STANDARDIZATION ROADMAP
FOR ELECTRIC VEHICLES

VERSION 2.0

Prepared by the

Electric Vehicles Standards Panel

of the

American National Standards Institute

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AEYCH LLC	Hank McGlynn (SAE)
Alliance of Automobile Manufacturers	Giedrius Ambrozaitis
American National Standards Institute	Joe Bhatia, Susanah Doucet, Bei Gu, Rachel Howenstine, Gary Kushnier, Jim McCabe,*** Leslie McDermott, Liz Neiman, Elise Owen, Jessica Roop, Fran Schrotter
Amperex Technology Ltd.	Bob Galyen (SAE)*, Joern Tinnemeyer (SAE)
Poul Andersen Consulting	Poul Andersen
Argonne National Laboratory	Theodore Bohn (DOE), Hina Chaudhry
Association of Global Automakers	John Cabaniss, Julia Rege
ATIS	Steve Barclay, Thomas Payne, Paul Savitz
Audi AG	Martin Conrads
Autoliv Americas, ATC	Doug Stein (SAE)
Automotive Manufacturing Technical Education Collaborative	Sam Collier
Better Place	Liran Katzir, Frank Kitzantides,* Hugh McDermott, Ziva Patir
The Bishop Group	Paul Bishop (IEEE)
CenterPoint Energy	Greg Angst
Chrysler	Rich Scholer (SAE)
Corning	James E. Matthews, III**
Coulomb Technologies, Inc.	Shantanu Kothavale,* Richard Lowenthal
CSA America	Shawn Paulsen, Cliff Rondeau
Delphi	David Lambert (Global Automakers), Laurie Moore
Duke Energy	Michael D. Rowand, Mike Waters
Eaton	Matt Guth, Kevin Lippert
EDF Energy R&D UK Centre	Panagiotis Papadopoulos
Edison Electric Institute	Steven Rosenstock
EFACEC	Antonio Guimaraes
EIS Alliance	Chris Kotting
Electric Power Research Institute	Mark Duvall, John Halliwell
Elite Electronic Engineering Inc.	Craig Fanning
Energetics	Fred Wagner (DOE)
EnerNex	Dr. Aaron Snyder
Ericsson	Stephen Hayes (ATIS)
Federal Energy Regulatory Commission	Jessica Cockrell, Ray Palmer

FirstEnergy Technologies	Timothy Croushore
Ford	John Bilezikjan (SAE)
General Electric	Phil Piqueira, Heather Pugliese, Patrick Salas
General Motors	George Bellino (SAE), Slav Berezin (SAE), Gery Kissel (SAE), David Reeck
Gridmerge	Robert Cragie
Don Heirman Consultants	Don Heirman
Hendry and Associates	Anne Hendry
Honda	Tommy Chang (Global Automakers)
Hubbell	John Goodsell, Dennis Oddsen
IEEE	Paul Bishop, Michael Kipness, Tim Kostyk, Russ Lefevre
International Association of Electrical Inspectors	David Clements
International Code Council	Bruce E. Johnson, David Karmol, Kim Paarlberg, Kermit Robinson
Intertek	Rich Byczek*
ITT Interconnect Solutions	Lee Wolfel
Dale Kardos & Assoc. Inc.	Dale Kardos* (Global Automakers)
LastMile TT	Vishant Shah
Leviton	Ken Brown (NEMA)
Magna E-Car	Zilai Zhao
Mitsubishi Electric Research Labs	Zafer Sahinoglu
Mitsubishi Motors Corporation	Bowu Reed
Mitsubishi Research Institute	Yuichiro Shimura
Motorcycle Industry Council	Pamela Arnette, Mel Stahl
National Electrical Contractors Association	Michael Johnston
National Electrical Manufacturers Association	Ryan Franks, Harry Massey, Andrei Moldoveanu, Paul Molitor*
National Fire Protection Association	Kathleen Almand, Ryan Depew, Christian Dubay, Mark Earley,* Ken Willette*
National Highway Traffic Safety Administration	Phil Gorney
National Institute of Standards & Technology	Tanya Brewer, Marc Buttler, Dr. Allen Hefner, Dr. Jeffrey Mazer, Mary H. Saunders
National Renewable Energy Laboratory	Mike Simpson (DOE)
Gregory C. Nieminski, LLC	Greg Nieminski (EPRI)
Nissan USA	Joe Thompson (Global Automakers)
Open Secure Energy Control Systems	Stan Klein
P3 North America	Arthur Holland (SAE)
Pacific Northwest National Laboratory	Krishnan Gowri (DOE), Rick Pratt (DOE)
Panasonic	Mike Stelts
PRBA – The Rechargeable Battery Association	George Kerchner
Public Utilities Commission of Texas	Julie Black
Qualcomm	Mark Klerer
Rocky Mountain Institute	Ben Holland
RSR Technologies, Inc.	Dr. Tim Ellis, Dr. Jacob Hohn

SAE International	Peter Byk,* Patricia Ebejer, Jack Pokrzywa, Gary Pollak,* Gary Schkade, Keith Wilson*
San Diego Gas & Electric	JC Martin
Schneider Electric	Steve Hsu, Alan Manche,* James T. Pauley**
SEW-Eurodrive	Tim Schumann
Siemens	Chun Fan, Rick Kluth, John Young
Sony Electronics, Inc.	Dr. Paul J. Hearty
Southern California Edison	Richard Hodson, Joshua McDonald,* Jose Salazar
ST Microelectronics	James Allen (HomePlug Powerline Alliance, IEEE)
TDI Power	John Santini
Telecommunications Industry Association	Cheryl Blum, Herb Congdon
ThinkSmartGrid	Mike Coop
TKstds Management	Tom Kurihara (IEEE)
Tseng InfoServ, LLC	Mitch Tseng
TUV SUD Canada	Erik Spek (VdTÜV)
Underwriters Laboratories, Inc.	Joseph Bablo,* Sonya Bird, Kenneth Boyce, Kent Donohue, Laurie Florence,* Maurice Johnson, John Thompson
U.S. Department of Energy	Linda Bluestein, Keith Hardy, Lee Slezak
VdTÜV	Volker Blandow, Sebastian Oertel
Xanthus Consulting International	Frances Cleveland

*Asterisk following a name denotes Working Group Co-Chair.

**Double asterisk following a name denotes ANSI EVSP Co-Chair.

***Triple asterisk following a name denotes ANSI staff lead.

Parentheses signify participation on behalf of an organization.

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Summary of Major Changes From Version 1.0

<u>High-Level Structural and Content Changes</u>

The general structure of the roadmap version 1.0 has been retained. In addition to the inclusion of this summary of major changes from version 1.0, other changes in structure and content are as follows:

- A new section 1.6 has been added to highlight definitions used in the document, specifically electric vehicle supply equipment (EVSE).
- Section 2.1 was renamed How the Roadmap was Developed *and Promoted* to include summary text about domestic and international coordination efforts.
- A new section 2.2.4 was added on the World Forum for the Harmonization of Vehicle Regulations (WP.29).
- Other Cross-Sector Initiatives was renumbered section 2.2.5. This section now includes an expanded description of the work of the Smart Grid Interoperability Panel Vehicle to Grid Domain Experts Working Group (SGIP V2G DEWG) and its roadmap, plus information about regional and state initiatives.
- Sections 3.2.2 and 4.2.2 on Infrastructure Communications have been divided into parallel subsections covering Communications Architecture for EV Charging; Communications Requirements for Various EV Charging Scenarios; Communication and Measurement of EV Energy Consumption; Cyber Security and Data Privacy; and, Telematics Smart Grid Communications. It is clarified that standardization generally relating to smart device communications, the connected vehicle, and intelligent transportation systems is out of scope; rather, the focus is communications standardization that is essential or unique to the PEV charging infrastructure (e.g., communications between an EV, EVSE and Energy Service Provider).
- Subsections 3.2.3.2 and 4.2.3.2 have been renamed EV Charging – *Signage* and Parking. The text includes discussions of public signage for EV charging and EV parking space allocation.
- Subsections 3.3.1.1 and 4.3.1.1 have been renamed Electric Vehicle Emergency Shut Off – High Voltage Batteries, Power Cables, Disconnect Devices; *Fire Suppression, Fire Fighting Tactics and Personal Protective Equipment*. The aspect regarding fire suppression, fire fighting tactics and personal protective clothing is new.
- Subsections 3.3.1.2 and 4.3.1.2 have been renamed Labeling of EVSE and Load Management Disconnects *for Emergency Situations*.
- Subsections 3.3.1.4 and 4.3.1.4 have been renamed *Electrical Energy Stranded in an Inoperable RESS; Battery Assessment and Safe Discharge Following an Emergency Event.* The discussion of stranded energy is new.

- New subsections 3.3.1.5 and 4.3.1.5 have been added on Disaster Planning / Emergency Evacuations Involving Electric Vehicles. Battery recharge in emergencies is addressed here.
- Workforce Training has been renumbered subsections 3.3.1.6 and 4.3.1.6.
- Section 4 gap statements now include an indication whether or not a gap is grid related and a descriptor of the status of progress since the release of version 1.0 of the roadmap. Thus, the status of progress is described as: Closed (completed) or, using a traffic light analogy, as Green (moving forward), Yellow (delayed in progressing), Red (at a standstill), Not Started or Unknown. New gaps for version 2.0 are identified as such. Any significant changes from version 1.0 are summarized in an update statement.
- Section 5 has been renamed Summary of Gap Analysis and provides a table summarizing the findings of the gap analysis in section 4 described above. On the far right of the table, a column has been added on the Status of Progress since the release of version 1.0 of the roadmap. A key at the top of the table defines the descriptors used to assess the status of progress.
- Section 6 has been renamed On the Horizon and briefly describes technology opportunities and next steps.
- Appendix A has been substantially updated to provide a primer on EV communications.

Summary of Gap Analysis Changes

In roadmap version 2.0, a total of 58 issues are reviewed (versus 52 in version 1.0). Of these:

- 14 are issues where no gap was identified (versus 16 in version 1.0), meaning where it was felt that existing standards and/or regulations adequately address the issue:
    - 13 of these are carried over from version 1.0;
    - 1 is a new issue, that being “Disaster Planning / Emergency Evacuations Involving Electric Vehicles.”
- 44 gaps or partial gaps are identified (versus 36 in version 1.0); a “gap” is where no standard or conformance program currently exists to address a safety, performance, or interoperability issue). Of these:
    - 30 of the gaps are near-term priorities (versus 22 in version 1.0) which means they should be addressed in 0-2 years;
        - 7 new gaps that are near-term priorities are introduced in version 2.0; the status of progress on all of them is green:
            - A new near-term gap on “Electromagnetic Compatibility (EMC)” (4.2.1.4) has been added with the recommendation to complete work on IEC 61851-

21, Parts 1 and 2, and SAE J2954 to address EMC issues related to electric vehicle charging.

- A new near-term gap on “Standardization of EV Sub-meters” (4.2.2.3) has been added with the recommendation to develop standards or guidelines related to the functionality and measurement characteristics of the new types of sub-meters that are coming out for EVs, including embedded sub-meters in the EVSE or EV. NEMA and the NIST U.S. National Working Group on Measuring Systems for Electric Vehicle Fueling and Submetering (USNWG EVF&S) are listed as potential developers.

- A new near-term gap on “Coordination of EV Sub-metering activities” (4.2.2.3) has been added with the recommendation that 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. Specifically, these are identified as NEMA, the USNWG EVF&S, and the SGIP V2G DEWG.

- A new near-term gap on “Cyber Security and Data Privacy” (4.2.2.4) has been added that there is a need for guidelines and standards to address cyber security and data privacy concerns associated with PEVs and smart grid communications. The recommendation is to complete work to develop SAE J2931/7, and to revise ISO/IEC 15118-1 and NISTR 7628, volume 2.

- A new near-term gap on “Telematics Smart Grid Communications” (4.2.2.5) has been added that there is a need to develop use cases related to non-utility aggregation control and vehicle information in order to assess the existing functionalities, and to determine any missing requirements within the context of existing standards, Energy Service Provider (ESP) business requirements, and telematics networks to support smart grid load management. The recommendation is to complete work on SAE J2836/5™.

- A new near-term gap on “Electrical energy stranded in an Inoperable RESS” (4.3.1.4) provides that standards to enable common method assessment of rechargeable energy storage systems (RESS) condition and stability, and removal of the energy stranded from an inoperable RESS, are needed to increase the safety margin to persons who may become exposed to the device in an inoperable state for various reasons and conditions during the RESS life cycle. The recommendation is for NHTSA and the Argonne National Laboratory to carry out a research project that they have begun to independently identify a solution set to the issue of electrical energy stranded in a damaged or inoperable RESS, and that work should be completed on SAE J3009 to address a similar scope.

        - A new near-term gap on "Workforce Training – Charging Station Permitting" (4.3.1.5) has been added to develop and promote a "Code Official Toolkit" related to EVSE permitting.

    - 4 of the gaps that were near-term priorities identified in version 1.0 are now closed or will be shortly:

        - The partial gap on "Power quality" (4.2.1.3) will be closed with the publication of SAE J2894/2.

        - The partial gap on "EVSE charging levels" (4.2.1.3) with respect to DC charging levels is now closed with the publication of the new version of SAE J1772™.

        - The partial gap on "Off-board charging station and portable EV cord set safety within North America" (4.2.1.3) is closed with the publication of the new tri-national standard based on UL 2594.

        - The partial gap on "EV coupler safety within North America" (4.2.1.3) is closed with the publication of the new tri-national standard based on UL 2251.

    - 19 of the gaps that are near-term priorities are still open from version 1.0. The status of progress can be described as follows: 14 are green, 2 are yellow, none are red, 2 are not started, and 1 the status is unknown. Significant developments include:

        - The gap on "Charging of roaming EVs between EVSPs" (4.2.2.2) notes that NEMA's EVSE section organized a working group to develop a standard that supports roaming that allows charging services from a provider other than the home EVSP. The standard will include inter-operator interfaces to address the various stages of a charging session (e.g., authentication/authorization, charging data records, billing record exchange.) The NEMA working group also is looking to develop a radio-frequency identification (RFID) credential protocol specification so that all EVSEs that implement the specification will be able to read RFID cards that conform to the specification. IEC also has initiated work on IEC 62831 Ed. 1.0, User identification in Electric Vehicle Service Equipment using a smartcard, which describes the physical and protocol layers of an RFID card used in charging spots.

        - The gap on "Access control at charging stations" (4.2.2.2) indicates that NEMA's EVSE section set up a working group to look at this issue. It decided that offline access control lists were a low priority and deferred action on offline access control to a later phase of work.

- 11 of the near-term priorities from version 1.0 were substantially revised:

  - The recommendation on “Delayed battery overheating events” (4.1.1.2) was revised to say that this issue should be addressed in future rulemaking and/or revisions of SAE J2929 based on the results of the DOT/NHTSA-funded SAE Cooperative Research Project. NHTSA has been added as a potential developer.

  - The UN Subcommittee of Experts on the Transport of Dangerous Goods was added as a potential developer to the gap on “Packaging and transport of waste batteries” (4.1.1.4) as there is a proposal before it.

  - Regarding “Graphical symbols” (4.1.3.1), the text has been updated to note NHTSA sponsored research on functional safety and failure modes. The roadmap version 1.0 gap statement and recommendation have been re-focused on communication of information to the driver. NHTSA has been added as a potential developer and the priority level has been changed from near-term to long-term. Regarding the roadmap version 1.0 gap statement and recommendation relating to graphical symbols for “parts under the hood,” this aspect is addressed in section 4.3.1.1 on EV emergency shut off.

  - The gap on “Wireless charging” (4.2.1.1) was modified to account for IEEE and IEC/TC 69 work, with both added as potential developers.

  - The text and recommendation relating to “Battery swapping – safety” (4.2.1.2) have been updated to note the new project IEC 62840 in IEC/TC 69.

  - The text on “EV coupler interoperability with EVSE globally” (4.2.1.3) has been updated to note the publication of the SAE J1772™ AC/DC combination coupler and that the forthcoming IEC 62196-3 will describe the SAE J1772™ coupler and several other different DC coupler configurations used elsewhere. The gap statement notes the publication of SAE J1772™. The recommendation notes the need to incorporate SAE J1772™ into IEC 62196-3 and the need to build out the charging infrastructure to accommodate variations in coupler configurations for particular markets as necessary, in particular with respect to DC charging. CHAdeMO, and “vehicle and charging station manufacturers,” have been added alongside SAE and IEC as “potential developers.”

  - The text, gap statement, recommendation and list of potential developers on “Vehicle as supply” (4.2.1.5) have been substantially reworked to focus specifically on the need for harmonization of the DER communications model between SAE J2836/3™, IEC/TR 61850-90-8, and SEP 2.0. Potential changes to other standards to address integration of inverter-based DER devices with the grid, or architecture and safety aspects of reverse power flow, are contemplated in the text but not included as a gap.

- The roadmap version 1.0 text, gap statement, recommendation and potential developers on "Communication of standardized EV sub-metering data" (4.2.2.3) have been revised to be specific about communication of EV sub-metering data between third parties and service providers and to complete work on the Green Button Sub-metering Profile of ESPI.

- The partial gap on "Electric Vehicle Emergency Shut Off" (4.3.1.1) largely has been addressed with the publication of SAE J2990. The text, gap statement and recommendation have been substantially modified to more broadly capture the scope of safety concerns facing emergency responders including the possibility that additional standardization work may be needed with respect to fire suppression, fire fighting tactics and personal protective equipment.

- The text, gap statement and recommendation on "Labeling of EVSE and load management disconnects" (4.3.1.2) have been clarified to address labeling for emergency situations. UL and NEMA have been added as potential developers.

- The gap on "Battery assessment and safe discharge following an emergency event" (4.3.1.4) has been modified to include an assessment of battery stability. Emergency responders are no longer identified as the specific user of battery discharge procedures since second responders (tow operators, roadside assistance) and OEM representatives also may need such training. The development of such procedures is now described as contingent upon research underway by NHTSA / Argonne National Laboratory on stranded energy. Argonne and NFPA have been added as potential developers. Text regarding safe battery *recharge* in emergencies has been removed and a new roadmap section on Disaster Planning / Emergency Evacuations Involving Electric Vehicles has been added to separately address that concern.

- 13 of the gaps are mid-term priorities (versus 12 in version 1.0) which should be addressed in 2-5 years;
    - 1 new mid-term gap on "Workforce Training – Colleges and Universities" (4.3.1.5) has been added to develop higher education programs focused on electric vehicle

charging infrastructure development from the standpoint of land use, community planning and architecture.

- Of the 12 mid-term priorities from version 1.0 that are still open, the status of progress can be described as follows: 4 are green, 2 are yellow, 1 is red, 4 are not started, and 1 is unknown. Significant developments include:

  - Because of resource issues, work on the power rating method standards (4.1.1.1) SAE J2907 and J2908 has been canceled and will be re-opened under a new J number at a future date yet to be determined.

  - The gap on "Locating and reserving a public charging station" (4.2.2.2) notes that NEMA's EVSE section organized a working group to develop a standard that permits EV drivers to universally locate a public charging spot. It decided that reserving a public charging spot was a low priority and deferred action on reservations to a later phase of work.

  - In relation to the gap on "Accessibility for persons with disabilities to EVSE" (4.2.3.7), additional text has been added to the roadmap describing the two-step process for addressing accessible EV parking and charging in relevant standards and codes including the ICC A117.1, IBC®, IgCC™, and IZC®. Non-accessible EV parking and charging also is addressed in the roadmap text.

- 2 of the mid-term priorities from version 1.0 have been substantially revised:

  - The gap on "Loss of control/dual mode failure in the battery" was reworked as "Functional safety in the charging system" (4.1.1.2). The gap statement and recommendation have been updated to note NHTSA-funded research, that the issue may be with the charging system rather than the battery, and that NHTSA rulemaking may result. NHTSA has been added as a potential developer and the priority level has been changed from mid-term to near-term.

  - The text and potential developers for "Guarding of EVSE" (4.2.3.6) have been updated. NFPA has work on premises security and, so, has been added as a potential developer. It does not appear that NHTSA has jurisdiction in this area and neither it nor the American Association of State Highway and Transportation Officials (AASHTO) have developed guidelines or standards for guarding of EVSE. No other agencies or organizations have been identified at this time that are working on this issue.

- 1 of the gaps is a long-term priority (versus 2 in version 1.0) and should be addressed in 5+ years.

- As noted earlier, the gap on “Graphical Symbols” (4.1.3.1) is still open from version 1.0. The status is not started.

- 2 of the long-term priorities from version 1.0 have been substantially revised:

  - The text and recommendation on “Battery recycling” (4.1.1.5) have been updated to note relevant work by SAE. The priority level has been changed from long-term to near-term.

  - The text on “Battery secondary uses” (4.1.1.6) has been updated to note some of the considerations in the work thus far by the SAE committee. The priority level of the gap has been changed from long-term to mid-term.

Additional Significant Text Changes

- Text regarding the work of the Electric Vehicle Safety Informal Working Group (EVS-IWG) of WP.29 has been added to Subsection 4.1.1.2 on Battery Safety.

- The work of the SAE EV Crash Test Safety Procedures Task Force has been noted in Subsection 4.1.1.7 on Crash Tests / Safety.

- Text regarding the North American harmonization effort based on UL 2231, Parts 1 and 2, has been added to Subsection 4.2.1.3 under EV Supply Equipment and Charging Systems.

- Additional information about the IEC 61851 series of standards, including on light electric vehicles, and the IEC 62196 series, has been added to Subsection 4.2.1.3 on Electric Vehicle Supply Equipment (EVSE).

- New Subsection 4.2.2.1 on Communications Architecture for EV Charging includes more information on the relationship between the SAE communications standards and the corresponding ISO/IEC 15118 series.

- New Subsection 4.2.2.2 on Communications Requirements for Various EV Charging Scenarios includes text about European work related to communication between EVSEs and charging network operating systems including the Open Charge Point Protocol (OCPP), eMI[3] and Green eMotion, as well as inter-operator interoperability, including the Open Clearing House Protocol (OCHP) and Hubject joint venture.

- New Subsection 4.2.2.3 on Communication and Measurement of EV Energy Consumption includes expanded text on sub-metering, third party sub-metering use cases, and standardization activities including communications formats between a third party data management agent and a billing agent and on functional and measurement characteristics of third party sub-meters.

- Additional text regarding challenges associated with the EVSE installation permitting process is included in Subsection 4.2.3.3.

Executive Summary

Electric vehicles ("EVs," a/k/a electric drive vehicles) offer the potential to significantly reduce the United States' (U.S.) use of imported oil, create a multitude of well-paying jobs through the establishment of a broad, domestic EV industry, and reduce on-road vehicular emissions. In order to achieve this potential, and broadly penetrate the consumer market, EVs must be undeniably safe, become more cost competitive, and otherwise satisfy user expectations and needs.

While there are many types of EVs, including those powered by fuel cells and other technologies, 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. PEVs include battery-powered all electric vehicles (AEVs), sometimes referred to as battery electric vehicles (BEVs), and plug-in hybrid electric vehicles (PHEVs). Some plug-in models are also extended range electric vehicles (EREVs) that function as an AEV, plus have a feature to extend vehicle range beyond the battery (e.g., via a gasoline generator and other possibilities). Conventional hybrid EVs (HEVs) which are recharged by an internal combustion engine are yet another type of EV and, while not the focus of this roadmap, are noted where there are relevant safety and other considerations.

Given the current range limitations of plug-in EVs on battery power alone, 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 PEV or charging system utilized.

Equally important is the establishment of a comprehensive and robust support services sector that includes training of emergency first responders, vehicle technicians, electrical installers and inspectors, as well as education of authorities having jurisdiction, building owners, and consumers.

Never has there been a more auspicious time for EVs than the present. Nonetheless, while the times appear especially promising, EVs do face significant challenges to widespread adoption. In order for EVs to be broadly successful, the following challenges must be successfully addressed:

Safety: While inherently neither more nor less safe than conventional internal combustion engine vehicles, EVs do have unique safety complexities and risks which must be understood and accounted for as part of the vehicle life cycle.

Affordability: Cost is a critical issue which must be continually addressed in order for EVs to become widely accepted and broadly penetrate the consumer market.

Interoperability: The ability to recharge anywhere in a secure fashion will greatly enhance EV driver flexibility and user convenience.

Performance: The ability to extend the driving range of EVs on a single battery charge without the need for range extension is largely due to energy storage capabilities (batteries) and a function of technology development.

Environmental Impact: The demand from both regulators and consumers for "greener" vehicles (i.e., more fuel-efficient, less reliant on fossil fuels) must be met.

Standards, code provisions, and regulations, as well as conformance and training programs, cross over all these areas and are a critical enabler of the large-scale introduction of EVs and the permanent establishment of a broad, domestic EV and infrastructure industry and support services environment.

Roadmap Goals, Boundaries and Audience: 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) convened the Electric Vehicles Standards Panel (ANSI EVSP or "the Panel"). The decision to form the Panel was made at a meeting of key stakeholders in March 2011 which ANSI convened in response to suggestions that the U.S. standardization community needed a more coordinated approach to keep pace with electric vehicle initiatives moving forward in other parts of the world. This effort draws upon participants from the automotive, utilities, and electrotechnical sectors as well as from standards developing organizations (SDOs or "developers") and government agencies.

In April 2012, the ANSI EVSP released the *Standardization Roadmap for Electric Vehicles – Version 1.0* ("roadmap"). The goals of this update to the roadmap remain the same, namely to:

1. Facilitate the development of a comprehensive, robust, and streamlined standards and conformance landscape; and

2. Maximize the coordination and harmonization of the standards and conformance environment domestically and with international partners.

Accordingly, the focus of this roadmap is to comprehensively identify, inventory, and assess existing standards, relevant codes and regulations, and related conformance and training programs, ascertain gaps and recommended solutions. This includes identification of prioritized timeframes for when standardization should occur and SDOs that may be able to lead the work.

It is important to emphasize that the focus of this roadmap is not merely to identify gaps and then to suggest development of new standards or conformance programs to fill them. Rather, it is also to identify opportunities where gaps potentially can be filled by revising or harmonizing existing standards and conformance programs.

Several high level boundaries have been established in the development of this roadmap. The focus is on PEVs, charging systems, and associated support services. Standards and conformance activities are emphasized that have direct applicability to the U.S. market for PEVs and charging infrastructure. Additionally, this roadmap has been developed with an eye toward international activities and harmonization, and a strong emphasis is placed upon establishing priorities for near-term standardization needs (0-2 years), while also assessing mid-term (2-5 years), and long-term (5+ years) requirements.

This roadmap is targeted toward a broad audience including SDOs; U.S. federal, state, and municipal governments; and the automotive, electrotechnical, and utilities industries, among others.

Entities Operating in the EV Space: The U.S. standards system acknowledges that there are multiple paths to achieving globally relevant standards. Many SDOs and consortia operate on an international scale and what matters is that the standards are developed according to the principles of the World Trade Organization's Technical Barriers to Trade Agreement. Coordination and harmonization among international standardizing bodies is an aspirational goal that will help to foster innovation and grow global markets for EVs. Suffice it to say that the deployment of EVs in the United States will be shaped by the standards activities of a number of SDOs, both U.S.-based and non-U.S. based, as well as codes, regulations, conformance and training programs, and related activities of many stakeholders, including U.S. federal government agencies, inter-governmental bodies, and other cross-sector initiatives.

Roadmap Structure: The broad electric vehicle and infrastructure system is very complex and dynamic, undergoing continual evolution and adaption, with many parties involved. In order to develop this roadmap, it was necessary to frame activities under three broad domains: vehicles, infrastructure, and support services. Within those three domains, seven broad topical areas of relevance to standards and conformance programs for electric vehicles were identified: energy storage systems, vehicle components, and vehicle user interface within the vehicle domain; charging systems, communications and installation within the infrastructure domain; and education and training within the support services domain.

While some distinct issues within the topical areas are solely applicable to one specific domain, in general they are highly interrelated and interdependent. In many, if not most cases, important issues related to standards and conformance programs cross over at least two of the domains simultaneously, if not all three. Understanding the interrelationships and interfaces between the domains, topical areas, and issues is essential.

Section 2 of the roadmap provides additional background regarding how this roadmap was developed and promoted, and some of the key players that are shaping the standardization landscape for PEVs and charging infrastructure.

Section 3 of the roadmap provides the context and explanation for why specific issues were considered important and subsequently assessed as part of this roadmap. Sections 3 and 4 parallel one another in structure to facilitate ease of use, cross comparisons, and consideration of issues across domains and topical areas.

Section 4 is the gap analysis of standards, codes, regulations, conformance programs, and harmonization efforts. This evaluation looks at existing and needed standards and conformance programs that are relevant to the rollout of electric vehicles and charging infrastructure in the United States. Where gaps are identified, recommendations for remediation are noted. Based on an assessment of the acuteness of risk, a priority for addressing each gap is noted, along with an indication of the potential developer(s) who could undertake the work. Gap statements also include an indication whether or not a gap is grid related and a descriptor of the status of progress since the roadmap version 1.0 was released.

Section 5 provides a table summarizing the findings of the gap analysis in section 4.

Section 6 briefly describes what is on the horizon in terms of technology opportunities and next steps.

Additionally, this roadmap is supplemented by the *ANSI EVSP Roadmap Standards Compendium* (“compendium”), a searchable spreadsheet which inventories standards that are directly or peripherally related to each issue, while also identifying related issues to which the standards potentially apply. Like the roadmap itself, the compendium has been updated since its original publication in April 2012.

Summary of Gaps and Recommendations: Presently, this roadmap has identified a total of 44 gaps or partial gaps and corresponding recommendations across the three domains and seven topical areas. Thirty of these gaps / recommendations have been identified as near-term priorities, thirteen as mid-term priorities, and one as a long-term priority.

Specifically, with regard to near-term safety and other priorities, the following gaps/partial gaps have been identified: functional safety in the charging system; delayed battery overheating events; safe storage of lithium-ion batteries; packaging and transport of waste batteries; battery recycling; audible warning systems; wireless charging; battery swapping (both safety and interoperability); power quality; EVSE charging levels; off-board charging station and portable EV cord set safety within North America; EV coupler safety within North America; EV coupler interoperability with EVSE globally; conformance programs for EV coupler interoperability within the U.S. market; electromagnetic compatibility (EMC); vehicle as supply / reverse power flow; use of alternative power sources; charging of roaming EVs between EVSPs; access control at charging stations; communication of standardized EV sub-metering data; standardization of EV sub-meters; coordination of EV sub-metering activities; cyber security and data privacy; telematics smart grid communications; electric vehicle emergency shut off – high voltage batteries, power cables, disconnect devices; fire suppression, fire fighting tactics and personal protective equipment; labeling of EVSE and load management disconnects for emergency situations; electrical energy stranded in an inoperable RESS; battery assessment and safe discharge following an emergency event; and, workforce training – charging station permitting.

In this context, a gap refers to a significant issue – whether it be related to safety, performance, interoperability, etc. – that has been identified and that should be addressed in a standard, code, regulation, or conformance program but for which currently none is published or known to exist that adequately addresses the issue. Gaps can be filled through the creation of entirely new standards, code provisions, regulations, or conformance programs, or through revisions to existing ones. In some cases work may already be in progress to fill the gap.

A partial gap refers to a situation where a significant issue has been identified that is partially addressed by an existing standard, code, regulation, or conformance program. No gap means there is no significant issue that has been identified at this time or that is not already adequately covered by an existing standard, code, regulation, or conformance program.

Next Steps: While this roadmap represents a specific snapshot in time, it maintains a distinctively outward looking, over the horizon posture that will continue to facilitate discussions with domestic, regional and international partners regarding coordination and harmonization of standardization activities and adaption to technological and policy changes.

Depending upon the needs of stakeholders, and available resources, periodic updates on significant electric vehicle standardization activities and progress to address the gaps identified in this roadmap will be made. Issues that are new or that require further discussion also may be explored. The aim behind any such efforts will be to continue to help guide, coordinate, and enhance the standards landscape as needed to support the widespread introduction of PEVs and charging infrastructure.

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1. Introduction

Electric vehicles ("EVs," a/k/a electric drive vehicles) offer the potential to significantly reduce the United States' (U.S.) use of imported oil, create a multitude of well-paying jobs through the establishment of a broad, domestic EV industry, and reduce on-road vehicular emissions. In order to achieve this potential, and broadly penetrate the consumer market, EVs must be undeniably safe, become more cost competitive, and otherwise satisfy user expectations and needs.

While there are many types of EVs, including those powered by fuel cells and other technologies, 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. PEVs include battery-powered all electric vehicles (AEVs), sometimes referred to as battery electric vehicles (BEVs), and plug-in hybrid electric vehicles (PHEVs). Some plug-in models are also extended range electric vehicles (EREVs) that function as an AEV, plus have a feature to extend vehicle range beyond the battery (e.g., via a gasoline generator and other possibilities). Conventional hybrid EVs (HEVs) which are recharged by an internal combustion engine are yet another type of EV and, while not the focus of this roadmap, are noted where there are relevant safety and other considerations.

Given the current range limitations of plug-in EVs on battery power alone, 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.

Equally important is the establishment of a comprehensive and robust support services sector that includes training of emergency first responders, vehicle technicians, electrical installers and inspectors, as well as education of authorities having jurisdiction, building owners, and consumers.

Standards, code provisions, and regulations, as well as conformance and training programs, cross over all these areas and are a critical enabler of the large-scale introduction of EVs and the permanent establishment of a broad, domestic EV and infrastructure industry and support services environment.

1.1 Situational Assessment for Electric Vehicles

Several factors are driving the keen interest in EVs. Certainly, U.S. government concerns over energy security and dependency on imported petroleum from increasingly unstable foreign markets is a primary driver. The potential of EVs to offer a solution to this problem, to contribute to the reduction of greenhouse gas emissions, and to promote economic growth and jobs creation in the new technologies, has spurred substantial government investment in electric vehicle research and infrastructure. In his 2011 State of the Union address, U.S. President Barack Obama announced the goal of putting one million electric vehicles on U.S. highways by 2015. There is also increasing demand for low-emission, fuel-efficient and affordable vehicles from consumers who want to demonstrate their commitment to the environment.

Never has there been a more auspicious time for EVs than the present. In recent years, there have been major advances in energy storage technologies (most especially lithium-ion based technologies) that have led to significant improvements in energy- and power density along with reduced costs. There have also been steady achievements with regard to hybrid power train developments, power electronics, and electric machines. Corporate average fuel economy (CAFÉ) requirements for 2016 and beyond provide an additional impetus behind EVs. And never before has there been such a broad interest and commitment by the automobile industry to the success of EVs.

Nonetheless, while the times appear especially promising, EVs do face significant challenges to widespread adoption. In order for EVs to be broadly successful, the following challenges must be successfully addressed: safety, affordability, interoperability, performance, and environmental impact. These also can be viewed as core values that will directly impact consumer acceptance of EVs. Standards, codes, regulations, and related conformance and training programs, are essential components that will aid in successfully addressing these concerns.

Safety: While inherently neither more nor less safe than conventional internal combustion engine vehicles, EVs do have unique safety complexities and risks which must be understood and accounted for as part of the vehicle life cycle. Given the high voltages and currents in EVs, battery and cable safety is especially important. This is true not only in accident situations for occupants and rescue personnel, but during charging, vehicle/battery repair, replacement, and recycling. Standards play an invaluable role in ensuring the safety of EV systems (and risks to technology manufacturers) especially if standards lead or at a minimum keep pace with and foreshadow technology evolution. Forward-leaning safety standards, codes, and regulations, complemented by conformance programs and training, are in fact essential to avoiding accidents and public safety risks that potentially could adversely affect the widespread viability of EVs.

Affordability: Cost is a critical issue which must be continually addressed in order for EVs to become widely accepted and broadly penetrate the consumer market. EVs are more expensive than conventional vehicles, largely driven by battery capital and replacement costs which are related to economies of scale, manufacturing technology, and raw materials. Likewise, the cost of infrastructure technology and installation needs to be reduced to bring the overall EV system life cycle cost in line with that of conventional vehicles.

While standards, codes, and regulations do not directly impact the cost of EV systems, they do so indirectly. For example, comprehensive, clear, and forwardly insightful standards and codes reduce risk and uncertainty for technology developers and investors, serving as an insurance policy of sorts. A well designed and fully developed standard and code environment encourages competition through facilitation of new market entrants and increased private sector investment. Standards for recharging will also lower costs for manufacturers and consumers.

Interoperability: The ability to recharge anywhere in a secure fashion will greatly enhance EV driver flexibility and user convenience. Well established interoperability standards and communications systems which facilitate the ability to remotely locate, price compare, and reserve charging sites along travel routes will be invaluable, especially in the early years of EV deployment given the relative scarcity of charging infrastructure. Billing under different charging scenarios must be seamless and efficient.

It will be important for standards to be designed to facilitate upgrade paths and flexible compatibility with quickly evolving communications and smart grid technologies. A bit further out possibly, but also important, are standards to facilitate vehicle energy to home and grid applications. Significantly greater interoperability will lead to manufacturing efficiencies for both the vehicle and built infrastructure leading to greater affordability and reduced financial risk.

