCaaS is a model of who owns charging infrastructure, electricity suppliers vs. EV charging services providers. DCaaS is basically a business proposal to allow electricity suppliers to provide DC electricity directly to customers. In the DCaaS business case, the utility would own power conversion / storage equipment, and electronics / controls. To enable DCaaS, State PUCs would have to allow utilities to own certain assets. Presently, State PUCs allow utilities to own certain assets, but not others. PUC tariffs and billing methods would need to be developed for DCaaS and allowed by the States. Currently, with the exception of metering, there are no standards for DCaaS and regulations and codes would need to be developed. North Carolina and California are currently looking at regulations and codes for DCaaS.

Charging as a Service (CaaS) is a general term which applies to vendors who build, own, and maintain EV Infrastructure on behalf of a fleet. This business model varies across different vendors, but typically provides solutions for equipment, installation, software, site maintenance, and/or driver support for an agreed upon recurring fee. The service may be onsite or offsite relative to the fleet's primary business address. For Charging-as-a-Service (CaaS), a third party owns charging infrastructure and bills monthly for use of equipment and consumed energy / maintenance. CaaS basically encompasses all the elements of bundling the capital expense of EV charging. This would include such things as the cost of capital equipment, operating expenses, insurance, etc. In short, CaaS is really a policy consideration with no specific standards related issues.

Fast Charging Stations / Microgrids:[69]

The principal purpose of a fast charging station (FCS) is to charge EVs as quickly as permitted by the EV battery and the power capabilities of the FCS chargers. Fast charging stations can be compatible with light, medium, and heavy-duty EVs including off-road, marine, aircraft, and rail applications. The FCS aggregates and coordinates the energy management of multiple fast chargers and the energy resources incorporated into the station while optimizing the charging of individual transportation systems. The FCS also coordinates operation with and manages energy drawn from the grid. The FCS is comprised of one or more fast chargers and associated EV supply equipment (EVSE). The FCS may also incorporate local energy resources, including renewable energy resources such as solar photovoltaic (PV) generation and battery energy storage systems (BESS).

Given the fast-evolving EV offerings and charging requirements, the FCS cannot be defined based on specific EV charging requirements, nor on the power and current levels and capabilities of the largest individual EV chargers composing the FCS. The FCS control system is comprised of a charge management system (CMS) and an energy management system (EMS) function. The CMS is controlled by the EMS, the EV chargers being considered the main load of the FCS. The EMS dispatches the generation and storage assets to meet the EV charging requirements. If the EMS and CMS functions are decoupled and independent, the term charge station management systems (CSMS) is used instead of CMS to describe the EV charging equipment. The implementation of the CMS and EMS functions, which depends on the design of the FCS, can be distributed in separate physical units or combined in a centralized control system. The fast chargers can be either locally or remotely controlled.

The implementation of a FCS can take many forms and manage different types of assets, including generation from renewable energy sources and energy storage systems. Currently, there are two main structures for the FCS as illustrated in the following figures. The charging management system, or FCS control system, may be split into 2 components: the FCS control system and EMS, controlling the DER assets and charge management system, controlling the aggregated EV charger hubs. Figure **B.1** shows a possible implementation of a fast charging station configured as a microgrid. It features a local dc bus, MV or LV. The interface to the local distribution grid is an ac/dc converter. All generators and loads are connected to the dc bus, including the EV chargers. Figure **B.2** shows an alternative implementation of a

[69] Text in this section is drawn from the draft standard IEEE P2030.13, Guide for Electric Transportation Fast Charging Station Management System Functional Specification.

fast charging station featuring a local ac bus, MV or LV. The interface to the local distribution grid is usually a transformer. All generators and loads are connected to the ac bus, including the EV chargers, and may require an ac/dc converter interface.

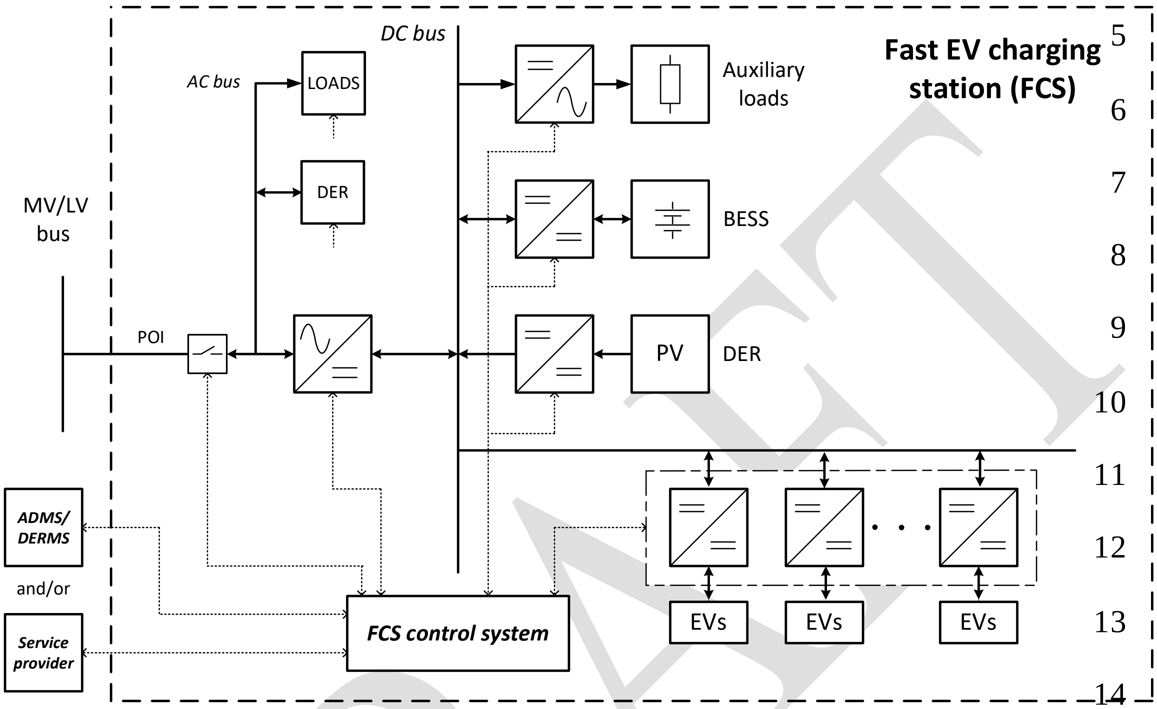


Figure B.1 – Generic FCS Configuration and Assets – Local DC Bus[1]

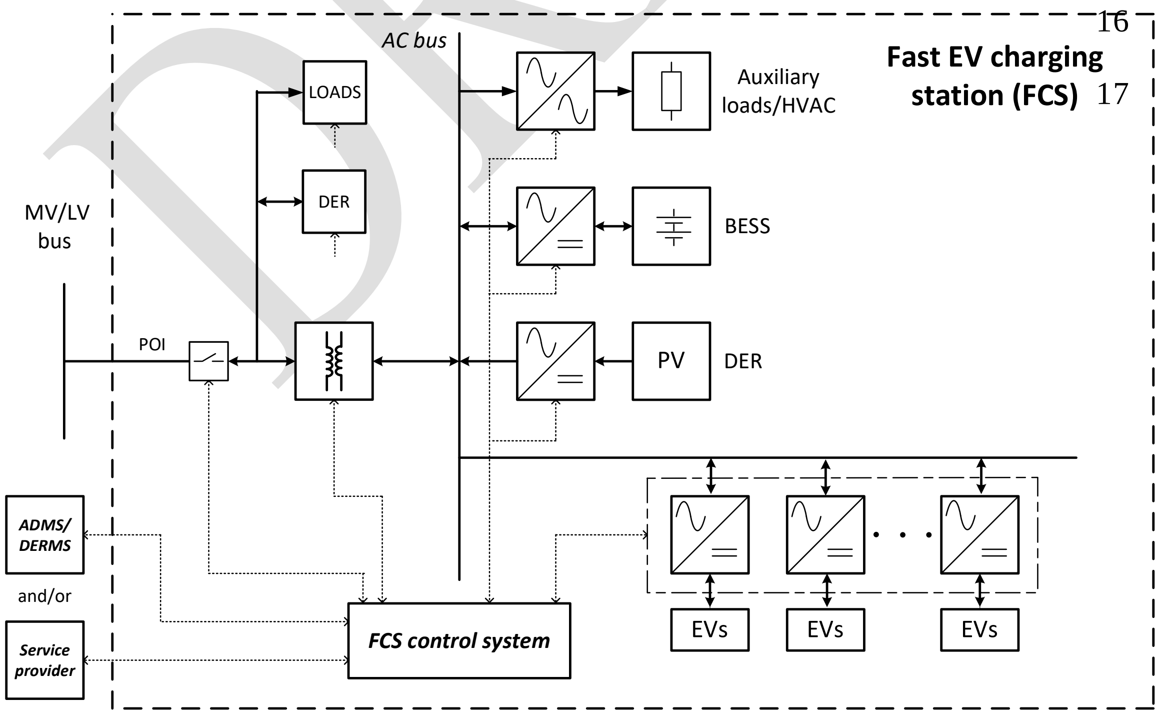


Figure B.2—Generic FCS Configuration and Assets – Local AC Bus[1]

[1] Figures B.1 and B.2 reprinted with permission from Geza Joos, excerpted from P2030.13 D2.4, © 2022.

