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CALIFORNIA
Vehicle-Grid Integration (VGI) Roadmap:
Enabling vehicle-based grid services

February 2014

The California ISO thanks the California Energy Commission and the California Public Utilities Commission for their support in the development of the VGI Roadmap. We also acknowledge the commitment to this effort shown by our industry stakeholders who participated in workshops leading up to the draft roadmap. Stakeholder engagement and ongoing feedback were critically important. Additionally, the ISO recognizes the work of DNV-GL, which facilitated the stakeholder process, integrated comments and developed the roadmap tracks.

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1. EXECUTIVE SUMMARY

Vehicle electrification presents an unprecedented opportunity, through charging strategies and aggregation, to contribute to the reliable management of the power grid, without impacting consumer driving habits.

The State of California, long a leader in promoting implementation of sustainable, clean energy resources, is at the forefront of policies that fight climate change while advancing a green economy. Through an executive order in 2012, Governor Jerry Brown set a target of 1.5 million zero-emission vehicles (ZEVs) on California roads by 2025.[1] To realize this goal, the Governor's Interagency Working Group on Zero-Emission Vehicles published a ZEV Action Plan.[2] The plan identifies actions across a number of agencies and organizations that when executed advance California's ZEV goals.

This Vehicle-Grid Integration (VGI) Roadmap accomplishes one of the ZEV Action Plan activities—mapping a way to develop solutions that enable electric vehicles (EV) to provide grid services while still meeting consumer driving needs.

As the main grid operator for the state, the California Independent System Operator Corporation (ISO) took the lead in drafting the VGI Roadmap in coordination with the Governor's Office, the California Energy Commission, the California Public Utilities Commission and the California Air Resources Board. The effort included a comprehensive stakeholder review process to ensure the roadmap captured the ideal course of actions. The intention is to keep consumers in the driver's seat during the transformation to a cleaner grid by enabling managed EV charging consistent with grid conditions. Eventually, two-way interfaces between EVs and the bulk power network could benefit both EV owners and the grid-at-large.

Creative approaches identified in this roadmap are expected to lead to EV charging behavior that is beneficial or at least not adverse to grid reliability. This roadmap also promotes the aggregation of EV resources that can be bid into the ISO's wholesale market as grid services—leveraging the synergies between EVs and the grid.

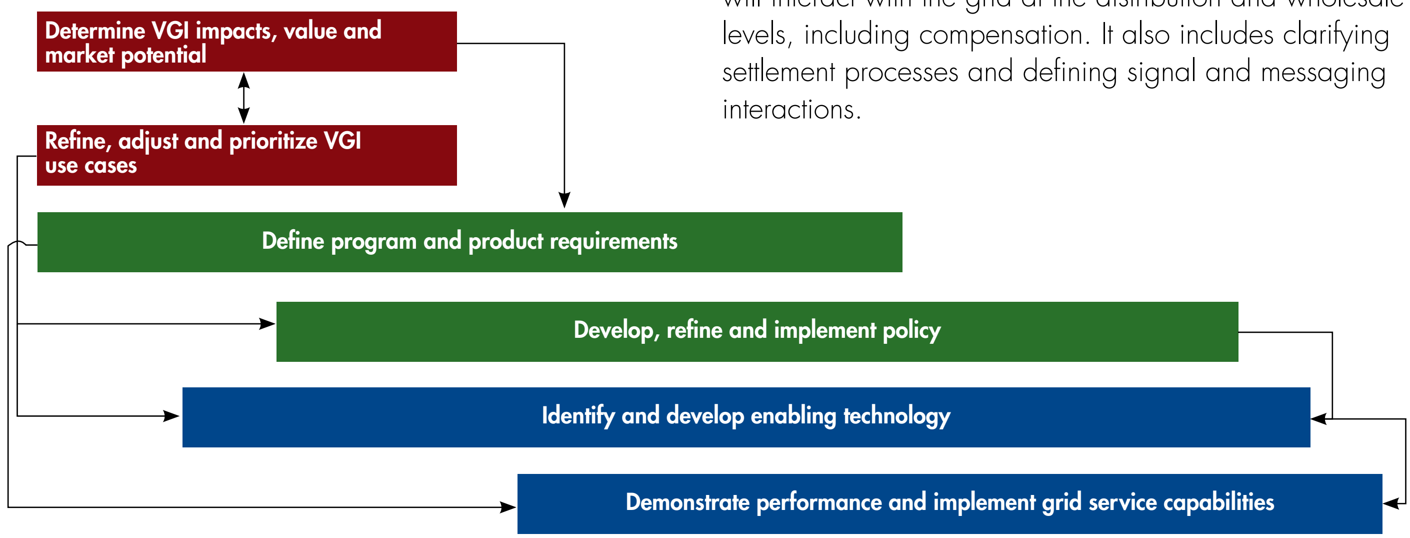
Vehicle electrification and smart grid technology implementation present an opportunity for EVs, through charging strategies and aggregation, to support and provide valuable services to contribute to reliable management of the electricity grid. At a minimum, managed or smart charging strategies are needed to ensure that EVs do not increase peak load, requiring additional generation or capacity expansions. Ideally, charging is coordinated with grid conditions and the ability for aggregation of EVs to respond to grid operator signals. The VGI Roadmap provides a high-level plan to enable this combination of activities.