Performance: The ability to extend the driving range of PEVs on a single battery charge without the need for range extension is largely due to energy storage capabilities (batteries) and a function of technology development. As standards, codes, and regulations help to reduce overall risk, it is likely that more technology firms will enter the market and investment will increase, thereby leading to a quickened pace of technology advancement. Standards for fast charging will help to define this market, accelerate development of more cost effective fast charging systems, enhance user convenience, and extend EV driving range. These factors will enhance business and consumer confidence in, and electric driving performance of, PEVs, making them increasingly attractive as a practical and reliable alternative to conventional vehicles.

Environmental Impact: The demand from both regulators and consumers for "greener" vehicles (i.e., more fuel-efficient, less reliant on fossil fuels) must be met. This will continue to drive technological developments and standardization efforts within the auto industry. This includes batteries with enhanced storage capacity as well as investigation of renewables as alternative power sources. The ability to safely and efficiently recharge EVs in residential, commercial and public settings without adverse grid impacts is essential, and also the subject of standardization activity and technological advancements.

1.2 Roadmap Goals for EVs and Charging Infrastructure

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)[1] convened the Electric Vehicles Standards Panel (ANSI EVSP or "the Panel"). In April

[1] ANSI is a non-profit organization that coordinates the U.S. private sector standards and conformance system – a system that relies upon close collaboration and partnership between the public and private sectors. ANSI represents thousands of member companies, organizations, and individuals who rely upon standards and conformance to increase efficiency, create market acceptance, improve competitiveness, and foster international commerce. For more than ninety years, ANSI and its members have worked to demonstrate the strength of private sector-led and public sector-supported, market-driven, standards-based solutions that are characterized by consensus, openness, and balance. ANSI is the U.S. member of the International Organization for Standardization (ISO) and, via the U.S. National Committee, the International Electrotechnical Commission (IEC).

2012, the ANSI EVSP released the *Standardization Roadmap for Electric Vehicles – Version 1.0* (“roadmap”).[2] The goals of this update to the roadmap remain the same, namely to:

1. Facilitate the development of a comprehensive, robust, and streamlined standards and conformance landscape; and

2. Maximize the coordination and harmonization of the standards and conformance environment domestically and with international partners.

Accordingly, the focus of this roadmap is to comprehensively identify, inventory, and assess existing standards, relevant codes and regulations, and related conformance and training programs, ascertain gaps and recommend solutions. This includes identification of prioritized timeframes and potential standards developing organizations (SDOs or “developers”) that may be able to lead the work. This roadmap also aspires to discuss coordination of SDOs and oversight bodies (domestic and international), as well as provide a framework to monitor the evolving technical and policy landscape for EVs and infrastructure with regard to standards and conformance programs.

It is important to emphasize that the focus of this roadmap is not merely to identify gaps and then to suggest development of new standards or conformance programs to fill them. Rather, it is also to identify opportunities where gaps potentially can be filled by revising or harmonizing existing standards and conformance programs.

1.3 Roadmap Boundaries

In order to manage scope, emphasize priorities, and adhere to a compressed timetable, several high level boundaries have been established in the development of this roadmap:

- The emphasis is on standards and conformance programs that are specific to on-road plug-in EVs (PEVs) consisting of battery-powered all electric vehicles (AEVs) and plug-in hybrid EVs (PHEVs), charging infrastructure, and associated support services, as opposed to other types of EVs or more general road vehicle and electrical infrastructure standardization activity.

- Standards and conformance programs that address the key challenges and core consumer values of safety, affordability, interoperability, performance, and environmental impact are targeted.

- Standards and conformance activities that have direct applicability to the U.S. market for PEVs and charging infrastructure are the primary focus.

[2] http://publicaa.ansi.org/sites/apdl/evsp/ANSI_EVSP_Roadmap_April_2012.pdf

- This roadmap has been developed with an eye toward international activities and harmonization, especially with regard to Canada and the European Union (EU). Harmonization refers to efforts to align or make equivalent the requirements in standards and conformance programs.
- As a result of the acute need for standards and conformance programs to keep pace with the rapidly evolving EV environment, a strong emphasis is placed upon establishing priorities for near-term standardization needs (0-2 years), while also assessing mid-term (2-5 years) and long-term (5+ years) requirements.

1.4 Roadmap Audience

This roadmap is targeted toward a broad audience including standards development organizations (SDOs); U.S. federal, state, and municipal governments; and the automotive, electrotechnical, and utilities industries, among others.

This roadmap may assist SDOs in identifying priority areas, establishing boundaries, and identifying opportunities for collaboration, consolidation, and harmonization. In addition, as specific gaps are identified for the overall EV standards landscape, it will be easier for SDOs to prioritize their activities over the near-term, mid-term, and long-term timeframes.

This roadmap will assist federal and state government entities in establishing a coherent and coordinated U.S. EV policy, and participating in or tracking the progress of associated technical activities. It will also assist harmonization efforts with regional and international entities on needed standards and conformance programs.

This roadmap will serve municipal governments and other like entities in understanding the issues and complexities surrounding EVs, infrastructure, and supporting services, and where to find resolution when looking to establish EV deployment strategies in local communities.

This roadmap will help industry to target standards participation efforts, and aid in the development of EV technologies and related conformance programs. It will also enable industry to identify commercial opportunities, to gain insights to support business strategies and technology sequencing, and to reduce safety and economic risks.

1.5 Roadmap Structure

The broad electric vehicle and infrastructure system is very complex and dynamic, undergoing continual evolution and adaptation, with many parties involved. In order to develop this roadmap, it was necessary to frame activities under three broad domains: Vehicles, Infrastructure, and Support Services. Within those three domains, seven broad topical areas of relevance to standards and conformance programs for electric vehicles were identified: Energy Storage Systems, Vehicle Components, and Vehicle User Interface within the Vehicle Domain; Charging Systems, Communications and Installation within the Infrastructure Domain; and Education and Training within the Support Services Domain. Figure 1 illustrates this.

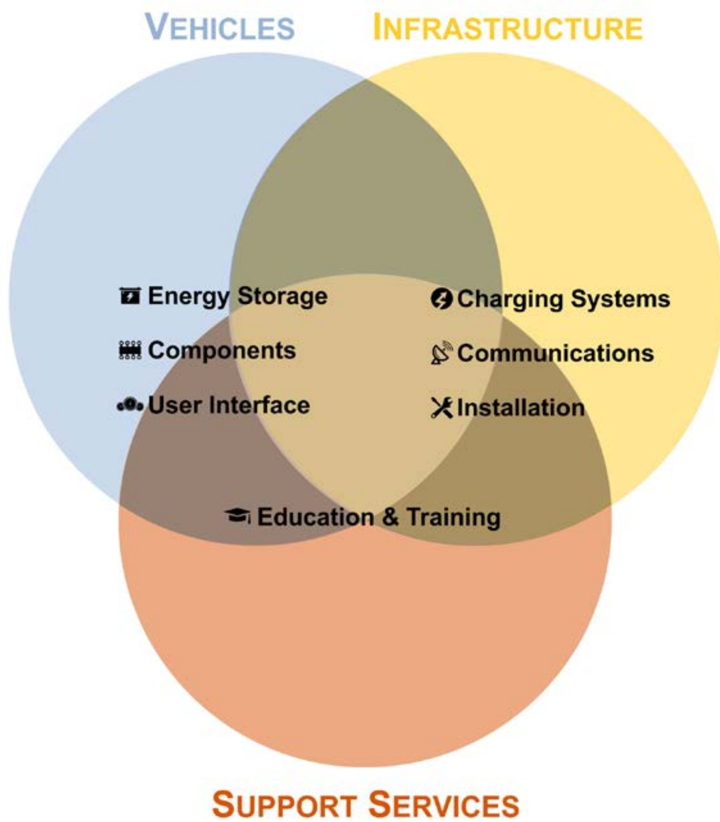

Figure 1: Domains and Topical Areas for the Standardization Roadmap for Electric Vehicles

While some distinct issues within the topical areas are solely applicable to one specific domain, in general they are highly interrelated and interdependent. In many, if not most cases, important issues related to standards and conformance programs cross over at least two of the domains simultaneously, if not all three. Understanding the interrelationships and interfaces between the domains, topical areas, and issues is essential.

Section 2 of the roadmap provides additional background regarding how this roadmap was developed and promoted, and some of the key players that are shaping the standardization landscape for PEVs and charging infrastructure.

Section 3 of the roadmap provides the context and explanation for why specific issues were considered important and subsequently assessed as part of this roadmap. Sections 3 and 4 parallel one another in structure to facilitate ease of use, cross comparisons, and consideration of issues across domains and topical areas.

Section 4 is the gap analysis of standards, codes, regulations, conformance programs, and harmonization efforts. This evaluation looks at existing and needed standards and conformance programs that are relevant to the rollout of electric vehicles and charging infrastructure in the United States. Where gaps are identified, recommendations for remediation are noted. Based on an assessment of the acuteness of risk, a priority for addressing each gap is noted, along with an indication of a potential developer(s) who could undertake the work.

In this roadmap update, section 4 gap statements now include an indication whether or not a gap is grid related and a descriptor of the status of progress since the release of version 1.0 of the roadmap. Thus, the status of progress is described as: Closed (completed) or, using a traffic light analogy, as Green (moving forward), Yellow (delayed in progressing), Red (at a standstill), Not Started or Unknown. New gaps for version 2.0 are identified as such. Any significant changes from version 1.0 are summarized in an update statement.

Section 5, the Summary of Gap Analysis, provides a table summarizing the findings of the gap analysis in section 4 described above. On the far right of the table, a column has been added on the Status of Progress since the release of version 1.0 of the roadmap. A key at the top of the table defines the descriptors used to assess the status of progress.

Section 6 briefly describes what is on the horizon in terms of technology opportunities and next steps.

This roadmap is supplemented by the *ANSI EVSP Roadmap Standards Compendium,* a searchable spreadsheet which inventories standards that are directly or peripherally related to each issue, while also identifying related issues to which the standards potentially apply.[3] Like the roadmap itself, the compendium has been updated since its initial publication in April 2012.

1.6 Definitions

For purposes of defining the scope of this roadmap, the ANSI EVSP agreed to apply the definition of electric vehicle found in the 2011 and 2014 versions of NFPA 70®, the National Electrical Code® (NEC®), given below, with the primary focus being on-road vehicles containing a battery that is recharged via the electrical grid, and related infrastructure.

> *Electric Vehicle*. An automotive-type vehicle for on-road use, such as passenger automobiles, buses, trucks, vans, neighborhood electric vehicles, electric motorcycles, and the like, primarily powered by an electric motor that draws current from a rechargeable storage battery, fuel cell, photovoltaic array, or other source of electric current. Plug-in hybrid electric vehicles (PHEV) are considered electric vehicles. For the purpose of this article, off-road, self-propelled electric vehicles, such as industrial trucks, hoists, lifts, transports, golf carts, airline ground support equipment, tractors, boats, and the like, are not included.

[3] The *ANSI EVSP Roadmap Standards Compendium* can be found at www.ansi.org/evsp.

In addition to what is not included in the NFPA 70® definition, the Panel further agreed to not include aircraft, or vehicles on fixed guideways (e.g., rails, monorails) such as trains or trolleys. While not relevant to the infrastructure discussion applicable to PEVs and PHEVs, the panel agreed to consider in part hybrid electric vehicles (HEVs) that are recharged by internal combustion engines to the extent that they pose safety concerns, e.g., for emergency responders.

As used throughout this roadmap, the term electric vehicle supply equipment (EVSE) encompasses both of the following definitions that will be found in article 625 of the NEC® 2014 version:

> *Electric Vehicle Charging System.* A system of components that provide a dc output that is supplied to the vehicle for the purpose of recharging electric vehicle storage batteries; and
>
> *Electric Vehicle Supply Equipment System.* A system of components that provide an ac output that is supplied to the vehicle for the purpose of providing input power to an on-board charger.

2. Background

2.1 How the Roadmap was Developed and Promoted

The ANSI EVSP was convened to conduct the standardization needs assessment for EVs, with a view to assuring that the technologies and infrastructure are effective, safe, and ready to accommodate a major shift in our national automotive landscape. Drawing participants from the automotive, utilities, and electrotechnical sectors as well as from standards developing organizations (SDOs) and government agencies, the Panel is a continuation of a series of standards coordinating activities where ANSI has brought together stakeholders from the private and public sectors to work in partnership to address national and global priorities. As ANSI itself does not develop standards, the Panel is strictly a coordinating body intended to inventory and assess but not duplicate current work. The actual development of standards for EVs and related infrastructure is carried about by various SDOs.

The decision to form the Panel was made at a meeting of key stakeholders in March 2011 which ANSI convened in response to suggestions that the U.S. standardization community needed a more coordinated approach to keep pace with electric vehicle 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 the U.S. Department of Energy and the Idaho National Laboratory (see workshop report and proceedings at www.ansi.org/edv).

Formally launched in May 2011, the ANSI EVSP set out to produce a strategic roadmap of the standards and conformance programs needed to facilitate the safe, mass deployment of electric vehicles and charging infrastructure in the United States. From the outset, the Panel was also envisioned as a resource to better enable the United States to speak with a coherent and coordinated voice in policy and technical discussions with regional and international audiences on needed standards and conformance programs related to electric vehicles.

Seven working groups were organized to conduct the standardization needs assessment. The working groups mirrored the topical areas within this roadmap: Energy Storage Systems, Vehicle Components and Vehicle User Interface within the Vehicle Domain; Charging Systems, Communications and Installation within the Infrastructure Domain; and Education and Training within the Support Services Domain.

Following an initial plenary meeting held in June 2011, the working groups met virtually over the course of several months to identify existing and needed standards and conformance programs, as well as gaps and harmonization issues. Individual working group members subsequently drafted sections of the roadmap based on the discussions. These were reviewed by the working groups individually and later collectively at the Panel's second plenary meeting held in November 2011 and in subsequent conference calls. The roadmap development process was characterized by open participation and consensus-based decision-making.

Version 1.0 of this roadmap was released in April 2012. Beginning in July 2012, the working groups reconvened via monthly conference calls to discuss implementation of the roadmap's recommendations, updates on the status of work, and progress to close the identified gaps. The Vehicle Domain working groups met jointly as the Vehicle Systems working group and also considered some of the relevant issues in the Support Services Domain, as did the Installation working group.

Since the release of version 1.0, ANSI has widely promoted the roadmap to various audiences. Domestically, this has included DOE, NHTSA, EPRI, and the SGIP, among others. Internationally, the roadmap has been shared with the IEC Strategic Group #6 on Electrotechnology for Mobility. In July 2012, ANSI and the China Association of Standardization organized a technical workshop on EV standardization in Beijing. In August 2012, the roadmap was presented at the U.S.-China EV and battery technology workshop in Boston. In November 2012, ANSI and the European standards organizations CEN and CENELEC held a transatlantic eMobility standardization roundtable in Brussels, transatlantic cooperation having attracted high level government attention via the Transatlantic Economic Council (TEC) and its eMobility work plan. Cooperation on eMobility standardization also has been the subject of a bilateral dialogue between ANSI and the German standards body DIN. All of these efforts have facilitated greater understanding of standards priorities and fostered a healthy dialogue on cooperation, harmonization and alignment of standards and regulations.

2.2 Entities Operating in the EV Standards Space

The deployment of electric vehicles is both a national issue and a global challenge. While in some cases national requirements will define the specific approach to an issue, in many areas international norms will provide the necessary direction. The U.S. standards system acknowledges that there are multiple paths to achieving globally relevant standards. Many SDOs and consortia operate on an international scale and what matters is that the standards are developed according to the principles of the World Trade Organization's Technical Barriers to Trade Agreement, which are also consistent with ANSI's *Essential Requirements: Due process requirements for American National Standards*. The process must be consensus-based, open, with balanced participation – and include all the other elements that are the hallmarks of the U.S. standards system. Coordination and harmonization among international standardizing bodies is an aspirational goal that will help to foster innovation and grow global markets for EVs.

Suffice it to say that the deployment of EVs in the United States will be shaped by the standards activities of a number of SDOs, both U.S.-based and non-U.S. based, as well as codes, regulations, conformance and training programs, and related activities of many stakeholders, including U.S. federal government agencies, inter-governmental bodies, and other cross-sector initiatives. Listed below are some of the principal SDOs, government agencies, organizations, and initiatives that are influencing the roll-out of EVs in the United States.

2.2.1 U.S.-based SDOs

SAE International: SAE standards development activity covers a wide range of EV issues. These include the charge coupler standard SAE J1772™, described in IEC 62196-2, which was revised in 2012 to include both alternating current (AC) and direct current (DC) charge capability, and which will be described in the forthcoming IEC 62196-3. SAE also has published a power quality specification SAE J2894. SAE is also working on documents related to vehicle to grid and vehicle to off-board charger communications (the J2836™ and J2847 series of documents and J2931 and J2953), and is working closely to harmonize these standards with its IEC and ISO/IEC counterparts. SAE also is working on J2954, a wireless charging standard and, again, is working with IEC on harmonization. Other EV issues addressed by SAE standards include battery design, packaging, labeling, safety, transport, handling, recycling, and secondary uses; energy transfer systems, terminology, etc. SAE International administers the U.S. mirror committee (a/k/a U.S. technical advisory group or TAG) for ISO/TC 22/SC 21 on electrically propelled road vehicles. See http://ev.sae.org/.

Underwriters Laboratories Inc.: UL standards for EVs address safety-related concerns for batteries (UL 2271 and UL 2580); electric vehicle supply equipment (EVSE) (UL 2594); personnel protection systems (UL 2231-1 and UL 2231-2); EV charging system equipment (UL 2202); plugs, receptacles and connectors (UL 2251); on-board cables (UL 2733); connectors for use with on-board EV charging systems (UL 2734); electric utility (smart) meters (UL 2735), etc. UL has published requirements for electric vehicle power supplies (UL 2747) and is developing requirements for electric vehicle wireless charging equipment (UL 2750). UL administers the U.S. mirror committee (U.S. TAG) for IEC/TC 69 on electric road vehicles and electric industrial trucks. UL also administers the U.S. mirror committee (e-TAG) for IEC SMB SG6, Electrotechnology for Mobility. See http://www.ul.com/electricvehicle/.

National Fire Protection Association: NFPA's standards development activities include NFPA 70®, the National Electrical Code® (NEC®), which is adopted throughout the U.S. and is adopted as part of, or incorporated into, all U.S. model building codes and residential construction codes. It provides a uniform standard for residential, commercial, and industrial electrical installations for EV charging equipment in North America. NFPA is also very active in conducting EV safety training for emergency first responders under a grant from the U.S. Department of Energy and in partnership with several vehicle manufacturers. NFPA and SAE have co-hosted an annual U.S. national EV safety standards summit since 2010 (see reports at http://www.evsafetytraining.org/Resources/Research.aspx).

IEEE: IEEE publishes the IEEE 1547 series of Standards for Interconnecting Distributed Resources with Electric Power Systems and the IEEE P2030.1 Draft Guide for Electric-Sourced Transportation Infrastructure. IEEE also publishes and develops Power Line Communication (PLC) standards: 1901-2010 Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for High Rate Wireless Personal Area Networks (WPANs), and IEEE P1901.2, Draft Standard for Low Frequency (less than 500kHz) Narrow Band Power Line Communications for Smart Grid Applications. See http://electricvehicle.ieee.org/.

International Code Council: ICC publishes the International Building Code® (IBC®) and International Residential Code® for One- and Two-Family Dwellings (IRC®), the model codes used as the commercial and residential codes in all 50 states, and the International Fire Code (IFC®) used by 43 states as the fire code. As such, any new or revised standard or codes with specific provisions relating to EVs or EVSE, such as the National Electrical Code®, will need to be integrated into or referenced by the I-Codes®. Training will need to be provided to code officials and fire inspectors if such requirements are to gain wide acceptance and use at the state and local levels of government, where building requirements are adopted and enforced.

National Electrical Contractors Association: NECA has developed NECA 413 for the electrical contracting industry. This standard describes the procedures for installing and maintaining EVSE for AC Levels 1 and 2 and DC fast charging.

National Electrical Manufacturers Association: NEMA's EVSE systems section is working to promote the EVSE infrastructure around the world. NEMA has worked with UL and the Canadian Standards Association (CSA) and counterparts in Mexico to harmonize EVSE safety requirements in North America. NEMA's EVSE systems section also has established two working groups to address communications gaps and issues identified in version 1.0 of this roadmap. NEMA organized a working group to develop a standard that permits EV drivers to universally locate a public charging spot and to support roaming that allows charging services from a provider other than the EV user's home charging provider. NEMA also has set up a second working group to address gaps related to EVSE embedded metering and communication. See http://evseready.org/.

Alliance for Telecommunications Industry Solutions: ATIS is exploring two use cases: charging an EV from someone else's private home and charging from a public charging portal, with respect to both connected vehicle and smart grid standardization. ATIS will investigate the role that telecom operators can provide in these use cases with respect to cellular and fixed wide area communications, service layer capabilities such as security, quality of service (QoS), priority, device provisioning, management, and charging. This investigation will include the identification of any gaps in information and communications technology (ICT) standardization needed to satisfy these use cases.

2.2.2 Non U.S.-based SDOs

International Electrotechnical Commission: There are a number of IEC technical committees (TC) and subcommittees (SC) dealing with EVs including IEC/TC 69, which has produced the IEC 61851 standards on Electric vehicle conductive charging, and IEC/23H, which is responsible for the IEC 62196 standards on Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles. In January 2011, IEC and e8, a global organization of the world's leading electricity companies (now known as the Global Sustainable Electricity Partnership), brought together major stakeholders for a roundtable to determine priorities for the development of EV-related standards that will enable global interoperability and connectivity. See http://www.iec.ch/newslog/2011/nr0411.htm. In October 2011, the IEC Standardization Management Board (SMB) formed Strategic Group 6, Electrotechnology For Mobility, to provide the SMB and IEC TCs with a strategic vision and assistance to address standardization needs on systems and products to be used for interfacing plug-in electric vehicles with electricity supply infrastructure.

International Organization for Standardization: ISO has entered into a memorandum of understanding with IEC to improve cooperation on standards for electric vehicles and automotive electronics. The agreement creates a framework of cooperation between ISO/TC 22, road vehicles, with a number of IEC TCs/SCs. The agreement covers on-board equipment and performance of road vehicles, and the interface between externally chargeable vehicles and electricity supply infrastructure. Annex A of this agreement lists ISO and IEC (TCs and SCs) standardization activities in the field of electrotechnology for road vehicles. Annex B of this agreement lists current modes of cooperation. See http://www.iso.org/iso/mou_ev.pdf.

CEN CENELEC: The European Standards Organizations (ESOs) CEN, the European Committee for Standardization, and CENELEC, the European Committee for Electrotechnical Standardization, formed a Focus Group that produced in June 2011 a Report on European Electro Mobility *Standardization for Road Vehicles and Associated Infrastructure* in response to the European Commission/European Free Trade Association (EFTA) mandate M/468 concerning the charging of electric vehicles. A second edition of the Report was published in October 2011 with minor amendments, following Technical Board discussion. See www.cen.eu/go/eMobility. The mandate was focused on ensuring electric vehicle charging interoperability and connectivity in all EU member states, as well as addressing smart charging, and safety and electromagnetic compatibility of EV chargers. A CEN CENELEC eMobility Co-ordination Group (eM-CG) has been established to ensure that the recommendations contained in the report are implemented. Cooperation between the eM-CG and the ANSI EVSP is being pursued. ANSI, CEN and CENELEC convened a transatlantic eMobility standardization roundtable in November 2012 and have discussed cooperation on EVs at ANSI-ESO meetings.

2.2.3 U.S. Federal Government Agencies

U.S. Department of Energy: DOE is supporting the development of this standardization roadmap and the growth of the EV market on a number of fronts.

Announced by President Barack Obama in March 2012, DOE's EV Everywhere Grand Challenge[4] seeks to assist U.S. companies in making PEVs as affordable and convenient for American consumers as gasoline-powered vehicles within the next 10 years. The DOE has held a number of workshops and released a Blueprint document which describes PEV technology, deployment barriers, and steps needed to realize the goal of the initiative.

DOE's Workplace Charging Challenge is an initiative intended to expand access to workplace charging across the country, making PEVs more convenient.

[4] http://www1.eere.energy.gov/vehiclesandfuels/electric_vehicles/index.html

DOE continues to invest in research to develop advanced technologies to improve vehicle performance and increase fuel economy. Areas of investigation include: advanced lightweight and propulsion materials, advanced battery development, power electronics, advanced heating, ventilation and air conditioning systems, and fuels and lubricants.

DOE's Transportation Electrification Demonstration Projects are a nationwide effort to mine data to assist in the widespread deployment of EV charging stations. The projects include the deployment of 13,000 electric vehicles, the installation of more than 20,000 charging stations, and funding of programs for first responders on how to handle accidents involving EVs. Data collected in the projects include vehicle and charger performance, charging patterns and public charger use, the impact of various rate structures on charging habits, and the impact of vehicle charging on the electric grid. Experiential information is also being collected with regard to operational impacts and deployment issues such as the soft value of EV charging for retail establishments, and permitting challenges for commercial applications.

DOE participates, alongside U.S. automakers, national laboratories and utilities, in the U.S. DRIVE Grid Interaction Tech Team which is working to identify and support the reduction of barriers to the large scale introduction of grid connected vehicles. DOE also has programs for advanced vehicle testing and has issued a number of grant-funded projects to promote education of the workforce in relation to EVs.

U.S. General Services Administration: In May 2011, GSA launched the federal government's first Electric Vehicle Pilot Program to further the president's goals of reducing the country's dependence on oil imports by one-third by 2025 and putting 1 million advanced technology vehicles on the road. The pilot is a targeted investment to incorporate electric vehicles and charging infrastructure into the federal government's vehicle and building portfolios over time. GSA is continuing to expand the pilot program in 2013 with the purchase of additional vehicles.

National Highway Traffic Safety Administration: An agency of the U.S. Department of Transportation (DOT), NHTSA maintains the U.S. Federal Motor Vehicle Safety Standards (FMVSS) and Regulations to which manufacturers of motor vehicle and equipment items must conform and certify compliance. In addition to having to comply with crashworthiness, crash avoidance and other standards also applicable to conventional vehicles, EVs sold in the U.S. must additionally comply with FMVSS 305 which addresses electrolyte spillage, intrusion of propulsion battery system components into the occupant compartment, and electrical shock. In January 2013, NHTSA proposed a new safety standard that will require EVs to be equipped with audible alerts so that blind and other pedestrians can detect a nearby EV when being operated at low speed. Research projects are also underway on crash avoidance and performance.

2.2.4 World Forum for Harmonization of Vehicle Regulations (WP.29)

As the name implies, WP.29 provides a forum for the development of Global Technical Regulations (GTR) for vehicles which can be adopted by governments around the world. The Secretariat is provided by the United Nations Economic Commission for Europe (UNECE). NHTSA is the U.S. representative to WP.29.

The Electric Vehicle Safety Informal Working Group (EVS-IWG) and the Electric Vehicles and the Environment Informal Working Group (EVE-IWG) were established in November 2011 following a joint proposal by the U.S., Japan, and the EU to establish two working groups to address safety and environmental issues associated with electric vehicles (EVs). Both WGs are chaired by the U.S.

The EVS-IWG is working to develop one or more GTRs on common requirements to address safety issues associated with EVs, their components and batteries.

The EVE-IWG is presently focusing on acting as a forum for exchanging information related to the impacts of EVs on the environment. It is our understanding that the EVE-IWG also intends to publish a Reference Guide for EV environmental regulation, currently in development, by mid-2014.

The WP.29 Working Party on Noise (GRB) has established an informal working group, the Quiet Road Transport Vehicles (QRTV) Working Group, to carry out activities that are considered essential to determine the viability of “quiet vehicle” audible acoustic signaling techniques and the potential need for their global harmonization. The U.S. proposed that a GTR be developed in June 2011.

2.2.5 Other Cross-Sector Initiatives

Smart Grid Interoperability Panel: The SGIP, formed in November 2009, engages stakeholders from the entire smart grid community in a participatory public process to identify applicable standards, gaps in currently available standards, and priorities for new standardization activities for the evolving smart grid. SGIP was established to support the National Institute of Standards and Technology (NIST) in fulfilling its responsibilities under the Energy Independence and Security Act of 2007. In January 2013, the SGIP transitioned to a self-financed, legal entity that retains partnership with the government (SGIP 2.0).

Vehicle to Grid Domain Expert Working Group (V2G DEWG)

Within the SGIP there are working groups of experts within a particular domain. As electric vehicle to grid interaction has been determined to be a critical issue, a Vehicle to Grid Domain Expert Working Group (V2G DEWG) was created in 2009 to analyze vehicle to grid interoperability. The V2G DEWG provides a strategic view of interoperability needs and standards gaps related to the interaction and communications between the electric vehicle, the charging system, the power grid, and the user. The V2G DEWG has eight subgroups: Roadmap, Cyber Security, Privacy, EV as Source, Roaming, Regulatory Issues, Sub-metering and Advanced Use Cases. Work is coordinated with other SGIP DEWGs on Cybersecurity, Business & Policy, Distributed Renewables, Generation, and Storage.

When the V2G DEWG identifies critical roadblocks or gaps in any of these areas, an SGIP Priority Action Plan (PAP) is formed. These tactical PAPs facilitate and coordinate stakeholders and SDOs in overcoming standards related challenges. The first SGIP V2G-related PAP was PAP 11 focused on common information for EVs. This PAP was closed out in 2011 with the successful approval by the SGIP of three SAE documents: J2836™, J2847, and J1772™. These have been entered into the SGIP catalog of standards, a library of standards, best practices, and guides for development and deployment of an interoperable smart grid.

The SGIP can redirect issues identified by the V2G DEWG that are out of scope of the SGIP to the ANSI EVSP and share with the ANSI EVSP information on electric vehicle infrastructure standardization needs and gaps. The ANSI EVSP in turn can identify standardization needs and gaps that can inform the work of the V2G DEWG and facilitate the development of SGIP PAPs. In October 2012, the V2G DEWG and the ANSI EVSP Communications WG held a joint meeting to review the organization of, and gaps identified in, the communications section of the ANSI EVSP roadmap (version 1.0), and to discuss future work.

Staged Evolution of PEV Industry

The V2G DEWG's Roadmap subgroup has put together its own comprehensive framework to help strategize the development and timely adoption of new technologies, protocols, standards and business practices needed to support the vision of a robust PEV industry. The V2G DEWG's roadmap describes a staged evolution of the PEV industry as illustrated in Figure 2 below.[5] It is recognized that some Stage contents might conflict with regional and/or regulatory policy decisions or implementation timelines and thus individual goals or activities might occur earlier or later than elsewhere. Generally, it is suggested that Stage 1 is currently nearing completion (EOY 2012) and Stage 2 is just beginning.

Stage 1: PEV Introduction and Planning
Goals: PEV Impact Assessment, and Interoperability Development Completion
Key Process Areas: PEV charging equipment standardization (e.g., Communication, Interoperability). PEV end-to-end acquisition process (e.g., Program Enrollment, Installation). Pilot Tariff and Services Impact Analysis. Distribution transformer load analysis and failure prediction.

Stage 2: Testing and Piloting of Integrated Architectures
Goals: Physical and Communications Interoperability. Widespread Adoption of PEV Programs for Demand/Supply Balance and Customer Control.
Key Process Areas: Accurate measurement of PEV power consumption (e.g., sub-metering). Service provider/utility back office integration. Management of charging rates.

Stage 3: Interoperability and Deployment
Goals: PEVs securely utilized as power source; integrated with renewables.
Key Process Areas: PEV/Grid Physical interoperability. Advanced use cases for power flow and communication (e.g., bi-directional).

Stage 4: Advanced Functionality
Goals: PEV as a fully integrated DER. Optimized system level efficiencies. System is secure, scalable and sustainable.
Key Process Areas: End-to-end integrated communication systems. Decentralized control and pricing systems.

Figure 2: Staged Evolution of PEV Industry

[5] For the V2G DEWG's complete Roadmap in spreadsheet form, see: http://collaborate.nist.gov/twiki-sggrid/pub/SmartGrid/V2GRoadmap/SGIP_PEV_Roadmap_Framework_1.0.xlsx

In Figure 2, the Stage titles express broad statements about the overarching timeline activities they represent. The Goals are meant to define gating factors so that the next stage can begin. The Key Process Areas give an overview of what must be focused on to meet the Goals. Each of the Key Process Areas includes additional specific activities or objectives (see Roadmap link) that ensure the completion of the Key Process Areas and thus the Goals. These are organized under three headings: System Functionalities (Integrated Communications, Distributed Energy Resources, Measurement, Advanced Control Methods, Consumer Interfaces), System Qualities (Safety/Reliability, Security, Privacy) and Market Structures (Role of Third Parties, Billing, and Regulatory and Business Practices).

TransAtlantic Business Dialogue: The TABD has supported the development of an EV agenda as an advisor to the Transatlantic Economic Council (TEC). In March 2011, TABD members Audi and Ford drafted an eMobility work plan for the TEC. The European Automobile Manufacturers Association (ACEA), the Alliance of Automobile Manufacturers and others provided input and the plan was endorsed by the TABD. In May 2011, the plan was submitted to the TEC Co-Chairs within the White House and the European Commission. It was further refined in preparation for the November 2011 TEC meeting. The October 2011 ANSI – ESO Conference on Transatlantic Standardization Partnerships included a session on eMobility/electric vehicles, organized in partnership with the TABD. At that event, EU Trade Commissioner Karel De Gucht called on participants to organize a transatlantic eMobility standardization roundtable. ANSI, CEN and CENELEC convened such a roundtable in Brussels in November 2012. In December 2012, the TABD merged with the European-American Business Council to form the Transatlantic Business Council (TBC) with TABD operating as a distinct program within the new organization.

National Electric Transportation Infrastructure Working Council: Sponsored by the Electric Power Research Institute (EPRI), the IWC is a group of individuals whose organizations have a vested interest in the emergence and growth of the EV and PHEV industries, as well as the electrification of truck stops, ports, and other transportation and logistic systems. IWC members include representatives from electric utilities, vehicle manufacturing industries, component manufacturers, government agencies, related industry associations, and standards organizations. IWC committees meet several times a year.

Electric Drive Transportation Association: EDTA is an industry association dedicated to advancing electric drive as a foundation for sustainable transportation. Since 1989, EDTA has led efforts to provide federal support for electric drive research, demonstration and manufacturing, and to provide significant incentives for the purchase of electric vehicles and chargers, and the promotion of EV infrastructure development in the U.S.

Regional and State Initiatives: There are multi-stakeholder and government supported efforts underway at the regional, state and municipal level to facilitate the rollout of EVs. Some examples include the following:

Northeast Electric Vehicle Network

The Transportation and Climate Initiative (TCI) of the Northeast and Mid-Atlantic states, which is facilitated by Georgetown University's Climate Center, launched the Northeast Electric Vehicle Network in October 2011 to support the rollout of EVs in that region. TCI, together with the New York State Energy Research and Development Authority (NYSERDA) and sixteen of the Northeast region's Clean Cities Coalitions, received a grant from the U.S. Department of Energy (DOE) to lay the groundwork for the Northeast Electric Vehicle Network. Under the DOE grant, the project partners have engaged stakeholders and conducted a literature review of market barriers to EV deployment in the Northeast. They have also created several guidance documents for the TCI region including, among others, siting and design guidelines for electric vehicle supply equipment, a report on EV-ready codes for the built environment, and a guide to planning and policy tools for creating EV-ready towns and cities. See www.northeastevs.org.

California Plug-in Electric Vehicle Collaborative

The California Plug-In Electric Vehicle (PEV) Collaborative is a multi-stakeholder public-private partnership working to enable the plug-in electric vehicle market in California. The Collaborative includes elected and appointed officials, automakers, utilities, infrastructure providers, environmental organizations, research institutions and others. The Collaborative has developed a strategic plan *Taking Charge* for California's PEV market through 2020 and formed a number of working groups to implement the plan's recommendations. The Collaborative has held workshops for local government officials to support regional planning and local market development. It has also launched a number of reports, communication guides, and a resource center to support these efforts. See www.pevcollaborative.org.

3. Identification of Issues

Section 3 introduces the issues that are subsequently assessed in the standardization gap analysis in section 4 of the roadmap. The interrelationship of issues, combined with the dynamic nature of electric vehicle and infrastructure technology and the evolving policy environment, poses some unique challenges to the development of a comprehensive, coordinated, and streamlined *Standardization Roadmap for Electric Vehicles*.

3.1 Vehicle Domain

For purposes of this roadmap, the Vehicle Domain generally encompasses the technologies, equipment, components, and issues that fall within the strict confines of the electric vehicle itself up to and including the vehicle inlet portion of the charge coupler. The following sections under the Vehicle Domain, 3.1.1 Energy Storage Systems, 3.1.2 Vehicle Components, and 3.1.3 Vehicle User Interface, discuss the relevant issues that fall under these topical areas and why they are important with regard to standardization, harmonization, and conformance activities. The interrelationship of issues within the Vehicle Domain is illustrated in Figure 3.