The FCS may manage a number of DER including local generation from renewable energy resources, in the form of solar PV generation, BESS, and other energy sources, in the form of diesel- or gas-powered generators, fuel cells, or combined heat and power (CHP) generators. These may be required if the FCS needs to be operated in islanded mode, either during a blackout, at the request of the distribution system operator (DSO), or in normal operation if economically justified. The FCS is connected to the energy power system at one point of interconnection (POI) with power exchanges occurring only at this point of interconnection. The power flow across the POI can be bi-directional. The FCS is normally connected to the electric power system (EPS) at the POI through a disconnect device, a breaker or a contactor with appropriate protective relays, or through an ac/dc power electronic interface. In the event the disconnect device opens, the FCS can be operated in islanded mode, if the sizing of the generation assets allow this mode of operation, and the FCS control system can operate in islanded mode.

The FCS grid interconnection requirements are dictated by the DSO with which the FCS may interact directly through the advanced distribution management system (ADMS) or with a distributed energy resource management system (DERMS). EV vehicle-to-grid (V2G) capabilities may be exploited if the FCS is designed to accommodate fleet parking slots where the EV may be expected to be parked for a specified length of time. The fast chargers can be designed to exploit V2G capabilities, allowing energy to be fed back to the EPS. The V2G capability provides additional battery energy storage capacity to the FCS and, when aggregated, enables the FCS more flexibility in feeding power into the EPS. This additional storage can be exploited if there is excess energy available after all the FCS load requirements are met, and if returning power to the grid is built into the agreement between the DSO and FCS operator. EV charging curtailment, load shifting, peak shaving, load curtailment (load management) capabilities algorithms are functions of the FCS control system that may be requested by the DSO as part of the grid services provided by the FCS to the EPS.

4.2.1. Power (electrical) Systems and Safety

Power (electrical) Systems and Safety encompasses the transfer and interconnection of electrical power through the distribution system or directly from the transmission system, including safety therein, to the EV charging site. Within the distribution system, power distribution involves the transfer and interconnection of medium voltage (4-69 kV) AC power from the EV substation to the EV charging site. Interconnection is achieved through a “dead front” feed post connecting the medium and low voltage sides. A “dead front” is a component of an electrical system that is intended to carry or control, but not utilize, electrical energy and contains no live parts exposed to a person on the operating side of the equipment. Well established, existing codes and standards exist for “dead fronts,” ingress protection (IP) for rated enclosures, and ratings for insulators. Examples include IEC ratings for ingress protection and UL standards which are intended to align with installation codes. Safety is key, well understood, and established criteria are in place, including clear definitions and requirements for approach boundaries and lineman qualifications. There are limited issues such as examples of insulation failures on the medium voltage side and the limited number of qualified linemen to handle medium voltage. At high power transfer levels above 1 MW, when connecting directly to the transmission system, there are no major issues or gaps with regard to power systems and safety. This is important when considering heavy-duty truck plazas and other enroute charging sites which will utilize very high levels of power and likely connect directly to the electrical transmission system, as opposed to the distribution system.

In general, there are no significant codes and standards barriers nor gaps with regard to traditional medium voltage AC and DC power distribution and interconnection, nor high voltage transmission and interconnection. It is basically an evolving world of well-established codes and standards, and the need is not new nor updated standards, but rather better interpretation of known standards depending upon specific applications. Gaps revolve more around lead times to implement the existing standards, as well as setting consistent norms and best practices. At the EV charging site itself, AC architectures are generally well understood. However, there are several codes and standards gaps related to AC and DC site architectures coupled with electric power systems.

Gaps:

The following identifies codes and standards gaps identified by the ANSI Electric Vehicle Standards Panel with regard to Power (electrical) Systems and Safety.

Gap G4: Dynamic Capacity Management (DCM). DCM relates to managing local distribution capacity constraints and balancing supply and demand on the grid with the requirements of the EV charging station and other loads on the grid. Open Automated Demand Response (OpenADR 2.0) is one way of managing capacity for DCM focusing on energy and demand response, as well as pricing communications. Newer iterations of OpenADR are expected to improve grid coordination. Presently, program guides on OpenADR and IEEE 2030.5 exist. Questions remain though as to clarification of further grid coordination mechanisms to be supported, as well as consumer information to enhance understanding of these standards.

R&D Needed: Yes, to determine ways to do DCM

Recommendation: Continue to pursue various ways to do DCM (e.g., within the context of OpenADR) to identify and incorporate advanced grid coordination mechanisms. Determine if existing program guides on OpenADR and IEEE 2030.5 are sufficient or if additional consumer information is needed.

Priority: Medium

Organization(s): IEEE, OpenADR Alliance, and others as appropriate

Gap G5: Safety and Protection of DC architectures are not standardized. Technology is not well established nor is it currently known how to do a thorough DC protection system design (especially with regard to islanding). Short circuit protection for complex energy sources (e.g., multiple energy sources and bidirectional power flow) is the primary gap. IEEE P2030.12 is a draft guide for microgrid protection systems. The National Electrical Code (NEC) does address DC microgrids, principally driven by photovoltaics and energy storage. There is considerable cross-over with the solar industry within SunSpec and for microgrids within the Emerge Alliance. In Europe, the Open Society (OS) Foundation is working to develop guidelines and transfer them to the International Electrotechnical Commission (IEC) for formal standardization.

R&D Needed: Yes

Recommendation: Continue to pursue standardization of safety and protection for DC architectures, especially within the IEEE P2030 suite of standardization activities.

Priority: Medium

Organization(s): IEEE

Gap G6: Fault Current Signatures for AC and DC Architectures under Islanding Conditions. Identifiable fault currents can be an issue for AC and DC architectures. Specifically, the magnitude and signature of fault currents within AC and DC architectures can be too low to trip protection and provide safety.

R&D Needed: Yes

Recommendation: The issue of fault currents is largely covered in UL 1741 and UL 9741. UL 1741 covers AC and DC systems, while UL 9741 covers DC systems and references UL 1741 for AC systems. UL 1741 Supplement SC includes a safety overvoltage protection function in the event the EV exceeds 120 percent of nominal unit voltage. The V2G interconnection criteria will follow national grid interconnection standards. However, coordination in front and behind the meter is needed when systems are islanding, especially within the context of hybrid (AC/DC intertwined) and DC architectures, and non-linear loads. Explore fault currents under islanding conditions and, as appropriate, implement codes and standards development to address safety and grid interconnection performance aspects.

Priority: Medium

Organization(s): UL, FERC, NERC

<u>Gap G7</u>: "Ride Through" Requirements for EVSE under Grid Service Conditions. "Ride Through" requirements encompass how systems/devices will behave when conditions on either side of the point of interconnection (EV Station or grid) are not normal. There is a dichotomy: first, for the distribution network within the EV station itself especially under islanding (i.e., not connected to the grid) conditions, and, second, on the grid side specifically at the systems level with regard to voltage and frequency. When EVSE are supplying power to the grid, "Ride Through" requirements need to be defined under specific conditions. "Ride Through" is not applicable in this context for DC systems.

<u>R&D Needed</u>: Yes

<u>Recommendation</u>: Explore "Ride Through" requirements for EVSE under grid service conditions. "Ride Through" requirements are covered under IEEE 1547, with V2G specifically covered under IEEE 1547.1. UL 9741 covers AC coupled output and interconnection, with the latest version addressing vehicle-to-everything (V2X). UL 1741 Supplement SC will address situations where vehicles have onboard AC inverters. As appropriate, implement codes and standards development.

<u>Priority</u>: Medium

<u>Organization(s)</u>: IEEE, UL

<u>Gap G8</u>: DC-as-a-Service (DCaaS). A thorough review of standards is needed for applicability. This includes electrical power standards and any other standards for DC distribution, as well as for fast charging stations and DC microgrids. DCaaS is a business proposition and involves standards, codes, policy development, and coordination to ultimately be successful. Monetization of the business proposition requires an approved DC tariff which does not exist.

<u>R&D Needed</u>: No

<u>Recommendation</u>: Pursue a comprehensive review of codes and standards for applicability to DCaaS. Determine which existing codes and standards apply in specific situations and identify any existing gaps. Work with public utility regulators to establish DC tariffs.

