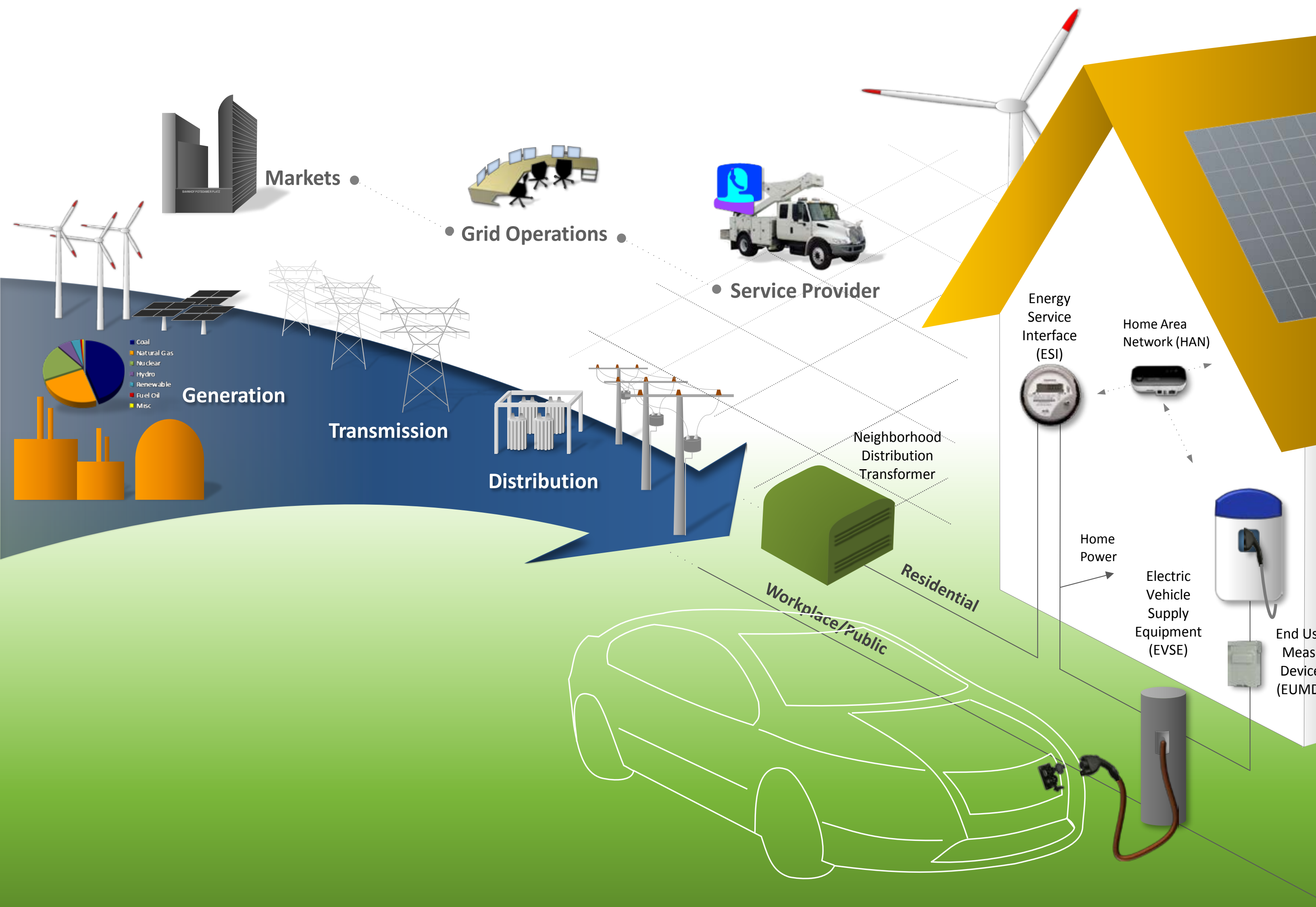
USDRIVE

DRIVING RESEARCH AND INNOVATION FOR VEHICLE EFFICIENCY AND ENERGY SUSTAINABILITY

Grid Interaction Technical Team Roadmap

June 2013



This roadmap is a document of the U.S. DRIVE Partnership. U.S. DRIVE (Driving Research and Innovation for Vehicle efficiency and Energy sustainability) is a voluntary, non-binding, and nonlegal partnership among the U.S. Department of Energy; USCAR, representing Chrysler Group LLC, Ford Motor Company, and General Motors; Tesla Motors; five energy companies — BP America, Chevron Corporation, Phillips 66 Company, ExxonMobil Corporation, and Shell Oil Products US; two utilities — Southern California Edison and DTE Energy; and the Electric Power Research Institute (EPRI).