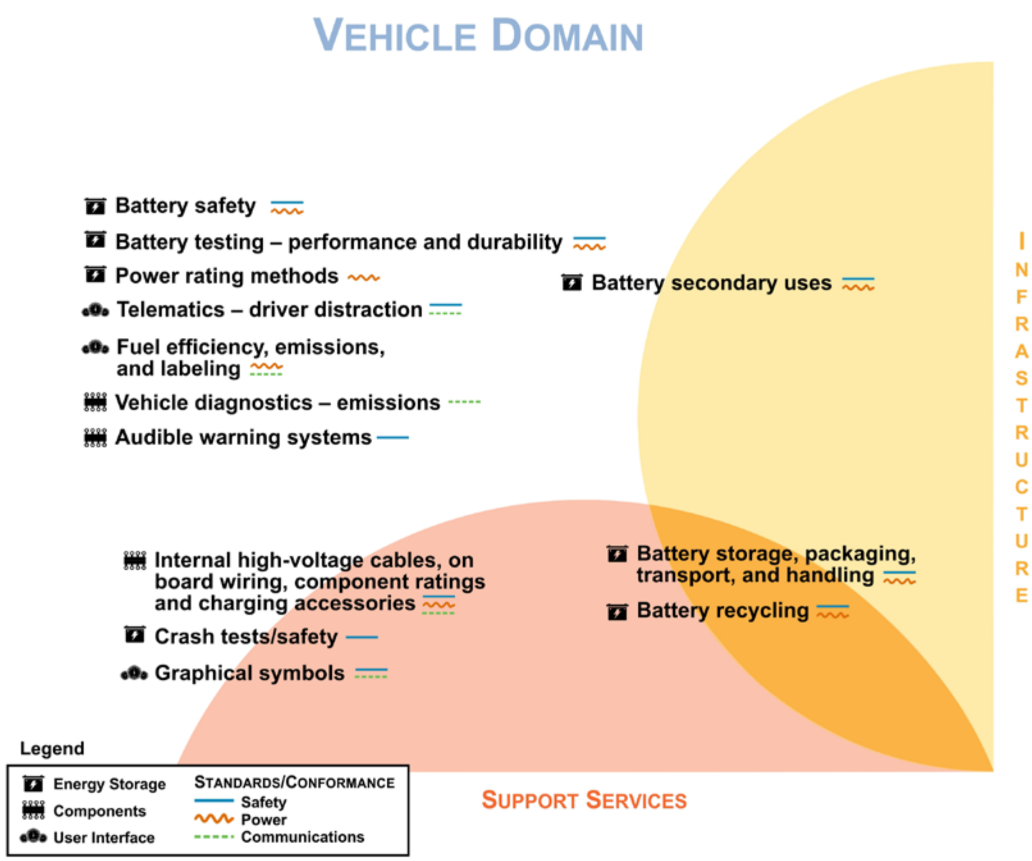

Figure 3: Interrelationship of Issues within the Vehicle Domain

Terminology

On a general note from the outset, it is important for consistent vocabulary to be used for electric vehicle terminology to assist in the development of standards for electric vehicles, as this will provide a consistent understanding of important concepts.

3.1.1 Energy Storage Systems

The topical area of Energy Storage 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, packaging, transport and handling; battery recycling; battery secondary uses; and crash tests/safety.

3.1.1.1 Power Rating Methods

Power rating methods are important for hybrid electric vehicles and battery-powered all 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.

3.1.1.2 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 a 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.

3.1.1.3 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. Test standards related to battery abuse, product safety, or transportation/handling are addressed in other sections of the Energy Storage Systems topical area of this roadmap.

3.1.1.4 Battery Storage, Packaging, Transport and Handling

Battery Storage

EV Batteries (including HEV and PHEV) will require storage throughout many stages of their life cycle, namely – prior to market distribution by manufacturers, in import/export locations, logistic centers, in battery swapping (switching) stations including warehousing, in repair workshops as well as garages following accidents, 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 (particularly significant for battery swapping stations during charging), 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.

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 or battery swapping stations; and
- Battery packaging for the transportation of used and damaged batteries.

Transport by ground, air and sea of EV batteries (including those for HEVs and PHEVs) 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.

3.1.1.5 Battery Recycling

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, and are projected to take up nearly 40% of the consumable world lithium by 2020. 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, which makes it hard to develop industrial-scale precise recycling processes with high recovery rates and efficiency. Additionally, not all battery chemistries may have a value (e.g., iron phosphate).

3.1.1.6 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 grid support, line balancing and backup stabilization.

The nascent second life 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.

3.1.1.7 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.

3.1.2 Vehicle Components

Key on-board vehicle areas addressed within this roadmap include: safety issues associated with internal high voltage cables and on-board wiring, component ratings, and charging accessories; vehicle diagnostics – emissions; and audible warning systems.

3.1.2.1 Internal High Voltage Cables, On-Board Wiring, Component Ratings and Charging Accessories

The advent of the electric vehicle poses unique opportunities and challenges from a safety perspective. In terms of vehicle component standards, the high voltage cables entail the primary conductive media internal to the vehicle. This area does not include the cabling systems commonly used in 12V and 24V systems that form the basic wiring systems in conventional vehicles. Instead, this topic focuses on the systems and subsystems associated with the primary drive mechanisms for the vehicle. For hybrid electric vehicles, this includes the cabling associated with any electricity transferred from the internal combustion engine to the storage device, as well as regenerative braking technology and the charging station. For plug-in electric vehicles, this is only the braking and charging connections to the drive train. Both AC and DC technologies are considered. Concerns over the internal, high voltage cables relate to both the safety of the operator and the integrity and efficiency of the propulsion and storage systems for the EV.

3.1.2.2 Vehicle Diagnostics – Emissions

An issue for plug-in hybrid electric vehicles and hybrid electric vehicles (but not for battery-powered all electric vehicles), is vehicle diagnostics with respect to the detection of system faults within the vehicle's emissions control system.

3.1.2.3 Audible Warning Systems

Organizations of, and for, persons who are blind or have low vision have expressed concerns that electric vehicles and some hybrid electric vehicles may not be audibly detectable by the blind. Safety standards related to sound emission/audible warning systems can serve to address this concern.

3.1.3 Vehicle User Interface

A reliable, safe customer experience is critical to electric vehicles gaining acceptance in the marketplace. One step toward improving this experience is using communication tools that are readily identifiable and understood by the vehicle owner and those that service or otherwise interact with the vehicle. Topics addressed in this section include: graphical symbols; telematics – driver distraction; and fuel efficiency, emissions, and labeling.

3.1.3.1 Graphical Symbols

Due to the global nature of the industry, the use of universal graphical symbols that are easily understood regardless of the language of the driver will assist in effective communication of such important information as the battery fuel gauge, state of charge, and health.

3.1.3.2 Telematics – Driver Distraction

Telematics is the combination of telecommunication and programmable computerized services to assist drivers with navigation, emergency assistance, convenience features such as remote door locks, climate conditioning, access to internet/cloud services, on-board diagnostics, service reminders, and other infotainment services. This section discusses driver interaction with such information and communications systems, and more specifically the potential for driver distraction from the task of driving.

3.1.3.3 Fuel Efficiency, Emissions, and Labeling

Fuel economy and vehicle emissions are among several factors that consumers will evaluate in deciding whether or not to purchase an electric vehicle. It is therefore important that vehicle labels provide clear and accurate information. As more electric vehicles appear on the market, it will become increasingly important for consumers to be able to compare among different manufacturers and models. Consumers will also want to compare and contrast features and value across the different types of available EVs (AEVs, PHEVs, HEVs) in the same way that they have traditionally evaluated vehicles powered by internal combustion engines.

3.2 Infrastructure Domain

For purposes of this roadmap, the Infrastructure Domain generally encompasses the technologies, equipment, components, and issues that fall within the confines of the charging infrastructure up to and including the connector portion of the charge coupler. The following sections under the Infrastructure Domain, 3.2.1 Charging Systems, 3.2.2 Infrastructure Communications, and 3.2.3 Infrastructure Installation, discuss the relevant issues that fall under these topical areas and why they are important with regard to standardization, harmonization, and conformance activities. The interrelationship of issues within the Infrastructure Domain is illustrated in Figure 4.

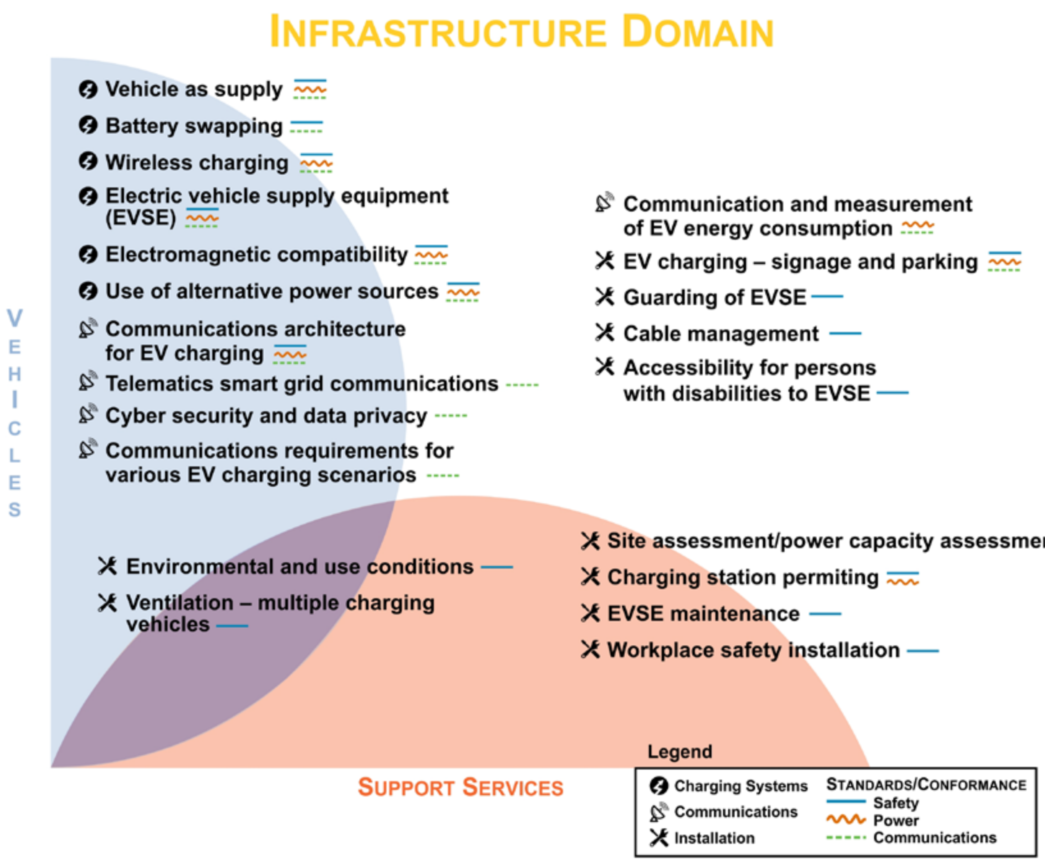

Figure 4: Interrelationship of Issues within the Infrastructure Domain

3.2.1 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.

Topics addressed in this section include: wireless charging; battery swapping; electric vehicle supply equipment; electromagnetic compatibility; vehicle as supply; and use of alternative power sources.

3.2.1.1 Wireless Charging

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. Although at this time the standards for wireless charging are not complete, there is a significant interest in this technology. It is important to have harmonized standards to ensure a safe, interoperable charging experience.

3.2.1.2 Battery Swapping

The limited range of current plug-in electric vehicles is a major obstacle when it comes to consumer adoption and the migration from traditional internal combustion engine-powered transportation solutions to a clean battery-powered solution. The current estimated range of battery-powered all electric vehicles is around 80-120 miles with a battery weight of around 550-600 pounds. In a plug-in hybrid electric vehicle, range can be extended via a gas-powered generator. In general, the current range of PEVs on battery power alone is satisfactory for most daily commuter driving, but it does not provide the ability to drive long distances, hence the need for range extension. Accordingly, there is a need for a supporting infrastructure of charging networks covering homes, offices, parking, shopping and industrial areas, and highways where PEVs can plug-in to recharge.

An alternative approach to addressing the range extension issue is via a network of battery swapping (switching) stations (BSS). A BSS is an electro-mechanical installation of robotics, electrical and mechanical drives used for the switching of batteries for electric vehicles and that may include battery charging devices and telecommunication ports. This technology exists today and has been used in niche segments for many years, enabling the replacement of a depleted battery with a fully charged one in less than 5 minutes. The fully automated process removes the battery from the vehicle and moves it to a battery rack, so the battery can be charged in optimal conditions. A fully charged battery is then taken from the battery rack and inserted into the vehicle. Battery swapping stations could be located along all key highways or major roads, thus enabling electric vehicles to drive for extended ranges. Battery swapping stations are currently being mass deployed in Israel, Denmark, and China.

Battery swapping technology would require removable batteries with common interfaces that connect with the battery outside the vehicle. EV batteries are currently very heavy, which requires that they be carefully handled. Therefore, removable batteries will require a common mechanical interface to lock and remove the battery from the vehicle by actuation of "twist-like" devices by external actuators which are part of a switching station. Other issues pertinent to common battery packs and modules include electrical interface, cooling integration, data transfer integration, and dimensions.

3.2.1.3 Electric Vehicle Supply Equipment (EVSE)

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 charging experience.

EVSE Charging Levels/Modes

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. The most available means of charging an electric vehicle is to use a standard grounded electrical receptacle in accordance with NEC® Article 625 requirements. This is most practical at home where receptacle outlets are readily available and downtime for the vehicle potentially allows the longest charging period throughout the day. Charging at higher AC voltages, or using DC voltages, can provide a faster charge. These AC voltage levels are available in homes, as well as municipalities, workplaces, and retail locations. DC chargers and high power AC supply equipment can provide high power charging, reducing the time it takes to charge a vehicle.

EV Supply Equipment and Charging Systems

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).

EV Couplers

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 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.

3.2.1.4 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.

3.2.1.5 Vehicle as Supply

The topic of vehicle as supply describes the vehicle serving as a power source for other than vehicle applications. Reverse power flow (RPF) is when the EV transfers power to off-board equipment as further described below.

Pure reverse flow is very useful for powering loads at a remote site; this capability is called Vehicle to Load (V2L). An EV can also use pure reverse power flow for providing a "jump start" to another EV; this capability is called Vehicle to Vehicle (V2V). And pure reverse flow from an EV can be used to provide emergency backup power for a home following a loss of grid power; this is called Vehicle to Home (V2H). Because these are all off-grid applications, the on-board or external inverter must regulate both the voltage and the frequency and it is the connected loads that determine how much energy flows from the vehicle battery.

When a vehicle provides reverse power flow into a live electric grid this is called Vehicle to Grid (V2G). A small, modular storage device connected to the grid is considered to be a distributed energy resource (DER). The grid-connected EV that is capable of reverse power flow is a DER device. The real value of an EV to the grid is its ability to serve as a DER device and provide precisely controlled bi-directional power flow – not just reverse flow. The bi-directional converter can be located on-board the vehicle or externally in the EVSE. When the grid-tied bi-directional converter is providing power to the grid it must operate as a current source, synchronized to the grid voltage and frequency. The grid-tied bi-directional converter can be commanded to deliver a precise forward or reverse power flow. If there is a power failure, the inverter must automatically turn off. This is for the safety of workers that may be repairing downed lines.

The term V2G has become associated with the concept of an aggregator coordinating the power flow of many EVs to provide frequency regulation for the grid. This is only one of many ways that an EV can serve the bulk grid and the distribution system as a DER. An EV with DER capability can be used solely within a home by a home energy management system to manage the power demand of the home on the external grid. This is not a V2H application because the home loads are still connected to a live grid. However, a grid-tied inverter system can be configured to automatically disconnect the home from the grid and switch from V2G to V2H operating mode following a grid power failure. This is routinely done today with grid-tied solar PV inverter systems.

An EV could route power from an on-board inverter to a vehicle-mounted panel with NEMA receptacles. This would be very convenient for directly connecting tools or appliances to the panel for V2L or using a cord set for V2V. The EV could also be connected to the home through a transfer switch in the same manner as any other portable genset to provide V2H capability. The EV to EVSE connection would be used for V2G.

An external inverter would use the EV to EVSE connection and extract DC power from the vehicle battery to generate the AC power. A premises-mounted EVSE could be used for V2G and V2H modes with automatic switching. A portable unit could be used for V2L and V2V applications.

3.2.1.6 Use of Alternative Power Sources

EVs support and complement the increased possibility of an infrastructure with distributed generation of power, and direct connection of power sources to the EV for charging purposes. This includes efficiency benefits of DC generation and DC use, without losses associated with conversion to and from AC, for example use of photovoltaic (PV) for direct DC charging of electric vehicles. It also allows the EV battery to serve as a storage device for alternative energy systems, for example solar power generated during the day or wind power generated at night, which can be reclaimed later as needed.

3.2.2 Infrastructure Communications

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. Energy Service Providers want to be able to push charging to off-peak hours to protect grid assets.

Additionally, value-added services such as demand response/load control, pricing, locating and reserving charging stations, reverse energy flow, and charge management can provide 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.

Topics discussed in this section include: communications architecture for EV charging; communications requirements for various EV charging scenarios; communication and measurement of EV energy consumption; cyber security and data privacy; and telematics smart grid communications. Standardization work that relates generally to smart device communications, the connected vehicle, and intelligent transportation systems is beyond the scope of this roadmap. Rather, this communications section is focused on standards that are essential or unique to the PEV charging infrastructure, such as those governing communications among an EV, EVSE and an Energy Service Provider.

Appendix A contains a more detailed, high level description of the need for communications in different sections of the EV charging infrastructure, and the various stakeholders or actors involved in PEV charging that need to communicate with each other.

3.2.2.1 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 an 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) End Use Measurement Device (EUMD), and (7) EV Services Provider (EVSP).

Figure 5 shows a sample communications-oriented architecture containing the primary actors, including three different locations where charging may occur.

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.

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

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

<u>*Home Charging*</u>

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 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 happen over a Home Area Network, or it may use the customer's internet connection, or it may use its own cellular data connection.

Commercial 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, 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.

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.

Communications High Level Architecture

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.

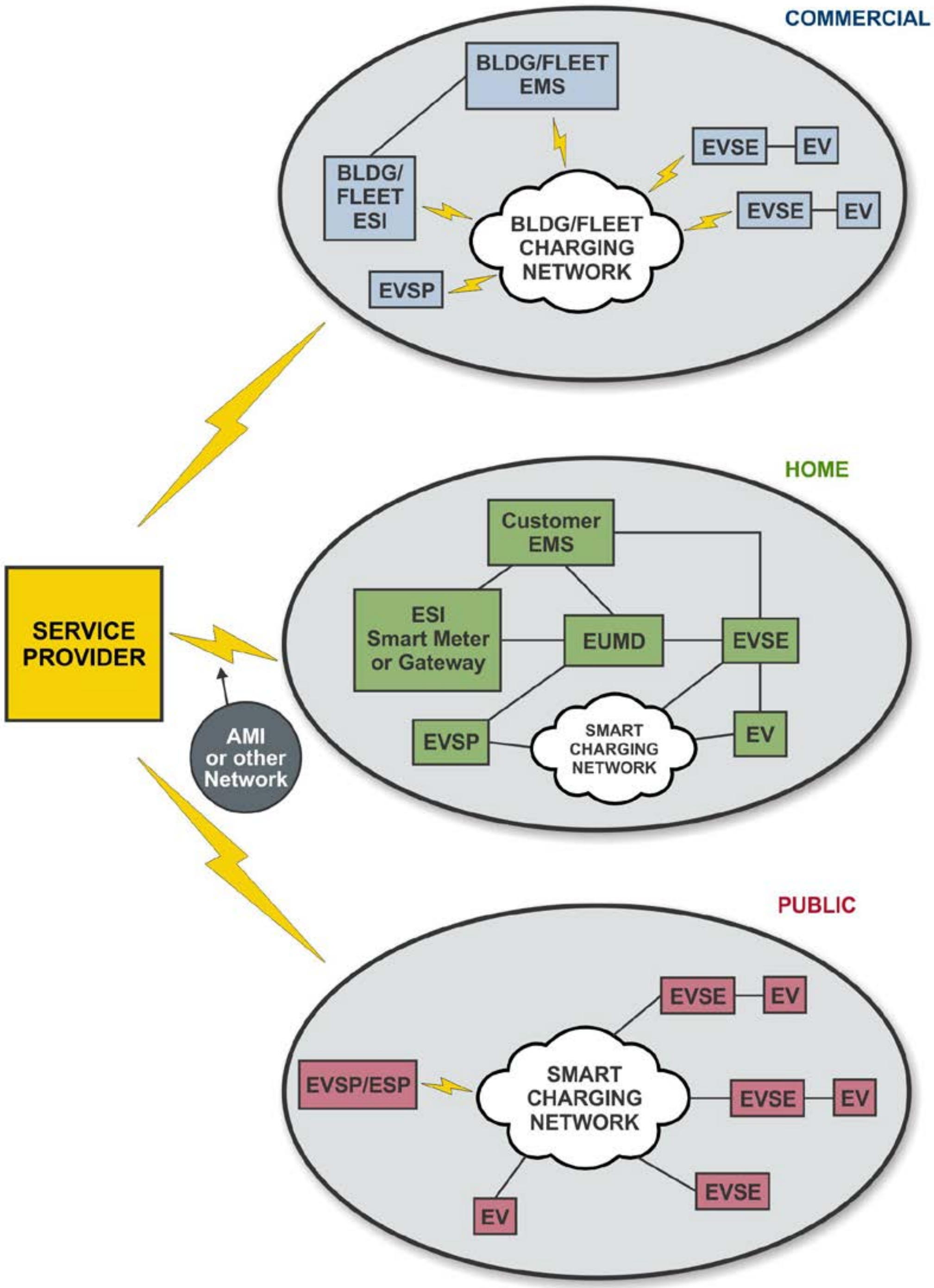

Figure 5: Sample Communications-Oriented Architecture for Commercial, Home, and Public Charging

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 takes place via a Home Area Network (HAN). 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.

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 OpenADR 2.0 or ESPI, and may act as an aggregator, providing a single communication point with the ESP for all the EVSEs in its purview. Creating and/or harmonizing standards specific to public charging communication is desirable in order to provide services such as finding and reserving charging stations.

3.2.2.2 Communications Requirements for Various EV Charging 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 Reserving Charging Stations: 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.

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 (2G/3G/4G).

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.

3.2.2.3 Communication and Measurement of EV Energy Consumption

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 and HAN 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 would include 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 Measurement Interface (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.

3.2.2.4 Cyber Security and Data Privacy

Cyber security and data privacy issues associated with the introduction of PEVs and smart grid communications have been the focus of attention of two of the SGIP V2G DEWG subgroups, whose work has informed further work by SAE and the IEEE. A list of such issues can be found in the IEEE-USA position statement *Breaking Our Dependence On Oil By Transforming Transportation,* available at http://www.ieeeusa.org/policy/positions/Transportation0512.pdf.

3.2.2.5 Telematics Smart Grid Communications

Automakers are reviewing existing smart grid integration and communications architectures and requirements to determine whether the utilization of existing vehicle telematics protocols and structures are desired for PEV load management, ancillary services, and other utility, independent system operators (ISOs) / regional transmission organizations (RTOs) services. Original equipment manufacturers (OEMs) perceive several inherent industry benefits for implementing an integrated telematics communications architecture such as: the ability to accelerate OEM implementation of PEV/utility communications; provide common OEM services to all utilities; enable significant savings in OEM vehicle development/production costs; allow versatility for integration with various utility smart grid architectures; and provide for global applicability.

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), 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. OEMs and other stakeholders are in the process of evaluating requirements to support possible interaction between utilities and OEMs for PEV load management through telematics.

3.2.3 Infrastructure Installation

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; EV charging – signage and parking; charging station permitting; environmental and use conditions; ventilation – multiple charging vehicles; guarding of EVSE; accessibility for persons with disabilities to EVSE; cable management; EVSE maintenance; and workplace safety.

3.2.3.1 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.

3.2.3.2 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.

3.2.3.3 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.

Residential Installation: 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.

Commercial/Public Installation: 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.

3.2.3.4 Environmental and Use Conditions

Electric vehicle infrastructure equipment may be used in a wide variety of conditions. Environmental factors that may affect the safety, durability, performance or life of the electric vehicle infrastructure equipment 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 product to function in the expected manner. Ability to prevent ingress of 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.

Infrastructure equipment also may be exposed to potentially corrosive agents such as salts whether through installation in proximity to bodies of salt water or through exposure to anti-icing salts applied to roads.

Hazardous or classified locations 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 of fire and/or explosion hazards. As it relates to electric vehicles, these may be relevant 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.

3.2.3.5 Ventilation – Multiple Charging Vehicles

Ventilation concerns must be addressed if charging stations are installed in enclosed areas such as parking garages located in or under commercial buildings or multi-family residential dwellings. Public officials and building operators will be concerned both with the possibility of off-gassing and heat generation during charging operations, both of which may affect ventilation standards or codes. Vehicle charging locations may be designated in, or only permitted for, ventilated areas of enclosed buildings.

3.2.3.6 Guarding of EVSE

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

3.2.3.7 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.

3.2.3.8 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.

3.2.3.9 EVSE Maintenance

While it is expected that most EVSE will require relatively little maintenance, it is considered best practice to consistently follow a maintenance regimen to reduce safety risks and extend the service life of EVSE. EVSE manufacturers typically provide recommended maintenance practices as part of service manuals, and other information is available to provide guidance with regard to maintenance of EVSE and electrical equipment in general.

3.2.3.10 Workplace Safety

Safety Programs and Safe Work Practices: Safety in electrical construction, installation, and maintenance must be addressed proactively across a broad spectrum of workplace tasks and hazards. Safety in construction requires establishing sound and effective safety principles and contractor safety programs. Best practices for such programs include having in place a policy with goals, a plan, methods of implementation, measurements, recordkeeping, and ongoing auditing and assessment. Safety requires communication, coordination and cooperation between employees and the employer as it is a shared responsibility. Ultimately, employers are responsible for developing and maintaining effective safety programs and for ensuring that employees implement safe electrically-related work practices.

Shock, Arc-Flash, and Arc Blast Protection: Workplace safety for electrical workers requires compliance with applicable electrical safety related work requirements. Work generally should always be performed in an electrically safe work condition, and installation and maintenance should not be performed on equipment or systems that are energized. Energized work must be justified and it must be proven that it is not feasible to de-energize the system or that doing so would introduce additional or increased hazards. In situations where justified energized work must be performed, appropriate personal protective equipment (PPE) must be worn. Effective safety-related work practices and principles must be integrated into the planning stages and installation of electrical work, as well as into initial planning and design of EVSE installations.

3.3 Support Services Domain

For purposes of this roadmap, the Support Services Domain generally includes the supporting peripheral activities, both under incident response and normal operating conditions, necessary to the well-being of the broad electric vehicle and infrastructure environment. Standards, and education and training programs for service personnel, are the primary focus with safety the paramount concern.

Incident response

Incident response is the activity performed by service providers when the EV has been damaged or disabled as result of an incident either on the road or at a garage/parked location where vehicle service is not normally performed. Incident response may be prompted by a breakdown, involvement in an accident, or the EV being at the scene of an incident, such as a fire, where a building or EV charging equipment may be involved and there is a need to stabilize or remove the EV to avoid its further involvement.

Standards and training can help ensure the safety of emergency responders as they stabilize EVs in the field, provide medical service to and extract trapped passengers from them, extinguish fires, and remove vehicles from the roadway. When EVs are plugged into chargers during incidents, standards and training can also provide information regarding the safe disconnecting of chargers from power sources.

Normal operations

Normal operations include driving and charging of EVs, and servicing and maintenance activities performed at service locations, including dealerships, service garages, fleet lots, and at vehicle owners' residences.

Standards and training can help ensure the safety of service technicians and vehicle owners as they operate or service EVs every day including performing charging functions, working on EV motive systems, and changing out batteries.

The following issues under the topical area of Education and Training outline important considerations within the Support Services Domain for EVs and supporting infrastructure: electric vehicle emergency shut off – high voltage batteries, power cables, disconnect devices; fire suppression, fire fighting tactics and personal protective equipment; labeling of EVSE and load management disconnects for emergency situations; original equipment manufacturer (OEM) emergency response guides; electrical energy stranded in an inoperable rechargeable energy storage system (RESS); battery assessment and safe discharge following an emergency event; disaster planning / emergency evacuations involving electric vehicles; and, workforce training. The interrelationship of issues within the Support Services Domain is illustrated in Figure 6.

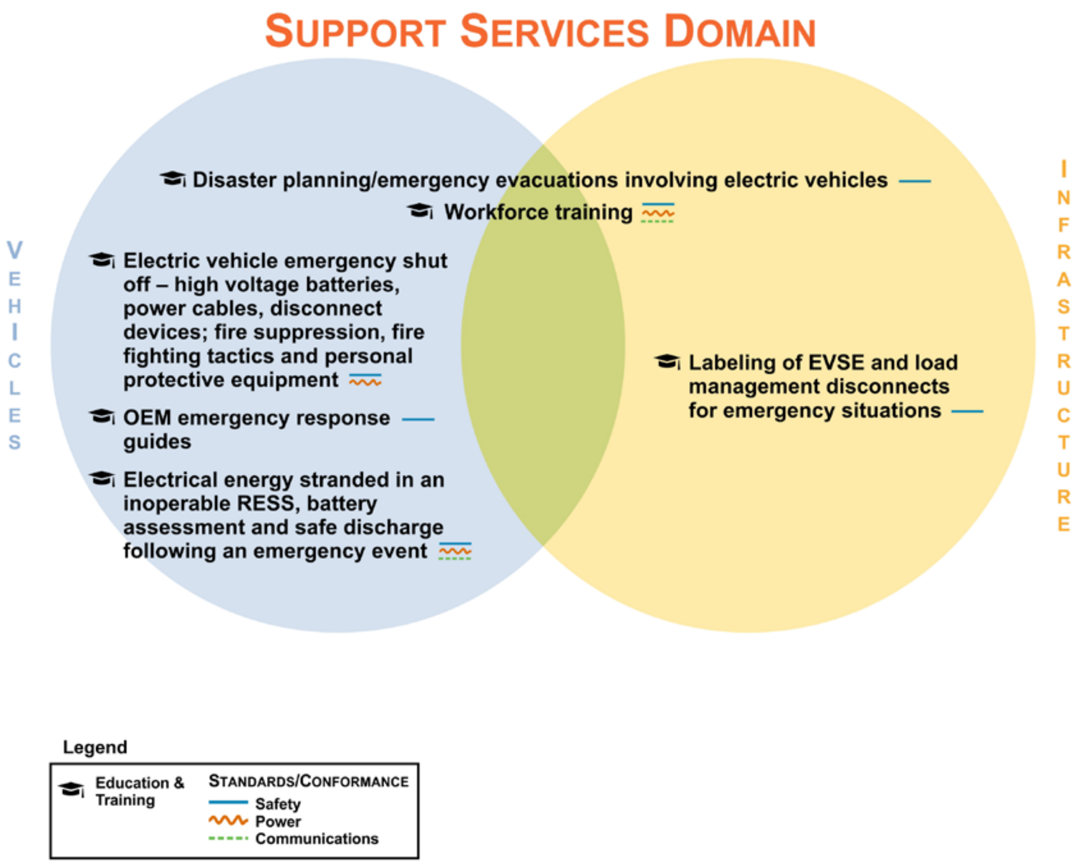

Figure 6: Interrelationship of Issues within the Support Services Domain

3.3.1 Education and Training

Education and training regarding the unique characteristics of EVs and their support equipment is needed for the various trades including service technicians, tow operators, emergency responders (including fire service, emergency medical services, and law enforcement), fire investigators, incident investigators, and electrical inspectors and installers. Some education is required for vehicle owners including fleet operators.

Emergency responders to incidents involving electric vehicles need to know how to safely stabilize crashed vehicles; extract vehicle occupants; handle EV batteries; remove disabled vehicles from the scene; and, handle incidents involving EVs that are being charged at public or private EVSEs.

Vehicle service technicians need to know how to identify power components in EVs (including batteries, cables, and disconnects) and how to safely remove, install, store, and recycle EV batteries during non-emergency operations.

Electricians and electrical inspectors need to know how to properly install EVSE and demonstrate to building owners and homeowners how to operate EVSE and any associated load management equipment.

Fleet operators and vehicle owners need to know how to charge their vehicles and how to properly disable the EV power source to their vehicle once charging is completed.

3.3.1.1 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, fire fighting tactics and personal protective equipment are also necessary to ensure safety.

3.3.1.2 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.

When EVSEs are used in conjunction with load management equipment, locations and connections to the load management equipment should be easily identifiable and have ready access. In these cases, the EVSE may be energized through a load management device which may measure other loads on a service or feeder to determine whether there is adequate capacity to supply power to an EVSE. Another configuration may permit the sharing of a 240-volt branch circuit with another 240-volt appliance instead of being directly connected to a dedicated branch circuit with its own disconnecting means such as a circuit breaker or fuse. The load management device in this configuration would only permit EVSE operation when other loads are not present on the branch circuit.

3.3.1.3 OEM Emergency Response Guides

Vehicle manufacturers produce emergency response guides (ERGs) which provide instructions and schematic details of safety procedures for their vehicles. These show access points, disconnect locations, and chassis dismemberment locations valuable to first responders and rescuers particularly when extrication of a vehicle passenger is required.

3.3.1.4 Electrical Energy Stranded in an Inoperable RESS; Battery Assessment and Safe Discharge Following an Emergency Event

A rechargeable energy storage system (RESS) is a completely functional electrical energy storage device consisting of the battery pack(s) and the ancillary subsystems necessary for physical support, protection and enclosure, thermal management, and control (including electronic control). The automotive application of an RESS during normal operating conditions relies greatly on advanced electronic-management systems to control the energy flow into the pack during charging and energy discharge from the battery pack when needed for propulsion of the vehicle.

In most electrically propelled vehicles, during unintended or abnormal events (such as a vehicle crash), vehicle safety systems, including high-voltage electrical contactor switches are designed to open the high-voltage circuit, isolating the energy within the battery and placing the electrical propulsion system in a non-operative mode. These systems provide safety from electrical shock as required for compliance with FMVSS No. 305, as well as unintended propulsion. However, current RESS design principles governing the contactor safety device prevent the remaining energy in the pack from being accessed or removed. In certain cases, this energy will be contained in an undamaged battery without incident and, after proper diagnostic evaluation by trained personnel, the battery may be returned to operation at the discretion of the OEM.

In other circumstances, when the RESS, including the high voltage battery, has been damaged, there is an increased risk to responders and others from stranded energy. A damaged RESS may result in loss of the ability to maintain thermal stability within the high voltage battery. The safety risks increase in relation to the level of energy as measured by the battery pack's state of charge (SOC). This combination of a damaged RESS and high SOC can result in elevated potential safety risks, in the form of electric shock and exothermic release of the stranded energy (venting, fire, or explosion), to the people handling the vehicle and the battery pack, such as emergency first and second responders, repair technicians, or battery recyclers.

In addition, it is generally assumed that at the end of battery life, if by age or premature damage, every battery will have to be discharged for safety reasons before secondary use or recycling.

3.3.1.5 Disaster Planning / Emergency Evacuations Involving Electric Vehicles

A longer term issue that has been raised is disaster planning and the need for guidelines or standards to deal with emergency evacuation situations especially those involving large numbers of electric vehicles on the road at the same time. If traffic congestion caused a number of electric vehicles to become depleted of charge on major evacuation routes (e.g., bridges and tunnels), this could become a serious issue.

3.3.1.6 Workforce Training

In addition to the training requirements described above, as the electric vehicle market grows and creates jobs, there is an increasing need for widespread occupational training and education to support the life cycle of EVs and associated infrastructure.

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4. *Gap Analysis of Standards, Codes, Regulations, Conformance Programs and Harmonization Efforts*

Section 4 presents the details of the gap analysis of standards, codes, regulations, and conformance programs, be they existing or in development, with particular focus on those that are pertinent to the rollout of electric vehicles in the United States. This assessment also includes a review of relevant harmonization activities underway.

In this context, a gap refers to a significant issue – whether it be related to safety, performance, interoperability, etc. – that has been identified and that should be addressed in a standard, code, regulation or conformance program, but no standard, code, regulation or conformance program currently is published or known to exist that adequately addresses the issue. Gaps can be filled through the creation of entirely new standards, code provisions, regulations, or conformance programs, or through revisions to existing ones. In some cases, work may already be in progress to fill a gap.

A partial gap refers to a situation where a significant issue has been identified that is partially addressed by an existing standard, code, regulation or conformance program.

No gap means there is no significant issue that has been identified at this time or that is not already adequately covered by an existing standard, code, regulation or conformance program.

Note: If no information is provided in the sections that follow on conformance programs or harmonization efforts, it means that either the issue was not addressed or no gap was identified at this time with respect to the issue.

Additional details regarding the identified standards, codes, regulations, and conformance programs described in this section can be found in the ***ANSI EVSP Roadmap Standards Compendium*****.**

4.1 Vehicle Domain

Terminology

There are published standards devoted to general technical terms as well as published standards specific to electric vehicle terminology. The goal should be to encourage the use of consistent terminology related to electric vehicles. Standards include:

- ISO 8713, Electric road vehicles – Vocabulary, published in 2012, establishes a vocabulary of terms used in relation to electric road vehicles and focuses on terms specific to electric road vehicles.

- SAE J1715, Hybrid Electric Vehicle (HEV) & Electric Vehicle (EV) Terminology, published in 2008, is intended as a resource for those writing other electric vehicle documents, specifications, standards, or recommended practices. SAE J1715 is in the process of being split into two parts among the SAE Hybrid Committee and SAE Battery Committee. The new standard will be designated parts 1 and 2.

Partial Gap: **Terminology.** There is a need for consistency with respect to electric vehicle terminology.