<u>Priority</u>: Medium

<u>Organization(s)</u>: IEEE, NFPA, SunSpec, Emerge Alliance, public utility regulators

Issues Identified, Assessed, and Determined Not to Be Gaps:

The following identifies additional issues discussed by the ANSI Electric Vehicle Standards Panel with regard to Power (electrical) Systems and Safety. After deliberations, it was determined that these issues are not currently gaps with regard to codes and standards.

Point of Interconnection (POI) - Power quality between the charging station and traditional AC and DC electrical supply systems. This issue is stable and largely covered at the POI by IEEE 519-2014. There are no gaps for DCaaS at the POI with regard to power quality.

Lack of a standardized interface for EV charging/DERs – standardized electrical behaviors and responses. UL 9741 covers this behavior for stationary storage and mobile storage vehicles (i.e., EVs). DER applications are covered under UL 1741. UL 1741 Supplement SC will address bi-directional EVSE for EV AC V2G export for EVs using SAE J3072 communications.

Published Standards and Guidance Documents:

The following identifies standards, codes, guidance documents, etc. relevant to Power (electrical) Systems and Safety. These standards and codes generally relate to power and/or software aspects and a brief description is provided below.

- **ANSI C.12.32-2021, Electricity Meters for the Measurement of DC Energy.** Establishes acceptable performance criteria for revenue grade Direct Current (dc) watt hour Meters and demand Meters. Accuracy Class designations, Current, Voltage, environmental tests, and electromagnetic compatibility (EMC) test are covered.
- **IEC 61850 Communications Networks and Systems for Power Utility Automation.** This is a series of international standards defining communication protocols for intelligent electronic devices at electrical substations. It enables integration of all protection, control, measurement, and monitoring functions and provides a means for high-speed substation protection applications.
- **IEEE 519-2014, IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems.** This legacy standard defines the voltage and current harmonics distortion criteria for the design of electrical systems. This standard reference focuses upon power quality and the point of common coupling.
- **IEEE 1547-2018, IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.** This standard focuses upon technical specifications for, and testing of, the interconnection and interoperability between utility electric power systems (EPSs) and Distributed Energy Resources (DERs). It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. It also includes general requirements, response to abnormal conditions, power quality, islanding, and test specifications and requirements for design, production, installation evaluation, commissioning, and periodic tests. This standard includes requirements for bi-directional power flow and requires that a DER device (including bi-directional chargers) will need to include IEEE 2030.5, SunSpec Modbus, or IEEE 1815 (DNP3) communication interface.
- **IEEE 2800-2022, IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems.** This standard establishes uniform technical minimum requirements for the interconnection, capability, and lifetime performance of inverter-based resources interconnecting with transmission and sub-

transmission systems. Included in this standard are performance requirements for reliable integration IBRs into the bulk power system, including, but not limited to, voltage and frequency ride-through, active power control, reactive power control, dynamic active power support under abnormal frequency conditions, dynamic voltage support under abnormal voltage conditions, power quality, negative sequence current injection, and system protection.

- **UL 916, Energy Management Equipment**. This standard covers requirements for energy management and associated sensing devices rated at 600 volts or less and is intended for installations in accordance with NFPA 70®. This equipment energizes or de-energizes electrical loads for use of electrical power.
- **UL 1741, Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources**. UL 1741 is the official industry standard for the certification of inverter safety and includes safety tests in addition to IEEE 1547.1 conformance tests UL 1741 includes requirements for Power Control Systems (PCS) that are similar to load EMS for generation equipment. The UL 1741 standard has incorporated a **Supplement A (SA)** to validate compliance for "grid support utility interactive inverters," **Supplement B (SB)** to validate compliance with grid support functions, and a pending **Supplement C (SC)** to incorporate the updated SAE J3072 V2G AC standard. **UL 1741 SA** is a standard for inverters more capable of dealing with a volatile grid and "future proofing" for inverters to actively manage grid functions. Products that meet this requirement are known as "Grid Support Inverters," "Smart Inverters," or "Advanced Inverters." **UL 1741 SB** is the updated version that incorporates the testing needed to comply with certification requirements in IEEE 1547.1-2020. **UL 1741 SC** (once published) will enable V2G AC EVSE to be labeled and accepted by local Authorities Having Jurisdiction (AHJs).
- **UL 9540, Energy Storage Systems and Equipment.** This is a safety standard for an energy storage system and equipment intended for connection to a local utility grid or standalone application. It designates key issues associates with ESSs, including safety of the battery systems and functional safety. UL 9540 encompasses two older standards: UL 1973 (for the stationary battery pack) and UL 1741 (for the inverter). **UL 9540A, Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems**, is a method of evaluating thermal runaway propagation in an ESS and includes fire testing.
- **UL 9741, Outline of Investigation for Electric Vehicle Power Export (EVPE) Equipment.** UL 9741 covers bidirectional EV charging equipment that charges EVs from an electric power system (EPS) and includes functionality to export power from the EV to an EPS. It is used with UL 1741 for power exporting devices. UL 9741 is being updated to accommodate the SAE J3072 V2G update.
- **Measurement Instrument Directive 2014/32/EU**. This is a European CE Directive that outlines safety requirements for all measuring instruments sold within the European Union (EU). While it was not developed specifically for use in North America, this directive potentially could see future use in North America.
- **NFPA 70®, National Electrical Code® (NEC®), Current Edition 2023**. Adopted in all 50 states, this is the benchmark for safe electrical design, installation, and inspection to protect people and property from electrical hazards. This code provides safety for any installation/interconnection and applies to

non-utility behind-the-meter (BTM) applications. Article 705, Interconnected Electric Power Production, Part II, covers Microgrid Systems.

- **NFPA 855 Standard for the Installation of Stationary Energy Storage Systems.** This standard provides the minimum requirements for mitigating the hazards associated with energy storage systems. This standard helps to safeguard the installation of modern energy storage systems (ESS) and lithium battery storage. NFPA 855 addresses the dangers of toxic and flammable gases, stranded energy, and increased fire intensity.
- **NIST Handbook 44 Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices** (2023 Edition)**.** HB 44 is a nationally adopted standard for evaluating and verifying the accuracy of weighing and measuring equipment. HB 44 Section 3.40 relates to electric vehicle fueling stations.
- **NIST Handbook 105.** This is the guide for states to certify a transfer standard for electricity that they maintain for commerce in their state. This is analogous to transfer standards maintained for mass and volume. In 2023, a special publication SP2022, guide for electrical measurement accuracy verification, will be issued leading to an updated Handbook 105-10.

In-Development Standards and Guidance Documents:

These standards, codes, and other guidance documents or initiatives relevant to Power (electrical) Systems and Safety are currently in progress.

- **IEEE P2030.12, Draft Guide for the Design of Microgrid Protection Systems.** Microgrid deployment requires a microgrid control system and a microgrid protection system. The design of both systems needs to consider the nature of the microgrid assets, which may include a significant amount of DERs, and the modes of operation, either grid-connected or islanded modes. This guide covers the design and selection of protective devices and the coordination between them for the different modes of operation of the microgrid. It proposes different approaches to detect and take proper actions and dependably and securely protect the microgrid and its equipment.
- **IEEE P2030.13, Guide for Electric Transportation Fast Charging Station Management System Functional Specification** (draft D2.4)**.** This is a guide for development of a functional specification for electric transportation fast charging management and control systems, including the energy management and grid interaction functions. A set of core functions are presented including: electric transportation energy storage discovery and evaluation of charging requirements; monitoring and control of charging profiles; charging station energy estimation; energy scheduling and management; charging station grid interaction; and grid power exchange management.

4.2.2. Communications / Controls

The landscape for communications, interoperability, and control of EVs is rapidly evolving for utility grid and site operators. Utility implementation of smart charging (V1G) and V2G will require the use of multiple communication protocols to satisfy the need for EV flexibility, with many choices existing for applications level communications. Ultimately, the speed at which industry understands, adopts, and utilizes good communications and connectivity standards can be a strongly enabling or potentially constraining factor to the pace of vehicle-grid-integration and EV adoption. However, the lack of industry agreement on preferred communications protocols for vehicle-grid-integration offers no clear path and poses significant challenges moving forward.

Communication and connectivity protocols define the format, meaning, and method of information exchange between devices and systems. Communication protocols can be proprietary, the exclusive property of an organization, or they can be open standards. For utility EV applications, protocols must be open and standards-based to accommodate the number and variety of charger vendors, EV manufacturers, and grid interfaces and systems. Interoperability standards, including open protocols, address the interfaces and communications between devices and systems, and the degree of interoperability is related to the maturity of the protocol and its ecosystem. The control architecture is another important consideration in identifying and specifying the required standardization of messaging protocols between the distribution utility, charging infrastructure, and the EV. Communications, interoperability, and control are largely agnostic with regard to AC or DC power distribution and AC or DC system architecture at the charging site.