VISION: *Electric vehicle charging creates a reciprocal relationship between battery-powered cars and the power grid in a way that produces mutual benefits. Without compromising the driving habits of consumers, incentives should be pursued as a way to aggregate vehicle charging to develop valuable grid services.*

[1] California Executive Order B-16-2012.

[2] The Governor's Interagency Working Group on Zero-emission Vehicles published a Draft Action Plan for public comment in 2012, and a first edition in 2013.

The following diagram summarizes the path to enable EVs to provide grid services. The roadmap begins with a value assessment drawing from VGI use cases. The use cases include the extent of vehicle aggregation, communication needs, and the grid service being provided. As the value assessment progresses, use cases are adjusted, refined and prioritized. At the same time, program development begins. As the California Public Utilities Commission (CPUC) and stakeholders develop programs, they are evaluated in the context of existing policy. This evaluation identifies needs for new policy and refinements to existing policy. For use cases requiring little or no policy development, activities commence to implement and test the grid service capabilities. Policy work continues to support other valued use cases. Enabling technology development advances on a separate supporting path.



The roadmap is organized in three inter-dependent tracks:

1. determine VGI value;
2. develop enabling policy; and
3. support enabling technology development.

Track 1, "Determine VGI Value," will determine the value and increase understanding of market potential for grid services enabled by VGI. This value determination will support how program developers and operators define VGI programs and facilitate industry investment decisions. Articulating value based on use cases is critical in Track 1. The track activities include articulating VGI impacts to the electricity system, identifying and quantifying VGI value streams and cost components, and estimating VGI market potential for various VGI use cases.

Track 2, "Develop Enabling Policies, Regulations, and Business Processes," includes activities to define wholesale and retail products and programs and associated policy. The program development will identify how VGI resources will interact with the grid at the distribution and wholesale levels, including compensation. It also includes clarifying settlement processes and defining signal and messaging interactions.

Track 3, "Support Enabling Technology Development," includes activities to develop enabling technology including standards that support VGI aggregation, communication, and control requirements. Enabling VGI technology will facilitate EV aggregations to support grid services as articulated in the use cases. Policymakers, grid operators, and original equipment manufacturers (OEMs) must coordinate to enable VGI use cases that include two-way power flow.

Steps to enable EV aggregations to provide grid services are already underway in California. Rulemaking proceedings and standard development efforts that will define the future for VGI are in progress.[3] Research, development and demonstrations have begun to explore the potential for VGI services and to enhance enabling technologies. This roadmap is the first step toward defining future steps towards meeting the goal of EV aggregations contributing to grid reliability.

[3] Most notably, the CPUC has an active rulemaking on Alternative Fueled Vehicle Programs, Tariffs and Policies, R.13-11-007, which is in support of Executive Order B-116-2012 and which will conduct activities associated with this VGI Roadmap.