Recommendation: Complete work to revise SAE J1715. ***Priority:*** Mid-term. ***Potential Developer:*** SAE, ISO. ***Grid Related:*** No. ***Status of Progress:*** Green. ***Update:*** SAE J1715 is still in revision and is targeted for publication in the Spring of 2013.

4.1.1 Energy Storage Systems

4.1.1.1 Power Rating Methods

In version 1.0 of this roadmap, there was a statement that two standards are under development to address power rating methods for electric vehicles:

- SAE J2907, Power rating method for automotive electric propulsion motor and power electronics sub-system, which provides a test method and conditions for rating the performance of electric propulsion motors as used in hybrid electric and battery electric vehicles.
- SAE J2908, Power rating method for hybrid-electric and battery electric vehicle propulsion, which provides a test method and conditions for rating performance of complete hybrid-electric and battery electric vehicle propulsion systems reflecting thermal and battery capabilities and limitations.

Gap: **Power rating methods.** It was noted in roadmap version 1.0 that standards for electric vehicle power rating methods are still in development.

Recommendation: Complete work to develop SAE J2907 and J2908. ***Priority:*** Mid-term. ***Potential Developer:*** SAE. ***Grid Related:*** No. ***Status of Progress:*** Red. ***Update:*** With respect to the roadmap version 1.0 gap, work on the power rating method standards SAE J2907 and J2908 has been canceled because of resource issues. It will be re-opened under a new J number at a future date yet to be determined.

4.1.1.2 Battery Safety

EV battery safety standards development has been identified as a priority by standards development organizations including IEC, ISO, SAE and UL, the regulatory body NHTSA, 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 follows:

IEC

- IEC 62660-2, Secondary batteries for the propulsion of electric road vehicles – Part 2: Reliability and abuse testing for lithium-ion cells, was published in 2010. Although not specifically identified as a safety standard, it does include tests which address safety issues such as short circuit and overcharge.

ISO

- ISO 6469-1, Electric road vehicles – Safety specifications – Part 1: On-board rechargeable energy storage system (RESS), published in 2009, provides general safety criteria to protect persons within and outside of the vehicle and applies to batteries and other RESS.

- ISO 6469-3, Electrically propelled road vehicles – Safety specification – Part 3: Protection of persons against electric shock, published in 2011, addresses electrical safety of the RESS within the overall vehicle.

- ISO 12405-1, Electrically propelled road vehicles – Test specification for lithium-ion traction battery packs and systems – Part 1: High-power applications, was published in 2011. It is primarily focused on performance. However, it does contain tests that pertain to lithium-ion battery safety such as short circuit, overcharge, and over discharge tests.

- ISO 12405-2, Electrically propelled road vehicles – Test specification for lithium-ion traction battery packs and systems – Part 2: High-energy applications, was published in 2012. It is similar to its Part 1 counterpart for high power applications and contains tests related to lithium-ion battery safety.

- ISO 12405-3, Electrically propelled road vehicles – Test specification for lithium-ion traction battery packs and systems – Part 3: Safety. This standard, currently in development, will be the ISO safety standard for lithium batteries for EV applications.

SAE

- SAE J1766, Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing, was published in 2005 and is currently under revision. It specifically addresses electric vehicle safety concerns resulting from a vehicle crash event.

- SAE J2464, Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing, revised in 2009, provides a series of tests with which to determine an RESS response to a potential abuse condition.

- SAE J2929, Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells, defines a minimum set of acceptable safety criteria for a lithium-based rechargeable battery system to be considered for use in a vehicle propulsion application as an energy storage system connected to a high voltage power train. A revision to the standard was published in February 2013.

UL

- UL 2580, Batteries for Use in Electric Vehicles, was published as an Outline of Investigation in 2009, and as ANSI/UL 2580 in October 2011. This standard evaluates the cells, cell modules and battery pack's ability to safely withstand simulated abuse conditions. The standard is non-chemistry specific and includes construction requirements and tests to address safety of the electric energy storage assembly and modules which can consist of batteries and/or electrochemical capacitors.

NHTSA

- NHTSA FMVSS 305, Electric Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection. Last revised in 2011, it is a set of requirements intended to reduce deaths and injuries during a crash, which occur because of electrolyte spillage from propulsion batteries, intrusion of propulsion battery system components into the occupant compartment, and electrical shock.

EVS-IWG

As noted earlier, the EVS-IWG under WP.29 is working to develop a Global Technical Regulation (GTR) that would address potential safety risks of EVs while in use and after a crash event, including electrical shocks associated with the high voltage circuits of EVs and potential hazards associated with lithium-ion batteries and/or other rechargeable energy storage systems (RESS) (in particular, containing flammable electrolyte). The GTR would also set provisions and test protocols to ensure the vehicle system and/or electrical components perform safely, are appropriately protected, and are electrically managed while recharging from external electricity sources, whether at a residence or other charging location.

In 2012, the EVS-IWG met twice, once in April and later in October, in Washington, DC and Bonn, Germany, respectively. The EVS-IWG terms of reference were approved at the 2nd meeting in Bonn. At the 2nd meeting, the International Organization of Automobile Manufacturers (OICA) provided a detailed presentation of its proposal for GTR consideration (much of which is based on adopting provisions contained in UNECE R100, Uniform Provisions Concerning the Approval of Battery Electric Vehicles with Regard to Specific Requirements for the Construction and Functional Safety). The OICA proposal focuses on: 1) provisions for protection of electrical shock for in-use and post-crash, and 2) provisions to ensure safety performance of RESS for in-use and post-crash. Further consideration of the OICA proposal will continue in 2013.

With regard to the timelines for establishing the GTR, two options are being considered: 1) develop the GTR in two phases, and 2) develop a complete and comprehensive GTR in a single phase. In Option 1, Phase 1 would be based on the OICA proposal while Phase 2 would address RESS items that require more research. Under Option 2, the EVS-IWG would attempt to address all issues in a single phase.

As proposed by OICA, the GTR would apply to all vehicles of Category 1-1 and 1-2, with a gross vehicle mass (GVM) of 4,536 kilograms or less, equipped with electric power train containing high voltage bus, excluding vehicles permanently connected to the grid. Per the OICA proposal, the following vehicles would be excluded:

a) A vehicle with four wheels whose unladed mass is not more than 350 kg, not including the mass of the batteries in case of electric vehicles, whose maximum design speed is not more than 45 km/h, and whose engine cylinder capacity does not exceed 50 cm^3 for spark (positive) ignition engines, or whose maximum net power output does not exceed 4 kW in the case of other internal combustion engines, or whose maximum continuous rated power does not exceed 4 kW in the case of electric engines.

and

b) A vehicle with four wheels, other than that classified under a) above, whose unladed mass is not more than 400 kg, not including the mass of batteries in the case of electric vehicles and whose maximum continuous rated power does not exceed 15 kW.

The EVS-IWG held its third meeting in mid-April in Tokyo, Japan and a fourth meeting is tentatively scheduled for October 2013 in Beijing, China.

* * *

Although there has been active work in the battery safety standards area, the committee identified two gaps that need to be addressed.

Functional safety in the charging system

With funding from the U.S. Department of Transportation (DOT) and NHTSA, SAE International has undertaken a Cooperative Research Project (CRP) to Develop Repeatable Safety Performance Test Procedures for Rechargeable Energy Storage Systems (RESS), in partnership with five major automotive original equipment manufacturers (OEMs) actively working on RESS. This research will include investigation of failure modes and the results will be considered by NHTSA in connection with future rulemaking (e.g., this could be a functional safety standard, FMVSS for battery system safety, or a proposal for a GTR). SAE TEVVBC1 also plans to integrate the results of this research into future revisions of SAE J2929. The CRP report is targeted for release in October 2013.

Gap: **Functional safety in the charging system.** Potential faults in the charging system, both on-board and off-board, are the subject of NHTSA sponsored research and may need to be addressed in future rulemaking and/or standardization.

Recommendation: Future NHTSA rulemaking and/or revisions to SAE J2929 should consider the results of the DOT/NHTSA-funded SAE Cooperative Research Project with respect to fault events in the charging system which could lead to overcharging. ***Priority:*** Near-term. ***Potential Developer:*** NHTSA, SAE. ***Grid Related:*** No. ***Status of Progress:*** Green. ***Update:*** The roadmap version 1.0 gap statement and recommendation have been updated to note NHTSA-funded research, that the issue may be with the charging system rather than the battery, and that NHTSA rulemaking may result. NHTSA has been added as a potential developer and the priority level has been changed from mid-term to near-term. Recent updates to SAE J2929 do not address charging system failure; rather, they relate to electromagnetic compatibility (EMC) to ensure the safety functions of the battery are not impacted.

Delayed battery overheating events

All of the current tested failure modes of battery systems can be classed as "real time" with regard to outcome. If a European Council for Automotive R&D (EUCAR) hazard level of greater than 2 happens – the EUCAR rating system is used in SAE J2464 – it is assumed that it happens within minutes or a few hours at most. It is now known that some faults that can create EUCAR 2 or higher events may not surface for days or even weeks. This possibility introduces a new hazard potential that could surface at any 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 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.

Gap: **Delayed battery overheating events.** The issue of delayed battery overheating needs to be addressed.

Recommendation*:* Address the issue of delayed battery overheating events in future rulemaking and/or revisions of SAE J2929 based on the results of the DOT/NHTSA-funded SAE Cooperative Research Project. ***Priority:*** Near-term. ***Potential Developer:*** NHTSA, SAE. ***Grid Related:*** No. ***Status of Progress:*** Yellow. ***Update:*** The roadmap version 1.0 recommendation has been updated to note NHTSA-funded research which may result in future rulemaking. NHTSA has been added as a potential developer. Version 2 of SAE J2929 has been published. However, the topic of delayed battery overheating events is not addressed in this revision; it is pending the results of the NHTSA sponsored research.

4.1.1.3 Battery Testing – Performance and Durability

The principal areas of interest relating to standards for battery performance and durability testing are as follows:

Cell level performance testing: Specifically in the IEC realm, there are multiple standards for defining and measuring common performance characteristics, with emphasis on the loading conditions expected in electric vehicle or hybrid electric vehicle applications.

Pack level performance testing: Specifically, in the ISO 12405-1 and 12405-2 standards, attention is given to the distinction between high energy and high power applications. These also attempt to define and measure common performance characteristics based on EV or HEV applications.

There is a need to focus on harmonization of key battery performance parameters for electric vehicle applications. For example: "12kWh capacity" alone does not provide sufficient information due to varying methods of measuring and calculating battery capacities. This is particularly key at the cell level, as the cells are the primary determination to battery charge/discharge currents and capacities.

Durability and environmental endurance requirements: Some work has been done to define life-cycle testing parameters under simulated environmental conditions. However, for environmental test conditions, reliance appears to be on existing generic automotive or electronics testing requirements, which will require further modification for battery applications.

Environmental durability test requirements (e.g., temperature, humidity, vibration, etc.) could also be better defined, as current practices are to adapt existing automotive electronics requirements to the battery and battery management system on a case-by-case basis.

SAE is revising J1798, Recommended Practice for Performance Rating of Electric Vehicle Battery Modules, published in 2008, which provides for common test and verification methods to determine electric vehicle battery module performance.

In addition, UL has defined requirements and testing and certification services for batteries.

Gap: **Battery performance parameters and durability testing.** There is a need for further work on EV battery performance parameters and environmental durability test requirements.

Recommendation: Complete work on SAE J1798 and if possible consider harmonization with ISO 12405-2. ***Priority:*** Mid-term. ***Potential Developer:*** SAE, ISO. ***Grid Related:*** No. ***Status of Progress:*** Yellow. ***Update:*** There is not a lot of progress to date on SAE J1798.

4.1.1.4 Battery Storage, Packaging, Transport and Handling

Battery Storage

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

- IEC 60068, Environmental testing. Part 1: General and guidance, provides guidance regarding testing of equipment such as batteries under different environmental conditions, which it expects to be exposed to during storage and operations.

- ICC publishes the International Fire Code® (IFC®).

- NFPA 1, Fire Code, Chapter 52 covers stationary battery installations, which would come into play where batteries are used in a fixed energy storage facility.

- NFPA 13, Standard on Installation of Sprinkler Systems, addresses fire protection of storage occupancies. This document's technical committee is working on requirements for handling and storing EV batteries based on the results of the National Fire Protection Research Foundation report on lithium-ion batteries.

- NFPA 30A, Standard for Motor Fuel Dispensing Facilities and Repair Garages, covers fire protection requirements for fueling and service stations including service garages. This document's technical committee is also looking at requirements for safe handling of EV batteries at these locations.

- NFPA 70®, the National Electrical Code®, Article 480, Storage Batteries, 2011, covers the installation of electrical conductors, equipment, and raceways; signaling and communications conductors, equipment, and raceways; and optical fiber cables and raceways.

- SAE J2950, Recommended Practices (RP) for Transportation and Handling of Automotive-type Rechargeable Energy Storage Systems (RESS). This standard addresses identification, handling, and shipping of un-installed RESSs to/from specified locations (types) required for the appropriate disposition of new and used items.

- OSHA 1910, storage batteries, where provisions shall be made for sufficient diffusion and ventilation of gases from storage batteries to prevent the accumulation of explosive mixtures.

- IEC 62840, Electric Vehicle Battery Exchange Infrastructure Safety Requirements, is a new work item within IEC/TC 69 that encompasses storage of lithium-ion batteries.

- NFPA's Fire Protection Research Foundation has also started a research project looking at fire suppression techniques related to burning of EV batteries.

Gap: **Safe storage of lithium-ion batteries.** At present, there are no published standards addressing the safe storage of lithium-ion batteries specifically, whether at warehouses, repair garages, recovered vehicle storage lots, auto salvage yards, or battery exchange locations.

Recommendation*:* A standard on safe storage practices for EV batteries must be developed, addressing both new and waste batteries and the wide range of storage situations that may exist, including when the batteries are separated from their host vehicle. ***Priority:*** Near-term. ***Potential Developer:*** SAE, NFPA, ICC, IEC/TC 69. ***Grid Related:*** No. ***Status of Progress:*** Green. ***Update:*** The roadmap version 1.0 gap statement has been modified to say there are no *published* standards addressing safe storage. IEC 62840 and the research project of the NFPA's Fire Protection Research Foundation are noted in the text.

Battery Packaging, Transport and Handling

So far, only limited standards work has been done in this area including:

- SAE J1797, Recommended Practice for Packaging of Electric Vehicle Battery Modules, published in 2008. 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.

- As noted above, there is also SAE J2950, Recommended Practices (RP) for Transportation and Handling of Automotive-type Rechargeable Energy Storage Systems (RESS).

- ISO/IEC PAS 16898, Electrically propelled road vehicles – Dimensions and designation of secondary lithium-ion cells, was published in 2012 and a revision is targeted for publication in 2013.

At the end of 2010, the United Nations (UN) specifically classified lithium-ion batteries as part of its amendments to the model regulations on the transport of dangerous goods. Thus, transportation of *new* batteries is now 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:

- 3090, Lithium Metal Batteries (including lithium alloy batteries);

- 3091, Lithium Metal Batteries Contained In Equipment (including lithium alloy batteries) or Lithium Metal Batteries Packed With Equipment (including lithium alloy batteries);

- 3480, Lithium-ion Batteries (including lithium-ion polymer batteries); and

- 3481, 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, section 38) also cover packaging limitations to ensure proper containment against pressure and temperature changes, mechanical drops, etc.

The Portable Rechargeable Battery Association (PRBA) and the International Association for the Promotion and Management of Portable Rechargeable Batteries (RECHARGE) submitted a joint proposal on this issue to the UN Subcommittee of Experts (UN SCOE) on the Transport of Dangerous Goods. The proposal was discussed at the Subcommittee's June /July 2012 meeting, the result of which was that the groups were invited to submit a new proposal.

Gap: **Packaging and transport of waste batteries.** Current standards and regulations do not adequately cover transportation aspects of *waste* batteries (damaged, aged, sent for repair, end-of-life) in terms of packaging, loading limitations, combination with other dangerous goods on same transport, etc.

Recommendation*:* There is a need for a harmonized approach toward communication, labeling, packaging restrictions, and criteria for determining when a battery is waste. ***Priority:*** Near-term. ***Potential Developer:*** UN SCOE on the Transport of Dangerous Goods, ISO/TC 22/SC21, SAE or UL. ***Grid Related:*** No. ***Status of Progress:*** Green. ***Update:*** The UN SCOE was added as a potential developer as there is a proposal before it.

Gap: **Packaging and transport of batteries to workshops or battery swapping stations.** Unloading a battery in a battery swapping station is extremely challenging with the original packaging used for dangerous goods transportation. There is a need for standards for intermediate packaging to cover transport to battery swapping stations.

Recommendation*:* Intermediate packaging is required between the import location of the battery and battery swapping stations and needs to be standardized around geometry, safety and matching to UN packaging requirements. ***Priority:*** Mid-term. ***Potential Developer:*** ISO/TC 22/SC21, IEC/TC 69, SAE or UL. ***Grid Related:*** No. ***Status of Progress:*** Not started.

4.1.1.5 Battery Recycling

The following documents are directed at all battery types including Lithium batteries:

- SAE J2974, Technical Information Report on Automotive Battery Recycling. In development and targeted for publication by the end of 2013, this document provides a compilation of current recycling definitions, technologies and flow sheets and their application to different battery chemistries.

- SAE J2984, Identification of Transportation Battery Systems for Recycling Recommended Practice. Published in June 2012 with a revision targeted for the Spring of 2013, this document includes a chemistry identification system intended to support the proper and efficient recycling of rechargeable battery systems used in transportation applications with a maximum voltage greater than 12V (including SLI batteries).

In terms of regulations, lithium-ion battery recycling compliance requirements are limited to a few states in the U.S., including California, Oregon and Florida. The lack of harmonization and clear battery producer responsibility (in contrast to requirements in Europe for example) may potentially limit the battery recycling schemes in the U.S. Nevertheless, federal grants are given as an incentive to develop these recycling technologies and meet the demands of eMobility in the U.S.

Gap: **Battery recycling.** Standards are needed in relation to EV (li-ion) battery recycling.

Recommendation*:* Complete work on SAE J2974 and J2984. EV (li-ion) battery recycling standards are desirable to address 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. ***Priority:*** Near-term. ***Potential Developer:*** SAE, IEC. ***Grid Related:*** No. ***Status of Progress:*** Green. ***Update:*** The roadmap version 1.0 text and recommendation have been updated to note relevant work by SAE. The priority level has been changed from long-term to near-term.

4.1.1.6 Battery Secondary Uses

SAE TEVVBC15, Secondary Battery Use Committee, is tasked with developing standards to address battery second life applications and has begun initial investigation of this topic. Most OEMs predict a 70-80% capacity remaining in the lithium-ion battery after automotive initial purpose. Assuming the replacement pack is returned to an authorized dealer or support facility, a simple test or state of health record can assess the next steps. SAE J2950 can be used to safely ship batteries for storage or repackaging for alternative uses. SAE J2936 can be used to correctly label the battery for handling. Logistics will be required to facilitate different battery chemistries, various sizes and matching. Battery management systems should be utilized as needed to maintain safety. Appropriate packaging methods are also needed to avoid abuse.

Gap: **Battery secondary uses.** There is a need for standards to address battery second life applications for grid storage and other uses.

Recommendation*:* 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. ***Priority:*** Mid-term. ***Potential Developer:*** SAE, UL. ***Grid Related:*** No. ***Status of Progress:*** Green. ***Update:*** The text has been updated to note some of the considerations in the work thus far by the SAE committee. The priority level has been changed from long-term to mid-term. UL has been added as a potential developer.

4.1.1.7 Crash Tests / Safety

FMVSS 305

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. In 2010, FMVSS 305 was updated so as to align it more closely with the April 2005 version of SAE J1766, Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing. In July 2011, the standard was again amended in response to petitions for reconsideration filed subsequent to the publication of the 2010 final rule. As amended, 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.

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). The recent rulemakings 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 of the isolation resistance of DC high voltage sources that comply with the 100 ohms/volt electrical isolation requirement. As amended, 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. This differs from the previously-existing standard that similarly applied to passenger cars, MPVs, trucks and buses that have a GVWR of 4,536 kg or less but that was limited to vehicles that use more than 48 nominal volts of electricity as propulsion power and whose speed attainable in 1.6 km on a paved level surface is more than 40 km/h.

SAE EV Crash Test Safety Procedures Task Force

SAE has formed an EV Crash Test Safety Procedures Task Force under the Impact and Rollover Test Procedures Standards Committee. The scope of the task force is to create and maintain information reports and recommended practices that relate to laboratory and personnel safety when conducting dynamic crash testing of EVs. Published work shall reflect the current industry "best practices" for testing and provide a basis for industry harmonization of these methods, to the extent possible. There is an understanding that these methods will change over time. Laboratory tasks being looked at include vehicle receiving and inspection, vehicle preparation, crash tests, post-crash inspection, and post-crash storage. The documents will address battery system failures due to electrical and mechanical abuse, personal protective equipment, training, emergency procedures, thermal runaway risk, toxic emissions, and other battery health assessments. The group hopes to publish an information report by the Spring of 2013.

As noted earlier, NFPA's Fire Protection Research Foundation has also started a research project looking at similar questions related to burning of EV batteries and recommendations for suppression efforts.

SAE J2929 has added a section on rollover, but this will not cover all the issues that this task force is exploring.

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

4.1.2 Vehicle Components

4.1.2.1 Internal High Voltage Cables, On-Board Wiring, Component Ratings and Charging Accessories

EV-specific standards related to this topic include:

- IEC/TR 60783, Wiring and Connectors for Electric Road Vehicles, which applies to cabling and connectors used in battery electric road vehicles. These recommendations are not applicable to the low tension wiring (e.g. 12 V) for the auxiliary and signaling accessories, such as horn, lighting, signaling lamps, wipers, etc., nor do they apply to connections between cells of the traction battery. Rather, this document provides general rules for all external wiring and connectors which are used for interconnecting the traction components and sub-systems. The rules are applicable to the heavy current, the light current, and the signal harnesses. Currently, this publication has the status of a technical report, hence the "TR" designation.

- SAE J2894/1, Power Quality Requirements for Plug In Electric Vehicle Chargers. The intent of this published document is to develop a recommended practice for PEV chargers, whether on-board or off-board the vehicle, that will enable equipment manufacturers, vehicle manufacturers, electric utilities and others to make reasonable design decisions regarding power quality. The three main purposes are: 1) To identify those parameters of a PEV battery charger that must be controlled in order to preserve the quality of the AC service; 2) To identify those characteristics of the AC service that may significantly impact the performance of the charger; and, 3) To identify values for power quality, susceptibility and power control parameters which are based on current U.S. and international standards. These values should be technically feasible and cost effective to implement into PEV battery chargers.

- SAE J2894/2, Power Quality Requirements for Plug In Electric Vehicle Chargers - Test Methods. This standard, targeted for publication in June 2013, describes the test methods for the parameters/requirements in SAE J2894/1. It addresses automatic charger restarts after a sustained power outage, as well as the ability to ride through momentary outages.

- UL 62, Flexible Cords and Cables, which covers electric vehicle cable constructed as described in, and listed for use in accordance with, Article 400 of NFPA 70®, the National Electrical Code®. The cable is used to supply power, signal, and control to electric vehicles during the charging process. Electric vehicle cable consists of two or more insulated conductors, with or without grounding conductors, with an overall jacket.

- UL 458A, Power Converters/Inverters for Electric Land Vehicles, which covers power converters and power inverters intended for use in electric vehicles. This category covers fixed and stationary power converters, and accessories having a nominal rating of 600 V or less, direct or alternating current. This category also covers fixed, stationary and portable power inverters having a DC input and a 120 or 240 V AC output. These converters/inverters are intended for use within electric land vehicles where not directly exposed to outdoor conditions. This category also covers converters/inverters that are additionally intended to charge batteries.

- UL 2202, Electric Vehicle Charging System Equipment, which covers charging system equipment, either conductive or inductive, intended for use with electric vehicles. The equipment can be located on- or off-board the vehicle.

- UL 2733, Surface Vehicle On-Board Cable, which covers single-conductor or single, coaxial cable intended for the connection of components in an electric vehicle. The cable is rated 60, 75, 90 or 105°C (140, 167, 194 or 221°F), 300 or 600 V AC or DC, -30°C (-22°F), oil resistant, water resistant, and suitable for exposure to battery acid.

- UL 2734, Connectors for Use in On-board Electric Vehicle Charging Systems, which covers component connectors intended to interconnect both communication and power-circuit conductors rated up to 30 A and up to 600 V AC or DC within an on-board electric vehicle charging system.

General standards that may be applicable in the EV components environment include:

- IEC 61316, Industrial cable reels, which applies to cable reels with a rated operating voltage not exceeding 690 V AC/DC and 500 Hz with a rated current not exceeding 63A, primarily intended for industrial use, either indoors or outdoors, for use with accessories complying with IEC 60309-1.

- SAE J1654, High Voltage Primary Cable. This SAE Standard covers cable intended for use at a nominal system voltage up to 600 VDC or 600 VAC. It is intended for use in surface vehicle electrical systems.

- SAE J1673, High Voltage Automotive Wiring Assembly Design. This SAE Recommended Practice covers the design and application of primary on-board wiring distribution system harnesses to road vehicles. This document applies to any wiring systems which contains one or more circuits operating between 50V DC or AC RMS and 600 V DC or AC RMS excluding automotive ignition cable.

- SAE J1742, Connections for High Voltage On-Board Road Vehicle Electrical Wiring Harnesses - Test Methods and General Performance Requirements. Procedures included within this specification are intended to cover performance testing at all phases of development, production, and field analysis of electrical terminals, connectors, and components that constitute the electrical connection systems in high power road vehicle applications that operate at either 20 V to 600 volts regardless of the current applied, or any current greater than or equal to 80 A regardless of the voltage applied. These procedures are applicable only to terminals used for in-line, header, and device connectors and for cable sizes up to 120 mm2 (4/0).

- UL 1004-1, Traction Motors, which covers motors intended as the prime mover and installed in or on vehicles for highway use, such as passenger automobiles, buses, trucks, vans, bicycles, motorcycles and the like. These motors have been investigated for construction and operation at rated output. They have additionally been investigated for the severity and profile of shock and vibration likely to be encountered by motors mounted in road vehicles.
- USCAR-37, High Voltage Connector Performance Supplement to SAE/USCAR-2. Procedures included within this specification supplement are, when used in conjunction with SAE/USCAR 2, intended to cover performance testing at all phases of development, production, and field analysis of electrical terminals, connectors, and components that constitute the electrical connection systems in high voltage (60~600V) road vehicle applications. These procedures are applicable to terminals used for in-line, header, and device connector systems with and without shorting bars.

In Europe and in other countries around the world, electric vehicles and on-board components are subject to review through both European and UN regulations. These regulations include European Regulations 2007/46/EC or 2002/24/EC and the UNECE Regulation R100. UNECE R100 is the UN regulation which tests specific requirements for the construction, functional safety and hydrogen emissions of battery-powered all electric vehicles. UNECE R100 is required by many countries before an electric vehicle can be road registered, and is also required before European Community Whole Vehicle Type Approval (ECWVTA) can be issued. Safety regulations and requirements within UNECE R100 include: vehicle constructional requirements (e.g., prevention of gas accumulation and correctly rated circuit breakers); protection against electric shock through the assessment of covers and enclosures associated with high voltage components; assessment of access to high voltage components according to protection degrees, etc.

In the U.S., FMVSS 305, Electric Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection, is similar to R100 in Europe. In addition, all motor vehicles and items of motor vehicle equipment are covered by the Motor Vehicles Safety Act in the U.S., meaning they are covered by NHTSA’s recall and remedy provisions in the event there exists a safety-related defect.

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

4.1.2.2 Vehicle Diagnostics – Emissions

In 1993, pursuant to the Clean Air Act, the U.S. Environmental Protection Agency (EPA) published a final rulemaking requiring manufacturers of light-duty vehicles and light-duty trucks to install on-board diagnostic (OBD) systems on such vehicles beginning with the 1994 model year. The regulations promulgated in that final rule require manufacturers to install OBD systems which monitor emission control components for any malfunction or deterioration causing exceedance of certain emission thresholds, and which alert the vehicle operator to the need for repair. That rulemaking also requires that, when a malfunction occurs, diagnostic information must be stored in the vehicle's computer to assist the technician in diagnosis and repair.

Since the inception of the program, vehicle manufacturers have been allowed to satisfy federal OBD requirements by installing OBD systems satisfying the OBD II requirements promulgated by the California Air Resources Board (CARB).

Because hybrid electric vehicles and plug-in hybrid electric vehicles are equipped with conventional internal combustion or diesel engines, they comply with CARB and EPA OBD requirements. In some cases, there are special OBD requirements that are specific to these hybrid and plug-in hybrid electric vehicles.

CARB's OBD II rules can be found at:

- Title 13, California Code Regulations, Section 1968.2, Malfunction and Diagnostic System Requirements for 2004 and Subsequent Model-Year Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles and Engines (OBD II); and
- Title 13, California Code of Regulations, Section 1968.5, Enforcement of Malfunction and Diagnostic System Requirements for 2004 and Subsequent Model-Year Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles and Engines.

For copies, see http://www.arb.ca.gov/msprog/obdprog/obdregs.htm.

Note: In December 2011, CARB proposed amendments to its OBD II regulation which, among other things, would clarify how certain requirements are to be applied to hybrid and plug-in hybrid electric vehicles. The proposed amendments were adopted by the Board at a hearing held in January 2012. A copy of the regulation as amended is available at:

http://www.arb.ca.gov/msprog/levprog/leviii/leviii.htm.

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

4.1.2.3 Audible Warning Systems

Numerous activities are underway to address the concern that electric and some hybrid electric vehicles may not be audibly detectable by the blind. These include NHTSA rulemaking (stemming from the Pedestrian Safety Enhancement Act of 2010), Japanese and UNECE guidelines requiring EVs and HEVs to generate a pedestrian alert sound, SAE and ISO technology neutral procedures for measuring vehicle sound at low speeds, and the previously noted WP.29 effort to develop a Global Technical Regulation (GTR).

In accordance with the Pedestrian Safety Enhancement Act of 2010, electric and hybrid electric vehicles must emit an alert sound that allows blind and other pedestrians to reasonably detect a nearby electric or hybrid vehicle operating below a certain cross-over speed. The alert sound must be in compliance with a new safety standard that NHTSA is required to create in accordance with the law. The NHTSA notice of proposed rulemaking was published in the Federal Register on 14 January 2013 with comments due by 15 March 2013. The law requires NHTSA to finalize the new standard by 4 January 2014. Under the law, the new standard is required to be in effect within 36 months of publication of the final rule.

NHTSA has proposed to incorporate by reference portions of SAE J2889-1, Measurement of Minimum Noise Emitted by Road Vehicles, which was published in September 2011. At the request of NHTSA, SAE issued a revised version of J2889/1 in May of 2012 to include metrics and measurement procedures for changes to pitch and volume for innate and synthetic vehicle sounds. The SAE work product is the basis for ISO 16254, an identical sound measurement standard in development.

Outside the U.S., electric and hybrid electric vehicles are being designed to comply with voluntary guidelines. The Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has voluntary guidelines which require that EVs and HEVs generate a pedestrian alert sound whenever the vehicle is moving forward at any speed less than 20 km/h and when the vehicle is operating in reverse. MLIT guidelines do not require vehicles to produce an alert sound when the vehicle is operating but stopped, such as at a traffic light. The manufacturer is allowed to equip the vehicles with a switch to deactivate the alert sound temporarily. In Europe, the UNECE has adopted guidelines covering alert sounds for EVs and HEVs that are closely based on the Japanese guidelines. The guidelines will be published as an annex to the UNECE Consolidated Resolution on the Construction of Vehicles (R.E.3).

The WP.29 work on a GTR is currently ongoing and will likely continue in parallel with the NHTSA rulemaking activity which is ongoing.

<u>Partial Gap:</u> **Audible warning systems.** Creation of the NHTSA safety standard and compliance with it will effectively close any gap with respect to audible warning systems for electric vehicles sold in the U.S. market. Ongoing standards work in SAE and ISO, and in WP.29 with respect to the development of a Global Technical Regulation would provide a means for international harmonization around this issue.

<u>Recommendation</u>*:* Continue work on safety standards to address EV sound emission and measurement. ***<u>Priority:</u>*** Near-term. ***<u>Potential Developer:</u>*** SAE, ISO, NHTSA, WP.29. ***<u>Grid Related:</u>*** No. ***<u>Status of Progress:</u>*** Green.

4.1.3 Vehicle User Interface

4.1.3.1 Graphical Symbols

There are several international standards and guidelines relating to graphical symbols and how to develop them. These are general in nature and not specific to electric vehicles, but may be utilized by standards development groups to develop a set of electric vehicle graphical symbols standards. There are also some publications that relate specifically to markings on electrical equipment and instrumentation for electric vehicles. These include:

- IEC 60445, Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals, conductor terminations and conductors, published in 2010, which contains rules for markings of electrical equipment including colors for conductors.

- IEC TR 60784, Instrumentation for electric road vehicles, published in 1984, provides high level guidance on information that should be provided to the driver regarding operating and other states of an electric vehicle battery.

PEVs include indicators on battery state of charge, if there is a system failure, etc. but these vary by OEM. There is an SAE committee working on an "electronic fuel gauge" document that is waiting for additional input from committee members on the direction of future work.

In terms of Federal Motor Vehicle Safety Standards and Regulations, there is:

- NHTSA FMVSS 101, Controls and Displays, most recently published in 2009, which provides performance requirements for the location, identification, color, and illumination of motor vehicle controls, telltales and indicators. It is not electric vehicle specific.

As described earlier, a DOT/NHTSA-funded SAE Cooperative Research Project is looking at functional safety studies and failure modes. Once these issues are better understood, it is possible that future rulemaking could explore having a consistent symbol for high voltage failures.

Gap: **Graphical symbols for electric vehicles.** Standards for graphical symbols for electric vehicles are needed to communicate important information to the driver such as state of charge, failure or normal system operation which can be understood regardless of the driver's language.

Recommendation*:* Develop EV graphical symbols standards to communicate information to the driver. ***Priority:*** Long-term. ***Potential Developer:*** SAE, NHTSA, ISO, IEC. ***Grid Related:*** No. ***Status of Progress:*** Not started. ***Update:*** The text has been updated to note NHTSA sponsored research on functional safety and failure modes. The roadmap version 1.0 gap statement and recommendation have been re-focused on communication of information to the driver. NHTSA has been added as a developer and the priority level has been changed to long-term. Regarding the roadmap version 1.0 gap statement and recommendation relating to graphical symbols for "parts under the hood," this aspect is addressed in section 4.3.1.1 on EV emergency shut off.

4.1.3.2 Telematics – Driver Distraction

The following are relevant with respect to conventional vehicles and are not specific to EVs:

- Auto Alliance Driver Focus Telematics Guidelines. This guideline provides 24 design principles for telematics systems human-machine interaction design to minimize the potential for driver distraction. Each design principle has a rationale, design criteria and evaluation procedure to help designers implement the requirements. Four categories of design principles for navigation, telephone call management, electronic messaging, and interactive services are currently addressed in this document.

- NHTSA Driver Distraction Guidelines. In February 2012, NHTSA issued proposed nonbinding, voluntary guidelines to promote safety by discouraging the introduction of excessively distracting devices in vehicles. These guidelines cover original equipment in vehicle device secondary tasks (i.e., communications, entertainment, information gathering, and navigation tasks not required for driving) performed by the driver through visual-manual means. See: https://www.federalregister.gov/articles/2012/02/24/2012-4017/visual-manual-nhtsa-driver-distraction-guidelines-for-in-vehicle-electronic-devices. These NHTSA guidelines are still in the proposal stage.

- NHTSA – FMVSS 101. This standard specifies performance requirements for location, identification, color, and illumination of motor vehicle controls, telltales and indicators. The purpose of this standard is to ensure the ready access, visibility and recognition of motor vehicle controls and to facilitate the proper selection of controls under daylight and night time conditions, in order to reduce the safety hazards caused by the diversion of the driver's attention from the driving task and by mistakes in selecting controls.

No gaps have been identified at this time.

4.1.3.3 Fuel Efficiency, Emissions and Labeling

In July 2011, a new federal regulation titled, "Revisions and Additions to Motor Vehicle Fuel Economy Label" was issued (Federal Register: Vol. 76, No. 129, pages 39478 – 39587, [Docket ID; EPA–HQ–OAR–2009–0865; FRL–9315–1; NHTSA–2010–0087]). This was a joint rule issued by both the Environmental Protection Agency (EPA) and NHTSA. The regulation establishes new requirements (40 CFR Parts 85, 86, and 600, and 49 CFR Part 575) for the fuel economy and environmental label that will be posted on the window sticker of all new automobiles sold in the U.S. The rule became effective in September 2011 and the labeling requirements apply for model year 2013 and later.

This joint final rule by EPA and NHTSA represents the most significant overhaul of the federal government's fuel economy label or "sticker" since its inception over 30 years ago. The redesigned label will provide new information to American consumers about the fuel economy and consumption, fuel costs, and environmental impacts associated with purchasing new vehicles. The new rule will result in the development of new labels for certain advanced technology vehicles entering the U.S. market, in particular plug-in hybrid electric vehicles and electric vehicles. This rule uses miles per gallon gasoline equivalent for all fuel and advanced technology vehicles available in the U.S. market including plug-in hybrids, electric vehicles, flexible-fuel vehicles, hydrogen fuel cell vehicles, and natural gas vehicles.