Given the nascent state of the managed charging and vehicle-to-grid markets, the landscape of protocol standards and technologies is evolving rapidly across multiple dimensions. The problem is not so much the need for new standards for communications, interoperability, and control, but reaching consensus on utilization of existing ones and harmonization therein. As a result, while the value and need for standards is clear, the path to achieving widespread agreement is neither clear nor simple.

Gaps:

The following identifies codes and standards gaps identified by the ANSI Electric Vehicle Standards Panel with regard to Communications and Controls.

Gap G9: Structured information and energy services exchange with utilities. There is a need for structured information and energy services exchange to enable utilities to balance utility-side availability of renewables with EV site requirements, and for EVs to provide grid services**.** This gap specifically encompasses the need for structured information exchange to enable balance and negotiation, not command and control. This includes how to measure, communicate, and confirm transfer of information. In short, it is an energy services exchange and value proposition gap and incorporates information transfer at the distribution level.

R&D Needed: Yes, further development and demonstration

Recommendation: Continue to pursue improved mechanisms for structured information and energy services exchange within the context of IEEE P2030.5 and IEEE P2030.13. Additionally, the North American Energy Standards Board (NAESB) is working on the transmission side, while the US DOE Grid Modernization Laboratory Consortium (GMLC) has looked at this extensively over the last five years.

Priority: Medium

Organization(s): IEEE, NAESB, and GMLC

Issues Identified, Assessed, and Determined Not to Be Gaps:

The following identifies additional issues discussed by the ANSI Electric Vehicle Standards Panel with regard to Communications and Controls. After deliberations, it was determined that these issues are not currently gaps with regard to codes and standards.

Interfacing grid management and charging station management systems (CSMS). IEEE 2030.13 and the Open Charge Point Protocol 2.0 (OCPP 2.0) cover this issue. Additionally, OpenADR is a protocol used between the grid and other entities (including the CSMS) to communicate demand response signals. IEC 63110 is a work in progress which is a parallel to OCPP.

In the event of a DER fault, how will the EVSE/site behave and communicate its effect upon the utility. There are formal processes in place to handle associated issues including existing robust systems and best practices. For example, there are contingencies in place should there be any communication faults or latency (ISO 26262, functional safety) that requires back-ups for critical systems. Furthermore, IEEE 1547 covers grid aspects.

Published Standards and Guidance Documents:

The following identifies standards, codes, guidance documents, etc. relevant to Communications and Controls. A brief description is provided below.

- **IEC 61850 Communications Networks and Systems for Power Utility Automation.** This is a series of international standards defining communication protocols for intelligent electronic devices at electrical substations. It enables integration of all protection, control, measurement, and monitoring functions and provides a means for high-speed substation protection applications.
- **IEC 61968.** This is a series of standards that define information exchanges between electrical distribution systems. This includes all the major elements of an interface architecture for Distribution Management Systems (DMS). **IEC 61968-3:2021, Application integration at electric utilities - System interfaces for distribution management - Part 3: Interface for network operations**, provides utilities with the means to supervise main substation topology (breaker and switch state), feeder topology and control equipment status through SCADA, AMI and other data sources. It also provides the means for handling network connectivity and loading conditions.
- **IEEE 1547-2018, IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.** This standard focuses upon technical specifications for, and testing of, the interconnection and interoperability between utility electric power systems (EPSs) and Distributed Energy Resources (DERs). It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. It also includes general requirements, response to abnormal conditions, power quality, islanding, and test specifications and requirements for

design, production, installation evaluation, commissioning, and periodic tests. This standard includes requirements for bi-directional power flow and requires that a DER device (including bi-directional chargers) will need to include IEEE 2030.5, SunSpec Modbus, or IEEE 1815 (DNP3) communication interface.

- **IEEE 1815.1-2015, IEEE Standard for Exchanging Information Between Networks Implementing IEC 61850 and IEEE Std 1815™ [Distributed Network Protocol (DNP3)].** This document specifies a standard approach for mapping between IEEE 1815 (Distributed Network Protocol (DNP3) and IEEE 61850.
- **IEEE 2030.5-2018, Standard for Smart Energy Profile Application Protocol.** This is a standard for communication between smart grid and consumers providing a means to manage energy usage and generation, and to enable a secure, interoperable, and plug and play ecosystem of smart grid devices. This standard defines the application layer with transmission control protocol / internet protocol (TCP/IP) providing functions in the transport and Internet layers to enable utility management of the end user energy environment, including demand response, load control, time of day pricing, management of distributed energy distribution, electric vehicles, etc. There is a particular emphasis upon integration of DERs.
- **IEEE 2030.7-2017, IEEE Standard for the Specification of Microgrid Controllers**. The microgrid energy management system (MEMS) controls the functions that define the microgrid as a system that can manage itself, operate autonomously or grid connected, and seamlessly connect to and disconnect from the main distribution grid for the exchange of power and the supply of ancillary services. This standard addresses the functions above the component level associated with the proper operation of the MEMS that are common to all microgrids, regardless of topology, configuration, or jurisdiction. Testing procedures are addressed.
- **IEEE 2030.11-2021, IEEE Guide for Distributed Energy Resources Management Systems (DERMS) Functional Specification.** IEEE 2030.11 provides overall guidance for the application and deployment of DERMS and DERMS control systems. It proposes a set of core functions, including: DER discovery/visualization; monitoring of real and reactive power loads and voltage at specific nodes; and related functional requirements. It also provides guidance on DER production estimation and scheduling; dispatch of real and reactive power; and provision of DER ancillary services such as voltage and frequency control/support. It also gives direction on how to integrate two existing and increasingly popular ways to aggregate DERs into DERMS: namely virtual power plants (VPPs) and microgrids.
- **Modular Energy Systems Architecture (MESA) Standards Alliance.** This is an industry association of electric utilities and technology suppliers. MESA's mission is to accelerate the interoperability of Distributed Energy Resources (DERs), in particular utility-scale energy storage systems (ESS), through the development of open and non-proprietary communication specifications, based on standards. MESA has developed and published two specifications: MESA-DER (formerly MESA-ESS) and MESA Device/SunSpec Smart Storage. The MESA-DER profile based on DNP3 will soon become an IEEE international standard (IEEE P1815.2). MESA specifications are also tied to SEP 2.0, OpenFMB, and SunSpec.

- **Open Automated Demand Response (OpenADR).** The OpenADR Alliance was created to standardize, automate, and simplify Demand Response (DR) and Distributed Energy Resources (DER) to enable utilities and aggregators to cost-effectively manage growing energy demand and decentralized energy production, and customers to control their energy future. OpenADR is an open, highly secure, and two-way information exchange model and Smart Grid standard. It provides a non-proprietary, open, standardized and secure DR interface that allows electricity providers to communicate DR signals directly to existing customers using a common language and existing communications such as the Internet.
- **Open Charge Point Interface (OCPI).** OCPI is an open protocol used for connection between charge station operators and service providers. This protocol facilitates automated roaming for EV drivers across several EV charging networks.
- **Open Charge Point Protocol 2.01 (OCPP 2.01).** This protocol initially was an initiative of the ELaadNL foundation in the Netherlands with the aim to create an open application protocol which allows EV charging stations and central management systems from different vendors to communicate with each other. It evolved into the Open Charge Alliance (OCA) which has launched an independent OCPP certification program through which EVSE manufacturers and charging station management system providers (CSMS / back office) are now able to conform their OCPP 1.6 implementations according to the official OCPP specification. **OCPP 2.01** incorporates improvements for things found in the first implementations of OCPP 2.0 during Plugfests and in the field. Improvements have been made in the areas of security, ISO 15118, Smart Charging, and the extensibility of OCPP.
- **Open Field Message Bus (OpenFMB)**. The OpenFMB interoperability framework is a standard ratified in 2016 by the North American Energy Standards Board (NAESB) which enables grid edge interoperability and distributed intelligence. OpenFMB provides a reference architecture and framework for allowing intelligent nodes to interact with each other. These nodes manage distributed resources that communicate via common semantics and federate data locally for control and reporting.
- **SAE J3072-202103, Interconnection Requirements for Onboard, Grid Support Inverter Systems.** This standard establishes requirements for a grid support inverter system function integrated into a PEV connecting in parallel with an electric power system by way of conductively coupled EVSE. It defines communication between the PEV and EVSE required for the PEV onboard inverter to be configured and authorized by the EVSE for discharging at the site. The requirements herein are intended to be used in conjunction with IEEE 1547 and IEEE 1547.1.