The Grid Interaction Technical Team is one of 12 U.S. DRIVE technical teams ("tech teams") whose mission is to accelerate the development of pre-competitive and innovative technologies to enable a full range of efficient and clean advanced light-duty vehicles, as well as related energy infrastructure.

In March 2012, DOE announced a 10-year vision for plug-in electric vehicles (PEVs), called the "EV Everywhere Grand Challenge." EV Everywhere aims to enable American innovators to rapidly develop and commercialize the next generation of technologies to achieve the cost, range, and charging infrastructure necessary for widespread PEV deployment. As demonstrated in its guiding Blueprint document, EV Everywhere aligns with U.S. DRIVE technical areas focused on electrochemical energy storage, electrical and electronics, materials, vehicle systems and analysis, and grid interaction (for more information, please see www.vehicles.energy.gov/electric_vehicles/10_year_goal.html).

For more information about U.S. DRIVE, please see the U.S. DRIVE Partnership Plan, www.vehicles.energy.gov/about/partnerships/usdrive.html or www.uscar.org.

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Mission

The mission of the Grid Interaction Technical Team (GITT) is to support a transition scenario to large scale grid-connected vehicle charging with transformational technology, proof of concept and information dissemination. The GITT facilitates technical coordination and collaboration between vehicle-grid connectivity and communication activities among U.S. DRIVE government and industry partners.

Scope

Unlike other U.S. DRIVE technical teams, GITT does not have long-term technical targets; the team focuses rather on near-term needs of the automotive and utility industries to provide safe, reliable and secure vehicle-grid interfaces, hence the GITT addresses enablers for connectivity between light duty plug-in vehicles, the charging infrastructure and the electric power grid, encompassing the following:

- Harmonization of Global Connectivity Standards
- Enabling Technology Development
- Enhanced Viability of Fast/Consumer-Friendly Charging
- Managed Vehicle Charging Loads Consistent with Smart Grid
- Reduced Cost of Electric Charging Infrastructure

Gaps/Barriers

With electric and plug-in hybrid vehicles already on the market and production pending by essentially all the major manufacturers, standards for the EV-grid interface need to be adopted to ensure that EVs are compatible with residential, workplace and public charging infrastructure. Members of the team directly support the development and verification of standards for connecting to and communicating with electric vehicle supply equipment (EVSE) and the grid as well as develop enabling technologies to implement the standards at the vehicle-grid interface.

- Supporting standards committees that address AC and DC conductive charging, non-conductive (wireless) charging and interoperability, including test equipment and procedures for verifying conformance with standards.
- Developing interface components that comply with automotive and smart grid communication standards.

Codes and Standards

Connectivity and communication standards for automobiles are being developed by many organizations, including but not limited to, the Society of Automotive Engineers (SAE) and the Institute of Electrical and Electronics Engineers (IEEE) centered in the United States, the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) centered in Europe and by organizations such as the China Automotive Technology and Research Center (CATARC) for the Chinese government.

The vehicle connection to residential electric systems and the electric power grid necessitates the involvement of several other standards bodies not typically referenced in the production of automobiles, such as the American National Standards Institute (ANSI), the National Institute of Standards and Technology (NIST), Underwriters Laboratories (UL) and the National Fire Protection Association (NFPA).

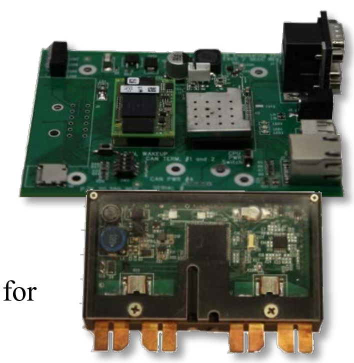
The automotive members of the GITT are major contributors to the standards committees and DOE supports direct participation by the national laboratories — with support ranging from drafting/reviewing standards to chairing committees and verifying standards in the vehicle and electrical/electronic laboratories. To facilitate harmonization, selected IEC/ISO committees and the “non-automotive” organizations are directly supported as well.