The following four SAE standards are referenced in the regulation:

- SAE J1634, Electric Vehicle Energy Consumption and Range Test Procedure;
- SAE J1711, Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid-Electric Vehicles, Including Plug-in Hybrid Vehicles;
- SAE J2572, Recommended Practice for Measuring Fuel Consumption and Range of Fuel Cell and Hybrid Fuel Cell Vehicles Fuelled by Compressed Gaseous Hydrogen; and
- SAE J2841, Utility Factor Definitions for Plug-In Hybrid Electric Vehicles Using Travel Survey Data.

The redesigned label provides expanded information to American consumers about new vehicle fuel economy and fuel consumption, greenhouse gas and smog-forming emissions, and projected fuel costs and savings, and also includes a smartphone interactive code that permits direct access to additional web resources. Additional information for advanced technology vehicles includes driving range and battery charge time.

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

4.2 Infrastructure Domain

4.2.1 Charging Systems

4.2.1.1 Wireless Charging

SAE International is currently in the process of developing a design standard, SAE J2954, Wireless Charging of Electric and Plug-in Hybrid Vehicles. The standard will cover all equipment aspects of stationary charging, from grid to vehicle charging with a key focus on interoperability between the primary (charging mat) and secondary (pick-up located on vehicle) when the two aforementioned components are manufactured by two different suppliers. The SAE taskforce is reviewing the state of the art of wireless charging (e.g., inductive, magnetic resonance) and compiling an interoperability study. The document, which initially will be published as a guideline, is due out in 2013. It will be a working document as further research for this technology is currently underway, and it will become a standard for publication in 2015.

UL is developing UL 2750 to cover safety aspects of wireless charging in parallel with the development of SAE J2954.

The IEEE Standards Association has initiated pre-standardization activity related to electric vehicle wireless power transfer (EVWPT) focused on dynamic wireless charging in light of the range limitations of EVs and the costs of vehicle energy storage. This is intended to complement SAE J2954 which is centered on stationary charging.

The IEEE will:

- Develop a peer-reviewed technology strategy guideline and technology roadmap for the development of EVWPT infrastructure solutions (with respect to different use cases and covering both stationary and dynamic wireless charging) and a focus on future standardization needs; and

- Develop a white paper for dynamic wireless charging which can be utilized as input for future joint IEEE/SAE standardization activities (considering both vehicle integration and infrastructure integration aspects).

IEC/TC 69 has undertaken work on IEC 61980-1, Electric vehicle wireless power transfer systems (WPT) – Part 1: General requirements, in cooperation with SAE and the Japan Automobile Research Institute (JARI).

Gap: **Wireless charging.** Standards and guidelines for wireless charging are still in development.

Recommendation*:* Complete work on SAE J2954, UL 2750, IEEE deliverables and IEC 69180-1. ***Priority:*** Near-term. ***Potential Developer:*** SAE, UL, IEEE, IEC/TC 69. ***Grid Related:*** Yes. ***Status of Progress:*** Green. ***Update:*** The text and roadmap version 1.0 gap statement and recommendation have been modified to account for IEEE and IEC/TC 69 work, with both added as potential developers.

4.2.1.2 Battery Swapping

To date, standards development activities with regard to battery swapping have been relatively limited. In June 2011 the Chinese released for public comments nine standards that deal with battery swapping including: terminology, general requirements, testing specifications and construction codes.

The CEN/CENELEC focus group report on European Electro-Mobility specified the need for international battery swapping standards addressing safety, energy needs, exchangeability, ready access, data and communication framework.

A new project has been established within IEC/TC 69 titled IEC 62840 Ed. 1.0, Electric vehicle battery exchange infrastructure safety requirements. Publication is anticipated in mid-2015. At the kick-off meeting for this project in February 2013, it was determined to work on a series of standards that deal with safety, communication, interoperability and performance related to battery swapping. Progressing the new work item on safety from a working draft to a committee draft will remain the initial focus, while preparing new work item proposals for the additional work.

Gap: **Battery swapping – safety.** Currently, there is a need to define minimum requirements for the safe operation of battery swapping stations, as deployment of battery swapping systems is currently underway in several countries around the world.

Recommendation*:* Complete work on IEC 62840 to define minimum requirements for the safe operation of battery swapping stations. ***Priority:*** Near-term. ***Potential Developer:*** IEC/TC 69. ***Grid Related:*** No. ***Status of Progress:*** Green. ***Update:*** The text and recommendation have been updated to note the new project IEC 62840 in IEC/TC 69.

Gap: **Battery swapping – interoperability.** Standards are needed to help facilitate the penetration of battery swapping in the market. Issues to be addressed related to removable batteries include electrical interfaces, cooling integration, data transfer integration, and common mechanical and dimensional interfaces.

Recommendation: Define interoperability standards related to battery swapping. ***Priority:*** Near-term. ***Potential Developer:*** IEC/TC 69. ***Grid Related:*** No. ***Status of Progress:*** Not started. ***Update:*** Currently, there is some ongoing work on the standardization of battery packs in ISO TC 22/SC21. The inaugural meeting of the working group for IEC 62840 in IEC/TC 69 raised an indication of interest in work on interoperability related to battery swapping.

4.2.1.3 Electric Vehicle Supply Equipment (EVSE)

Power Quality

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. SAE International has published SAE J2894, Power Quality Requirements for Plug-in Electric Vehicle Chargers. SAE J2894/1, published in December 2011, contains the requirements while SAE J2894/2, targeted for publication in June 2013, contains the test procedures for those requirements.

SAE J2894/1 contains both requirements for the power quality of the vehicle chargers and the characteristics of the electric grid. It includes power quality requirements on the power factor, AC to DC conversion efficiency, harmonic current distortion, and inrush current. This document also describes what the normal characteristics of the electric grid are and the characteristics of some events that could occur on the electric grid. These events include voltage swell, surge, sag, and distortion, as well as momentary outage and frequency variations.

SAE J2894 notes that generators that would be used in a home do not have the same power quality as the electric grid and that user experiences could be affected by vehicle chargers that do not work properly due to the use of these generators. SAE J2847/1 and J2836/1™ are referenced in J2894/1 to link the communications and power quality documents. SAE J2894 discusses what is known as "cold load pickup," which is when power is restored after a loss of utility power with many devices still connected and on that attempt to restart at the same time. All of these devices, including vehicle chargers then draw their respective inrush currents, leading to a possible current of up to five times normal load. A restart load rate is described in order to keep this initial load to a manageable level.

Partial Gap: **Power quality.** SAE J2894/1 was published in December 2011. At the time of publication of roadmap version 1.0, SAE J2894, Part 2, was still in development.

Recommendation*:* Complete work on SAE J2894, Part 2. ***Priority:*** Near-term. ***Potential Developer:*** SAE. ***Grid Related:*** Yes. ***Status of Progress:*** Closed. ***Update:*** With the publication of SAE J2894/2, the partial gap on power quality identified in version 1.0 of this roadmap will be closed.

EVSE Charging Levels/Modes

SAE J1772™, the Recommended Practice for Electric Vehicle and Plug In Hybrid Electric Vehicle Conductive Charge Coupler, organizes the potential charging options into different "levels." IEC 61851 organizes charging into four "modes" based on the EVSE connection to the AC mains. These standards identify the voltage, number of phases, maximum current, and required branch circuit protection for each level or mode. These parameters, coupled with the battery charge parameters, dictate the length of time the vehicle will take to charge. To determine the charge time, consider that the higher the level or mode, the higher the voltage and current, and therefore the quicker the charge. Battery properties and vehicle characteristics must also be taken into account in order to determine the charging time.

While the SAE and IEC standards for conductive charging dictate different power parameters for each level or mode, the operational parameters of the vehicle and EVSE generally remain the same from level to level or mode to mode. In future applications, very high power and/or high voltages may require additional safeguards to address these special applications. Specifications such as vehicle state voltages and control pilot circuit parameters are consistent for each level within SAE and each mode within IEC standards. This allows EV drivers to utilize any of the AC levels/modes of charging available, provided that the connector meets the SAE J1772™ or the car is compatible with one of the IEC connector types available on that station.

EVSE manufactured for the U.S. market, and vehicles sold and operated in the U.S., generally follow the SAE J1772™ standard. EVSE manufactured for the European market, and vehicles sold and operated in Europe, generally follow the IEC 61851 standards.

In October 2012, a revision of SAE J1772™ was published which integrates AC and DC charging into one vehicle inlet/charging connector (the "combination coupler"). AC and DC charging incorporated the same low level control pilot communication scheme. DC charging requires high level digital communications for charge control. The 2010 version of SAE J1772™ defined AC Level 1 and AC Level 2 charge levels and specified a conductive charge coupler and electrical interfaces for AC Level 1 and AC Level 2 charging. The October 2012 revision incorporates DC charging where DC Level 1 and DC Level 2 charge levels, charge coupler and electrical interfaces are defined. The standard was developed in cooperation with the European automotive experts who also adopted and endorsed a combination coupler strategy in their approach.

Figure 7 describes the SAE charging configurations and ratings terminology.

▸ AC L1: 120V AC single phase - Configuration current 12, 16 amp - Configuration power 1.44, 1.92kw	▸ DC L1: 200 – 500V DC - Rated Current ≤ 80 amp - Rated Power ≤ 40kw
▸ AC L2: 240V AC single phase - Rated Current ≤ 80 amp - Rated Power ≤ 19.2kw	▸ DC L2: 200 – 500V DC - Rated Current ≤ 200 amp - Rated Power ≤ 100kw
▸ AC L3: To Be Determined (TBD)	▸ DC L3: TBD

Figure 7: SAE Charging Configurations and Ratings Terminology (Used with Permission of SAE International)

Voltages are nominal configuration operating voltages, not coupler rating.
Rated power is at nominal configuration operating voltage and coupler rated current.

SAE J1772™ has the following information:

> It is recommended that residential EVSEs input current rating be limited to 32 amp (40 amp branch breaker) unless the EVSE is part of a home energy management system. Residential EVSEs with input current ratings of greater than 32 amp without home energy management may require substantial infrastructure investment by the resident owner, utility, or both.

As noted, SAE J1772™ is used in the U.S. Many of the requirements found in SAE J1772™ are included in the IEC 61851 series of standards. IEC 61851, Parts 1 and 22, and the forthcoming Parts 23 and 24 include or will include other connectors that are used in Europe and other areas. The IEC 61851 series, developed by IEC/TC 69, addresses safety aspects and EVSE and the IEC 62196 series, developed by IEC/SC 23H, addresses the safety, dimensional compatibility and interchangeability of the connectors. All of these aspects are covered in SAE J1772™.

Europe has variations for the infrastructure since they have Case A, B & C, described in IEC 61851-1 and IEC 62196-1. Case A is when the cable is fixed to the vehicle. Case B is when the cable has a connector on both ends. Case C is when the cable is fixed to the EVSE. They also have Modes 1, 2, 3 & 4. The Modes and requirements are described in IEC 61851-1 (Ed. 2 (2010 edition) as follows (below text is directly excerpted from the standard):

- **Mode 1 charging:** connection of the EV to the a.c. supply network (mains) utilizing standardized socket-outlets not exceeding 16 A and not exceeding 250 V a.c. single-phase or 480 V a.c. three-phase, at the supply side, and utilizing the power and protective earth conductors.

  NOTE 2 In the following countries, mode 1 charging is prohibited by national codes: US.

  NOTE 3 The use of an in-cable RCD can be used to add supplementary protection for connection to existing a.c. supply networks.

  NOTE 4 Some countries may allow the use of an RCD of type AC for mode 1 vehicles connected to existing domestic installations: JP, SE.

- **Mode 2 charging:** connection of the EV to the a.c. supply network (mains) not exceeding 32 A and not exceeding 250 V a.c. single-phase or 480 V a.c. three-phase utilizing standardized single-phase or three-phase socket-outlets, and utilizing the power and protective earth conductors together with a control pilot function and system of personnel protection against electric shock (RCD) between the EV and the plug or as a part of the in-cable control box. The inline control box shall be located within 0,3 m of the plug or the EVSE or in the plug.

  NOTE 5 In the USA, a device which measures leakage current over a range of frequencies and trips at predefined levels of leakage current, based upon the frequency is required.

  NOTE 6 In the following countries, according to national codes, additional requirements are necessary to allow cord and plug connection to a.c. supply networks greater than 20 A, 125 V a.c.: US.

NOTE 7 For mode 2, portable RCD as defined in IEC 61540 and IEC 62335 is applicable.

NOTE 8 In Germany the inline control box (EVSE) shall be in the plug or located within 2,0 m of the plug.

- **Mode 3 charging:** connection of the EV to the a.c. supply network (mains) utilizing dedicated EVSE where the control pilot function extends to control equipment in the EVSE, permanently connected to the a.c. supply network (mains).
- **Mode 4 charging:** connection of the EV to the a.c. supply network (mains) utilizing an offboard charger where the control pilot function extends to equipment permanently connected to the a.c. supply.

It is recognized that vehicle manufacturers may have to design vehicles with regional kits that will allow the appropriate connector and voltage interface for the region of use.

Partial Gap: **EVSE charging levels.** At the time of release of version 1.0 of this roadmap, the levels for DC charging within SAE J1772™ had yet to be finalized.

Recommendation*:* Complete work to establish DC charging levels within SAE J1772™. ***Priority:*** Near-term. ***Potential Developer:*** SAE. ***Grid Related:*** Yes. ***Status of Progress:*** Closed. ***Update:*** With the publication of the new version of SAE J1772™, the gap identified in version 1.0 of this roadmap with respect to DC charging levels in SAE J1772™ is now closed.

EV Supply Equipment and Charging Systems

Off-board charging stations and portable EV cord sets are covered by UL 2594, Standard for Electric Vehicle Supply Equipment. Off-board chargers are covered by UL 2202, the Standard for Electric Vehicle (EV) Charging Equipment.

A North American harmonization effort has taken place based on UL 2594 involving CSA C22.2 No. 280 and similar requirements in Mexico to cover the safety requirements for off-board charging stations and portable EV cord sets, with respect to risk of fire, shock and injury to persons. As a result of this work, a tri-national standard was published in February 2013: NMX-J-677-ANCE/CSA C22.2 NO. 280-13/UL 2594, Standard for Electric Vehicle Supply Equipment. This aligns with the timing of the revision cycle of the 2014 National Electrical Code® (NEC®). There are additional technical items that will be addressed in a Phase 2 harmonization effort through the Council for Harmonization of Electrotechnical Standards of the Nations of the Americas (CANENA) upon the completion of this initial phase of harmonization.

UL 2594 references UL 2231 (Parts 1 and 2) as well as UL 2251, Standard for Plugs, Receptacles and Couplers for Electric Vehicles whose requirements are also being harmonized with CSA and ANCE to create North American standards.

In September 2012, the first two of these standards were published as North American standards. These were based on UL 2231-1 and 2231-2 respectively.

- 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.

These documents cover devices and systems intended for use in accordance with the NEC® Article 625 to reduce the risk of electric shock to the user from accessible parts, in grounded or isolated circuits for charging electric vehicles. They are intended to be read together.

Partial Gap: **Off-board charging station and portable EV cord set safety within North America.** At the time of release of version 1.0 of this roadmap, the harmonization of equipment safety standards within North America based on the UL 2594 standard was still underway.

Recommendation*:* Finish North American harmonization effort based on UL 2594 addressing off-board charging station and portable EV cord set safety ***Priority:*** Near-term. ***Potential Developer:*** UL, CSA, ANCE (Mexico), NEMA. ***Grid Related:*** Yes. ***Status of Progress:*** Closed. ***Update:*** With the publication of the tri-national North American standard based on UL 2594 in February 2013, the partial gap identified in version 1.0 of this roadmap regarding off-board charging station and portable EV cord set safety within North America is closed. There will be a need to address NEC® 2014 technical issues in the new tri-national standard. There are additional technical items that will be addressed in a Phase 2 harmonization effort through CANENA.

There is currently no harmonization effort in progress for UL 2202. However, the harmonization of the safety requirements for off-board chargers would be needed to address safety concerns in the same manner as harmonization of UL 2594 as stated above.

Partial Gap: **Off-board charger safety within North America.** Harmonization of equipment safety standards within North America is needed.

Recommendation*:* There appears to be a need to harmonize the safety requirements for off-board chargers with the U.S., Canada, and Mexico. ***Priority:*** Mid-term. ***Potential Developer:*** UL, CSA, ANCE (Mexico), NEMA. ***Grid Related:*** Yes. ***Status of Progress:*** Not started.

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, Ed. 2.0, Electric Vehicle Conductive Charging Systems, Part 1: General Requirements, (Ed. 3.0 currently under development with an anticipated publication date of March 2014); and

- IEC 61851-22, Ed. 2.0, Electric Vehicle Conductive Charging Systems, Part 22: AC Electric Vehicle Charging Stations (will be withdrawn upon publication of IEC 61851-1, Ed. 3.0).

The following standards are also under development in IEC/TC 69:

- IEC 61851-21-1, Ed. 1.0, Electric vehicle conductive charging system – EMC requirements for electric vehicle for conductive connection to an a.c./d.c. supply (publication anticipated in March 2014); and

- IEC 61851-21-2, Ed. 1.0, Electric vehicle conductive charging system – EMC requirements for off board electric vehicle charging systems (publication anticipated in March 2014).

These two new parts are intended to replace the existing IEC 61851-21, Ed. 1.0 (2001) Electric vehicle conductive charging system - Part 21: Electric vehicle requirements for conductive connection to an a.c./d.c. supply. This original Part 21 will be withdrawn, and replaced by the two subparts 1 and 2 noted above. The electrical requirements are being split and included in IEC 61851-1 and ISO 6469-3 and ISO 17409. The work to develop a 2nd edition of Part 21 has been stopped and will likely be canceled when Parts 21-1 and 21-2 are published.

Also being developed are:

- IEC 61851-23, Ed. 1.0, Electric vehicle conductive charging system – D.C. electric vehicle charging station (publication anticipated in December 2013); and

- IEC 61851-24, 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 (publication targeted for February 2014).

The IEC 61851-1 and 61851-22 standards have 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.

Partial Gap: **Off-board charger, off-board charging station and portable EV cord set safety globally.** There are some differences between the IEC 61851 series of standards and the North American standards. 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.

Recommendation*:* Work to harmonize the IEC 61851 series standards and the North American standards. ***Priority:*** Mid-term. ***Potential Developer:*** UL, IEC. ***Grid Related:*** Yes. ***Status of Progress:*** Not started.

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, and all will eventually be using the new harmonized tri-national standard (based on UL 2594).

EV Couplers: Safety and Harmonization Efforts

Today, UL 2251, Standard for Plugs, Receptacles and Couplers for Electric Vehicles, exists to cover for EV couplers. A North American harmonization effort has taken 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. As a result of this work, a tri-national standard was published in February 2013: NMX-J-678-ANCE/CSA C22.2 No. 282-13/UL 2251, Standard for Plugs, Receptacles and Couplers for Electric Vehicles.

Partial Gap: **EV coupler safety within North America.** At the time of publication of version 1.0 of this roadmap, harmonization of EV coupler safety standards within North America based on the UL 2251 standard was still underway.

Recommendation*:* Finish efforts to harmonize standards addressing EV coupler safety within North America. ***Priority:*** Near-term. ***Potential Developer:*** UL, CSA, ANCE (Mexico), NEMA. ***Grid Related:*** Yes. ***Status of Progress:*** Closed. ***Update:*** With the publication of the tri-national standard based on UL 2251 in February 2013, there are no gaps in standardization for EV coupler safety in North America and the partial gap identified in version 1.0 of this roadmap is closed. There are additional technical items that will be addressed in a Phase 2 harmonization effort through CANENA.

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

- IEC 62196-1, Ed. 2.0, Plugs, Socket-Outlets, Vehicle Connectors and Vehicle Inlets – Conductive Charging of Electric Vehicles – Part 1: General Requirements; and

- IEC 62196-2, Ed. 1.0, 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.

Based upon the continuing development of EV couplers and EV charging stations, IEC 62196 parts 1 and 2 are in a revision phase started in 2012 and continuing through 2013, with publication of new editions expected in the first half of 2014.

In addition to IEC 62196 parts 1 and 2, a new Part 3, Dimensional Compatibility and Interchangeability Requirements for Dedicated DC and combined AC/DC Pin and Contact-Tube Vehicle Couplers, is being developed. It will be similar to Part 2 in that it will standardize and contain all of the details to build either DC or AC/DC vehicle couplers. Publication is anticipated during the first half of 2014.

The IEC 62196 standards are similar in many respects to the North American standards. They go further in that the Part 2 and the developing Part 3 include or will include the specific vehicle inlet and connector interface (configuration) drawings, ratings information and other details to allow interchangeable devices to be made by many manufacturers. They also insure that other types of vehicle couplers used in other countries will not mismatch with the devices recommended by U.S. manufacturers.

There are some differences between IEC 62196 series standards and the existing North American 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 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. The fact that harmonized standards do not exist globally creates the situation where different connectors are being used in different geographic areas. In some cases, these differences cannot be eliminated because of differences in the infrastructure. In other cases, harmonization would be a good thing, but at the moment it would appear to be more of a mid-term goal.

Partial Gap: **EV coupler safety globally.** There are some differences between the IEC 62196 series standards and the North American EV coupler safety standards. While not a gap per se with respect to the U.S. market, global harmonization would help to reduce costs for vehicle manufacturers.

Recommendation*:* Work to harmonize the IEC 62196 series standards and the North American EV coupler safety standards. ***Priority:*** Mid-term. ***Potential Developer:*** UL, IEC. ***Grid Related:*** Yes. ***Status of Progress:*** Not started.

<u>Conformance Programs</u>

Section 1962.2, Title 13, of the California Code of Regulations, requires 2006 and later model year vehicles to be equipped with a conductive charger inlet port which meets all the specifications contained in SAE J1772™. This is also a requirement in states that have adopted the California Air Resources Board (CARB) zero emission vehicle (ZEV) requirements pursuant to section 177 of the federal Clean Air Act (42. U.S.C. Sec. 7507) ("S.177 states"). In March 2012, section 1962.2, Title 13, was amended so as to permit a manufacturer to apply for approval to use an alternative to the AC inlet specified in SAE J1772™ provided that the following conditions are met: (a) each vehicle is supplied with a rigid adaptor that would enable the vehicle to meet all of the remaining system and on-board charger requirements described in J1772™, and (b) the rigid adaptor and alternative inlet must be tested and approved by a Nationally Recognized Testing Laboratory (NRTL).

Various other 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, and all will eventually be using the new harmonized tri-national standard (based on UL 2251).

<u>EV Couplers: Interoperability with EVSE and Harmonization Efforts</u>

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.

As noted above, compliance requirements with respect to SAE J1772™ and the charger inlet port are specified in California's ZEV requirements which also apply to S.177 states. As such, it is currently the de facto EV charge coupler standard in the U.S.

Outside of the U.S. market, EV couplers are diverse:

- For AC charging, different connectors exist in Europe and China, while Japan uses the SAE J1772™ EV coupler and Korea has adapted SAE J1772™ to allow for a detachable charge cable; and

- For DC charging, Europe and China are developing their own EV coupler, while Japan is using the CHAdeMO configuration, and Korea has looked at both CHAdeMO, a modification of it, and SAE J1772™.

This diversity in the EV coupler has caused the need for different products to be manufactured for different countries as well as modifications to vehicles that will be shipped around the world.

As explained earlier, SAE International has revised the SAE J1772™ standard to include both AC and DC fast charging capabilities via the AC/DC combination coupler. The forthcoming IEC 62196-3 will describe the new SAE J1772™ combination coupler as well several other different DC coupler configurations (Japan, China, and Europe).

To date, the CHAdeMO configuration has been widely deployed for DC charging in North America. It is anticipated that vehicles and infrastructure outfitted to accommodate the new SAE J1772™ combination coupler will come to market in 2013.

Harmonization of EV couplers on a global scale would help to reduce costs for manufacturers of PEVs and charging infrastructure. However, due to 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 is not likely to occur. Also, with the advent of DC quick charging, the need to harmonize AC connectors has become less of an issue. Once sufficient infrastructure is in place, it may prove difficult to switch connector types, so the harmonization effort for DC connectors would be considered a near-term goal if it is going to happen.

Partial Gap: **EV coupler interoperability with EVSE globally.** Different coupler configurations are used in different parts of the world. Global harmonization would help to reduce costs for manufacturers. At the time of release of version 1.0 of this roadmap, the revision of SAE J1772™ was still in progress; it has now been published.

Recommendation*:* Incorporate the new SAE J1772™ combination coupler into IEC 62196-3. Build out the charging infrastructure to accommodate variations in EV coupler configurations for particular markets as necessary, in particular with respect to DC charging. ***Priority:*** Near-term. ***Potential Developer:*** SAE, IEC, CHAdeMO, vehicle and charging station manufacturers. ***Grid Related:*** Yes. ***Status of Progress:*** Green. ***Update:*** The roadmap version 1.0 text has been updated to note the publication of the SAE J1772™ AC/DC combination coupler and that the forthcoming IEC 62196-3 will describe the SAE J1772™ coupler and several other different DC coupler configurations used elsewhere. The gap statement notes the publication of SAE J1772™. The recommendation notes the need to incorporate SAE J1772™ into IEC 62196-3 and the need to build out the charging infrastructure to accommodate variations in coupler configurations for particular markets as necessary, in particular with respect to DC charging. CHAdeMO, and "vehicle and charging station manufacturers," have been added alongside SAE and IEC as "potential developers."

Conformance Programs

SAE is developing J2953, Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE), which will address interoperability in terms of both hardware requirements and communication protocols between PEVs and EVSE for multiple suppliers. A draft of the first part is expected to be published in the Spring of 2013.

There is also a verification program currently being developed by Underwriters Laboratories, Inc. that may be used to prove that infrastructure equipment, which includes the vehicle connector, will be compatible with all vehicles that meet the SAE J1772™ protocol for AC charging. A similar program is under development in Japan for the CHAdeMO EV coupler.

Gap: **Conformance programs for EV coupler interoperability within the U.S. market.** A program(s) is needed for the U.S. market to verify compatibility between the EV coupler, the infrastructure and the vehicle.

Recommendation*:* Complete work on SAE J2953. Establish a program(s) to verify interoperability between infrastructure equipment, including the vehicle connector, and all vehicles that follow the SAE J1772™ protocol. ***Priority:*** Near-term. ***Potential Developer:*** SAE, UL. ***Grid Related:*** Yes. ***Status of Progress:*** Green.

Light Electric Vehicles (LEV)

IEC/TC 69 has approved a new work proposal for a new 61851 Part 3, with subparts, to include requirements for power supply systems for Light Electric Vehicles (LEV), including electric motorcycles, bicycles and scooters.

The proposed standards will include:

- IEC 61851-3-1, Electric Vehicles conductive power supply system - Part 3-1: General Requirements for Light Electric Vehicles (LEV) AC and DC conductive power supply systems;
- IEC 61851-3-2, Electric Vehicles conductive power supply system - Part 3-2: Requirements for Light Electric Vehicles (LEV) DC off-board conductive power supply systems;
- IEC 61851-3-3, Electric Vehicles conductive power supply system - Part 3-3: Requirements for Light Electric Vehicles (LEV) battery swap systems; and
- IEC 61851-3-4, Electric Vehicles conductive power supply system - Part 3-4: Requirements for Light Electric Vehicles (LEV) communication.

This work will be done jointly with ISO TC 22/SC 22 & SC 23, with IEC/TC 69 having the lead. A first meeting is planned for May 2013, with a target date for publication of July 2015.

The National Electrical Code® includes neighborhood electric vehicles and electric motorcycles in the definition of EV because these are on-road vehicles that are expected to use the same or similar charging infrastructure as a car. However, there is not yet any standards activity in the U.S. specific for LEVs except for UL 2271, Batteries for use in Light Electric Vehicles (LEV), which covers both on-road and off-road vehicles including electric bicycles, electric scooters and electric wheel chairs. These types of vehicles are not expected to use the same charging infrastructure as an EV. In addition, off-road vehicles are excluded in the NEC® definition of EV.

4.2.1.4 Electromagnetic Compatibility (EMC)

SAE J551-1, Performance Levels and Methods of Measurement of Electromagnetic Compatibility of Vehicles, Boats (up to 15 m), and Machines (16.6 Hz to 18 GHz), covers the measurement of radio frequency (rf) radiated emissions and immunity. Each part details the requirements for a specific type of electromagnetic compatibility (EMC) test and the applicable frequency range of the test method. The methods are applicable to a vehicle . . . powered by an internal combustion engine or battery powered electric motor. As all of the vehicle tests are evaluating the complete vehicle, the source of power is immaterial. SAE J551-1 adopts by reference IEC CISPR 12 and CISPR 25 which apply to all vehicles and other equipment. CISPR 25 is in the process of being updated to adapt the test methods to safely test high voltage components in the vehicle. The SAE J1113 series covers EMC testing of vehicle components.

Presently, the only EV-specific standard for EMC is SAE J551-5-2012, Performance Levels and Methods of Measurement of Magnetic and Electric Field Strength from Electric Vehicles, 9 kHz to 30 MHz, which covers conducted emission measurements that are applicable only to battery-charging systems which utilize a switching frequency above 9 KHz, are mounted on the vehicle, and whose power is transferred by metallic conductors. Conducted emission requirements apply only during charging of the batteries from AC power lines. Conducted and radiated emissions measurements of battery-charging systems that use an induction power coupling device are not covered; radiated emissions for an electric vehicle in operation at a constant speed are covered.

As noted earlier, the following standards are under development in IEC/TC 69, both with an anticipated publication date of March 2014:

- IEC 61851-21-1, Ed. 1.0, Electric vehicle conductive charging system – EMC requirements for electric vehicle for conductive connection to an a.c./d.c. supply; and
- IEC 61851-21-2, Ed. 1.0, Electric vehicle conductive charging system – EMC requirements for off board electric vehicle charging systems.

Apparently, concerns are being raised on the limits contained in the committee draft for vote (CDV) for IEC 61851-21-2 that are being worked with IEC CISPR/B and the IEC Advisory Committee on Electromagnetic Compatibility (ACEC). There is a current international 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 are to 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 main source is the IEC 61000 series. The 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 61000 series has broad applicability in the infrastructure segment of the EV space.

IEC CISPR/D and ISO/TC 22/SC 3/WG 3 have been meeting back-to-back on a regular basis to address the vehicle EMC issue while not connected to the power grid. CISPR has a liaison relationship with IEC/TC 69. In addition, CISPR/B has been interacting with IEC/TC 69 in regard to emissions and the applicability of CISPR 11 during charging.

The SAE Surface Vehicle EMC (SV) Standards Committee is also addressing EMC issues. Subsets of this committee form the U.S. TAGS for CISPR/D and ISO/TC 22/SC 3/WG 3, respectively. There are SAE product committees that are addressing the charging of electric vehicles. SAE J1772™ includes EMC requirements for the conductive charging interface unit, referring to UL 2231-2 and FCC part 15. SAE J2954 is under development and will address inductive charging of electric vehicles. The SV EMC Standards Committee is supporting the J2954 document development in regard to rf issues.

Gap: **Electromagnetic compatibility (EMC).** Standards to address EMC issues related to electric vehicle charging are still in development.

Recommendation*:* Complete work on IEC 61851-21, Parts 1 and 2, and SAE J2954 to address EMC issues related to electric vehicle charging. ***Priority:*** Near-term. ***Potential Developer:*** IEC/TC 69, SAE. ***Grid Related:*** Yes. ***Status of Progress:*** New gap / Green.

4.2.1.5 Vehicle as Supply

Activities related to the EV as a distributed energy resource (DER) are being pursued by SAE and by the International Electrotechnical Commission (IEC). In many areas, these activities are being coordinated, such as the use cases, the DER functions for EVs, and the abstract object modeling. However, in a few areas distinctly different approaches are being taken, primarily with respect to the expected communications architectures and the protocols between the EV and external systems.

This coordination has been strong for use cases and the DER functions. SAE J2836/3™, published in January 2013, provides use cases for EV communication as a DER to allow an EV to support V2G applications serving the bulk grid, the distribution system, and behind the meter in a facility. The information exchange with the EV for these use cases was derived from the IEC/TR 61850-90-7 (TR signifies technical report) published in February 2013 which, in part, defines object models for inverter-based storage devices. The IEC plans to incorporate the changes defined by this technical report in the next planned update of the IEC 61850-7-420 standard. SAE J2836/3™ includes some additional information for using an EV as a DER, versus a stationary storage device, which should also be included in the planned revision of IEC 61850-7-420.

However, divergence is occurring when these DER functions are mapped to protocols. SAE is planning to use the Smart Energy Profile 2.0 (SEP 2.0), while it is unlikely that the IEC will accept SEP 2.0 as the preferred protocol, partly due to its use of the RESTful web services approach.

The DER function in SEP 2.0 is based on IEC/TR 61850-90-7 but also includes the additional information required by SAE J2836/3™. SAE J2847/3, currently in development, shows how the Flow Reservation and DER functions of SEP 2.0 can be used to implement the use cases and V2G applications defined in J2836/3™. These additional information items are being provided back to the IEC for possible update of the object models in appropriate IEC documents (such as IEC/TR 61850-90-8 that is still in development and eventually IEC 61850-7-420).

While the primary purpose of SAE J2836/3™ is to present use cases for communication with a PEV as a DER, this document also provides a broader view of the issues associated with reverse power flow (RPF). It defines some "requirements" for reverse power flow, but because the document is only a technical information report, any actual requirements will need to be incorporated in future revisions of actual recommended practices and standards. SAE J2847/3 will achieve this for DER communications. Architecture and safety aspects associated with reverse flow would need to be incorporated in SAE J1772™ and other standards.

The customer interfaces and selection for these features will be included in SAE J2836/5™ and J2847/5. The /5 documents include the two networks that are: (1) the Customer Network for Customer to EV and Home Area Network (HAN)/Neighborhood Area Network (NAN) interface and (2) the Utility Network for Energy Services Interface (ESI) to EVSE/EV communication. As with the /3 documents, SAE J2836/5™ identifies the use case and general information that corresponds to SAE J2847/5 for messages details. This is a coordinated effort of the EV, EVSE and ESI for the various combinations of RPF.

Section 625.26, Interactive Systems, of the NEC® provides that EVSE and other parts of a system, either on-board or off-board the vehicle, that are identified for and intended to be interconnected to a vehicle, and also serve as an optional standby system or an electric power production source, or provide for bi-directional power feed, shall be listed as suitable for that purpose. When used as an "Optional Standby System" (i.e., V2H), the requirements of Article 702 shall apply, and when used as an "Electric Power Production Source" (i.e., V2G), the requirements of Article 705 shall apply. The on-board or external inverter is considered to be a "Utility-Interactive Inverter" for which there are special requirements in the NEC®. The NEC® adequately provides for an EV serving as either a standby system or a grid interactive system, and changes to the NEC® specifically to accommodate EV applications are not anticipated.

The safety standard UL 1741, Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources, applies to an EV engaged in V2G. For utility-interactive equipment, UL 1741 is intended to supplement and be used in conjunction with IEEE 1547™, Standard for Interconnecting Distributed Resources with Electric Power Systems, and IEEE 1547.1™, Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems.

IEEE 1547.4™, Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems, was released in July 2011 and may apply to certain V2G applications. IEEE 1547.8™, Recommended Practice for Establishing Methods and Procedures that Provide Supplemental

Support for Implementation Strategies for Expanded Use of IEEE Standard 1547™, is currently being developed and will introduce new advanced capabilities for utility-interactive inverters that could also impact V2G operations. Updates to Article 705 of the NEC® and UL 1741 may be required to accommodate new DER capabilities.

Gap: **Vehicle as supply / reverse power flow.** Differences exist between the DER model defined by SAE J2836/3™, IEC/TR 61850-90-7, IEC/TR 61850-90-8, and SEP 2.0.

Recommendation*:* Harmonize the information model for an EV as a DER between SAE J2836/3™, IEC/TR 61850-90-8, and SEP 2.0. ***Priority:*** Near-term. ***Potential Developer:*** SAE, IEC/TC 57, ZigBee Alliance and the HomePlug Powerline Alliance. ***Grid Related:*** Yes. ***Status of Progress:*** Green. ***Update:*** The roadmap version 1.0 text, gap statement, recommendation and list of potential developers have been substantially reworked to focus specifically on the need for harmonization of the DER communications model between SAE J2836/3™, IEC/TR 61850-90-8, and SEP 2.0. Potential changes to other standards to address integration of inverter-based DER devices with the grid, or architecture and safety aspects of reverse power flow, are contemplated in the text but not included as a gap.

4.2.1.6 Use of Alternative Power Sources

Much of the focus has been about electric vehicle charging using the bulk electric power system. But there may be cases where alternative power sources could be used to provide power for charging an EV. A solar PV array, small wind turbine, facility battery bank, or even another EV with reverse power flow capability could be used to provide power for charging an EV in a facility. These alternate sources could operate as optional standby systems under Article 702 of the NEC® or as electric power production sources under Article 705 of the NEC® and provide AC power to the facility. The AC power could be used for charging EVs and for other loads within the facility. However, it may be more efficient to use DC power distribution rather than AC power distribution for this purpose. All of the facility power sources as well as certain DC loads could connect to a DC power distribution system which would connect to the electric power system using a single converter.