2. WHAT IS VEHICLE-GRID INTEGRATION?

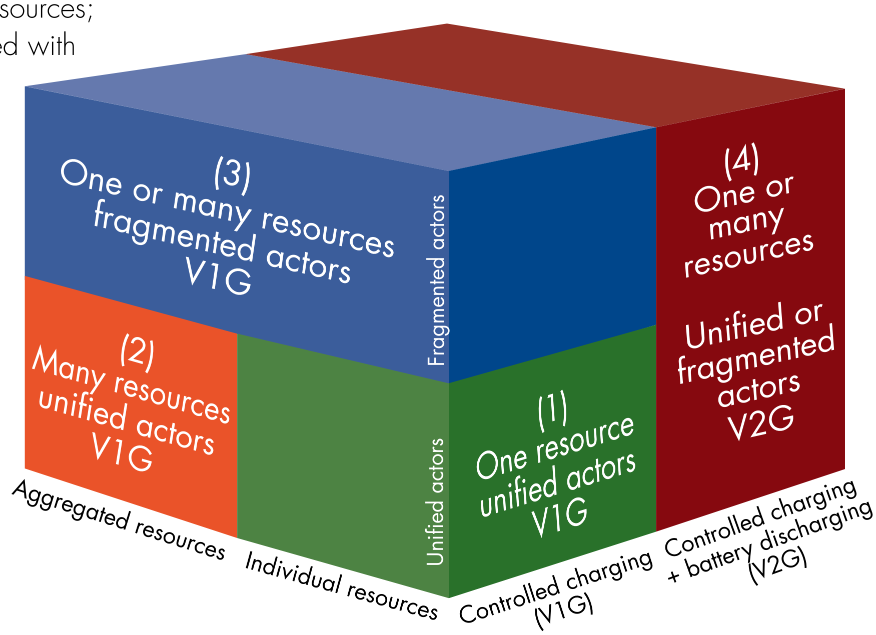
The term vehicle-grid integration or VGI, as used in this roadmap, encompasses the ways EVs can provide grid services. To that end, EVs must have capabilities to manage charging or support two-way interaction between vehicles and the grid. Managed charging refers to the technical capability to modulate the electric charging of the vehicle through delay, throttling to draw more or less electricity, or switching load on or off. Two-way interaction refers to the controlled absorption and discharge of power between the grid and a vehicle battery or a building and a vehicle battery. VGI is enabled through technology tools and products that provide reliable and dependable vehicle charging services to EV owners, and potentially additional revenue opportunities, while reducing risks and creating cost savings opportunities for grid operators. Such tools might include technologies such as inverters, controls or chargers, or programs and products, such as time of use tariffs or bundled charging packages.

Use cases can help define the many combinations possible with VGI and their benefits, costs, and possible regulatory barriers. In support of its rulemaking on alternative fuel vehicles (R.13-11-007) the CPUC has started to define VGI use cases.[4] Further refinement will likely occur throughout the rulemaking. The CPUC Energy Division's current VGI Framework is defined by three attributes, each with two potential options: whether the benefit to the grid is provided by an individual or aggregation of resources; the alignment of the objectives of actors involved with the PEV charging, and the direction of the power flow (one- or two-way) from the resource. Eight use cases exist given the combination of the three attributes. The CPUC prioritizes four groupings of these eight use cases with respect to resolving the regulatory considerations with each "dimension" and proposes a path toward implementation. The four use case categories are:

1. Unidirectional power flow (V1G) with one resource and unified actors
2. V1G with aggregated resources
3. V1G with fragmented actor objectives
4. Bidirectional power flow (V2G)

The framework, depicted as a cube, aims to conceptually bind the potential multitude of different use cases and programmatic tools to integrate vehicles with the grid. For example:

- Time-of-use price-based charging using a standard outlet to charge an EV in a residential setting could be classified in use case (1).
- Bidirectional power flow at multiple workplace electric vehicle supply equipment (EVSE), coordinated by an aggregator in response to information based on local grid conditions would be classified in use case (4).[5]



[4] The CPUC white paper, "Vehicle-Grid Integration" published on October 2013 provides more information about the relevance of VGI, descriptions of applications, and a proposed framework for defining VGI.

[5] Ibid pages 35 and 22.