In-Development Standards and Guidance Documents:

These standards, codes, and other guidance documents or initiatives relevant to Communications and Controls are currently in progress.

- **IEEE P1815, Standard for Electric Power Systems Communications-Distributed Network Protocol (DNP3).** Specifies the DNP3 protocol structure, functions, cyber security features and interoperable application options (subset levels). The specified subset level defines the functionality implemented in each device.

- **IEEE P2030, Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), End-Use Applications, and Loads.** When completed it will provide a knowledge base addressing terminology, characteristics, functional performance and evaluation criteria, and the application of engineering principles for smart grid interoperability of the electric power system with end-use applications and loads. It will also discuss alternate approaches to good practices for the smart grid.

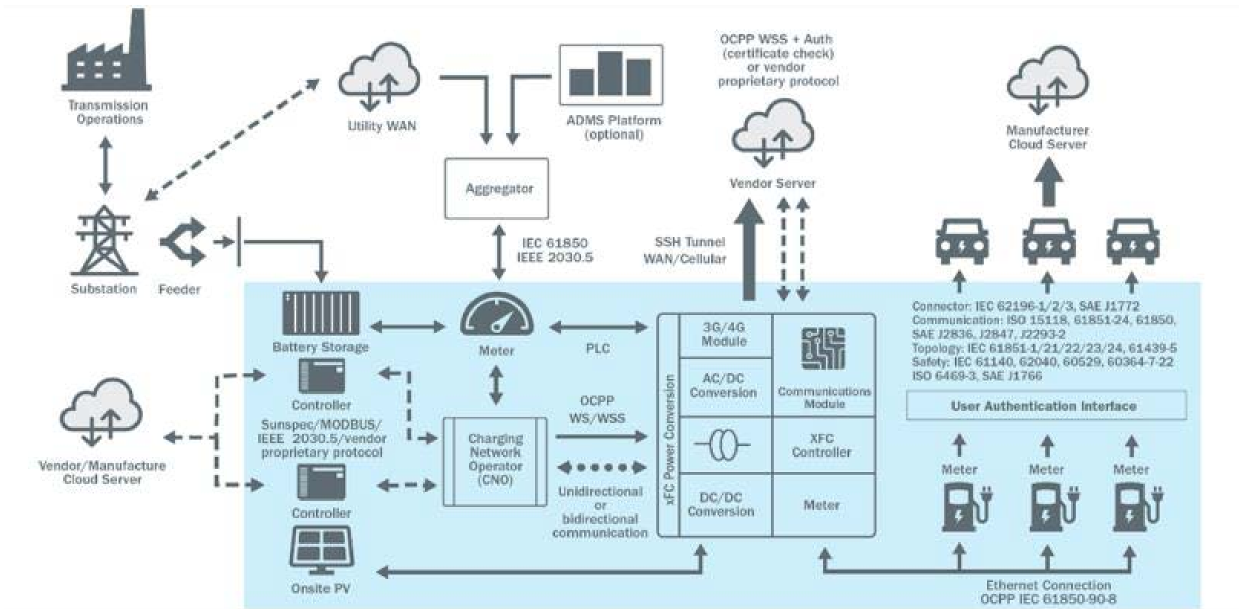
5. Cybersecurity

A lack of cybersecurity has the potential to be a major impediment to the large-scale adoption and integration of EVs with the grid. The vast cross-sectoral nature of the EV ecosystem, combined with the complexity of systems and technologies required to integrate EVs onto the grid, exposes a multitude of cybersecurity vulnerabilities. Apart from AC Level 1 chargers, EVSE has evolved rapidly to be networked and maintain a wide variety of communication functions. As communication networks for EVs, EVSE, and external systems increase, the attack surface also increases, leaving the charging infrastructure and wider EV ecosystem more open to exploitation of cybersecurity vulnerabilities. Cybersecurity breaches can affect the ability of charging equipment to function, expose personally identifiable and financial information, and more ominously affect safe operations of the charging equipment and the vehicles themselves, both during the charging processes and vehicle utilization.

A major challenge posed by compromised charging infrastructure is the threat it poses to the electric grid. A localized cyber-physical attack on a set of EVSE/charging stations can lead to a sudden addition or reduction of loads that can cause voltages imbalances and undesirable power quality impacts leading to local disruptions such as brownouts, market disruptions, and damaged equipment. Large-scale, coordinated cyber-physical attacks on charging infrastructure supporting large-scale EV implementation can also lead to wider grid disruptions, such as blackouts over large geographical areas. Finally, it is important to note that cybersecurity must be continually addressed as no EV ecosystem will ever be entirely secure and threats will continually evolve.

Challenges to secure the vast cross-sectoral EV ecosystem (including EVs, charging infrastructure, and the grid) result from the multi-stakeholder environment, multiple sectoral interfaces, centers of control, and conflicting jurisdictional requirements and responsibilities. These factors blur lines of responsibility and delineation of roles between stakeholders with regard to cybersecurity. Furthermore, there is an overall lack of inter-sectoral working experience, coordination, and trust amongst the EV ecosystem's stakeholders. Establishing and structuring trust is key in many areas including the PKI when providing system patching via over-the-air (OTA) updates, securing cloud services, achieving best-in-class network tools, as well as physical security. Trust is enhanced by greater user and information authentication through application of methodologies for data encryption, integrity, and secrecy, as well as more secure methodologies for command and control between stakeholders. Especially challenging are the interfaces and interconnections between each of the sectors and ecosystem components, and that cybersecurity for the EV ecosystem involves critical infrastructure and massive power devices. An additional barrier is that there are currently no specific guidelines for implementing EV charging cybersecurity.

The figure below presents a communication architecture developed through industry engagement to identify the majority of specific communications standards, interconnections, control elements, and connections to the grid of an extreme fast charging (XFC) infrastructure. Within the figure, the blue shading represents the charging facility itself, with on-site distributed energy resources (battery storage, onsite PV), control and conversion systems, communications, and extreme fast chargers. At the charge site, multiple entities and equipment are all communicating which need to be protected. In the upper left of the figure, important utility elements are shown including electricity transmission and distribution and associated control via the cloud. The balance of the figure largely presents various cloud services, including the vendor responsible for authorizing charging services and OEM communications with the electric vehicles. This figure helps illustrate the extent of the EV charging ecosystem that needs to be considered from a cybersecurity perspective.



Consequence-Driven Cybersecurity for High Power EV Charging Infrastructure"
(INL and NREL, October 2020)[1]

The U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA) National Electric Vehicle Infrastructure (NEVI) Formula Program will provide funding to States to strategically deploy EV charging stations and to establish an interconnected network to facilitate data collection, access, and reliability. A NEVI Formula Program Final Rule has been released which states the following in Section **680.106, Installation, operation, and maintenance by qualified technicians of electric vehicle charging infrastructure**

> (h) *Security*. States or other direct recipients must implement physical and cybersecurity strategies consistent with their respective State EV Infrastructure Deployment Plans to ensure charging station operations protect consumer data and protect against the risk of harm to, or disruption of, charging infrastructure and the grid.[70]
>
> (1) Physical security strategies may include topics such as lighting; siting and station design to ensure visibility from onlookers; driver and vehicle safety; video surveillance; emergency call

[70] https://www.federalregister.gov/d/2023-03500/p-375

boxes; fire prevention; charger locks; and strategies to prevent tampering and illegal surveillance of payment devices.

(2) Cybersecurity strategies may include the following topics: user identity and access management; cryptographic agility and support of multiple PKIs; monitoring and detection; incident prevention and handling; configuration, vulnerability, and software update management; third-party cybersecurity testing and certification; and continuity of operation when communication between the charger and charging network is disrupted. [71]

and

(l) *Customer Data Privacy*. Charging station operators must collect, process, and retain only that personal information strictly necessary to provide the charging service to a consumer, including information to complete the charging transaction and to provide the location of charging stations to the consumer. Chargers and charging networks should be compliant with appropriate Payment Card Industry Data Security Standards (PCI DSS) for the processing, transmission, and storage of cardholder data. Charging Station Operators must also take reasonable measures to safeguard consumer data. [72]

Gaps:

The following identifies codes and standards gaps identified by the ANSI Electric Vehicle Standards Panel with regard to cyber-physical security.

Gap S1: Comprehensive review of cybersecurity codes and standards for applicability to the EV charging ecosystem. Gaps should be identified and prioritized.

R&D Needed: No

Recommendation: Conduct a comprehensive inventory and review of standards with regard to cybersecurity applicability across the EV charging ecosystem. Ascertain potential gaps with regard to cybersecurity. In Winter 2023, Southern California Edison proceeded on a project for the California Energy Commission to explore cybersecurity codes and standards gaps with stage 1 focusing on identifying gaps and stage 2 to initiate addressing them.