The EMerge Alliance is developing standards for a 380 VDC power distribution system. 600 VDC systems have also been considered for use with PV arrays. It is not possible to directly connect an EV to a facility DC power bus because of differences between the EV battery voltage and the facility bus voltage and the need to precisely control the charging current into the EV battery. However this is easily done using a DC to DC converter, such as a buck-boost converter. The EVSE for DC charging is generally thought of as an AC-DC converter, or bi-directional converter for reverse power flow, but a DC-DC EVSE could easily be used if the facility used a DC power distribution system.

Solar: ANSI/UL 1703, the standard for safety of photovoltaic (PV) equipment, and other UL standards, address safety of PV modules. The National Electrical Code® contains requirements for PV systems in Article 690. Car “sheds” with PV panel roofs and directly coupled EVSE beneath are being constructed but are not specifically covered by standards at this time.

Wind: Small wind systems are addressed in NEC® Article 694. Consensus product standards are under development for wind systems and should be published shortly. Wind power as a supply source is also the subject of a proposed revision to the NEC® to include DC voltages up to 600 volts.

Battery banks: Battery banks are another alternative source of DC power. They can be charged off-peak and used to charge vehicles directly. Battery banks are being addressed by a code proposal on NEC® Section 625.4 to include power sources up to 600 volts DC.

V2G and V2H: As discussed in the prior section, Vehicle to Grid (V2G) and Vehicle to Home (V2H) power schemes have been discussed and anticipated. The reserved energy in an EV battery may be used for power quality, power efficiency, or emergency source measures. Articles 702 and 705 of the NEC® would apply to how the entire DC system connects through the utility-interactive inverter to the electric power system, but there is a gap for requirements between the EV and EVSE and the DC power distribution system.

Gap: **Use of alternative power sources.** The National Electrical Code® does not specifically address the integration of the EV and EVSE with a facility high voltage DC power distribution system for either charging or reverse power flow.

Recommendation*:* Develop NEC® requirements for high voltage DC power distribution systems and the integration of distributed energy resources and DC loads with the system*.* ***Priority:*** Near-term. ***Potential Developer:*** NFPA. ***Grid Related:*** Yes. ***Status of Progress:*** Green

4.2.2 Infrastructure Communications

4.2.2.1 Communications Architecture for EV Charging

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 3 – IEC/TC 69 Joint Working Group (JWG) developing the ISO/IEC 15118 standards. Other standards such as Smart Energy Profile 2.0 (SEP 2.0), developed by the ZigBee Alliance and the HomePlug Powerline Alliance and completed in April 2013, and Open Automated Demand Response (OpenADR), in development by the Open Smart Grid User's Group (OpenSG), are also incorporating EV charging-related communications.

Currently, charging-related communication between the EV and EVSE for conductive charging has been standardized in SAE J1772™ (and in IEC 61851-1). 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 determine if the EV requires indoor ventilation and 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 is currently developing standards for EV communication that go beyond SAE J1772™ and define communications functions for utility communications, DC charging, reverse power flow, diagnostics, Customer-to-EV/HAN/NAN, and wireless charging. Figure 8 shows the interaction between the SAE EV communications standards documents. These can be stand-alone (e.g., DC charging) or combined (reverse power flow with off-board conversion includes both SAE J2847/2 plus /3 messages). The figure uses a Venn diagram approach to show the fundamental documents (SAE J2836™, J2847 & J2931) "wrapped" by the interoperability document(s) J2953 and finally the security document J2931/7.

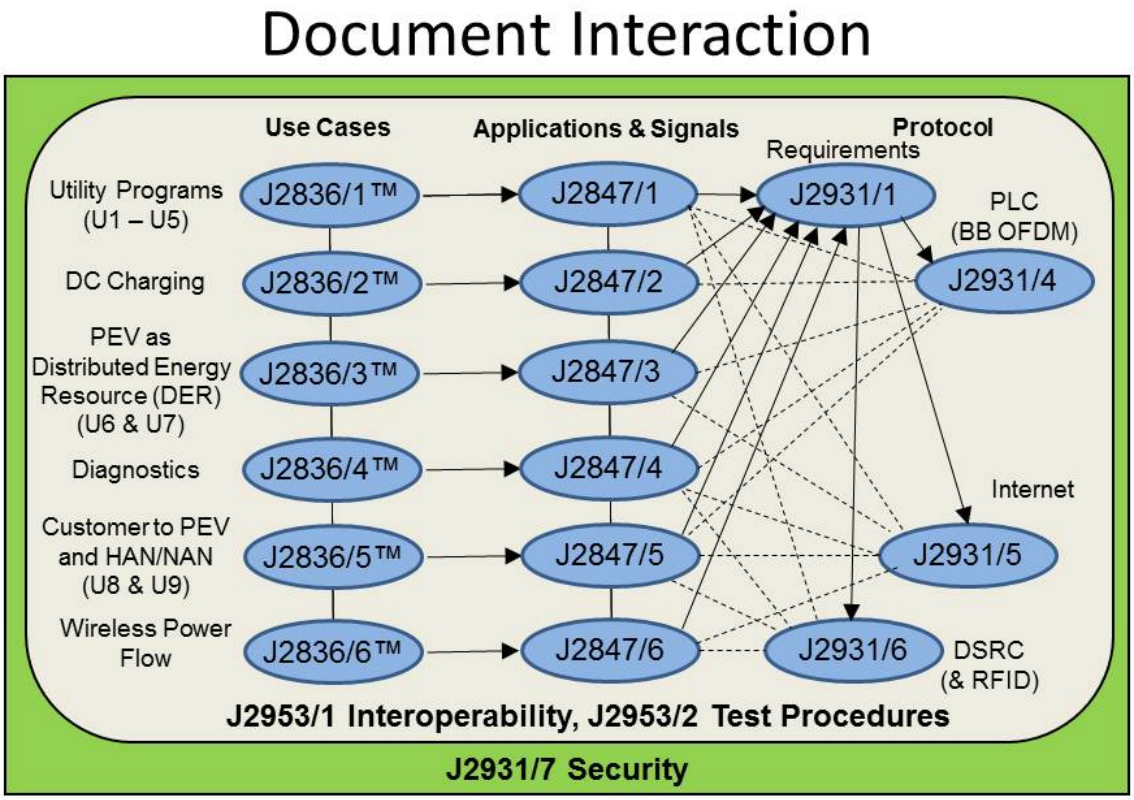

Figure 8: The Interaction of SAE EV Communication Standards Documents
(Used with Permission of SAE International)

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.

SAE J2931/4, published in July 2012, is based on HomePlug Green PHY™ which is an interoperable subset of IEEE 1901-2010 (which is, in turn, based on HomePlug AV). EPRI and the DOE national labs have done testing of PLC products to ensure that the technology meets the requirements in SAE J2931/1, published in January 2012. Additional testing is planned by vehicle manufacturers. EMC testing and standards implementation via field testing will provide feedback prior to a final determination leading to standards updates and a production release for PEVs and EVSEs.

SAE J2953, under development, identifies the interoperability criteria for the various mediums (PLC, telematics, DSRC, etc.) and associated communications protocols identified in J2931. Security is included specifically in J2931/7, under development, and may have slight variations dependent on Smart Energy Profile (SEP) 2.0 utility requirements, DC charging/discharging, and where the PEV is controlling the off-board unit for wireless charging communication.

Harmonization Efforts

The ISO/IEC Joint Working Group (JWG) is working on EV communication standards concurrently with SAE. The ISO/IEC 15118 EV communications standards are related to the SAE documents as follows: ISO/IEC 15118 part 1 identifies use cases, part 2 message details and communication protocol, and part 3 physical and data link communications layers. ISO/IEC 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 ISO/IEC 15118 series also includes DC charging use cases and messages that correspond to dash 2 of SAE J2836™ and J2847 (the same as in IEC 61851-24, Annex C).

Also to be developed are: ISO/IEC 15118-4, which defines the vehicle to grid communication network and application protocol conformance test cases to be applied to EVs and EVSEs implementing ISO/IEC 15118-2; and ISO/IEC 15118-5, which defines the vehicle to grid communication physical layer and data link layer conformance test to test the implementation of ISO/IEC 15118-3. Both of these documents will provide test cases representing the use cases in ISO/IEC 15118-1, and include standard test case attributes such as pre-conditions, test steps, expected results to evaluate a pass or fail, and post-conditions. SAE has a parallel standard J2953 focused on interoperability testing that will include test cases harmonized with ISO/IEC 15118-4 and 5.

In addition to the SAE and ISO/IEC standards, the Smart Energy Profile (SEP) 2.0 specification, based on the OpenHAN requirements, is expected to provide much of the EV-related services identified by regulators, policy makers, ESPs/utilities, EVSPs and vendors. Though not EV specific, this standard-in-progress pertains to the energy-related infrastructure (e.g., thermostats, plugs, meters, displays, EVSE, EV, etc.). It specifies communications to be used for pricing, demand response load control (DRLC), distributed energy resources (DER) control, metering, billing, and other functions. SEP 2.0 is harmonized with J2836/1™ and is being used as the basis of a revision to J2847/1.

In addition to the coverage of DRLC in the SEP 2.0 specification, Open Automated Demand Response (OpenADR) 2.0 contains EV-specific communication and is expected to be harmonized with SEP 2.0 for building infrastructure communication and aggregator functionality. It is anticipated that ESPs, and possibly EVSPs, will use OpenADR for their automated demand response requirements.

For open and interoperable machine-to-machine (M2M) communication between entities such as ESPs and EVSPs related to EV customer information (e.g., for pricing, metering, billing, and usage information), the North American Energy Standards Board (NAESB) has completed work on the Energy

Services Provider Interface (ESPI) standard. A sub-metering profile of Green Button Connect my Data (using the ESPI format) is nearing completion.

The ISO/IEC JWG and Zigbee Alliance / HomePlug Powerline Alliance are working with SAE to harmonize common standards related to utility and DC messaging.

SAE utility messages (SAE J2847/1) correspond with the SEP 2.0 criteria per the Smart Energy 2.0 Technical Requirements Document (TRD) and the Application Specification that has now passed public comment approval. SAE's J2836/1™ use cases were included in the ZigBee + HomePlug Smart Energy Marketing Requirements Document (MRD) that led to the TRD.

SAE is also working on the DC message format with the objective of harmonizing with ISO/IEC. DC charging information in SAE J2847/2 is being included in Annex C of IEC 61851-24, and ISO/IEC 15118-2 is being included in Annex D. In the future, these annexes may be replaced by a harmonized solution in the body of the IEC 61851-24 document. As PLC testing continues, it is expected that goals can be met and both utility and DC charging messages can be harmonized.

4.2.2.2 Communications Requirements for Various EV Charging Scenarios

Locating and Using Public Charging Stations (EVSE)

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. Presently, such a capability is available for only a subset of stations via Google Maps, websites of EVSPs, smartphone applications, or navigation applications/devices. Notably, DOE provides an Alternative Fuel Station Locator database which includes EV charging station information at: http://www.afdc.energy.gov/afdc/locator/stations/.

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.

Reserving Charging Stations (EVSE): 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.

Gap: **Locating and reserving a public charging station**. There is a need for a messaging standard to permit EV drivers to locate a public charging spot and reserve its use in advance.

Recommendation: Develop a messaging standard to permit EV drivers to universally locate and reserve a public charging spot. ***Priority***: Mid-term. ***Potential Developer***: SAE, ISO/IEC JWG, NEMA. ***Grid Related:*** Yes. ***Status of Progress:*** Green. ***Update:*** To address this roadmap version 1.0 gap, NEMA's EVSE section organized a working group (NEMA 5EVSE Network Roaming WG) to develop a standard that permits EV drivers to universally locate a public charging spot. It decided that reserving a public charging spot was a low priority and deferred action on reservations to a later phase of work.

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.

Gap: **Charging of roaming EVs between EVSPs**. There is a need to permit roaming EVs to charge at spots affiliated with a different EVSP.

Recommendation: Develop back end requirements as well as an interface standard that supports charging of roaming EVs between EVSPs. ***Priority***: Near-term. ***Potential Developer***: NEMA, IEC. ***Grid Related:*** Yes. ***Status of Progress:*** Green. ***Update:*** To address this roadmap version 1.0 gap, NEMA's EVSE section organized a working group (NEMA 5EVSE Network Roaming WG) to develop a standard that supports roaming that allows charging services from a provider other than the Home EVSP. The standard will include inter-operator interfaces to address the various stages of a charging session (e.g., authentication/authorization, charging data records, billing record exchange.) The NEMA working group also is looking to develop a radio-frequency identification (RFID) credential protocol specification so that all EVSEs that implement the specification will be able to read RFID cards that conform to the specification. IEC also has initiated work on IEC 62831 Ed. 1.0, User identification in Electric Vehicle Service Equipment using a smartcard, which describes the physical and protocol layers of an RFID card used in charging spots.

In addition, a new group called eMI^3 has been formed as an innovation platform under the aegis of ERTICO (www.ertico.com). This group has brought together several significant players and eMobility projects in the European EV mobility market, including auto OEMs, enterprise software vendors and EV Services Providers, who recognize that the business realities will result in the existence of multiple EV charging providers who need to interoperate in order to allow EV drivers to seamlessly charge across provider and geographic boundaries. Its scope is to harmonize and develop ICT (information and communication technology) standards and implementations in order to enable global EV services interoperability. The work to be undertaken in this group overlaps with the NEMA work. The two organizations are considering a liaison agreement to facilitate information exchange.

Access Control: In some cases, charging station owners may choose to restrict use of their charging stations. For example, an enterprise may restrict daytime charging to employees only, and allow non-employees to charge at night or during weekends. There are two facets of access control that can benefit from standardization. First, a standard definition of access control data and standard messaging to communicate the access lists to EVSEs would ease implementation of access control across EVSE vendors. Second, the ability to communicate access lists to EVSEs would allow for offline access control checks for situations when network connectivity of an EVSE is down.

Gap: **Access control at charging stations**. There is a need to develop data definition and messaging standards for communicating access control at charging stations.

Recommendation: Develop data definition and messaging standards for communicating access control at charging stations. ***Priority***: Near-term. ***Potential Developer***: NEMA. ***Grid Related:*** Yes. ***Status of Progress:*** Yellow. ***Update:*** The NEMA 5EVSE Network Roaming WG also looked at this roadmap version 1.0 gap. It decided that offline access control lists were a low priority and deferred action on offline access control to a later phase of work.

Communication Between EVSEs and Charging Network Operating Systems: The Open Charge Point Protocol (OCPP) was initiated by a Dutch consortium (called E-laad) of grid operators to provide interoperability between EVSEs and charging networks from different vendors and to reduce the effort required to support multiple EVSEs and/or networks. This standard is still evolving and will require a lot of work before it stabilizes. OCPP currently does not involve the grid (utilities) or EVs, and does not support forward-looking features like V2G energy transfer. In the U.S., some argue that the internal protocols between EVSE vendors and charging networks do not need to be standardized as long as external interfaces like SEP 2.0, OpenADR, etc. are supported.

The eMI^3 group in Europe is considering standards for communication between EVSEs and charging network operating systems. It is working with the Green eMotion Project (www.greenemotion-project.eu) to formulate a joint proposal to IEC for development of a standard for communication between EVSEs and the network back end. The proposed protocol may end up being OCPP, or an alternative proposed by Green eMotion, or some combination of the two.

There is also work ongoing in Europe in the area of inter-operator interoperability, similar to the NEMA work but possibly different in architecture. An example of this is the Open Clearing House Protocol (OCHP), which can be used by a charging network to communicate with a clearinghouse or broker, for the purpose of finding and reserving stations, and clearing and settlement of bills, when an EV charges on a "foreign" charging network. The Hubject joint venture in Europe also addresses the same set of needs, by developing a central platform that allows eMobility related services to be offered and consumed by different providers and consumers.

4.2.2.3 Communication and Measurement of EV Energy Consumption

Overview

The basis of the following assessment is for billing purposes only although metering communication could be used for customer information and control through the HAN (e.g., using SEP2.0) or vendor provided value added services (e.g., using smartphone applications).

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 (Figure 9). It is possible for the master meter and sub-meter to be on two different rates. Where used for billing today, because of volume, complexity, and existing capabilities, a manual process is usually used to collect, subtract, and bill sub-metering customers.

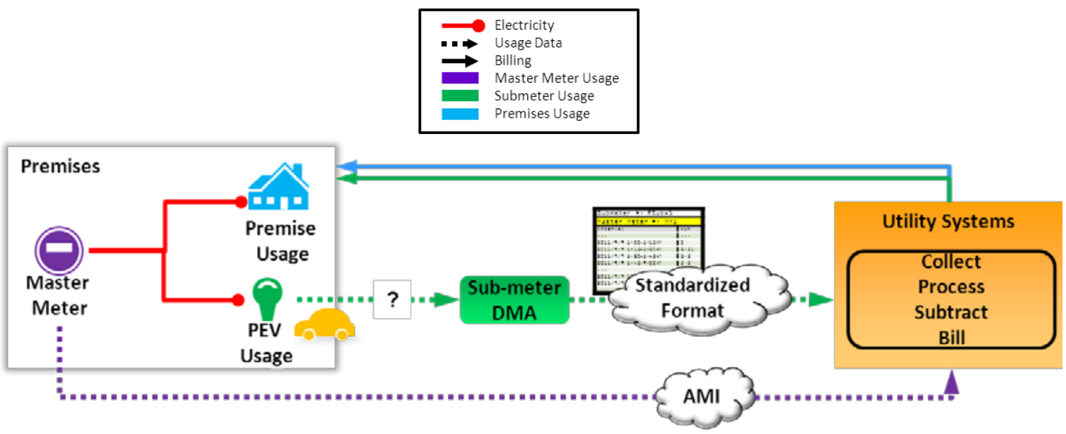

Figure 9: Third Party Sub-metering- The simplest use case as defined in the California Public Utilities Commission sub-metering activities.

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 (e.g., using Zigbee mesh communications). The SEP 2.0 HAN standard could be implemented on the sub-meter to send the data to back office systems.

Another sub-meter option currently being 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 theoretically be located anywhere downstream of the master meter including on a smart plug, on the EVSE, or even in the PEV. These use cases have been defined in the existing CPUC sub-metering protocol work.[6]

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 or expected metering communication standard (e.g., ANSI C12 developed by NEMA (ASC/C12), SEP 2.0). 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 premises usage, apply tariffs, and complete the billing processes. Though simple enough in theory, additional complications arise based on the location of the sub-meter (EVSE, smart plug, PEV, mobile cordset), 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 new types of metering and use cases create additional complexity including sub-meter measurement (accuracy), access, performance, security/privacy, and communications, for example, 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 premises 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. 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 SEP2.0 for utilities), depending on regulatory and utility policies.

Standardization Activities

Two broad areas of standardization related to sub-metering have been identified and are currently at some stage of completion. The first is the standardized 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. This work is ongoing in the

[6] http://www.cpuc.ca.gov/NR/rdonlyres/01349C2F-3934-4D3C-AEA5-905367C19A49/0/Submetering_Workshop_Joint_IOU.ppt

OpenADE working group, which is currently completing a Green Button Sub-metering Profile of ESPI that will include testing and certification.

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

Recommendation: Complete Green Button Sub-metering Profile of ESPI for communication of standardized EV sub-metering data, for example, between a third party and a billing agent (e.g., utility). ***Priority***: Near-term. ***Potential Developer:*** OpenADE/NAESB. ***Grid Related:*** Yes. ***Status of Progress:*** Green. ***Update:*** The roadmap version 1.0 text, gap statement, recommendation and potential developers have been revised to be specific about communication of EV sub-metering data between third parties and service providers and to complete work on the Green Button Sub-metering Profile of ESPI.

Besides the utility interface standard, requirements and guidelines related to the standardization of these third party sub-meters are being explored further by three separate activities discussed below: NEMA, NIST, and the Smart Grid Interoperability Panel V2G Domain Expert Working Group (SGIP V2G DEWG).

NEMA

NEMA has organized a working group (NEMA 5EVSE Submetering WG) that is developing a guide for EVSE embedded metering and communication. The purpose of this document is to provide guidance for EVSE applications that include an embedded meter incorporating a communication protocol for monitoring or monitoring and control. Recognizing that many codes, standards and regulatory documents relative to EVSE metering already exist, this guide will point to specific codes and standards already in place that determine the requirements specific to meter accuracy and communication protocols. Stakeholders expected to benefit from this document include EVSE manufacturers, utilities, automakers, smart meter manufacturers, EV drivers, EVSE owners, and regulators.

The scope of the NEMA guide provides that the embedded meter may or may not be a “revenue grade” meter. The document encompasses the North American types of meters that are emerging within EVSEs including embedded meters. It is intended to address the different form factors, capabilities, installations and certifications. The guide will also attempt to determine the optimal authority and jurisdictional span for metering certification. The guide will recommend a tiered key functionality for embedded meters including tamper resistance, accuracy, calibration, communication, security, and reliability. An example of the proposed approach is the NEMA ratings for embedded meters similar to NEMA enclosure ratings. The applicable EVSEs in the document include Level 1 and Level 2 (AC and DC).

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

In August 2012, NIST formed the U.S. National Work Group on Measuring Systems for Electric Vehicle Fueling and Submetering (USNWG EVF&S) 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 metered electricity is consumed by the end purchaser and that falls under the authority of entities such as the local utility commission.

The USNWG EVF&S's technical output may result in the revision of current standards or the development of new standards for requirements and testing procedures for commercial devices and systems used to assess fees and charges to consumers for electric vehicle fuel. The output of the USNWG EVF&S will be submitted to be published in documents such as NIST Handbook 130 *Uniform Laws and Regulations in the Areas of Legal Metrology and Engine Fuel Quality;* NIST Handbook 44 *Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices*; the NIST Handbook 105 Series for field standards; and NIST Examination Procedure Outlines.

SGIP V2G DEWG

The SGIP V2G DEWG has initiated a Priority Action Plan to establish a Sub-Meter Standards Working Group consisting of representatives from NEMA, USNWG EVF&S, national labs, automakers, utilities, and EVSE manufacturers to administer and coordinate the development of sub-meter standards for mobile and stationary applications. Presently, the requirements for standardization of sub-meters are not well defined nor understood by all involved parties. The primary elements to be addressed are access, accuracy, form factor, tamper resistance, performance, reliability, data requirements, security, testing and certification. The SGIP Priority Action Plan Sub-Meter working group is to: coordinate the definition of sub-meter requirements, map the requirements to existing meter standards, engage the cognizant organizations to address specified gaps in existing meter standards, and develop new standards if deemed necessary. The resulting standards documentation will be evaluated for approval by the SGIP for incorporation into the SGIP Catalog of Standards.

Gap: **Standardization of EV sub-meters**. Standards for EV sub-meters, including embedded sub-meters, need to be completed to address performance, security/privacy, access, and data aspects.

Recommendation: Develop standards or guidelines related to the functionality and measurement characteristics of the new types of sub-meters that are coming out for EVs, including embedded sub-meters in the EVSE or EV. Such standards should address different form factors, capabilities, installation, and certification. ***Priority***: Near-term. ***Potential Developer:*** NEMA, USNWG EVF&S. ***Grid Related:*** Yes. ***Status of Progress:*** New gap/ Green.

Gap: **Coordination of EV sub-metering activities**. Various existing activities (NEMA, USNWG EVF&S, SGIP V2G DEWG) need to be coordinated as much as possible.

Recommendation: 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. ***Priority***: Near-term. ***Potential Developer:*** NEMA, USNWG EVF&S, SGIP V2G DEWG. ***Grid Related:*** Yes. ***Status of Progress:*** New gap / Green.

4.2.2.4 Cyber Security and Data Privacy

SAE J2931/7, Security for Plug-in Electric Vehicle Communications, currently in development, is looking to define use cases and security requirements for the digital communications and data in transit between the following devices:

- Plug-in Electric Vehicle (PEV) and the Energy Service Interface (ESI);
- PEV and the Electrical Vehicle Supply Equipment (EVSE);
- EVSE and the Energy Management System, and/or ESI; and
- Wireless charging communication between the PEV and wireless charger.

It also looks at use cases and security requirements concerning protection of data at rest within the devices.

ISO/IEC 15118-1 includes a subsection on security but does not address things like how certificates can be stored, how data can be compromised, etc.

The current version of *NISTIR 7628, Guidelines for Smart Grid Cyber Security, Volume 2: Privacy and the Smart Grid* (published in August 2010, http://csrc.nist.gov/publications/nistir/ir7628/nistir-7628_vol2.pdf), includes a use case relating to privacy and EVs which keys off of the OECD Privacy Guidelines. NISTIR 7628, Volume 2, is in the process of being substantially reworked in light of SAE J2836™.

Gap: **Cyber security and data privacy.** There is a need for guidelines and standards to address cyber security and data privacy concerns associated with PEVs and smart grid communications.

Recommendation*:* Complete work to develop SAE J2931/7, and to revise ISO/IEC 15118-1 and NISTIR 7628, volume 2. ***Priority:*** Near-term. ***Potential Developer:*** SAE, ISO/IEC JWG, NIST. ***Grid Related:*** Yes. ***Status of Progress:*** New gap / Green.

4.2.2.5 Telematics Smart Grid Communications

Use cases are to be developed to determine whether Energy Service Provider requirements are not met by existing standards and architectures. Among these might be aggregation control for ancillary services, vehicle information for distribution load management, and access to dynamic consumer behavior data (e.g., instantaneous usage, consumption usage, volts, amps, VAR, power factor, etc.). The use cases will be defined in SAE J2836/5™ through mapping to existing use cases for J2836/1™, J2836/3™, and existing standards such as OpenADR 2.0 to assess and identify any gaps in the function sets.

Gap: **Telematics smart grid communications.** There is a need to develop use cases related to non-utility aggregation control and vehicle information in order to assess the existing functionalities, and to determine any missing requirements within the context of existing standards, Energy Service Provider business requirements, and telematics networks to support smart grid load management.

Recommendation*:* Complete work to develop SAE J2836/5 ™. ***Priority:*** Near-term. ***Potential Developer:*** SAE. ***Grid Related:*** Yes. ***Status of Progress:*** New gap / Green.

4.2.3 Infrastructure Installation

4.2.3.1 Site Assessment / Power Capacity Assessment

The National Electrical Code® (NEC®) provides minimum requirements for performing site assessments, specifically NEC® Articles 210, 215, and 220 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. Pursuant to a Tentative Interim Amendment (TIA) to the 2011 NEC®, 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 3 hours but is calculated at 125% of the nameplate current rating. Section 625.14 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 needs to occur:

- Conduct site visit;
- Inventory electrical equipment;
- Interview the facility occupants to determine the cyclical daily and seasonal loading of the facility;
- 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

The site assessment is also required to verify acceptable location(s) of the EVSE and conformance 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 any other state or local zoning regulations. Note that 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 detailed information about performing site assessments and installation of EVSE in new and existing electrical systems. NECA 413 covers the following related to performing effective site assessments:

- Supply Equipment/Charging Power Selection: AC Level 1, AC Level 2, Fast Charging;
- Charging Equipment (Type): Conductive, Inductive;
- Service or Power Capacity (load on new and existing systems or services);
- Electrical Load Calculations;
- Site Selection and Preparation;
- Zoning and Site Restrictions;
- 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
- Time of Use or Off-Peak Metering Installation(s).

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.

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

Harmonization Efforts

A harmonization assessment has been 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. This effort is nearly complete.

4.2.3.2 EV Charging – Signage and Parking

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. 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.[7]

The U.S. Department of Energy's Clean Cities program has been working with various stakeholders to raise awareness of the importance of clear and consistent signage for EV charging. This includes: working with agencies such as DOT, convening stakeholders to promote uniformity in way-finding and regulatory signage, identifying best practices and disseminating case studies on successful signage implementation, and encouraging sound and strategic investments in increased signage to support the deployment of EVs.

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

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[7] http://mutcd.fhwa.dot.gov/resources/interim_approval/ia13/

Parking Space Allocation

Currently, the model International Green Construction Code™ (IgCC™) has an elective provision requiring that for covered buildings[8] 5 percent of, but not less than two, parking spaces shall be reserved for low emission, hybrid and electric vehicles (IgCC™, PV2, Sec. 403.4.2). There are no current standards or model code provisions within either the IBC® or IgCC™ requiring EV only parking or charging. At some point, this may be desirable. Recommendations for new code provisions would have to be made and accepted as part of the normal code revision cycle. The state of California does have 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.

4.2.3.3 Charging Station Permitting

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.

[8] Generally, the IgCC™ scope covers all commercial buildings, except residential buildings. The IgCC™ applies to the construction of all buildings, both old and new, except IRC® buildings, R-3 occupancies, R-2 and R-4 occupancies 4 stories or less in height. These exceptions are regulated by ICC 700, the National Green Building Standard™, where the jurisdiction indicates so in Table 302.1.

Residential Permitting: 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®), published by NFPA. 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 2011 NEC® to cover EV charging systems and their installation. The DOE Clean Cities program has published information which may be used as a starting point for jurisdictions looking to establish permitting procedures for EVSE.[9]

Commercial/Public Permitting: 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 commercial buildings and residential buildings of 4 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.

No standards gaps have been identified at this time with respect to this issue. See, however, the education and training section in relation to raising awareness among code officials regarding this issue.

Harmonization Efforts

No gaps have been identified at this time as permitting is a local issue and as such does not really lend itself to harmonization.

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[9] http://www.afdc.energy.gov/vehicles/electric_deployment.html

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.

No gaps have been identified at this time.

4.2.3.4 Environmental and Use Conditions

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 enclosure type designations and related testing. Environmental considerations 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 as well as occupancy exposures. For example, in a parking garage, there may be more potential for exposure to vehicle impact damage. Parking garages may be required to comply with NFPA 88A, Standard for Parking Structures, 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 would be that electric vehicles are likely to use automotive service stations. Parts of these stations are considered to be hazardous locations in accordance with NFPA 30A, Code for Motor Fuel Dispensing Facilities and Repair Garages, 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.

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

4.2.3.5 Ventilation – Multiple Charging Vehicles

Most batteries used in electric vehicles manufactured by major automakers do not emit hydrogen gas in quantities that could cause an explosion. Preventive measures such as mechanical or passive ventilation are not required.

SAE Standards

SAE International's recommended practice SAE J-1718, Measurement of Hydrogen Gas Emission from Battery-Powered Passenger Cars and Light Trucks During Battery Charging, can be used to assess suitability for indoor charging. This standard includes provisions for tests during normal charging operations and potential equipment failure modes.

NEC® Code Provisions

Some electric vehicles will require ventilation because they use batteries that generate hydrogen. Section 625.29(D) of the NEC® has requirements for ventilation for single and multiple vehicles, and Section 625.15(B)&(C) provides ventilation labeling requirements for EVSEs.

ICC Code Provisions

The model International Residential Code® for One- and Two-Family Dwellings (IRC®) has specific requirements regulating ventilation requirements for "hydrogen generating and refueling operations." Such requirements could be referenced or modified for similar ventilation issues, should they exist with respect to EV charging operations. The IRC® scope includes one and two family dwellings, as well as multi-family dwellings of three stories or less in height.

The model International Building Code® (IBC®) has provisions requiring a ventilation system in all "Enclosed Parking Garages." The ventilation system must meet requirements of the International Mechanical Code® (IMC®), which is referenced in the IBC®. The IBC® scope includes all commercial buildings, as well as all residential buildings of more than 3 stories in height.

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

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.

4.2.3.6 Guarding of EVSE

In general, available information with regard to guarding of EVSE is limited. NFPA 730, Guide to Premises Security, 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. Specifically, Annex E is an informative annex which discusses the placement/design of bollards. 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.

Gap: **Guarding of EVSE.** There is a lack of standards that address charging station design with respect to physical and security protection of the equipment.

Recommendation*:* Guidelines or standards relating to guarding of EVSE should be developed. ***Priority:*** Mid-term. ***Potential Developer:*** NFPA. ***Grid Related:*** No. ***Status of Progress:*** Unknown. ***Update:*** The roadmap version 1.0 text and potential developers have been updated. NFPA has work on premises security and, so, has been added as a potential developer. It does not appear that NHSTA has jurisdiction in this area and neither it nor the American Association of State Highway and Transportation Officials (AASHTO) have developed guidelines or standards for guarding of EVSE. No other agencies or organizations have been identified at this time that are working on this issue.

4.2.3.7 Accessibility for Persons with Disabilities to EVSE

Accessibility and compliance with requirements for accessibility in adopted building codes, and state or federal accessibility requirements, i.e., the Americans with Disabilities Act (ADA) and Fair Housing Act (FHA), is an issue for EVSE. According to the Electric Drive Transportation Association, the "ADA does not specifically prescribe standards addressing the installation of charging infrastructure; however, it does provide general guidance in sections 206, 208, 403.5 and 502 related to routes, clearances, and parking spaces."[10] While some states have developed guidelines related to charging station accessibility, enforcement rests with the local authority having jurisdiction.

There are two steps needed to address accessible EV parking and charging in standards and codes. The first is to propose changes to a design standard (e.g., ICC A117.1) that addresses technical criteria for

[10] http://goelectricdrive.com/index.php/accessibility

how you design and build something to be accessible. The second is to propose changes to scoping requirements in a relevant code, for example, the IBC®, IgCC™, or International Zoning Code® (IZC®), for when something must be accessible and the number that must be accessible. A submittal to revise any code is premature without a reference to a design standard. Changes to ICC standards and codes must come from outside parties; ICC staff cannot make such proposals.

Since EV charging stations will need to be available in both non-accessible as well as accessible parking spaces, a code change proposal should suggest both a requirement for a certain percentage of parking spaces to have charging stations, including minimum numbers, as well as a percentage / minimum number of accessible parking spaces to have charging stations.

The DOE Clean Cities program is an information resource for guidance on accessibility in relation to EVSE installations.

Gap: **Accessibility for persons with disabilities to EVSE.** There is a lack of standards that address charging station design with respect to accessibility for persons with disabilities to EVSE.

Recommendation*:* Guidelines or standards relating to accessibility for persons with disabilities to EVSE should be developed. ***Priority:*** Mid-term. ***Potential Developer:*** ICC (ICC A117.1 and IBC®, IgCC™ or IZC®). ***Grid Related:*** No. ***Status of Progress:*** Yellow. ***Update***: Additional text has been added to the roadmap describing the two-step process for addressing accessible EV parking and charging in relevant standards and codes including the ICC A117.1, IBC®, IgCC™, and IZC®. Non-accessible EV parking and charging also is addressed in the roadmap text. These roadmap revisions were prompted in part because a proposal to specify a required number of EV charging locations in the parking requirements of the 2015 IBC® was rejected and no appeal or comments were subsequently filed. The proposal only applied to accessible parking spaces; it did not impose a general requirement or reference any standard. The proposal could be re-submitted for the 2018 code cycle. Technical criteria supporting such a proposal could be provided for in the A117.1 standard.

4.2.3.8 Cable Management

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

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.

Section 406 of the IBC® addresses Motor-Vehicle-Related Occupancies, with 406.2 addressing parking garages; however, cable management is not specifically addressed.

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.

Gap: **Cable management.** There is a lack of standards or code provisions that address functional management of EV cables in public parking spaces.

Recommendation*:* Guidelines or standards relating to EVSE cable management should be developed. ***Priority:*** Mid-term. ***Potential Developer:*** UL, NFPA. ***Grid Related:*** No. ***Status of Progress:*** Green.

4.2.3.9 EVSE Maintenance

NECA 413, a national electrical installation standard (NEIS), provides information with regard to maintaining EVSE. Specifically, Chapter 7 discusses maintenance in accordance with manufacturers' recommendations and provides guidelines for the care of EVSE, including periodic inspections for wear, damage, and vandalism, as well as cleaning.

NFPA 70B, Recommended Practice for Electrical Equipment Maintenance, applies to preventive maintenance for electrical, electronic, and communications systems and equipment. Systems and equipment covered are typical of those installed in industrial plants, institutional and commercial buildings, and large multifamily residential complexes. NFPA 70B is not intended to duplicate nor supersede manufacturer instructions for maintenance.

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

4.2.3.10 Workplace Safety

There are multiple published standards and codes that include general and specific requirements for safety in the workplace. The process of installing and maintaining EVSE must include application and implementation of all workplace safety rules and, specifically, electrical workplace safety requirements as provided in NFPA 70E-2012, Standard for Electrical Safety in the Workplace. The U.S. Government includes in the Code of Federal Regulations minimum requirements for workplace safety.

Minimum safety requirements for General Industry are provided in Part 1910, Occupational Safety and Health Administration (OSHA) Standards Subpart S – Electrical. Subpart S includes general information, design safety standards for electrical systems, safety-related work practices, safety-related maintenance requirements, safety requirements for special equipment, definitions, and reference documents in Appendix A. Minimum safety requirements for electrical construction are provided in Part 1926, OSHA Subpart K – Electrical. Subpart K includes general information, installation safety requirements, safety-related work practices, safety-related maintenance and environmental considerations, safety requirements for special equipment, and definitions.

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

4.3 Support Services Domain

4.3.1 Education and Training

Standards and education and training are important elements needed to ensure the safety and security of electric vehicle owners and those who service the vehicles or respond to vehicle emergencies, and to ensure safe EVSE installations and consistency of information.