As part of this VGI roadmap process, stakeholders have recommended additional use cases such as the following:

1. Time of use Rates: The use of EV rates to help integrate EVs with the grid. This would apply to both residential and commercial rate design and would seek to encourage off peak charging or charging at lower levels.
2. Charging Levels: The promotion of lower or varied charging levels to help integrate EVs with the grid. This could be done through education, outreach and rate design, and could apply to residential and commercial customers.
3. EV batteries in stationary applications: The use of EV batteries to provide grid benefits, and support EV integration.

As part of this VGI roadmap, Track 1 will refine the VGI use cases.

In addition, this roadmap defines activities to enable VGI for grid services. In particular, it seeks to bolster those areas that are lacking development but are needed to support enabling VGI. In addition, it reflects the need to coordinate VGI-related activities across the state. Furthermore, while VGI is dependent on the adoption of EVs and affected by the deployment of EVSE, this roadmap is specific to VGI. It explores those aspects that affect EV's ability to offer grid services, rather than those efforts needed to support deployment of EVs or EVSE.[6] As the technical, economic and policy issues associated with energy storage (ES), demand response (DR) and other distributed energy resources can be highly relevant to VGI, the VGI Roadmap advances activities that also address distributed energy resource issues at the wholesale and distribution levels.[7]

The process for the development of this roadmap included several stakeholder meetings to gather the input and advice of those directly involved in VGI activities. This document is largely based on these discussions, using content derived from stakeholder input. Furthermore, it was developed such that it can be a living document. As VGI efforts progress in the state, the roadmap can be updated to reflect new achievements and challenges. Because enabling VGI will require a number of players, the roadmap identifies several stakeholders, including investor-owned utilities, municipalities, EV and EVSE manufacturers, and third party aggregators, among others. It also seeks coordination among the California Energy Commission, California Public Utilities Commission (CPUC), the California Air Resources Board (CARB), the California ISO and the Governor's office.

[6] The VGI Roadmap considers technologies beyond solely EVs and EVSE which might influence VGI implementation or value streams, such as ES or DR. For example, a) ES and DR have the potential to help implement VGI-related behaviors by assisting with net load reductions and charging management (the ability of ES and DR to do this might be considered under Track 3); b) Stationary ES and other DR may ultimately compete with EV-based VGI services (the effect of ES and DR on VGI value might be considered under Track 1); and c) the development of a second-life battery market will likely influence the VGI-related behavior of customers (the potential 'conservation' of battery life for after-life sales or the potential of the sales might be considered under Track 1, for example). Furthermore, many initiatives underway affecting DR and ES are likely to impact VGI.

[7] In a separate, related effort, the ISO engaged Olivine to assess the barriers and challenges for DER participation in the ISO market. The report also includes high-level recommendations to address and remove these barriers. As EV aggregations are one type of DER many of the recommendations in the report are relevant to enabling vehicle-based grid services. This report can be found at: http://www.caiso.com/Documents/OlivineReport_DistributedEnergyResourceChallenges_Barriers_Draft.pdf

3. IDENTIFIED BARRIERS

This roadmap includes activities targeted at removing VGI-related barriers. Many barriers were identified through stakeholder workshop and comments. The following summarizes the key barriers identified:

- the value of VGI is not clear;
- VGI-eligible products, programs, and enabling policies must be defined and implemented; and
- technical functionality must be improved and technical standards and specifications must be developed and coordinated.

3.1 Value of VGI

Many stakeholders report that several aspects of VGI are technically feasible today but the economic, environmental and grid benefits are underdeveloped, inconsistent or unproven. In particular, stakeholders noted inconsistent awareness about the capabilities of VGI technologies, such as the ability to contribute to local voltage management. Also, stakeholders noted particular uncertainty about mid and longer term values due to potential changes in the electricity system, such as increased penetration of renewable energy and energy storage and modified approaches to integrating distributed energy resources. To spur investment in VGI and to promote customer adoption, the VGI value proposition must be understood and the benefits must outweigh the costs across the entire value chain.

Stakeholder Feedback: Snapshot 1

Market participation, policies and settlement rules need to be defined. VGI cannot thrive under a "one size fits all" approach. Customized and balanced solutions and products must be allowed. The role of tariffs should be considered. Intelligent time of use solutions that are customized to regions and use patterns may be required to ensure operation is consistent with grid conditions.