Priority: High

Organization(s): Industry, Government, SDOs

[71] https://www.federalregister.gov/d/2023-03500/p-377

[72] https://www.federalregister.gov/d/2023-03500/p-386

Gap S2: The lack of an end-to-end secure trust chain and encryption system for the EV charging ecosystem. This results from the use of different protocols and data transfer mechanisms between EV charging related systems. An entity trust chain is needed across all elements of the EV charging ecosystem incorporating a comprehensive public key infrastructure (PKI).

R&D Needed: Yes

Recommendation: Industry consensus and implementation is needed for a comprehensive end-to-end trust chain incorporating a PKI system for the EV charging ecosystem. Consideration could be given to the Cab Authority Browser (CAB) forum as a model to reach consensus. While it appears that in some cases EV-EVSE communications may be fully encrypted, it not clear that other communication channels within the EV ecosystem (e.g., from the charging stations to the EVSPs, and between CNOs) are fully secure. ISO 15118 provides guidance on secure communications, but gaps remain. IEEE P2030.5 indicates there must be end-to-end security but does not provide the means to achieve this. Close coordination should be established with the SAE EV Collaborative Research Project (CRP) which has developed a PKI system and is now shifting to implementation. The European Commission is adopting IEC 62351 and IEC 62443 (both of which reference ISO 15118-2 and 15118-20) to ensure system security, including cybersecurity protection of digital keys. ISO 15118-2 and ISO 15118-20 work together to support the EV to grid interface. As appropriate, implement codes and standards development to reflect implementation of an industry agreed upon PKI.

Priority: High

Organization(s): Industry including equipment and system manufacturers, CNOs, aggregators, PKI infrastructure developers, Government, Associations, and SDOs

Gap S3: Cybersecurity and Data Privacy. Due to the nature of cybersecurity, the interactions of systems, and the emerging threats environment, there is an ongoing need for guidelines and standards to address cybersecurity and data privacy concerns specific to EVs and smart grid communications. Architectures should be designed with cybersecurity in mind.

R&D Needed: No

Recommendation: Develop guidelines and standards to address cybersecurity and data privacy concerns specific to EVs and smart grid communications.

Priority: High

Organization(s): IEC, IEEE, ISO, NIST, SAE, UL

<u>Gap S4</u>: Robust "Security-by-Design" is needed for equipment and systems throughout the EV charging ecosystem.

<u>R&D Needed</u>: Yes

<u>Recommendation</u>: Assess cybersecurity requirements in the initial design phases of equipment and systems throughout the EV charging ecosystem. This should be a broad-based assessment examining cybersecurity risks across the EV ecosystem including such areas as mobile apps and platforms. Identify common methods including required and optional features and functions. Establish robust metrics identifying security-by-design; for example, passing vulnerabilities testing. Consider exploration of other industries with similar challenges. Identify gaps and provide recommendations to serve as a model and establish a framework for future codes and standards development. Implement codes and standards, as appropriate, to advance "Security-by-Design" practices.

<u>Priority</u>: Medium

<u>Organization(s)</u>: Auto OEMs, EVSE manufacturers, CNOs, EVSPs, utilities, Government, and SDOs

<u>Gap S5</u>: Digital Cybersecurity as Part of Interconnection Standards. Cybersecurity threats exist at the power system point of interconnection. The digital interconnection could be compromised which may affect the electrical interconnection. Presently, there appears to be no standards requirements nor other guidance for utilities to address digital cybersecurity challenges.

<u>R&D Needed</u>: Yes

<u>Recommendation</u>: Assess the need and requirements for cybersecurity as part of power system interconnection standards. Determine cybersecurity challenges facing the digital interface (such as digital entry points) and the hosting capability of existing systems. As part of interconnection agreements, electricity providers should query downstream entities on factors potentially affecting digital cybersecurity such as the number of inverters envisioned to be operating. As appropriate, undertake cybersecurity codes and standards development for power system interconnection.

<u>Priority</u>: Medium

<u>Organization(s)</u>: Electric utility industry, Government, Aggregators, and SDOs

<u>Gap S6</u>: Cybersecurity of Power Management under DER Aggregation Scenarios. Cybersecurity gaps exist with regard to aggregation of DERs for Grid Services and subsequent power management.

<u>R&D Needed</u>: Yes

<u>Recommendation</u>: Assess cybersecurity threats resulting from the aggregation of DERs and subsequent power management within the context of grid services. Identify requirements under multiple use case scenarios, considering broad elements such as the use of telemetry and ability of aggregators to ensure security. Consider IEEE P2030.5 and FERC 2222 as a starting place for guidance. As appropriate, implement codes and standards development to mitigate risks.

<u>Priority</u>: Medium

<u>Organization(s)</u>: Industry, Government, equipment and system developers, and SDOs

<u>Gap S7</u>: Cybersecure Firmware Updates.

<u>R&D Needed</u>: Yes

<u>Recommendation</u>: There is a need for secure firmware updates for equipment and systems within the EV charging ecosystem. Signed, authenticated firmware updates are required from trusted sources. Explore industry best practices. Ford is currently developing algorithms to protect firmware updates for vehicles and to provide proof that firmware is safe to upload. Determine needs and requirements, and as appropriate, implement codes and standards development.

<u>Priority</u>: Medium

<u>Organization(s)</u>: OEMs, EVSE manufacturers, EVSPs, and SDOs

<u>Gap S8</u>: EVSE Cyber-physical Vulnerabilities. EVSE have physical vulnerabilities that can serve as threat vectors and cascade to cybersecurity high consequence events.

<u>R&D Needed</u>: Yes

<u>Recommendation</u>: Compile a thorough assessment of EVSE physical vulnerabilities and ascertain the principal threat vectors within the overarching physical design. Examples may include such items as debug ports (JTAGs), lockable cabinets, and physical issues of the cable such as broken wire and the potential to wrap and extract information. Prepare recommendations for mitigation. Conduct standards development culminating in a recommended practice addressing EVSE physical vulnerabilities.

<u>Priority</u>: Low - Medium

<u>Organization(s)</u>: EVSE manufacturers, national laboratories, and SDOs

Issues for Future Consideration:

The following identifies additional issues discussed by the ANSI Electric Vehicle Standards Panel with regard to cybersecurity. After deliberations, it was determined that the following are not currently specific, actionable gaps with regard to codes and standards. Nonetheless, they are important issues for cybersecurity of the EV ecosystem. In the future, these issues may evolve to necessitate the development of new codes and standards requirements.

Cybersecurity Forum: There is a clear need for a broad, all-inclusive cybersecurity forum to openly discuss, identify, and resolve pressing cybersecurity issues with regard to the EV charging ecosystem that may eventually encompass codes and standards development activities. It could clarify roles and responsibilities of EV charging system stakeholders.

Baseline Cybersecurity Redundancy and Resiliency: As a result of constantly evolving cybersecurity threats, there is a need to encourage minimum cybersecurity redundancy and resiliency within the EV charging ecosystem. This would include retention of a minimum level of functionality and communication under any circumstances and could include implementation of mechanisms such as phase change materials. This is a gap in best practices and is a commercial issue. Potentially relevant guidance includes NISTIR 7628, NIST Cybersecurity Framework, NIST SP 800-53, and the NIST eXtreme Fast Charging (XFC) Infrastructure Cybersecurity Framework (CSF) Profile expected in the Fall of 2023.

Implementation of updated codes and standards: Equipment and system manufacturers should develop plans and processes to actively monitor and respond to the evolution of codes and standards development. This will enable awareness and adoption of the most current and relevant codes and standards with regard to cybersecurity for the EV charging ecosystem.

Incompatibility between new and legacy EVs and EVSE: Standards tend to support backward compatibility; however, the potential exists for man-in-the-middle attacks that could spoof the EV and

EVSE to revert to unsecured communications. Both the EV and EVSE would have to be compromised. This area is relatively unexplored and numerous scenarios exist that could be exploited.

Response and Recovery: Currently, there are no standards nor baseline guidance for response and recovery from cybersecurity attacks on the EV charging ecosystem. There is a need for governmental and industry entities to identify clear response and recovery requirements to address a broad spectrum and severity of cybersecurity attacks. Examples may include processes for collecting logs when systems go off-line and for reflashing. Proprietary logs currently exist in vehicles, but regulators need access to analyze whether a cybersecurity threat has been fully resolved. Examine industries with similar challenges. In the future, as appropriate, implement codes and standards development to address cybersecurity response and recovery.

Supply Chain: There is a need for governmental and industry entities to identify supply chain cybersecurity risks. Examine industries with similar challenges. Identify origins of hardware and software and the means to secure the supply chain process. Identify equipment being incorporated at stations, across the sector, and any commonalities to ascertain security. Establish metrics and measurements ratings for implementation of hardware and software over time.