Much of the information needed by personnel who respond to emergencies or service EVs and associated equipment is contained in original equipment manufacturer (OEM) or other manufacturer information. There are standards for professional qualifications for rescue technicians and incident managers (NFPA 1006 and 1026) but these cover generalized skills and safe methodologies without getting into the specifics of vehicles or equipment.

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

SAE J2990, Hybrid and EV First and Second Responder Recommended Practice, published in November 2012, provides a flow chart process to assess issues with the vehicle and battery. SAE J2990 also provides recommendations for vehicle identification, high voltage disabling, and critical items to be summarized from emergency response guides (ERGs) provided by vehicle manufacturers and others. OEMs will be encouraged to reference SAE J2990 when creating industry design standards.

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.

In May 2012, NFPA held a workshop on emergency responder personal protective equipment (PPE) for hybrid and electric vehicles.[11] The workshop brought together emergency responders and other stakeholders to develop guiding principles and recommended action steps to address the proper PPE for emergencies involving hybrid or electric vehicles, with a focus on minimizing the risk to emergency responders due to hazards involving electrically energized equipment. The recommendations from this workshop served as input to the development of SAE J2990.

NFPA's Fire Protection Research Foundation, in partnership with the Auto Alliance, DOE and NHTSA, has created a Technical Advisory Panel to research and develop best practices for fire suppression and fire fighting tactics for incidents involving electric vehicle batteries. The results of this work are expected by the third quarter of 2013 and may inform future revisions of SAE J2990 as well as NFPA 1971, Standard

[11] http://www.nfpa.org/assets/files//Research%20Foundation/EVPPEWorkshopPart1.pdf.

for Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting; NFPA 1951, Standards for Protective Ensembles for Technical Rescue Incidents; and NFPA 1999, Standard for Protective Clothing for Emergency Medical Operations.

Partial Gap: **Electric vehicle emergency shut off – high voltage batteries, power cables, disconnect devices; fire suppression, fire fighting tactics and personal protective equipment.** Standards / guidelines are needed so that emergency responders can safely manage emergency events involving electric vehicles.

Recommendation: Develop standards / guidelines so that emergency responders can quickly and easily recognize high voltage batteries and power cables, operate disconnect devices, avoid electrical shock hazards, and safely shut off power to an electric vehicle following an incident. Consider the need for further standardization work with respect to fire suppression, fire fighting tactics, and personal protective equipment, based on the results of research underway by NFPA's Fire Protection Research Foundation in partnership with others. ***Priority:*** Near-term. ***Potential Developer:*** NFPA, SAE, ISO, IEC. ***Grid Related:*** No. ***Status of Progress:*** Green. ***Update:*** With the publication of SAE J2990, the partial gap identified in version 1.0 of this roadmap with respect to vehicle emergency shut off largely has been addressed. In this version 2.0, the text, gap statement and recommendation have been substantially modified to more broadly capture the scope of safety concerns facing emergency responders including the possibility that additional standardization work may be needed with respect to fire suppression, fire fighting tactics and personal protective equipment.

Harmonization Efforts

CEN/CENELEC in their October 2011 eMobility Focus Group report recommended increased efforts to ensure emergency services are able to respond appropriately with respect to battery hazards caused by the use of electric vehicles, mechanical impact to the batteries, and exposure of batteries to fire or water. The report also noted that there is no unified language for safety labeling regarding EV batteries. The EU recognizes the need to standardize labels and graphics for the protection of first responders to deal with incidents, but no appropriate standards now exist in Europe.

4.3.1.2 Labeling of EVSE and Load Management Disconnects for Emergency Situations

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.

Where load management equipment is independent of the EVSE, then NFPA 70®, the National Electrical Code®, applies. NEC® Article 625 contains the requirements for installing EV charging stations and would be an ideal repository for language related to graphical symbols and color-coding to identify load management equipment and disconnects in emergency situations.

Gap: **Labeling of EVSE and load management disconnects for emergency situations.** Standards are needed to address labeling of EVSE and load management disconnects for emergencies.

Recommendation*:* Develop standards to address graphical symbols and warning labels on EVSE as well as disconnect instructions for emergency situations. Amend NEC® Article 625 to include requirements for graphical symbols and color-coding of load management equipment and disconnects for emergency situations. ***Priority:*** Near-term. ***Potential Developer:*** UL, NEMA, NFPA, SAE, ISO, IEC. ***Grid Related:*** No. ***Status of Progress:*** Unknown. ***Update:*** The roadmap version 1.0 text, gap statement and recommendation have been clarified to address labeling for emergency situations. UL and NEMA have been added as potential developers.

4.3.1.3 OEM Emergency Response Guides

ERGs written by the OEMs are more abridged than shop and owner's manuals and can be a valuable resource to emergency responders, though the amount of information is still lengthy and in non-standard formats across OEMs. NFPA has compiled the most crucial OEM information in their EV/Hybrid ERGs into a single database available in both standardized electronic and print formats for use by emergency responders and others as a quick reference on-scene guide. Manufacturers' labels and symbols are replicated, but once these are also standardized the database of ERGs will utilize the universal symbols. NFPA also makes individual OEM ERGs available online in PDF format at http://www.evsafetytraining.org/Resources/Auto-Manufacturer-Resources.aspx.

The previously mentioned May 2012 NFPA workshop included a recommendation to "continue efforts to standardize vehicle response guide information, including universal content, style and format, to facilitate universal implementation among emergency responders."

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

4.3.1.4 Electrical Energy Stranded in an Inoperable RESS; Battery Assessment and Safe Discharge Following an Emergency Event

The issue of stranded energy in an inoperable battery is being considered in SAE J3009, Stranded Energy – Reporting and Extraction from Vehicle Electrochemical Storage Systems, now under development. The intent of this document is to consider the type of information reported by the battery management system (BMS) and recommended discharge level dependent on a collision or vehicle fire. The document does not describe how the energy should be extracted.

In parallel, NHTSA and Argonne National Laboratory have started a project to develop safe assessment, architecture and discharge procedures to extract stranded energy from high-voltage vehicle batteries. The purpose is to reduce the risk of fire or electrical injury associated with stranded energy in an "accident-compromised" rechargeable energy storage system (RESS). The project will examine the range of conditions that may make the RESS inoperable through the life of the vehicle, including crash incidents and exposure to fire. The project's deliverables include defining a common interface port(s) to support diagnostic assessment and discharge capability to an RESS mounted in a vehicle. In addition to providing information on the condition / state of the battery, this may be a manual service disconnect. The research project will last until 2014.

The SAE J2990 task force is not addressing the issue of stranded energy.

Gap: **Electrical energy stranded in an inoperable RESS.** Standards to enable common method assessment of RESS condition and stability, and removal of the energy stranded in an inoperable RESS, are needed to increase the safety margin to persons who may become exposed to the device in an inoperable state for various reasons and conditions during the RESS life cycle.

Recommendation*:* Carry out research to independently identify a solution set to the issue of electrical energy stranded in a damaged or inoperable RESS. Complete work on SAE J3009 to address a similar scope. ***Priority:*** Near-term. ***Potential Developer:*** SAE, NHTSA/Argonne NL. ***Grid Related:*** No. ***Status of Progress:*** New gap / Green.

Gap: **Battery assessment and safe discharge following an emergency event.** There do not appear to be standards addressing the assessment of battery stability and the need for safe discharge of EV batteries following an emergency event.

Recommendation*:* Standards and/or guidelines to assess battery stability and the need for safe discharge following an emergency event are needed to identify safe practices for performing such assessment and discharge and what training, equipment and personal protective equipment may be required. The research on stranded electrical energy underway at NHTSA/Argonne NL is a first step before developing such guidelines. ***Priority:*** Near-term. ***Potential Developer:*** SAE, NHTSA/Argonne NL, NFPA. ***Grid Related:*** No. ***Status of Progress:*** Not started. ***Update:*** The roadmap version 1.0 gap statement and recommendation have been modified to include an assessment of battery stability. Emergency responders are no longer identified as the specific user of battery discharge procedures since second responders (tow operators, roadside assistance) and OEM representatives also may need such training. The development of such procedures is now described as contingent upon research underway by NHTSA / Argonne National Laboratory on stranded energy. Argonne and NFPA have been added as potential developers. Text regarding safe battery *recharge* in emergencies has been removed and a new roadmap section on Disaster Planning / Emergency Evacuations Involving Electric Vehicles has been added to separately address that concern.

4.3.1.5 Disaster Planning / Emergency Evacuations Involving Electric Vehicles

There do not appear to be any standards or guidelines in place that address disaster planning in terms of the need for quick recharging of EVs during emergency evacuation situations. While technically that may suggest a gap, the same can be said with respect to refueling gas powered vehicles under such conditions. In either case, a vehicle would need to be towed if it could not leave the road under its own power. There is no other readily apparent solution. As this issue initially was raised by a Federal

Emergency Management Agency (FEMA) representative, FEMA is invited to further consider planning for such scenarios.

No gap has been identified at this time.

4.3.1.6 Workforce Training

Emergency First Responder Training

NFPA's Electric Vehicle Safety Training Project, funded by the U.S. Department of Energy and NFPA, is a nationwide program to help firefighters, law enforcement officers, emergency medical services and other first responders prepare for the growing number of hybrid and electric vehicles in the United States. This program provides information and materials necessary to safely respond to emergency situations involving advanced hybrid and electric vehicles on the road today. The training is designed to: create awareness of unique emergency response needs for electric vehicles; drive awareness of the availability of training modules and reference materials; remove concerns about the inherent safety of electric vehicles and the ability to safely respond to emergency situations; and reassure the public that trained first responders know what to do in emergency situations.

Key topics of NFPA's training include:

- Overview of the EV electrical and safety systems;
- Identification of electric and hybrid vehicles;
- Immobilization process;
- Electrical disabling procedures;
- EV extrication awareness, including high-strength steel;
- Vehicle fire recommended practices;
- Emergency operations (battery fire, submersion); and,
- New challenges presented by vehicle charging stations and infrastructure.

NFPA's web portal, www.EVsafetytraining.org, serves as a central repository for all EV safety information for first responders. This website hosts training, videos, and simulations; includes an events calendar, blogging, and news; and has a separate area for each auto manufacturer's safety information.

NFPA's training is provided via the following platforms:

- Train-the-Trainer Classroom course: An 8-hour "Train the Trainer" Emergency Responder course that covers the breadth of the program, along with strategies and learning objectives needed to train a group of first responders. Currently being achieved through a partnership with the North

American Fire Training Directors, upon completion, attendees are capable of delivering the program to their own agency/department.

- EV Safety Training Classroom Course: A 4 hour face-to-face instructor-led program for firefighters, and a 3 hour face-to-face instructor-led program for law enforcement and emergency medical services, that provides instruction on how to respond to EV incidents.
- Online Self-Paced Study Course: An online, self-paced web version, complete with video, animations, simulations, data review exercises, and a final scenario room activity. A certificate is mailed to the user following successful completion of the course.
- Vehicle Specific Online Training: Chevrolet Volt Electric Vehicle safety training has been developed and released for the benefit of emergency responders on NFPA's EV web portal, with future model specific online training being released during the first quarter of 2012.
- Emergency Field Guide: This guide is a quick reference manual compiled from the manufacturers' emergency response guides, which contains the vital hybrid and electric vehicle safety information for a first responder on each make and model of hybrid or electric vehicle. This guide includes descriptions, diagrams, and locations of key high voltage EV components, as well as vehicle power down and emergency procedures in order to successfully identify, immobilize, and disable a hybrid or electric vehicle. This guide will be available in published and online formats.

Several first responder agencies have reported utilizing the training provided by vehicle manufacturers and other training consortiums. Law enforcement agencies have reported a need for increased access to first responder specific training. Law enforcement and emergency medical services need access to responder safety training designed for their respective roles but enabled to integrate with training of other responders to ensure efficient emergency operations.

Standards developing organizations can and should continue to foster such multi-discipline input into the development of standards and training programs regarding electric vehicles by including these perspectives on appropriate technical and standards development committees.

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

Harmonization Efforts

In contrast to the U.S., there is no centralized training portal for electric vehicle responder safety in Europe. Additionally, while the U.S. has developed a unified approach, where federal regulatory agencies, vehicle and charging station manufacturers, standards organizations and the first responder community have partnered to participate in the training and standards development process, no such partnership has evolved in the EU.

Second Responder/Normal Operations Training Programs

Organizations like the National Institute for Automotive Service Excellence (ASE), the American Automobile Association (AAA), and the Towing and Recovery Association of America Inc. (TRAA) have in place training programs and certifications for their technicians who perform service functions on electric vehicles. There does not appear to be a significant call for new training and/or certification programs at this time.

EVSE Installer and Inspector Training

EVSE installations must comply with local, state, and national codes and regulations. The installation process typically requires obtaining an electrical installation permit from local authorities, the use of a licensed contractor for the actual installation, and a final electrical review by a certified electrical inspector.

Article 625 of the National Electrical Code® (NEC®) sets forth installation safety requirements for typical hard-wired connections of EVSE, addressing wiring methods, equipment construction, control and protection, and equipment locations.

In order to support the build out of charging infrastructure for EVs nationally, a steadily expanding pool of qualified electrical installers and inspectors for EVSE is required.

The National Electrical Contractors Association (NECA) Workshop on Managing Electric Vehicle Supply Equipment (EVSE) – Electrical Contractors is a course that reviews necessary steps that must be performed to ensure system capacity of electrical power sources and service equipment and safe installation of EVSE branch circuits and feeders. It includes a review of applicable rules in the NEC® that must be applied to EVSE installations, including what constitutes qualifications of contractors and installers to perform EVSE installations. In addition to the minimum safety installation requirements of the NEC®, safe work practices and applicable workplace safety requirements are reviewed. Applicable performance and quality installation standards are integrated into this training program. Compliance with regulatory agencies is also reviewed specifically as it relates to required work permits, inspections, and approval of EVSE or vehicle charging equipment installations. The International Association of Electrical Inspectors (IAEI) has partnered with NECA to develop the EV training that NECA has been offering to its chapters. This information is available to IAEI to develop training for inspectors and installers, but to date has not been fully developed. Upon completion, it is expected to provide 1-2 hours of training but be more NEC® Article 625 oriented, somewhat akin to an electrical checklist.

The Electric Vehicle Infrastructure Training Program (EVITP) – Electrical Workers is a 14-18 hour class which comprehensively addresses the requirements, regulations, products and strategies which will enable electrical contractors and electricians to master successful, expert, and professional customer relations, installation, and maintenance of EV and PHEV infrastructure. Upon completion of this class, participants gain thorough knowledge and practical application of all covered EV infrastructure subjects including the critical areas of customer experience, protection of utility systems, and vehicle charging technical applications.

Additionally, Underwriters Laboratories, Inc. has developed a short (2.5 hour) e-learning course on Electric Vehicle Charging Station Installation for qualified electricians.

Charging Station Permitting

In addition to the model EVSE permitting template described earlier, the DOE Clean Cities program has put together an EVSE 101 video that includes information for electrical installers and inspectors. DOE funded projects are also exploring regional planning and workplace charging. The availability of this information needs to be made widely and easily accessible to electrical installers and inspectors in advance of when they find themselves faced with a potential EV charging station installation/permit application. It also needs to be promoted in publications and websites that are regularly read or visited by both the installer community and code officials (electrical, building and/or fire inspector). It is also important to raise awareness with architects, community planners, land use planners, zoning officials, and other authorities having jurisdiction over plans review of commercial real estate developments and large residential tract developments, as the involvement of these individuals will be critical to the future growth and development of EVSE installations.

Partial Gap: **Workforce training – charging station permitting.** From a training perspective, there may be a need to assemble and promote a "Code Official Toolkit" related to EVSE permitting.

Recommendation: Develop a Code Official Toolkit on EVSE permitting that includes, among other things, the DOE permit template, EVSE 101 video, and an FAQ document for code officials that explains, for example, the importance of safe and code-compliant EV charging station installation requirements, and relevant safety training programs. Consider creating a brief article that would highlight this issue and the Toolkit as resources to run in appropriate association newsletters to increase awareness of resources available to installers, inspectors and other authorities having jurisdiction. ***Priority:*** Near-term. ***Potential Developer:*** DOE, ICC, NECA, IAEI, NFPA. ***Grid Related:*** No. ***Status of Progress:*** New gap / Green.

College and University Programs

As electric vehicle use increases, institutions of higher learning are beginning to address occupational needs with education and training programs. Many of these programs are taking advantage of DOE funding designed to increase adoption of electric vehicle technology. Programs vary from skill level training for those repairing and maintaining electric vehicles and charging equipment, to engineering programs for the next generation of designers.

The following educational institutions are known to offer electric vehicle training programs:

- J. Sargeant Reynolds Community College: The J. Sargeant Reynolds Community College in Virginia is currently developing a career studies certificate in advanced automotive technologies for electric vehicles. The courses include instruction on electric vehicles, plug-in hybrid electric vehicles, fuel cell electric vehicles, and control electronics.

- Purdue University: Purdue University is currently working with a group of other universities to develop over 30 courses supporting electric vehicle technology and workforce needs. These courses support two and four year students and certificate and workforce development programs.

- University of Central Missouri: The automotive technology management program at the University of Central Missouri proposes to develop a new certificate program for non-degree seeking individuals interested in advanced vehicle systems including electric vehicles, plug-in hybrid electric vehicles, fuel cell electric vehicles, and other future technologies. The possibility of developing this program into a minor is also being examined by the university. In addition, materials from this program can be condensed and adapted for outreach to community colleges and OEM partners. The certificate program will consist of six courses with all but the basic electronics course being taught by faculty holding the Automotive Service Excellence (ASE) master certification.

- University of Michigan, Ann Arbor: The University of Michigan offers undergraduate and graduate courses and degree programs related to electrified vehicles, with all of them targeting regular B.S., M.S and M.Eng. degrees (i.e., engineering students or professional engineers).

Partial Gap: **Workforce training – college and university programs.** Identified higher education programs related to electric vehicles do not appear to cover some issues that relate to charging infrastructure development such as land use, community planning, and architecture.

Recommendation: Develop higher education programs focused on electric vehicle charging infrastructure development from the standpoint of land use, community planning and architecture. ***Priority:*** Mid-term. ***Potential Developer:*** Colleges and Universities. ***Grid Related:*** No. ***Status of Progress:*** New gap / Green.

5. Summary of Gap Analysis

Priority: Near-term (0-2 years); Mid-term (2-5 years); Long-term (5+ years).

Status of Progress on Gaps: Closed (completed), Green (moving forward), Yellow (delayed in progressing), Red (at a standstill), Not started, Unknown, or New Gap (for roadmap version 2.0).

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related	Status of Progress
1.	Terminology	4.1 / 69	**Terminology.** There is a need for consistency with respect to electric vehicle terminology	Complete work to revise SAE J1715. ***Update:*** SAE J1715 is still in revision and is targeted for publication in the Spring of 2013.	Mid-term	SAE, ISO	No	Green
2.	Power Rating Methods	4.1.1.1 / 70	**Power rating methods.** It was noted in roadmap version 1.0 that standards for electric vehicle power rating methods are still in development.	Complete work to develop SAE J2907 and J2908. ***Update:*** With respect to the roadmap version 1.0 gap, work on the power rating method standards SAE J2907 and J2908 has been canceled because of resource issues. It will be re-opened under a new J number at a future date yet to be determined.	Mid-term	SAE	No	Red
3.	Functional Safety in the Charging System	4.1.1.2/ 73	**Functional safety in the charging system.** Potential faults in the charging system, both on-board and off-board, are the subject of NHTSA sponsored research and may need to be addressed in future rulemaking and/or standardization.	Future NHTSA rulemaking and/or revisions to SAE J2929 should consider the results of the DOT/NHTSA-funded SAE Cooperative Research Project with respect to fault events in the charging system which could lead to overcharging. ***Update:*** The roadmap version 1.0 gap statement and recommendation have been updated to note NHTSA-funded research, that the issue may be with the charging system rather than the battery, and that NHTSA rulemaking may result. NHTSA has been added as a potential developer and the priority level has been changed from mid-term to near-term. Recent updates to SAE J2929 do not address charging system failure; rather, they relate to electromagnetic compatibility (EMC) to ensure the safety functions of the battery are not impacted.	Near-term	NHTSA, SAE	No	Green
4.	Delayed Battery Overheating Events	4.1.1.2 / 74	**Delayed battery overheating events.** The issue of delayed battery overheating needs to be addressed.	Address the issue of delayed battery overheating events in future rulemaking and/or revisions of SAE J2929 based on the results of the DOT/NHTSA-funded SAE Cooperative Research Project. ***Update:*** The roadmap version 1.0 recommendation	Near-term	NHTSA, SAE	No	Yellow

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related	Status of Progress
				has been updated to note NHTSA-funded research which may result in future rulemaking. NHTSA has been added as a potential developer. Version 2 of SAE J2929 has been published. However, the topic of delayed battery overheating events is not addressed in this revision; it is pending the results of the NHTSA sponsored research.				
5.	Battery Testing - Performance and Durability	4.1.1.3 / 74	**Battery performance parameters and durability testing.** There is a need for further work on EV battery performance parameters and environmental durability test requirements.	Complete work on SAE J1798 and if possible consider harmonization with ISO 12405-2. ***Update:*** There is not a lot of progress to date on SAE J1798.	Mid-term	SAE, ISO	No	Yellow
6.	Battery Storage	4.1.1.4 / 75	**Safe storage of lithium-ion batteries.** At present, there are no published standards addressing the safe storage of lithium-ion batteries specifically, whether at warehouses, repair garages, recovered vehicle storage lots, auto salvage yards, or battery exchange locations.	A standard on safe storage practices for EV batteries must be developed, addressing both new and waste batteries and the wide range of storage situations that may exist, including when the batteries are separated from their host vehicle. ***Update:*** The roadmap version 1.0 gap statement has been modified to say there are no *published* standards addressing safe storage. IEC 62840 and the research project of the NFPA's Fire Protection Research Foundation are noted in the text.	Near-term	SAE, NFPA, ICC, IEC/TC 69	No	Green
7.	Battery Packaging, Transport and Handling	4.1.1.4 / 77	**Packaging and transport of waste batteries.** Current standards and regulations do not adequately cover transportation aspects of *waste* batteries (damaged, aged, sent for repair, end-of-life) in terms of packaging, loading limitations, combination with other dangerous goods on same transport, etc.	There is a need for a harmonized approach toward communication, labeling, packaging restrictions, and criteria for determining when a battery is waste. ***Update:*** The UN SCOE was added as a potential developer as there is a proposal before it.	Near-term	UN SCOE on the Transport of Dangerous Goods, ISO/TC 22/SC21, SAE or UL	No	Green
8.	Battery Packaging, Transport and Handling	4.1.1.4 / 77	**Packaging and transport of batteries to workshops or battery swapping stations.** Unloading a battery in a battery swapping station is extremely challenging with the original packaging used for dangerous goods transportation. There is a need for standards for intermediate packaging to cover transport to battery swapping stations.	Intermediate packaging is required between the import location of the battery and battery swapping stations and needs to be standardized around geometry, safety and matching to UN packaging requirements.	Mid-term	ISO/TC 22/SC21, SAE or UL	No	Not started

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related	Status of Progress
9.	Battery Recycling	4.1.1.5 / 78	**Battery recycling.** Standards are needed in relation to EV (li-ion) battery recycling.	Complete work on SAE J2974 and J2984. EV (li-ion) battery recycling standards are desirable to address 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. ***Update:*** The roadmap version 1.0 text and recommendation have been updated to note relevant work by SAE. The priority level has been changed from long-term to near-term.	Near-term	SAE, IEC	No	Green
10.	Battery Secondary Uses	4.1.1.6 / 79	**Battery secondary uses.** There is a need for standards to address battery second life applications for grid storage and other uses.	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. ***Update:*** The text has been updated to note some of the considerations in the work thus far by the SAE committee. The priority level has been changed from long-term to mid-term. UL has been added as a potential developer.	Mid-term	SAE, UL	No	Green
11.	Crash Tests/ Safety	4.1.1.7 / 79	No Gap	N/A	N/A	N/A	No	N/A
12.	Internal High Voltage Cables, On-Board Wiring, Component Ratings and Charging Accessories	4.1.2.1 / 81	No Gap	N/A	N/A	N/A	No	N/A
13.	Vehicle Diagnostics - Emissions	4.1.2.2 / 83	No Gap	N/A	N/A	N/A	No	N/A

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related	Status of Progress
14.	Audible Warning Systems	4.1.2.3 / 84	**Audible warning systems.** Creation of the NHTSA safety standard and compliance with it will effectively close any gap with respect to audible warning systems for electric vehicles sold in the U.S. market. Ongoing standards work in SAE and ISO, and in WP.29 with respect to the development of a Global Technical Regulation would provide a means for international harmonization around this issue.	Continue work on safety standards to address EV sound emission and measurement.	Near-term	SAE, ISO, NHTSA, WP.29	No	Green
15.	Graphical Symbols	4.1.3.1 / 85	**Graphical symbols for electric vehicles.** Standards for graphical symbols for electric vehicles are needed to communicate important information to the driver such as state of charge, failure or normal system operation which can be understood regardless of the driver's language.	Develop EV graphical symbols standards to communicate information to the driver. ***Update:*** The text has been updated to note NHTSA sponsored research on functional safety and failure modes. The roadmap version 1.0 gap statement and recommendation have been re-focused on communication of information to the driver. NHTSA has been added as a potential developer and the priority level has been changed from near-term to long-term. Regarding the roadmap version 1.0 gap statement and recommendation relating to graphical symbols for "parts under the hood," this aspect is addressed in section 4.3.1.1 on EV emergency shut off.	Long-term	SAE, NHTSA, ISO, IEC	No	Not started
16.	Telematics – Driver Distraction	4.1.3.2 / 86	No Gap	N/A	N/A	N/A	No	N/A
17.	Fuel Efficiency, Emissions, and Labeling	4.1.3.3 / 87	No Gap	N/A	N/A	N/A	No	N/A
18.	Wireless Charging	4.2.1.1 / 88	**Wireless charging.** Standards and guidelines for wireless charging are still in development.	Complete work on SAE J2954, UL 2750, IEEE deliverables and IEC 69180-1. ***Update:*** The text and roadmap version 1.0 gap statement and recommendation have been modified to account for IEEE and IEC/TC 69 work, with both added as potential developers.	Near-term	SAE, UL, IEEE, IEC/TC 69	Yes	Green

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related	Status of Progress
19.	Battery Swapping	4.2.1.2 / 89	**Battery swapping – safety.** Currently, there is a need to define minimum requirements for the safe operation of battery swapping stations, as mass deployment of battery swapping systems is currently underway in several countries around the world.	Complete work on IEC 62840 to define minimum requirements for the safe operation of battery swapping stations. ***Update:*** The text and recommendation have been updated to note the new project IEC 62840 in IEC/TC 69.	Near-term	IEC/TC 69	No	Green
20.	Battery Swapping	4.2.1.2 / 89	**Battery swapping – interoperability.** Standards are needed to help facilitate the penetration of battery swapping in the market. Issues to be addressed related to removable batteries include electrical interfaces, cooling integration, data transfer integration, and common mechanical and dimensional interfaces.	Define interoperability standards related to battery swapping. ***Update:*** Currently, there is some ongoing work on the standardization of battery packs in ISO TC 22/SC21. The inaugural meeting of the working group for IEC 62840 in IEC/TC 69 raised an indication of interest in work on interoperability related to battery swapping.	Near-term	IEC/TC 69	No	Not started
21.	Power Quality	4.2.1.3 / 90	**Power quality.** SAE J2894/1 was published in December 2011. At the time of publication of roadmap version 1.0, SAE J2894, Part 2, was still in development.	Complete work on SAE J2894, Part 2. ***Update:*** With the publication of SAE J2894/2, the partial gap on power quality identified in version 1.0 of this roadmap will be closed.	Near-term	SAE	Yes	CLOSED
22.	EVSE Charging Levels/Modes	4.2.1.3 / 90	**EVSE charging levels.** At the time of release of version 1.0 of this roadmap, the levels for DC charging within SAE J1772™ had yet to be finalized.	Complete work to establish DC charging levels within SAE J1772™. ***Update:*** With the publication of the new version of SAE J1772™, the gap identified in version 1.0 of this roadmap with respect to DC charging levels in SAE J1772™ is now closed.	Near-term	SAE	Yes	CLOSED
23.	EV Supply Equipment and Charging Systems	4.2.1.3 / 93	**Off-board charging station and portable EV cord set safety within North America.** At the time of release of version 1.0 of this roadmap, the harmonization of equipment safety standards within North America based on the UL 2594 standard was still underway	Finish North American harmonization effort based on UL 2594 addressing off-board charging station and portable EV cord set safety. Once that is completed, address NEC® 2014 technical issues in the new tri-national standard. ***Update:*** With the publication of the tri-national North American standard based on UL 2594 in February 2013, the partial gap identified in version 1.0 of this roadmap regarding off-board charging station and portable EV cord set safety within North America is closed. There will be a need to address NEC® 2014 technical issues in the new tri-national standard. There are additional technical items that	Near-term	UL, CSA, ANCE (Mexico), NEMA	Yes	CLOSED

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related	Status of Progress
				will be addressed in a Phase 2 harmonization effort through CANENA.				
24.	EV Supply Equipment and Charging Systems	4.2.1.3 / 93	**Off-board charger safety within North America.** Harmonization of equipment safety standards within North America is needed.	There appears to be a need to harmonize the safety requirements for off-board chargers with the U.S., Canada, and Mexico.	Mid-term	UL, CSA, ANCE (Mexico), NEMA	Yes	Not started
25.	EV Supply Equipment and Charging Systems	4.2.1.3 / 93	**Off-board charger, off-board charging station and portable EV cord set safety globally.** There are some differences between the IEC 61851 series of standards and the North American standards. 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.	Work to harmonize the IEC 61851 series standards and the North American standards	Mid-term	UL, IEC	Yes	Not started
26.	EV Couplers: Safety and Harmonization Efforts	4.2.1.3 / 96	**EV coupler safety within North America.** At the time of publication of version 1.0 of this roadmap, harmonization of EV coupler safety standards within North America based on the UL 2251 standard was still underway.	Finish efforts to harmonize standards addressing EV coupler safety within North America. ***Update:*** With the publication of the tri-national standard based on UL 2251 in February 2013, there are no gaps in standardization for EV coupler safety in North America and the partial gap identified in version 1.0 of this roadmap is closed. There are additional technical items that will be addressed in a Phase 2 harmonization effort through CANENA.	Near-term	UL, CSA, ANCE (Mexico), NEMA	Yes	**CLOSED**
27.	EV Couplers: Safety and Harmonization Efforts	4.2.1.3 / 96	**EV coupler safety globally.** There are some differences between the IEC 62196 series standards and the North American EV coupler safety standards. While not a gap per se with respect to the U.S. market, global harmonization would help to reduce costs for vehicle manufacturers.	Work to harmonize the IEC 62196 series standards and the North American EV coupler safety standards.	Mid-term	UL, IEC	Yes	Not started
28.	EV Couplers: Interoperability with EVSE and Harmonization Efforts	4.2.1.3 / 98	**EV coupler interoperability with EVSE globally.** Different coupler configurations are used in different parts of the world. Global harmonization would help to reduce costs for manufacturers. At the time of release of version 1.0 of this roadmap, the revision of SAE J1772™ was still in progress; it has now been published.	Incorporate the new SAE J1772™ combination coupler into IEC 62196-3. Build out the charging infrastructure to accommodate variations in EV coupler configurations for particular markets as necessary, in particular with respect to DC charging. ***Update:*** The roadmap version 1.0 text has been	Near-term	SAE, IEC, CHAdeMO, vehicle and charging station manufacturers	Yes	Green

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related	Status of Progress
				updated to note the publication of the SAE J1772™ AC/DC combination coupler and that the forthcoming IEC 62196-3 will describe the SAE J1772™ coupler and several other different DC coupler configurations used elsewhere. The gap statement notes the publication of SAE J1772™. The recommendation notes the need to incorporate SAE J1772™ into IEC 62196-3 and the need to build out the charging infrastructure to accommodate variations in coupler configurations for particular markets as necessary, in particular with respect to DC charging. CHAdeMO, and "vehicle and charging station manufacturers," have been added alongside SAE and IEC as "potential developers."				
29.	EV Couplers: Interoperability with EVSE – Conformance Programs	4.2.1.3 / 99	**Conformance programs for EV coupler interoperability within the U.S. market.** No programs yet exist for the U.S. market to verify compatibility between the EV coupler, the infrastructure and the vehicle.	Complete work on SAE J2953. Establish a program(s) to verify interoperability between infrastructure equipment, including the vehicle connector, and all vehicles that follow the SAE J1772™ protocol.	Near-term	SAE, UL	Yes	Green
30.	Electromagnetic Compatibility (EMC)	4.2.1.4 / 101	**Electromagnetic compatibility (EMC).** Standards to address EMC issues related to electric vehicle charging are still in development.	Complete work on IEC 61851-21, Parts 1 and 2, and SAE J2954 to address EMC issues related to electric vehicle charging.	Near-term	IEC/TC 69, SAE	Yes	**NEW** gap / Green
31.	Vehicle as Supply	4.2.1.5 / 102	**Vehicle as supply / reverse power flow.** Differences exist between the DER model defined by SAE J2836/3™, IEC/TR 61850-90-7, IEC/TR 61850-90-8, and SEP 2.0.	Harmonize the information model for an EV as a DER between SAE J2836/3™, IEC/TR 61850-90-8, and SEP 2.0. ***Update:*** The roadmap version 1.0 text, gap statement, recommendation and list of potential developers have been substantially reworked to focus specifically on the need for harmonization of the DER communications model between SAE J2836/3™, IEC/TR 61850-90-8, and SEP 2.0. Potential changes to other standards to address integration of inverter-based DER devices with the grid, or architecture and safety aspects of reverse power flow, are contemplated in the text but not included as a gap.	Near-term	SAE, IEC/TC 57, Zibgee Alliance and the HomePlug Powerline Alliance	Yes	Green

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related	Status of Progress
32.	Use of Alternative Power Sources	4.2.1.6 / 104	**Use of alternative power sources.** The National Electrical Code® does not specifically address the integration of the EV and EVSE with a facility high voltage DC power distribution system for either charging or reverse power flow.	Develop NEC® requirements for high voltage DC power distribution systems and the integration of distributed energy resources and DC loads with the system	Near-term	NFPA	Yes	Green
33.	Locating and Using Public Charging Stations (EVSE)	4.2.2.2 / 108	**Locating and reserving a public charging station**. There is a need for a messaging standard to permit EV drivers to locate a public charging spot and reserve its use in advance.	Develop a messaging standard to permit EV drivers to universally locate and reserve a public charging spot. ***Update:*** To address this roadmap version 1.0 gap, NEMA's EVSE section organized a working group (NEMA 5EVSE Network Roaming WG) to develop a standard that permits EV drivers to universally locate a public charging spot. It decided that reserving a public charging spot was a low priority and deferred action on reservations to a later phase of work.	Mid-term	SAE, ISO/IEC JWG, NEMA	Yes	Green
34.	Roaming	4.2.2.2 / 109	**Charging of roaming EVs between EVSPs**. There is a need to permit roaming EVs to charge at spots affiliated with a different EVSP.	Develop back end requirements as well as an interface standard that supports charging of roaming EVs between EVSPs. ***Update:*** To address this roadmap version 1.0 gap, NEMA's EVSE section organized a working group (NEMA 5EVSE Network Roaming WG) to develop a standard that supports roaming that allows charging services from a provider other than the home EVSP. The standard will include inter-operator interfaces to address the various stages of a charging session (e.g., authentication/authorization, charging data records, billing record exchange.) The NEMA working group also is looking to develop a radio-frequency identification (RFID) credential protocol specification so that all EVSEs that implement the specification will be able to read RFID cards that conform to the specification. IEC also has initiated work on IEC 62831 Ed. 1.0, User identification in Electric Vehicle Service Equipment using a smartcard, which describes the physical and protocol layers of an RFID card used in charging spots. In addition, a new group called eMI[3] has been formed as an innovation platform under the aegis of ERTICO (www.ertico.com). This group has brought	Near-term	NEMA, IEC	Yes	Green

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related	Status of Progress
				together several significant players and eMobility projects in the European EV mobility market, including auto OEMs, enterprise software vendors and EV Services Providers, who recognize that the business realities will result in the existence of multiple EV charging providers who need to interoperate in order to allow EV drivers to seamlessly charge across provider and geographic boundaries. Its scope is to harmonize and develop ICT (information and communication technology) standards and implementations in order to enable global EV services interoperability. The work to be undertaken in this group overlaps with the NEMA work. The two organizations are considering a liaison agreement to facilitate information exchange.				
35.	Access Control	4.2.2.2 / 110	**Access control at charging stations**. There is a need to develop data definition and messaging standards for communicating access control at charging stations.	Develop data definition and messaging standards for communicating access control at charging stations. ***Update:*** The NEMA 5EVSE Network Roaming WG also looked at this roadmap version 1.0 gap. It decided that offline access control lists were a low priority and deferred action on offline access control to a later phase of work.	Near-term	NEMA	Yes	Yellow
36.	Communication of Standardized EV Sub-metering Data	4.2.2.3 / 112	**Communication of standardized EV sub-metering data**. Standards are needed for communication of EV sub-metering data between third parties and service providers.	Complete Green Button Sub-metering Profile of ESPI for communication of standardized EV sub-metering data, for example, between a third party and a billing agent (e.g., utility). ***Update:*** The roadmap version 1.0 text, gap statement, recommendation and potential developers have been revised to be specific about communication of EV sub-metering data between third parties and service providers and to complete work on the Green Button Sub-metering Profile of ESPI.	Near-term	OpenADE/ NAESB	Yes	Green
37.	Standardization of EV Sub-meters	4.2.2.3/ 113	**Standardization of EV sub-meters**. Standards for EV sub-meters, including embedded sub-meters, need to be completed to address performance, security/privacy, access, and data aspects.	Develop standards or guidelines related to the functionality and measurement characteristics of the new types of sub-meters that are coming out for EVs, including embedded sub-meters in the EVSE or EV. Such standards should address different form factors, capabilities, installation, and certification.	Near-term	NEMA, USNWG EVF&S	Yes	NEW gap / Green