3.2 Market Product Definitions, Requirements, and Processes

To realize VGI value, the rules and business processes must be clear. Stakeholders expressed uncertainty regarding VGI eligibility in providing grid services, technical and programmatic requirements, settlement processes, and signal and messaging processes. Aside from understanding VGI values, technology and service providers need requirements and process clarity to establish business models that can capture the program values. The ISO, CPUC and utilities need to clarify requirements for participation, notification and dispatch approaches, and settlement requirements, particularly related to metering and telemetry.

Stakeholder Feedback: Snapshot 2

Communication and control technologies and consistent technology platforms are essential for the VGI market to grow. Varying design standards for EVSE could lead to limited access for VGI services. Consistent requirements for EVSE should be established. In addition, the current EVSE technology lacks proper capabilities to provide seamless two-way communication between vehicle and grid. It is important that intelligent control solutions are devised for individual and aggregator use cases. Non-uniform communication protocols must be overcome and issues with UL standards must be resolved.

3.3 Technology and Coordination

Technology to support managed charging and two-way power flow is still in a research and development stage. Additional technology to support communication, control, two-way power flow, and other capabilities need to be advanced. Because many technology developers and original equipment manufacturers design their products for national or global markets, stakeholders expressed a strong desire that California electrical codes and standards be consistent with established codes and standards nationally if not globally. Stakeholders also identified limited coordination between manufacturers, grid operators and policymakers as an additional barrier.

4. VGI ROADMAP

The following sections include a description of each of the roadmap tracks as well as the activities supporting the track goals. Detailed activity timelines are provided in Appendix A.

4.1 Track 1: Determine VGI Value and Potential

This track will determine the value of VGI grid services and includes activities that enable stakeholders to formulate business models. Although VGI is a proven concept from a technology perspective, uncertainty remains about VGI physical impacts, costs and value and how these might evolve over time. Resolving these uncertainties across the VGI value chain and providing information to stakeholders will help promote consistent understanding and enable industry stakeholders to develop business models for the VGI market.

Articulating value based on use cases is critical in Track 1. Use cases define the extent of EV aggregation, communication needs, and the grid service being provided. Related to the extent of EV aggregation, the list of terms in Appendix E defines several aggregation approaches including unidirectional managed charging services (V1G), bidirectional vehicle-to-grid services (V2G), and vehicle-to-building services (V2B). Use cases also include considerations for different approaches such as variable pricing control, application at the distribution, wholesale, or customer site, and technology including charger, control type, etc. In addition, they may account for interactive effects of other distributed resources such as stationary storage and solar PV. They provide a manageable framework to analyze the economic, technical and business issues while ensuring the compatibility of multiple analyses.

Understanding existing and near-term opportunities is critical to kick-starting the VGI market, but it is also important to understand the future market potential because developing technologies for infrastructure requires substantial investments. Track 1 outcomes will help VGI stakeholders make informed investment decisions based on a clear appraisal of the scope of the VGI opportunity.

Clarifying the VGI value will provide information to policy makers and stakeholders in Track 2 for developing the needed policies, regulations and business processes. It will also provide guidance to stakeholders in Track 3 to develop enabling technologies.

Roadmap Activities for Determining VGI Value Track

The following table captures key activities included in this roadmap track. The Energy Commission, CPUC and ISO expect to involve stakeholders within the industry, such as consumer groups, utilities and municipal power entities, or VGI product makers or providers, as progress is made and as roadmap activities are assigned to stakeholders through associated policy or stakeholder processes.