Standardized Procurement Language: Explore methodologies and risk-based options to institute standardized procurement processes to enhance the security of equipment and systems acquisition for the EV charging ecosystem. Examine industries with similar challenges and related efforts such as the Department of Defense Procurement Section 1260H covering forbidden suppliers and the National Defense Authorization Act (NDAA) 889 for the procurement of certain blacklisted telecommunication and video surveillance equipment. There is a draft PNNL/INL document on Sample Cybersecurity Clauses for EV Charging Infrastructure Procurements being brought forward by the Joint Office for Energy and Transportation of DOE and DOT. Identify requirements. In the future, as appropriate, implement codes and standards development to address the development of standardized procurement language.

Data Management: Examine internal data handling methodologies within the EV station and across the EV charging ecosystem. Establish requirements for secure data management. As appropriate, implement codes and standards development for the design of secure data systems and handling.

Apps and User Behavior: Explore expectations and behaviors of individual app users to enforce cybersecurity across the EV charging ecosystem. Identify roles and responsibilities, permissions to be given, and appropriate actions for app users. Determine inappropriate actions and misuse of credentials. Establish requirements for secure app development and authentication of use. As appropriate, implement codes and standards development to address challenges therein.

Published Standards and Guidance Documents:

The following identifies standards, codes, and other guidance documents relevant to cybersecurity throughout the EV charging ecosystem. A brief description is provided below:

- **IEC 63119-1:2019 ED1, Information Exchange for Electric Vehicle Charging Roaming Service - Part 1: General** (2019-06-26). Establishes a basis for other parts of IEC 63119 specifying terms and definitions, general description of the system model, classification of information exchange and security mechanisms for roaming between EV service providers (EVSPs), charging station operators, and the clearinghouse.
- **IEC 61970:2023 SER ED1, Energy Management System Application Program Interface (EMS-API) – ALL PARTS** (2023-01-03). Relevant to automation, cybersecurity, smart cities, and smart energy.
- **IEC 62351:2023 SER ED1, Power Systems Management and Associated Information Exchange - Data and Communications Security - ALL PARTS** (2023-01-18)
- **IEEE 1686-2022 IEEE Standard for Intelligent Electronic Devices Capabilities.** This standard defines the functions and features to be provided in intelligent electronic devices (IEDs) to accommodate cybersecurity programs.
- **IEEE 2030.5-2018 Standard for Smart Energy Profile Application Protocol:** A standard for communication between smart grid and consumers providing a means to manage energy usage and generation, and to enable a secure, interoperable, and plug and play ecosystem of smart grid devices. This standard defines the application layer with TCP/IP providing functions in the transport and Internet layers to enable utility management of the end user energy environment, including demand response, load control, time of day pricing, management of distributed energy distribution, electric vehicles, etc. There is a particular emphasis upon integration of DERs.
- **ISO 15118-2:2014, Edition 1.0 (2014-03-31), Road vehicles -- Vehicle-to-Grid Communication Interface -- Part 2: Network and application protocol requirements**.
- **ISO 15118-20:2022, Edition 1.0 (2022-04-26), Road vehicles - Vehicle to grid communication interface - Part 20: Network and application protocol requirements.** ISO 15118-2 and -20 specify the communication between electric vehicles and plug-in hybrid vehicles with electric vehicle supply equipment (EVSE). Part 20 is the underlying communication technology to enable bidirectional power transfer for AC and DC (Combined Charging Systems – CCS) and incorporates enhanced cybersecurity features.
- **ISO/IEC 27001 series of standard for Information Security Management Systems (ISMS)** and their requirements. Additional best practices in data protection and cyber resilience are covered by more than a dozen standards in the ISO/IEC 27000 family. Together, they enable organizations of all sectors and sizes to manage security assets such as financial information, intellectual property, employee data, and information entrusted by third parties.
- **ISO/SAE 21434: 2021, Road Vehicles – Cybersecurity Engineering:** Specifies engineering requirements for cybersecurity risk management regarding concept, product development, production, operation, maintenance, and decommissioning of electrical and electronic (E/E) systems in road vehicles, including their components and interfaces. A framework is defined that includes requirements for cybersecurity processes and a common language for communicating and managing cybersecurity risk.

- **National Motor Freight Trucking Administration (NMFTA) / DOT:** NMFTA / DOT have developed cybersecurity requirements for medium- and heavy-duty electric vehicles. This includes a technical report entitled Extreme Fast Charging (XFC) Cybersecurity Threats, Use Cases and Requirements for Medium and Heavy Duty Electric Vehicles.
- **NFPA 70®, National Electrical Code® (NEC®) Current Edition 2023.** The 2023 version of the NEC includes new requirements related to cybersecurity. Section 110.3 (A) has added cybersecurity to the list of considerations for equipment acceptance. NEC Section 240.6 (D) requires cybersecurity evaluation for remotely-adjustable circuit breakers.
- **NIST Framework for Improving Critical Infrastructure Cybersecurity (Cybersecurity Framework)**: The NIST Cybersecurity Framework can be considered a best practice that describes a holistic approach to mitigating cyber threats across complex systems. The Framework consists of six concurrent and continuous functions: Identify, Protect, Detect, Respond, Recover, and Endure. This Framework provides an outline of critical areas to address with regard to cybersecurity, and when considered together these functions provide a high-level, strategic, lifecycle view of cybersecurity risk.
- **NIST SP 800.53 Rev 5 (2020): Security and Privacy Controls for Information Systems and Organizations**: This publication provides a catalog of security and privacy controls for information systems and organizations to protect organizational operations and assets, individuals, other organizations, and the Nation from a diverse set of threats and risks, including hostile attacks, human errors, natural disasters, structural failures, foreign intelligence entities, and privacy risks. The controls are flexible and customizable and implemented as part of an organization-wide process to manage risk.
- **NISTIR 7628 Rev 1: Guidelines for Smart Grid Cybersecurity**: Published in 2014, NISTIR 7628 provides an analytical framework that stakeholders can use to develop effective smart grid related characteristics, risks, and vulnerabilities. Stakeholders can use methods and supporting information as guidance for assessing risk and identifying and applying appropriate security requirements.
- **Open Charge Point Protocol 2.01 (OCPP 2.01)**: This protocol initially was an initiative of the ElaadNL foundation in the Netherlands with the aim to create an open application protocol which allows EV charging stations and central management systems from different vendors to communicate with each other. It evolved into the Open Charge Alliance (OCA) which has launched an independent OCPP certification program through which EVSE manufacturers and charging station management system providers (CSMS / back office) are now able to conform their OCPP 1.6 implementations according to the official OCPP specification. OCPP 2.01 incorporates improvements for things found in the first implementations of OCPP 2.0 during Plugfests and in the field. Improvements have been made in the areas of security, ISO 15118, Smart Charging, and the extensibility of OCPP.
- **SAE J2931/7_2018, Security for Plug-in Electric Vehicle Communications**, an SAE Information Report, establishes the security requirements for digital communication between Plug-In Electric Vehicles (PEV), the Electric Vehicle Supply Equipment (EVSE) and the utility, ESI, Advanced Metering Infrastructure (AMI) and/or Home Area Network (HAN).

- **UL 2941 Outline of Investigation for Cybersecurity of Distributed Energy & Inverter Based Resources** (Edition 1, January 13, 2023)
- **UL 2900-1, ANSI/CAN/UL Standard for Software Cybersecurity for Network-Connectable Products, Part1: General Requirements**. This standard provides methods by which a product shall be evaluated and tested for the presence of vulnerabilities, software weaknesses, and malware. It includes requirements regarding the presence of security risk controls in the architecture and design of a product.
- **UL 2900-2-2 Ed. 1-2016, Outline of Investigation for Software Cybersecurity for Network-Connectable Products, Part 2-2: Particular Requirements for Industrial Control Systems**
- **United Kingdom Electric Vehicles (Smart Charge Points) Regulations 2021**: Codifies the inclusion of smart functionality in privately owned chargers at homes and offices. As of December 2022, the regulation requires all new charge points to meet a set of security requirements.
- **USDOT Government Fleet and Public Sector EVSE Cybersecurity Best Practices and Procurement Language Report**: Review of current state of EVSE cybersecurity while providing guidance and best practices that can be used across the DOE and Federal electric vehicle and electric truck sectors.

In-Development Standards and Guidance Documents:

These standards, codes, and other guidance documents or initiatives relevant to cybersecurity are currently in progress.