- *AC Level 1 and 2 Charging Communication*. Development and verification of the SAE J2953 interoperability standard; test equipment and procedures to verify conformance.
- *DC Level 2 Charging Communication*. EV-EVSE compatibility with the new standard DC charge coupler (i.e., the SAE J1772v5 'combo') as well as the communication technology and messaging protocols must be verified. The immediate need is to develop a test methodology and equipment to assess these capabilities with minimal risk (i.e., due to the high power dc connection).
- *Wireless Charging*. With non-conductive charging systems close to being on the market, the focus is on development of the SAE J2954 standard, test fixture and verification procedures (i.e., safety, efficiency, etc.). In addition, wireless communication technology is being investigated since the pilot line of a conductive coupler is not present.

Enabling Technologies

The connection between an EV and the charging infrastructure is expected to be safe, secure and interoperable to facilitate refueling regardless of location or energy service provider. This requires an interface that can, at a minimum, communicate vehicle information. More sophisticated load management, i.e., as part of a smart grid, will require bi-directional communication between the EV, electric vehicle supply equipment (EVSE), electric service interface and the utility/grid operator (or a middleman, such as a private charging network).

Charge couplers for conductive AC and DC charging, as well as messaging protocols for EV-EVSE communication, have been harmonized in the US and Europe. However, communication has developed on different paths in the automotive and utility industries and translation is required to implement seamless communication with the grid. Hence, AC/DC EV communication controllers (EVCC) for EV-to-EVSE messaging and supply equipment communication controllers (SECC) for EVSE-grid messaging have been developed by Argonne National Laboratory (right) to verify messaging protocols. The communication controllers can be adapted for wireless charging messaging standards verification as well.



Potential regulatory measures impact technology development as well. Proposals ranging from lower EV electric rates to alternative fuel taxation schemes would require separate, revenue-grade measurement of energy use by EVs (aka, EV sub-metering). These regulations would necessitate new devices with the functionality of Argonne's End-Use Measurement Device (EUMD, right) for incorporation in the EV, EVSE or electric service interface.

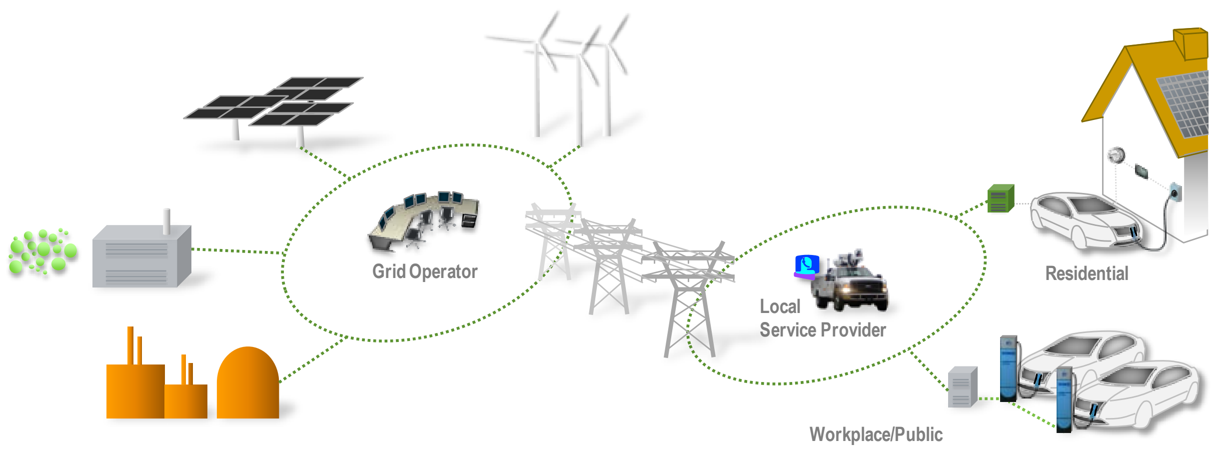
DOE has sponsored development of prototype metrology/communication modules and embedded software (i.e., the examples above) to support the definition and refinement of standards. Development of these technologies and methodologies in collaboration with the GITT has spurred technology and product development in the supplier community.