Goal	Roadmap activities
Confirm VGI electrical system impacts	Refine VGI use cases
	Develop tools and methods to assess VGI impacts to the electricity system
	Assess VGI impacts by • VGI type - V1G, V2G, V2B, B2G - aggregated, individual - unified, fragmented • approach (e.g., variable pricing, control, etc.) • application (distribution, wholesale, etc.) • technology (e.g., charger, controls type, etc.)
	Assess interaction with other capabilities
	Assess simultaneous effects throughout the grid
Determine VGI value	Develop tools and assess value from impacts
	Assess VGI value by • VGI type - V1G, V2G, V2B, B2G - aggregated, individual - unified, fragmented • approach (e.g., variable pricing, control, etc.) • application (distribution, wholesale, etc.) • technology (e.g., charger, controls type, etc.)
Confirm VGI market potential	Explore market certainty for grid services
	Study potential for adoption
Formulate VGI business models	Assess stakeholder needs for developing business models
	Develop programs to address needs
Research, development and demonstration (RD&D)	Coordinate existing RD&D
	Ensure results are published
	Identify additional research gap for further study
	Scale up pilots as necessary

Confirm VGI Electrical System Impacts

Goal: assess VGI physical impacts to the electrical system for each use case

The VGI grid impacts will be evaluated for each use case as each one will include different VGI types, approaches, applications and technologies.[8] The evaluation will clarify the broad range of VGI impacts to the electrical system. This includes the potential VGI responsiveness to wholesale and retail market products or programs. VGI applications could include aggregate real or reactive power responses for a given price signal. In addition, the activities will account for how different use cases may impact each other. For example, the assessment could include the impact on transmission system operations due to responses based on localized grid conditions, the impact on real power service due to reactive power responses, or how one program might affect the availability of VGI resources for another service.

[8] The CPUC white paper, "Vehicle-Grid Integration" published on October 2013 lists sample applications and a proposed framework for VGI use cases.

Determine VGI Value

Goal: translate VGI impacts into value, including estimates per application and stakeholder type (e.g., consumers, third parties, OEMs, the California ISO and utilities).

A consistent methodology and tools will need to be developed with values assessed for each use case. This activity will provide critical information for each party to understand the specific value of investing in the capabilities to participate in VGI products or programs.

Confirm VGI Market Potential

Goal: assist in the development of and sharing of information that helps stakeholders assess the extent and duration of the VGI services opportunity.

The VGI market potential can be influenced by 1) procurement requirements (such as storage procurement targets which include VGI resources), 2) potential for market adoption, 3) the competitiveness of potential substitutes, or a combination of the above. Studies under this activity will help explore market certainty for grid services, customer adoption trends, and comparison of VGI with substitutes.

Formulate VGI Business Models

Goal: assess what stakeholders need to develop business models.

This task will provide stakeholders with assistance in formulating business models around the products and programs defined in Track 2. The intention is not for the VGI Roadmap to develop business models, but to provide information on potential revenues over time, cost-benefit calculations, and business requirements.

Research, Development and Demonstration (RD&D)

Goal: conduct RD&D to determine VGI electricity system impacts, value and potential, and identify VGI-related grid needs that are not well understood today.

Some pilot studies are already under way in California and nationally (Appendix D provides more details on ongoing activities, as described by stakeholders via comment). Part of this activity is to ensure that the results of RD&D efforts related to Track 1 are published, research gaps are identified for further study, and pilots are scaled up as necessary.

4.2 Track 2: Develop Enabling Policies, Regulations and Business Processes

This track focuses on developing specific rules around products and programs for vehicle grid integration. The track goal is to clarify how services provided by VGI fit within the current—and evolving—context of California wholesale and non-wholesale grid services, and how new products and programs may be developed to enable potential VGI benefits.

The outcomes of this track will reduce stakeholder uncertainty regarding VGI eligibility to provide grid services, technical and programmatic requirements, settlement processes, and signal and messaging processes.

Track 2 forms the roadmap core by providing guidance to stakeholders on the means by which VGI resources can be valued and compensated. By clarifying eligibility and business processes, this track supports Track 1. The activities include clarifying technical requirements for VGI products and programs which provides a foundation for the "Support Enabling Technology Development" track by specifying technological needs.

Activities for the Develop Enabling Policies Track

The following table captures key activities under this track.