- **California Public Utilities Commission** is currently working on cybersecurity requirements for EVSE.
- **IEC 63119-4 ED1, Information Exchange for Electric Vehicle Charging Roaming Service**.
- **IEEE 1547.3-2007 Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems**: This guide is intended to facilitate the interoperability of distributed resources (DR) and help DR project stakeholders implement monitoring, information exchange, and control (MIC) to support technical and business operations of DR and transactions among the stakeholders. The focus is on MIC between DR controllers and stakeholder entities with direct communication interactions.
- **NIST Cybersecurity Framework Profile for Electric Vehicle Extreme Fast Charging (XFC) Infrastructure**. This effort encompasses development of a cybersecurity platform and CSF for XFC aligned with the cybersecurity controls recommendation. It is focused on the CSF profile, standards best practices, and guidance to entities engaged in designing, building, installing, and / or operating XFC infrastructure.
- **SAE J1939 Cybersecurity Task Force:** The task force focuses on cybersecurity and privacy issues. It is currently working on a technical report that will provide recommendations to vehicle manufacturers and component suppliers in securing the J1939-13 connector interface from cybersecurity risks.

- **SunSpec / Sandia DER Cybersecurity Workgroup**: The mission of the SunSpec / Sandia Cybersecurity Work Group is to support the deployment of Distributed Energy Resources (DER) by defining best practices in cybersecurity for DER and driving the concepts that emerge from these best practices into relevant national and international standards.

6. Next Steps

This roadmap should be widely promoted among interested stakeholders so that its recommendations see broad adoption.

To the extent R&D needs have been identified, the roadmap can be used as a tool to help direct funding to the areas of research needed for EVs.

In terms of standards activities, an ongoing dialogue among affected stakeholders would be beneficial to continue discussions around coordination, forward planning, and implementation of the roadmap's recommendations. Such a dialogue can also identify emerging issues that require further elaboration.

It is recognized that standardization activity will need to adapt as the ecosystem for EVs evolves due to technological innovations and regulatory developments, and as additional participants enter the EV market.

Depending upon the realities of the standards environment, the needs of stakeholders, and available resources, it is envisioned that some mechanism be established to monitor progress to implement the roadmap's recommendations.

Ultimately, the aim of these efforts would be to continue to guide, coordinate, and enhance standardization activity for EVs toward achieving the goal of EVs at scale.

[this page intentionally left blank]

Appendix A. Glossary of Acronyms and Abbreviations

1	AAA	Authentication, Authorization and Accounting
2	ABA	Architectural Barriers Act
3	AC	Alternating Current
4	ACL2	Alternating Current (AC) Level 2
5	ADA	Americans with Disabilities Act
6	ADMS	Advanced Distribution Management System
7	AFC	Alternate Fuel Corridors (NEVI Final Rule)
8	AHJ	Authorities having jurisdiction
9	AMI	Advanced metering infrastructure
10	ANCE	Asociación de Normalización y Certificación, A.C.
11	ANS	American National Standard
12	ANSI	American National Standards Institute
13	AWI	Approved work item (ISO)
14	BESS	Battery energy storage systems
15	BMS	Battery management system
16	CaaS	Charging-as-a-Service
17	CAB	Cab authority browser
18	CCS	Combined charging system
19	CFR	Code of Federal Regulations
20	CHP	Combined Heat and Power
21	CISPR	International special committee on radio interference
22	CMD	Connect my data
23	CMS	Charge management system
24	CNO	Charging network operator
25	CPUC	California Public Utilities Commission
26	CRP	Collaborative Research Project (SAE)
27	CSA	Canadian Standards Association
28	CSF	Cybersecurity framework
29	CSMS	Charge station management system
30	CSO	Charging station operator
31	CSV	Consolidated version
32	CTA	Consumer Technology Association
33	DC	Direct current
34	DCaaS	DC-as-a-Service
35	DCFC	Direct current fast charger
36	DCM	Dynamic capacity management
37	DER	Distribution/distributed energy resource
38	DERMS	DER Management System
39	DIN	Deutsches Institut für Normung
40	DMA	Data management agent
41	DNP	Distributed network protocol
42	DOE	U.S. Department of Energy

43	DOT	U.S. Department of Transportation
44	DR	Demand response
45	DSO	Distribution system operator
46	dWPT	Dynamic wireless power transfer
47	EERE	Office of Energy Efficiency & Renewable Energy
48	EESA	Electrical energy storage assemblies
49	EMC	Electromagnetic compatibility
50	eMI^3	eMobility ICT Interoperability Innovation Group
51	EMS	Energy management system (NEC)
52	EMSP	E-Mobility Service Provider
53	EPA	Environmental Protection Agency
54	EPAC	Electrically power assisted cycle
55	EPO	Examination procedure outlines (NIST)
56	EPRI	Electric Power Research Institute
57	EPS	Electric power system
58	ERTICO	European Road Transport Telematics Implementation Coordination
59	ESI	Energy service interface
60	ESP	Energy service provider
61	ESPI	Energy Services Provider Interface
62	ESS	Energy storage system
63	ETSI	European Telecommunications Standards Institute
64	EUCAR	European Council for Automotive R&D
65	EUMD	End use measurement device
66	EV	Electric vehicle
67	EVITP	Electric Vehicle Infrastructure Training Program
68	EVS	Electric vehicle safety
69	EVSE	Electric vehicle supply equipment
70	EVSP	EV services provider
71	FCS	Fast charging station
72	FHWA	Federal Highway Administration
73	FMVSS	Federal Motor Vehicle Safety Standards
74	GTR	Global technical regulation
75	GVWR	Gross vehicle weight rating
76	HAN	Home area networks
77	HB	Handbook
78	H-WPT	High-power wireless power transfer
79	IAEI	International Association of Electrical Inspectors
80	IATA	International Air Transport Association
81	IBC	International Building Code
82	ICAO	International Civil Aviation Organization
83	ICC	International Code Council
84	IEC	International Electrotechnical Commission
85	IEEE	Institute of Electrical and Electronics Engineers
86	IFC	International Fire Code

87	IgCC	International Green Construction Code
88	IMO	International Maritime Organization
89	IP	Ingress protection
90	IRC	International Residential Code
91	ISMS	Information Security Management Systems
92	ISO	International Organization for Standardization
93	ISOs	Independent system operators
94	ITS	Intelligent transport systems
95	JWG	Joint working group
96	Kw	Kilowatt
97	LEV	Light electric vehicles
98	MDU	Multi-dwelling Unit
99	MESA	Modular Energy Systems Architecture
100	MF-WPT	Magnetic field wireless power transfer
101	MIC	Monitoring, Information Exchange, and Control
102	MPVs	Multi-purpose vehicles
103	MUTCD	Manual on Uniform Traffic Control Devices
104	NAESB	North American Energy Standards Board
105	NEC	National Electrical Code
106	NECA	National Electrical Contractors Association
107	NEMA	National Electrical Manufacturers Association
108	NESC	National Electrical Safety Code
109	NEVI	National Electric Vehicle Infrastructure
110	NFPA	National Fire Protection Association
111	NHTSA	National Highway Traffic Safety Administration
112	NIST	National Institute of Standards and Technology
113	NMFTA	National Motor Freight Trucking Administration Inc.
114	NMX	Mexican standard (ANCE designation)
115	NPA	Notice of proposed amendments
116	NPRM	Notice of proposed rulemaking
117	NREL	National Renewable Energy Laboratory
118	NUEMS	Non-Utility electricity-measuring systems (NIST)
119	OCA	Open Charge Alliance
120	OCPI	Open Charge Point Interface
121	OCPP	Open Charge Point Protocol
122	OEM	Original equipment manufacturer
123	OpenADR	Open Automated Demand Response
124	OpenFMB	Open Field Message Bus
125	OSHA	The Occupational Safety and Health Administration
126	OTA	Over-the-air
127	PCI DSS	Payment card industry data security standards
128	PEV	Plug-in electric vehicle
129	PHMSA	Pipeline and Hazardous Materials Safety Administration
130	PKI	Public key infrastructure

131	PLC	Power line communication
132	POI	Point of Interconnection
133	PUCs	Public utility commissions
134	PV	Photovoltaic (solar)
135	RESS	Rechargeable energy storage system
136	RTOs	Regional transmission organizations
137	SC	Subcommittee
138	SCADA	Supervisory Control and Data Acquisition
139	SDO	Standards development organizations
140	SEPA	Smart Electric Power Alliance
141	SMS	Short message/messaging system
142	SOC	State of Charge
143	TC	Technical committee
144	TOU	Time of Use
145	UL	Underwriters Laboratory
146	UN	United Nations
147	USNWG	U.S. National Work Group (NIST)
148	V&V	Verification and Validation
149	V2G	Vehicle-to-grid
150	V2H	Vehicle-to-home
151	V2L	Vehicle-to-load
152	V2X	Vehicle-to-everything
153	VAC	Volts alternating current
154	VDC	Volts direct current
155	VTO	Vehicle Technologies Office
156	WPT	Wireless power transfer
157	XFC	Extreme fast charging

1