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related	Status of Progress
38.	Coordination of EV Sub-metering Activities	4.2.2.3 / 113	**Coordination of EV sub-metering activities**. Various existing activities (NEMA, USNWG EVF&S, SGIP V2G DEWG) need to be coordinated as much as possible.	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.	Near-term	NEMA, USNWG EVF&S, SGIP V2G DEWG	Yes	**NEW** gap / Green
39.	Cyber Security and Data Privacy	4.2.2.4 / 115	**Cyber security and data privacy.** There is a need for guidelines and standards to address cyber security and data privacy concerns associated with PEVs and smart grid communications.	Complete work to develop SAE J2931/7, and to revise ISO/IEC 15118-1 and NISTIR 7628, volume 2.	Near-term	SAE, ISO/IEC JWG, NIST	Yes	**NEW** gap / Green
40.	Telematics Smart Grid Communications	4.2.2.5 / 115	**Telematics smart grid communications.** There is a need to develop use cases related to non-utility aggregation control and vehicle information in order to assess the existing functionalities, and to determine any missing requirements within the context of existing standards, Energy Service Provider business requirements, and telematics networks to support smart grid load management.	Complete work to develop SAE J2836/5™.	Near-term	SAE	Yes	**NEW** gap / Green
41.	Site Assessment / Power Capacity Assessment	4.2.3.1 / 116	No Gap	N/A	N/A	N/A	Yes	N/A
42.	EV Charging – Signage and Parking	4.2.3.2 / 118	No Gap	N/A	N/A	N/A	Yes	N/A
43.	Charging Station Permitting	4.2.3.3 / 119	No Gap	N/A	N/A	N/A	Yes	N/A
44.	Environmental and Use Conditions	4.2.3.4 / 121	No Gap	N/A	N/A	N/A	No	N/A
45.	Ventilation - Multiple Charging Vehicles	4.2.3.5 / 122	No Gap	N/A	N/A	N/A	No	N/A
46.	Guarding of EVSE	4.2.3.6 / 123	**Guarding of EVSE.** There is a lack of standards that address charging station design with respect to physical and security protection of the equipment.	Guidelines or standards relating to guarding of EVSE should be developed. ***Update:*** The roadmap version 1.0 text and potential developers have been updated. NFPA has work on premises security and, so, has been added as a	Mid-term	NFPA	No	Unknown

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related	Status of Progress
				potential developer. It does not appear that NHSTA has jurisdiction in this area and neither it nor the American Association of State Highway and Transportation Officials (AASHTO) have developed guidelines or standards for guarding of EVSE. No other agencies or organizations have been identified at this time that are working on this issue.				
47.	Accessibility for Persons with Disabilities to EVSE	4.2.3.7/ 123	**Accessibility for persons with disabilities to EVSE.** There is a lack of standards that address charging station design with respect to accessibility for persons with disabilities to EVSE.	Guidelines or standards relating to accessibility for persons with disabilities to EVSE should be developed. ***Update***: Additional text has been added to the roadmap describing the two-step process for addressing accessible EV parking and charging in relevant standards and codes including the ICC A117.1, IBC®, IgCC™, and IZC®. Non-accessible EV parking and charging also is addressed in the roadmap text. These roadmap revisions were prompted in part because a proposal to specify a required number of EV charging locations in the parking requirements of the 2015 IBC® was rejected and no appeal or comments were subsequently filed. The proposal only applied to accessible parking spaces; it did not impose a general requirement or reference any standard. The proposal could be re-submitted for the 2018 code cycle. Technical criteria supporting such a proposal could be provided for in the A117.1 standard.	Mid-term	ICC (A117.1 and IBC®, IgCC™ or IZC®)	No	Yellow
48.	Cable Management	4.2.3.8 / 124	**Cable management.** There is a lack of standards or code provisions that address functional management of EV cables in public parking spaces.	Guidelines or standards relating to EVSE cable management should be developed.	Mid-term	UL, NFPA	No	Green
49.	EVSE Maintenance	4.2.3.9 / 125	No Gap	N/A	N/A	N/A	No	N/A
50.	Workplace Safety	4.2.3.10 / 125	No Gap	N/A	N/A	N/A	No	N/A

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related	Status of Progress
51.	Electric Vehicle Emergency Shut Off – High Voltage Batteries, Power Cables, Disconnect Devices; Fire Suppression, Fire Fighting Tactics and Personal Protective Equipment	4.3.1.1 / 126	**Electric vehicle emergency shut off – high voltage batteries, power cables, disconnect devices; fire suppression, fire fighting tactics and personal protective equipment.** Standards / guidelines are needed so that emergency responders can safely manage emergency events involving electric vehicles.	Develop standards / guidelines so that emergency responders can quickly and easily recognize high voltage batteries and power cables, operate disconnect devices, avoid electrical shock hazards, and safely shut off power to an electric vehicle following an incident. Consider the need for further standardization work with respect to fire suppression, fire fighting tactics, and personal protective equipment, based on the results of research underway by NFPA's Fire Protection Research Foundation in partnership with others. ***Update:*** With the publication of SAE J2990, the partial gap identified in version 1.0 of this roadmap with respect to vehicle emergency shut off largely has been addressed. In this version 2.0, the gap statement and recommendation have been modified to more broadly capture the scope of safety concerns facing emergency responders including the possibility that additional standardization work may be needed with respect to fire suppression, fire fighting tactics and personal protective equipment.	Near-term	NFPA, SAE, ISO, IEC	No	Green
52.	Labeling of EVSE and Load Management Disconnects for Emergency Situations	4.3.1.2 / 127	**Labeling of EVSE and load management disconnects for emergency situations.** Standards are needed to address labeling of EVSE and load management disconnects for emergencies.	Develop standards to address graphical symbols and warning labels on EVSE as well as disconnect instructions for emergency situations. Amend NEC® Article 625 to include requirements for graphical symbols and color-coding of load management equipment and disconnects for emergency situations. ***Update:*** The roadmap version 1.0 text, gap statement and recommendation have been clarified to address labeling for emergency situations. UL and NEMA have been added as potential developers.	Near-term	UL, NEMA, NFPA, SAE, ISO, IEC	No	Unknown
53.	OEM Emergency Response Guides	4.3.1.3 / 128	No Gap	N/A	N/A	N/A	No	N/A
54.	Electrical Energy Stranded in an inoperable RESS	4.3.1.4 / 128	**Electrical energy stranded in an inoperable RESS.** Standards to enable common method assessment of RESS condition and stability, and removal of the energy stranded in an inoperable RESS, are needed	Carry out research to independently identify a solution set to the issue of electrical energy stranded in a damaged or inoperable RESS. Complete work on SAE J3009 to address a similar scope.	Near-term	SAE, NHTSA/ Argonne NL	No	NEW gap / Green

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related	Status of Progress
			to increase the safety margin to persons who may become exposed to the device in an inoperable state for various reasons and conditions during the RESS life cycle.					
55.	Battery Assessment and Safe Discharge Following an Emergency Event	4.3.1.4 / 128	**Battery assessment and safe discharge following an emergency event.** There do not appear to be standards addressing the assessment of battery stability and the need for safe discharge of EV batteries following an emergency event.	Standards and/or guidelines to assess battery stability and the need for safe discharge following an emergency event are needed to identify safe practices for performing such assessment and discharge and what training, equipment and personal protective equipment may be required. The research on stranded electrical energy underway at NHTSA/Argonne NL is a first step before developing such guidelines. ***Update:*** The roadmap version 1.0 gap statement and recommendation have been modified to include an assessment of battery stability. Emergency responders are no longer identified as the specific user of battery discharge procedures since second responders (tow operators, roadside assistance) and OEM representatives also may need such training. The development of such procedures is now described as contingent upon research underway by NHTSA / Argonne National Laboratory on stranded energy. Argonne and NFPA have been added as potential developers. Text regarding safe battery *recharge* in emergencies has been removed and a new roadmap section on Disaster Planning / Emergency Evacuations Involving Electric Vehicles has been added to separately address that concern.	Near-term	SAE, NHTSA/ Argonne NL, NFPA	No	Not started
56.	Disaster Planning / Emergency Evacuations Involving Electric Vehicles	4.3.1.5 / 129	No Gap	N/A	N/A	N/A	No	N/A
57.	Workforce Training – Charging Station Permitting	4.3.1.6 / 133	**Workforce training – charging station permitting.** From a training perspective, there may be a need to assemble and promote a "Code Official Toolkit" related to EVSE permitting.	Develop a Code Official Toolkit on EVSE permitting that includes, among other things, the DOE permit template, EVSE 101 video, and an FAQ document for code officials that explains, for example, the importance of safe and code-compliant EV charging station installation requirements, and relevant safety	Near-term	DOE, ICC, NECA, IAEI, NFPA	No	NEW gap / Green

	Roadmap Issue	Section / page	Gap	Recommendation	Priority	Potential Developer	Grid Related	Status of Progress
				training programs. Consider creating a brief article that would highlight this issue and the Toolkit as resources to run in appropriate association newsletters to increase awareness of resources available to installers, inspectors and other authorities having jurisdiction.				
58.	Workforce Training – College and University Programs	4.3.1.6 / 133	**Workforce training – college and university programs.** Identified higher education programs related to electric vehicles do not appear to cover some issues that relate to charging infrastructure development such as land use, community planning, and architecture.	Develop higher education programs focused on electric vehicle charging infrastructure development from the standpoint of land use, community planning and architecture.	Mid-term	Colleges and universities	No	**NEW** gap / Green

6. On the Horizon

While this roadmap represents a specific snapshot in time, it maintains a distinctively outward looking, over the horizon posture that will continue to facilitate discussions with domestic, regional and international partners regarding coordination and harmonization of standardization activities and adaptation to technological and policy changes.

The DOE EV Everywhere Grand Challenge Blueprint[12] outlines technology challenges that must be overcome if the EV market is to become ubiquitous. Battery technology is focused on improving performance and reducing costs. In the short-term, the goal is to double lithium-ion battery pack energy density, whereas the longer-term goal is to explore other battery chemistries that may offer significantly greater energy densities than li-ion. Reducing the costs of electric drive systems is also a goal, through the development of advanced power electronics, electric motors and traction drive system technologies. The goals of reducing the weight of electric vehicles using lightweight metals and composites, and introducing more energy efficient climate control technologies, will help to extend vehicle range. Aside from enhancements to the vehicles, there are supporting efforts aimed at expanding the charging infrastructure such as the EV Everywhere Workplace Charging Challenge.

Developing technologies may also introduce new opportunities into the rapidly evolving landscape for EVs and charging infrastructure. For example, wireless charging potentially may offer a level of convenience that does not exist today. And as PEVs become more fully integrated into the smart grid, there is likely to be increased interest in exploiting their use as distributed energy resources.

Depending upon the needs of stakeholders, and available resources, periodic updates on significant electric vehicle standardization activities and progress to address the gaps identified in this roadmap will be made. Issues that are new or that require further discussion also may be explored. The aim behind any such efforts will be to continue to help guide, coordinate, and enhance the standards landscape as needed to support the widespread introduction of PEVs and charging infrastructure.

[12] http://www1.eere.energy.gov/vehiclesandfuels/electric_vehicles/pdfs/eveverywhere_blueprint.pdf

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Appendix A. EV Charging Actors and Communications

A.1 Introduction

This appendix provides an overview of the current and envisioned EV charging infrastructure, and at a high level describes the components of this infrastructure that may require or benefit from communications between those components. It lists the main actors involved in the communications and provides a sampling of various types of communications between them. The term ***actor*** refers to any system that communicates with another system for the purpose of enabling or enhancing some aspect of EV charging.

This appendix does not provide details about the overall electric grid, nor about the smart grid communications within the electric grid's generation, transmission and distribution systems. Rather, it focuses on those aspects of the electrical infrastructure and communications that are specific to charging EVs.

A.2 Role of Communications in EV Charging Infrastructure

The basic communications requirement for EV charging is to facilitate the transfer of power from the EVSE to the EV. The conductive charging interface standard in North America for all AC Level 1 and 2 EVSE, and DC combo charger products, is SAE J1772™. This standard provides the specifications for the AC-only and AC/DC combo connectors and vehicle inlets, and also provides the basic sequence of control pilot signals and charge control communications between the EV and the EVSE or DC charger, to ensure a safe interconnection and power transfer process.

Beyond the SAE J1772™ required charging communications, there are information and control communications technology functions that add new dimensions to the EV charging process. The added dimensions that communications offers to EV charging are the capability for utilities to monitor and interactively manage EV charging loads – to maintain the reliability and improve the efficiency of their respective distribution grids. Communications will also provide consumer interaction for automated access to utility special EV time of use (TOU) rate tariffs, incentivized demand response programs, charging status, and EV charging electricity consumption information. EV customers will be able to set specific schedule parameters and preferences for EV charging, enabling the ability to cost-effectively manage their charging behavior and minimize impact to the grid. This requires bi-directional communications functionality between the utility and the EV customers.

Consider the scenario of charging an EV in a single family home (e.g., in the garage). The utility communicates its EV TOU rate tariff and schedule information to the EV or to an EVSE. The customer accesses the information either directly using interactive displays in the EV and/or EVSE or through a smartphone, website, etc. The EV and/or EVSE can then be programmed by the customer to only allow charging during the times electricity rates are cheapest, typically at night and in the early morning during the utility off-peak period.

Another scenario involves a cluster of EVs in a residential area that if charged simultaneously may stress the capacity of the utility transformer. The utility, via communications connectivity to the EV, EVSE, or an entity that manages the EVSEs, may be able to query the EV load on a particular transformer, and if necessary, send out a demand response signal to the EVs and/or EVSEs to either stop charging or to curtail the charge power level for a specified period of time. The customer would have the ability to opt-out of the demand response event based on their specific circumstances.

An example of communications enhancing the electricity infrastructure is the Green Button initiative. This provides a way for consumers to download their electricity usage from their utilities or designated third parties. Coupled with smart metering infrastructure, consumers can view almost real-time data about their usage patterns.

Communications is a powerful enhancement to the basic charging scenario. In some cases it is actively required; in others it provides value beyond the actual charging itself and enables new applications to be created and delivered.

Communications is not limited to the communication between the utility, the EV and the EVSE. As the next section describes, the path from the producer (i.e., the utility) to the consumer of energy (i.e., the EV) may involve other intermediary systems that communicate with each other.

A.3 EV Charging Aspect of the Smart Grid

In order to understand the communications requirements of EV charging infrastructure, one must examine the different actors, applications and business models involved in EV charging.

EV charging is, at a very high level, similar to other markets where goods are created by a producer, delivered to a consumer via an intermediary, and offered for consumption via multiple outlets.

Consider applications such as TV or video content, which involve creation, transmission and distribution of content (e.g., TV programs) to end users over different communications media such as wireline (e.g., cable, DSL, fiber) or wireless (e.g., satellite, 3G/4G services, over-the-air HDTV). In each of the above media, different communication protocols may be used to accomplish tasks specific to the medium and to the business model that best supports that medium. Also, depending on whether the content is delivered to a private or a public destination, a user may need to be authenticated to access subscription content. For example, a consumer receiving over-the-air HDTV programming typically does not require authentication in order to view the content, whereas a consumer enjoying the same program on a device via the Internet must be authenticated by a service provider (e.g., Comcast, AT&T) and/or by the content provider (e.g., Netflix, HBO, Major League Baseball). A consumer may also have multiple ways to obtain information about available programming content. As an example, a user may view an electronic programming guide (EPG) on a set-top box connected to a television; may look up programming information on a service provider's website; may access EPG-style information on a website or via a mobile device application (e.g., TVGuide.com or a TVGuide app); or may obtain programming information via a specific channel’s website (e.g., networks, local origination stations).

This appendix is primarily concerned with the consumer end of the network. From the consumer's perspective, details of the overall service delivery network are of little concern. Rather, the consumption end of the network, often called the "last mile," is of vital importance. For example, the TV consumer is interested in the quality of the viewing experience, including high-quality video (which implies no pixelation or macroblocking), perfect or near-perfect (sub-100 ms) audio-video synchronization, and sufficiently low-latency remote control response. Other concerns include options for content delivery to multiple TVs in the home, cost of receiving the service, and capability to view service provider content on mobile devices, among many others. Similarly, with regard to EV charging, this appendix is mainly concerned with communication aspects of how the EV is charged and the user billed, rather than communication within utility (i.e., Energy Service Provider) networks.

Note that the business relationships are also different, based on the usage scenario. In order to view the same content in different scenarios, the consumer may need to establish transient or longer-term associations with the content provider, the distributor, the service provider, and others. Competition between various providers is almost always in the consumer's best interest. The different players or ***actors*** in the market may compete or cooperate to provide unique and/or cost-effective services.

Depending on variables such as the location of the charger, the business entity that owns and operates the charger, and the type of charging offered, different business models may be used in order to obtain a return on investment in the charging infrastructure. Also, the EV driver may be billed for multiple aspects of EV charging, such as monthly access fees, per-kWh tariffs, fees related to the time the EV occupied the EVSE/parking spot, fees related to additional services such as the ability to reserve stations, etc. Some examples of different business models are:

- For charging in a single family home, the business model may be the same as the existing model for the home's electricity consumption. Here the business relationship may be directly between the utility and the home owner.
- In a multi-dwelling unit (MDU) such as an apartment complex, the MDU owner may install several shared charging stations for use by their tenants. In this case, there may be an additional business relationship between the tenants and the MDU owner. For example, tenants may pay a monthly access fee and also pay per kWh fees. Also, access to the charging stations may be restricted to only those tenants that establish this business relationship. The management of the charging stations may be outsourced to an EV Services Provider.
- A retailer may offer free or subsidized charging at their premise, in order to attract a certain demographic of customers and to encourage them to stay longer at the store. At such locations, the retailer may offer additional incentives based on loyalty cards. An EV Services Provider may manage the charging stations at such locations.
- The hospitality (hotel) industry may offer free or subsidized charging for similar reasons.
- For public charging on city streets, the city may install and operate charging stations, optionally managed by an EV Services Provider. Since such charging stations may be used by a large number of drivers, the EV Services Provider may offer drivers the ability to search for EVSEs and reserve them. The EV Services Provider may derive revenue from the city as well as from the driver for these services.

- An EV manufacturer (OEM) or an affiliated telematics provider may offer services substantially similar to an EV Services Provider - in fact, they can be considered a type of EV Services Provider. The EV manufacturer may provide subsidized charging to its customers at EVSEs it operates.
- At commercial & industrial locations, EVSEs may be operated by a corporation for restricted use by its employees and visitors. Alternatively, use of the EVSEs may be restricted during certain times of the day only, or could be subsidized for employees but not for non-employee drivers.

The infrastructure communications required to support these different use cases and business models are varied and use different communication protocols to accomplish their purposes. For example, an EV may communicate with the utility via its telematics network, to download tariffs and make decisions about when to charge, based on cost. An EV may alternatively communicate with an EVSE to get the same information. Different EV Services Providers may compete for the EV driver's business.

Even though some business models today offer free EV charging, that is not likely to be the case in the future and eventually the consumer will need to pay for the electricity their EV is consuming. This means that the consumer must be recognized (i.e., authenticated), authorized (i.e., allowed access to the type/amount of charging for which they've paid) and their charging sessions must be accounted (i.e., metered), so that they can be billed appropriately.

Furthermore, the unique properties of EV charging bring with them additional requirements for communication.

Since an EV can take several hours to charge, the driver will typically be away while the EV is charging. Therefore, it is important that the driver be notified if there is a charging fault, or when charging is completed. In addition, being able to find charging stations and check whether they are available, check their pricing, and possibly reserve their use, is considered to be a useful value-add.

From the perspective of the utility, since EVs can consume a significant amount of energy, there needs to be a way to control or manage their load on the grid at times of peak demand. Communications allow the utility and EVs to be able to perform such functions in real time and in a flexible way. Intermediary actors may assist these communications. For example, a demand response aggregator or an Energy Management System may aggregate the load of a large number of EVs, and communicate with the utility on behalf of the group of EVs. An End Use Measurement Device (EUMD) may be provided to offer special tariffs and help customers shift loads for demand management.

EVs can also act as a distributed energy resource. They can then act as a source of energy and feed energy back into the home or into the grid when required. In order to do so, it may be necessary or desirable for communications to happen.

A.4 Functional View of EV Charging Infrastructure Communications

This section lists some of the functions that may be enabled or enhanced by EV charging infrastructure communications.

AAA (Authentication, Authorization and Accounting)

AAA (Authentication, Authorization and Accounting) functions are commonly deployed in multiple markets (such as cellular voice/data) and require communication between the consumer device (EV/EVSE) and the provider's AAA back end systems. Depending on the business model, an EV driver may need to be identified and authenticated, in order to access charging services that the driver has authorization to use. While charging is in progress, charging records must be sent to appropriate actors, so that the energy consumed by the EV is correctly recorded and used for billing and potential future taxation purposes.

Access Control

EVSE owners may wish to restrict charging services. A company may want to provide EV charging only to its employees, or it may wish to restrict charging services to its employees during working hours and allow anybody to charge outside of working hours. This requires access control mechanisms to be downloaded to the EVSEs, or a network where the EVSEs can query whether a driver can access the EVSEs.

Charging

The process of charging itself may require communications between the EVSE, the EV and other actors, to coordinate the direction, time, and amount of electricity. Basic communication between the EVSE and the EV, as defined in SAE J1772™ or IEC 61851-1, may be used to coordinate the amount of electricity and provide other charging related functionality. However, a higher-level communication is required to facilitate advanced functionalities, such as DC charging or bi-directional energy flow.

Depending on the scenario, infrastructure capabilities, and agreements in place, communications used for charging control may also address prices, customer preferences, local demand, or other criteria, and may be managed by the EV, EVSE, a local Energy Management System, third party, service provider, over the internet, or using mobile devices, among others. Additionally, driver notification messages may be necessary when faults occur, when the EV battery is full, or when other conditions occur.

Demand Response, Demand Shifting, Energy Storage and Distributed Energy Resource

From the standpoint of grid stability and customer costs, demand response, demand shifting, energy storage, and EV as distributed energy resource are applications that are considered to be important functions of the smart grid. Demand response can be considered a function of the service provider whereby, with permission of the EV operator, charging is temporarily stopped or limited due to local or distribution grid constraints. Demand shifting is more likely to be done by the EV operator based on pricing messages, EV tariffs (combined with EV measurement), facility demand, or a combination of these factors. Energy storage in relation to an EV consists of the use of on-board or off-board batteries that may be used to provide energy to or from the EV when electricity costs are high (e.g., during peak time periods) or, combined with reverse energy flow, during emergencies as a back-up power source. As a device that may be able to supply power or other ancillary services back to the grid, an EV can also be considered a distributed energy resource (DER).

EVs that participate in these functions may require communications between a service provider or intermediate entity such as an aggregator or an EV operator and the EVs/EVSEs.

Measurement (metering), Pricing (tariffs) and Billing

The discrete measurement of EV energy consumption can be considered a necessary function of EV charging for many reasons. In home charging scenarios, EV metering and tariffs provide utilities the ability to incentivize customers to shift charging to off peak times with less grid demand. To do this, utilities may provide special tariffs for the energy consumed by their EVs, that can be deducted from the bill if the meter is downstream of the premises meter (e.g., sub-metering) or billed separately if the EV usage is not recorded by the premises meter (e.g., separate metering). These meters (often called End Use Measurement Devices or EUMDs), which may be located near the premises meter, on an outlet, or in the EVSE or EV, must be able to communicate consumption and timing data back to the utility or third party (in certain circumstances) to apply the charges. In addition to the benefits of grid protection and reduced customer costs, these special tariffs and rates may also help drive the adoption of EVs.

In commercial charging scenarios, similar to home charging scenarios, utilities may provide special rates for the time and amount of charging. Facilities may also use the discrete measurement of EV charging to monitor and manage their own loads in order to minimize demand charges.

Many public charging scenarios involving EUMDs are possible. The charging provider may charge customers by how much energy their EVs have consumed (similar to gasoline stations). In this scenario a consumer must be able to see the amount that will be billed before starting an EV charging session. Alternatively, the charging provider also may offer different service plans, such that different consumers pay varying amounts for charging at the same station, based on their service plan (e.g., monthly contract). Another alternative is for a customer to be charged based on the time charging rather than the amount of energy consumed. Some of these scenarios may not require the use of EUMDs. Depending on the circumstance, the program (e.g., utility sub-metering, ISO ancillary service, etc.), and regulatory rules, the EUMD may need to meet certain standards for measurement. The EV, EVSE, third party, Energy Management System, or service provider may use EV tariffs, in combination with customer preferences, pricing schemes, local demand, and other criteria to provide communications and functionality to automatically manage charging.

Public Charging Station Locations Databases

An EV driver may be able to search for EVSEs (e.g., via the EV's navigation system, a smartphone, a computer, etc.) that are near the driver’s current or planned locations. The driver should also be able to know in advance whether the EVSEs are compatible with the driver’s EV, whether the EVSEs are available for charging, at what cost, and whether they can be reserved. This function will need a searchable Point Of Interest (POI) database of EVSE locations that contains for each listed EVSE a set of fixed attributes like location and type (e.g., L1/L2/DC/wireless charging), and a set of dynamically variable attributes (e.g., availability, pricing, fault status).

Reservations

Due to the time it takes to charge EVs and the currently limited number of publicly available EVSEs, it may be beneficial in some scenarios for an EV driver to be able to reserve an EVSE in advance.

A.5 Communications Architecture for EV Charging

Note: This is the same as roadmap section 3.2.2.1.

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 an 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) End Use Measurement Device (EUMD), and (7) EV Services Provider (EVSP).

Figure 5 shows a sample communications-oriented architecture containing the primary actors, including three different locations where charging may occur.

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.

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

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

Home 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 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 happen over a Home Area Network, or it may use the customer's internet connection, or it may use its own cellular data connection.

Commercial 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, 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.

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.

Communications High Level Architecture

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.

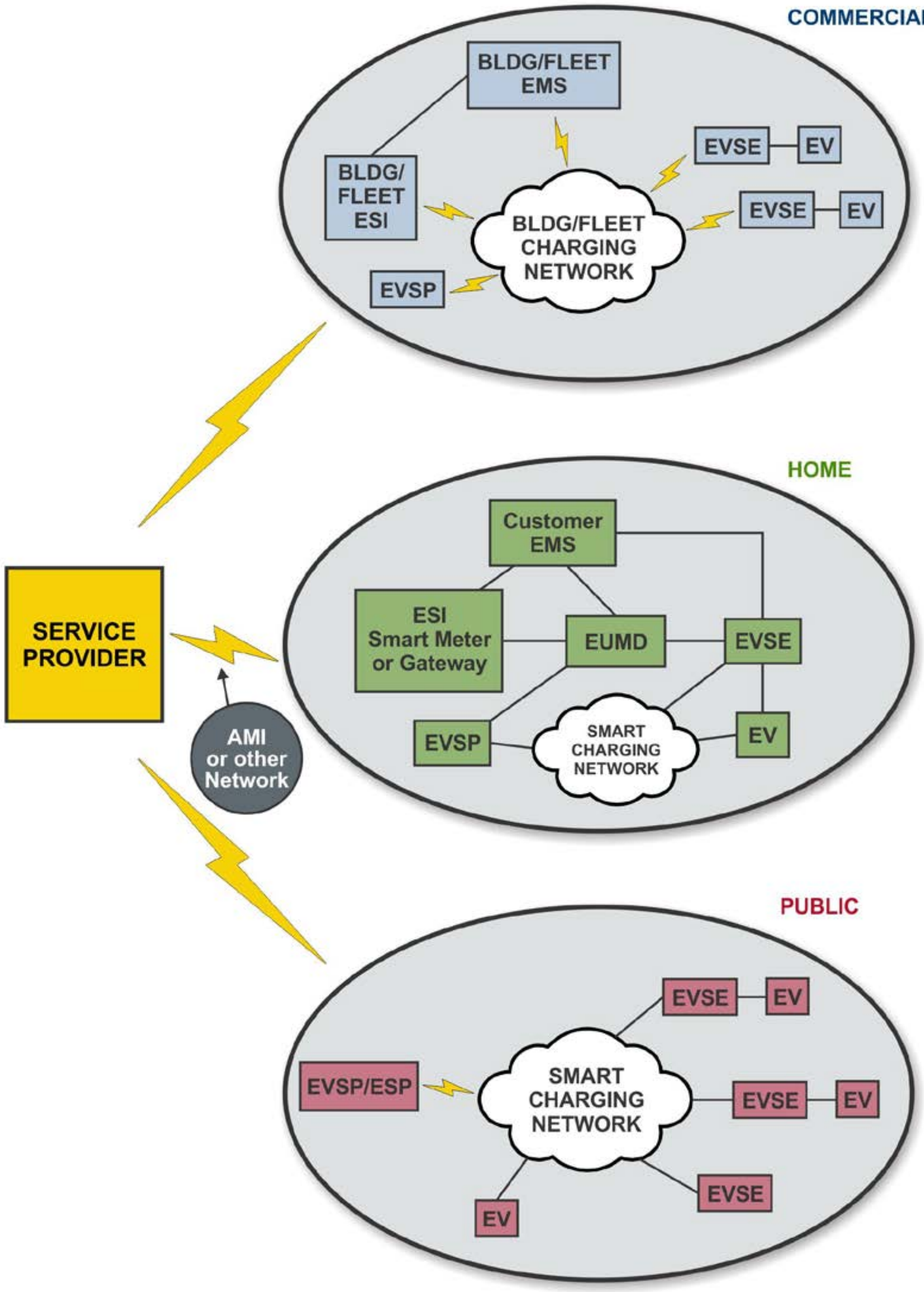

Figure 5: Sample Communications-Oriented Architecture for Commercial, Home, and Public Charging

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 takes place via a Home Area Network (HAN). 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.

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 OpenADR 2.0 or ESPI, and may act as an aggregator, providing a single communication point with the ESP for all the EVSEs in its purview. Creating and/or harmonizing standards specific to public charging communication is desirable in order to provide services such as finding and reserving charging stations.

A.6 Actors

EV

Electric Vehicle

EV Driver

A driver or operator of an EV. The term EV driver is used to include anybody who requests authorization to charge the EV (e.g., a fleet operator).

Electric Vehicle Supply Equipment (EVSE)

The conductors, the electric vehicle connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatuses installed specifically for the purpose of delivering energy from the premises wiring to the electric vehicle.

Energy Service Provider (ESP)

An entity that generates, transmits, and distributes electrical power (e.g., a utility). In this document, this term is also used to describe an Energy Retailer. An Energy Retailer is a seller of electricity and related services such as customer service and billing, but is not involved in generation, transmission and distribution.

Energy Management System (EMS)

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).

End Use Measurement Device (EUMD)

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.

EV Services Provider (EVSP a/k/a EVSE Host Management Services)

An entity that provides services related to EV charging, such as locating charging stations, reserving charging stations, subscription/fee-based charging, status/alerts via smartphones, etc. This entity may be an Energy Service Provider (such as a utility), a municipality, or an independent company providing these services.

A.7 Sample Types of Communications Between Actors

EV – EV Driver

Communication between an EV and its driver or operator. Although the user interface and possibly much of the communication involved may be proprietary, it may be useful to standardize a basic level of communication that covers alerts and status.

EV – EVSE

Communication between an EV and the EVSE to which it is physically connected. This communication is used for authentication, authorization of charging, metering and sign-off by the EV of metering data; communicating EV data such as state of charge (SOC) to the EVSE/EMS/grid; selection of charging plan and time based on available tariff information obtained from the EVSE, etc. Depending on whether the EV, the EVSE or both are intelligent, the communication to the grid may be performed by either (or both) of them.

EV – Energy Service Provider

The EV and the Energy Service Provider may communicate directly with each other (in certain scenarios such as when an EVSE acts as a PLC-ZigBee bridge or via OEM owned telematics link) and exchange messages related to pricing/tariffs, demand response, metering, etc.

EV – EMS

An EMS may control multiple devices that act as loads or sources in the home/building/premises. Communication between the EV and the EMS provides the EMS with information about the EV charging requirements, real-time status, errors, etc. The EMS may control charging parameters such as start/stop time and amount of energy dispensed. It may also act as an interface for the Energy Service Provider, by acting on demand response messages, adapting charging schedules based on the grid status, and managing reverse energy flow to the grid (V2G).

EV – EV Services Provider

An EV may communicate with an EV Services Provider and exchange messages related to state of charge (SOC), selection of charging parameters based on tariffs, demand response, etc.

EV Driver – EVSE

The interaction between an EV driver and an EVSE will probably take place via a user interface or via an EMS or EV Services Provider

EVSE – Energy Service Provider

The EVSE and the Energy Service Provider may communicate directly with each other and exchange messages related to pricing/tariffs, demand response, metering, etc.

EVSE – EV Services Provider

EVSEs are managed by an EV Services Provider. The communication involved relates to status, diagnostics, reservations, pricing, access control, metering data, demand response, etc.

EMS – Energy Service Provider

Communication between the EMS and an Energy Service Provider may include handling of demand response, DER (distributed energy resources, e.g., for energy flow from the EV to the grid), pricing/tariff related information, etc.

EUMD – EV Services Provider/Energy Service Provider

The billing entity, whether it is the EVSP or the ESP, may communicate with the EUMD in order to collect EV energy consumption data and apply billing parameters or tariffs. In certain scenarios, the EUMD data might also be used to validate program compliance (e.g., demand response or ancillary services).

EV Services Provider – Energy Service Provider

Communication between an EV Services Provider and an Energy Service Provider may include demand response and pricing related messaging, as well as charging records.

EV Services Provider – EMS

An EMS or home/building/premises automation system may query charging records from the EV Services Provider that manages the charging stations at the home/building/premises. Also, charging constraints such as time of charge, energy to be dispensed, and access control may need to be communicated to EVSEs via the EV Services Provider.

EV Services Provider – EV Services Provider

Two EV Services Providers may communicate directly or via a third party when the customer of one provider charges at a station managed by the other. This communication would include authentication, authorization, accounting, and settlement.

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Appendix B. Glossary of Acronyms and Abbreviations

See also *Appendix A. EV Charging Actors and Communications* and the *ANSI EVSP Roadmap Standards Compendium*.

AC – Alternating Current

AEV – Battery-Powered All Electric Vehicle

ANCE (Mexico) – La Asociación Nacional de Normalización y Certificación del Sector Eléctrico, A.C.

CANENA – Council for Harmonization of Electrotechnical Standards of the Nations of the Americas

CEN – European Committee for Standardization

CENELEC – European Committee for Electrotechnical Standardization

DC – Direct Current

DER – Distributed Energy Resource

DOE – U.S. Department of Energy

EMC – Electromagnetic Compatibility

EPRI – Electric Power Research Institute

EREV – Extended Range Electric Vehicle

ESO – European Standards Organization

EV – Electric Vehicle

EVSE – Electric Vehicle Supply Equipment

FMVSS – Federal Motor Vehicle Safety Standards

GTR – Global Technical Regulation

HAN – Home Area Network

HEV – Hybrid Electric Vehicle

IAEI – International Association of Electrical Inspectors

IBC® – International Building Code®

ICC – International Code Council

IEC – International Electrotechnical Commission

IEEE – Institute of Electrical and Electronics Engineers

IFC® – International Fire Code®

IgCC™ – International Green Construction Code™

IMC® – International Mechanical Code®

IRC® – International Residential Code® for One- and Two-Family Dwellings

ISO – International Organization for Standardization

IZC® – International Zoning Code®

NAN – Neighborhood Area Network

NEC® – NFPA 70®, the National Electrical Code®

NECA – National Electrical Contractors Association

NEMA – National Electrical Manufacturers Association

NFPA – National Fire Protection Association

NHTSA – National Highway Traffic Safety Administration

OEM – Original Equipment Manufacturer

PEV – Plug-in Electric Vehicle

PHEV – Plug-in Hybrid Electric Vehicle

PLC – Power Line Communication

RESS – Rechargeable Energy Storage System

RFID – Radio-Frequency Identification

RPF – Reverse Power Flow

SAE – SAE International

SGIP – Smart Grid Interoperability Panel

SDO – Standards Development Organization

UL – Underwriters Laboratories, Inc.

UNECE – United Nations Economic Commission for Europe

V2G – Vehicle to Grid

V2H – Vehicle to Home

V2L – Vehicle to Load

V2V – Vehicle to Vehicle

WP.29 – World Forum for Harmonization of Vehicle Regulations

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STANDARDIZATION ROADMAP
FOR ELECTRIC VEHICLES

VERSION **2.0**

www.ansi.org/evsp

ANSI
American National Standards Institute

1899 L Street NW, 11th Floor
Washington, DC 20036
T: 202.293.8020
E: info@ansi.org

www.ansi.org