Goal	Activities
Ensure coherence between state policies, programs and national standards	Identify process interaction and dependencies
	Identify and implement adjustments to existing processes, or establish processes for coordination
Define VGI-related products and programs	Define VGI eligible utility programs
	Define VGI eligible wholesale market products
Define VGI program or product eligibility	Specify definition for VGI resources participating in ISO regulation market, accounting for "Pay for Performance"
	Review DR market rules and define participating VGI resources
	Define other or additional products and programs for VGI
	Establish metrics for success
Clarify VGI-related product and program requirements	Specify interconnection rules
	Specify telemetry and metering requirements
	Specify communication requirements
Clarify settlement	Define billing processes, incorporate lessons learned from PEV subtractive billing pilots
	Define enrollment processes and eligibility
	Define penalties and payment mechanisms
Define verification and conflict resolution protocols	Review and define conflict resolution processes specific to VGI
	Review and define verification processes specific to VGI
Define signals and messaging	Define charging and discharging signals by product and program
Research, development and demonstration (RD&D)	Coordinate existing RD&D and ensure results are published for public consumption
	Identify additional research gap for further study and scale pilots as needed

Ensure Coherence between State Policies, Programs and National Standards

Goal: create a coordinated approach to VGI activities.

The VGI Roadmap is being developed within the context of an evolving electricity system in the state. As Appendices B and D illustrate, several state, national and international policy initiatives are underway which will shape the role of distributed energy resources in California and will define characteristics of EVs and EVSE. Given the relevancy of VGI with these other initiatives, and given the number of entities working on VGI within California, it is critical that VGI activities be coordinated. One example noted by stakeholders is the policy issue of net metering. Stakeholders pointed to the popularity of net-metered solar PV and EV ownership, and sought to clarify the interaction of VGI providing grid services with net-metering tariffs. Close coordination among utilities and the CPUC will help identify the requirements and allowance of net-metering tariffs for various combinations of EV and PV grid interconnection and usage. In addition, the CPUC's rulemaking on Alternative Fueled Vehicle Programs, Tariffs and Policies (R.13-11-007) will guide many activities in support of this VGI Roadmap.

Define VGI Products, Programs, and Eligibility

Goal: identify those grid services for which VGI can be compensated.

Although grid services products and programs do not exclude EVs' participation, they do not explicitly define requirements for their participation either. Activities under this track entail reviewing and revising the rules for current products and programs, or developing new ones depending on VGI capabilities and market needs. For example, in the CPUC October decision supporting the implementation of

AB 2514, EVs are explicitly stated as one of the customer use cases that can contribute to the investor-owned utilities' storage procurement targets. The roadmap also proposes that additional consideration should be given to the legal or market limitations of provision of service, such as technology patents or monopolies. In addition, the definitions should account for the different types of VGI (V1G, V2G, V2B, B2G, etc.) and different approaches to VGI (direct control, voluntary control, etc.)

Clarify VGI-related Product and Program Requirements

Once the products and programs are defined, the next step is for the ISO and CPUC to define the VGI participation requirements. This includes defining requirements for product and program participation, such as minimum size requirements, as well as defining the technical requirements for interconnection, metering and providing telemetry under abnormal conditions (e.g., stop charging under low frequency conditions standards). ISO and utility products and programs should be considered together. Stakeholders indicated that more clearly defining interconnection issues should be a priority, since a lack of clarity around this issue could be a barrier for VGI. Furthermore, stakeholders highlighted the importance of distinguishing the needs for V2G using an offboard 2-way inverter versus an onboard 2-way inverter, but also the desire to have simple interconnection rules such that VGI versus other ES, DR or distributed energy resources is not called out as a special case. In addition, stakeholders requested clarity about interconnection jurisdictions, particularly with regard to FERC-regulated wholesale interconnection processes such as those governed by the Wholesale Open Access Distribution Tariff (WDAT). One stakeholder raised the issue of whether WDAT-based interconnection is required for participation in wholesale markets. The same stakeholder commented that there is precedence for retail-level interconnections of behind-the-meter generators providing wholesale grid services, and pointed to behind-the-meter generation interconnection in PJM as a sample point of reference.

Clarify Settlement

Goal: define settlement processes by which VGI resources are paid (or pay) for products and services.