Smart Charging/Smart Grid Interface

Smart charging will likely be implemented at residential/individual, local/multi-vehicle and regional/aggregate fleet levels. From the vehicle perspective, each application will likely require similar vehicle sub-metering and bi-directional communication. But from the utility/grid perspective, each application could be subject to different regulatory constraints and could require equipment specific to the application. Team members (both industry and government) remain in contact with key regulatory entities (e.g., the California Public Utilities Commission) to assess the technical impact of potential regulations, such as sub-metering, as well as the Smart Grid implementation activities at NIST, DOE, etc. The technical efforts of the team will focus on refinement of the EV-grid interface components (individual vehicle level) and implementation of smart charging for multi-unit/workplace charging (e.g., aggregate smart charging control).

Strategy

Technical activities will continue to focus on near-term needs with long-term impact, e.g., EV-grid connectivity and communication standards. But the ultimate contribution of EVs will be realized in the broader context of intelligent energy management, i.e., when EVs are considered an integral part of a smart grid of renewable and conventional energy sources, energy storage and smart electric energy consumers — as represented in the following figure. Therefore, harmonization of connectivity and communication standards with other grid-connected devices will be addressed in the future.



Codes and Standards

Support to the SAE and IEC EV standards committees has contributed directly to the development and adoption of key connectivity standards and harmonization between the United States and Europe; the support will continue — at least through 2017 when it is expected that EV-grid standards will be in place (harmonized or not) in major markets throughout the world. The development of enabling technologies will continue as required to support the development and verification of interoperability standards or address a technology gap recognized by the team.

Enabling Technologies

Refinement of enabling technologies (i.e., the EUMD and EVCC/SECC) will continue as required to facilitate the development and validation of communication standards and to develop/validate the translation between automotive and utility messages. Due to the emphasis on grid integration, opportunities to adapt the components to other grid-connected devices will be explored.

Smart Charging/Smart Grid Interface

A laboratory demonstration of EV-grid integration will be performed (using grid simulation and hardware-in-the-loop techniques) to identify opportunities and requirements for technical alignment between EVs and other grid-connected devices.

Milestones

Codes and Standards

Key standards for connectivity and communication at the EV-grid interface will be adopted within the next few years. Though the actual dates will be determined by the standards committees, the support activities associated with the standards and rough completion dates are listed below:

- *SAE J2953 (interoperability) Standard*. Draft standard, develop test fixture and standard verification procedures; assess conformance to EV-EVSE-grid communication protocols (conductive charging — 2013-2014, inductive charging — 2014-2015).
- *SAE J1772 DC (charging communication) Standard*. Develop test fixture, high power PEV emulator and standard verification procedures; assess conformance to EV-EVSE communication protocols (2013-2015).
- *SAE J2954 (wireless charging) Standard*. Develop test fixture and standard verification procedures; assess conformance to power transfer/safety and wireless communication standards (2014-2015).

Enabling Technologies

With recent developments in system on chip technology, another version of the EUMD is being considered that would target a one-chip solution for sub-metering and communication. Successful development would greatly expand opportunities for sensing and communicating at numerous nodes in a smart grid and greatly increase the chances of implementing smart charging on a broad scale (est. 2014, depending on chip availability).

Future smart grids will require integration of EVs and other grid-connected devices using standard protocols; this suggests the possibility to apply the EUMDs and communication controllers developed for EV-grid communication to the grid interfaces with devices such as distributed energy resources, solar, wind and energy storage. The requirements and implications of application on a broader scale will be explored with other DOE labs and suppliers in the interest of harmonizing smart grid interface standards and technology, broadening the market (reducing risk and cost) and accelerating commercialization (2014-2015).

Smart Charging/Smart Grid Interface

EV-smart grid communication and smart energy management will be demonstrated using hardware-in-the-loop techniques with a simulated grid in 2013; this will potentially be followed by a collaborative grid integration activity in 2014-2015.