The current market is ambiguous about the process for paying or being paid for VGI services and programs. This activity will entail reviewing and revising rules of existing products and programs, or developing new products or programs, depending on VGI capabilities. Specific activities include defining ISO or utility program billing processes, enrollment processes and eligibility, and penalties and payment mechanisms. Activities, such as the Pacific Gas and Electric's billing pilots, will help inform these efforts. Additional activities by third parties engaging with customers are also feasible. The roadmap will consider the policies necessary to define those interactions as well, though these may be defined by third parties independently from the ISO-run or CPUC-approved programs.

Define Verification & Conflict Resolution Protocols

Goal: review verification (and associated requirements) and conflict resolution processes that are specific to VGI resources.

The current market has defined verification and conflict resolution protocols. This step would explore those protocols with regard to VGI and provide clarity where needed.

Define Signals & Messaging

Goal: define VGI-specific signaling and messaging processes between VGI participants and product and program operators.

This step would review current signal and messaging processes between market participants and market operators, identify how VGI would fit within the current processes, and explore the potential for additional capabilities. This work would fit within the larger context of distributed energy resources, but as part of this roadmap, would explore VGI in detail.

4.3 Track 3: Support Enabling Technology Development

This task focuses on supporting the technology that enables VGI by establishing a technology platform over which VGI can occur and to demonstrate and develop the performance of enabling technologies.

Activities include researching and identifying related standards and codes and defining VGI enabling technology to meet functional requirements. This track also includes testing, measuring, and improving technologies that enhance VGI performance. This track helps establish and confirm the basis for which market participation rules and interactions can be defined. To help lower costs and increase performance, support for additional research on VGI technology may be needed.

The capabilities of VGI-enabling technologies may influence the rules that define signals and messaging processes between eligible programs and associated resources. These rules will also depend on program requirements. Verification and conflict resolution protocols will be shaped by the technologies that help measure and track VGI interactions.

Activities for the Support Enabling Technology Development Track

The following table captures key activities in this track.

Goal	Activities
Develop enabling technology requirements	Develop grid operator requirements
	Research existing standards and identify any gaps
	Develop additional standards & protocols by • VGI type: V1G, V2G, V2B, B2G • application (distribution, wholesale, etc.)
	Develop specifications for state procurement of VGI technologies
Improve performance	Reduce costs of enabling technologies
	Enhance performance of enabling technologies
Identify and inform about performance	Test performance of VGI enabling technologies
	Trial technologies, approaches and applications
Research, development and demonstration (RD&D)	Coordinate existing RD&D
	Ensure results are published for public consumption
	Identify additional research gap for further study
	Scale up RD&D as necessary

Establishing a Technology Platform

Goal: create consistency across technologies to enable interoperability and to provide guidelines for product development, while allowing for variety in VGI products and services.

Defining grid operator requirements, standards and protocols, and state procurement specifications can help create consistency. Establishing grid operator and program requirements for VGI-enabling technologies also identifies those aspects which VGI technologies must conform to while enabling developers to make future innovations. A common standards format ensures compatibility among multiple technologies, eases adoption by customers and increases certainty for developers about the access their products will have and about how their technologies can work with others.

State standards should agree with existing EV and VGI standards. An initial suggested activity is to assess the standards under development and any gaps and then propose tasks needed to fill those gaps. Given the potential demand that the state could create for VGI-related infrastructure, including EVs and EVSE, developing state procurement specifications would clarify the technology requirements for a potentially large segment of demand. However, the state should actively avoid dictating a standard in the absence of activity by formal standards making bodies.

Improve, Test and Demonstrate Performance

Goal: continue developing VGI capabilities to improve performance and reduce cost, while demonstrating the capabilities of today's technologies.

Efforts to improve performance will explore ways to enhance VGI technical capabilities or reduce costs. Demonstrations will be used to prove out technical concepts; ensure technical standards and specifications are met; and publicize the potential of VGI-enabling technologies. Cost-benefit assessments can help guide research toward areas of high potential for cost reductions and benefits.

Additional Research, Development and Demonstration

Goal: conduct research, development, and demonstration to support VGI-enabling technology.

Some pilot studies are already under way in California and nationally (see Appendix C for more details). Part of this activity is to coordinate existing RD&D work that supports improving, testing and demonstrating VGI-enabling technologies, ensuring results are published for public consumption, identifying additional research gaps for further study, and scaling up research and demonstrations as necessary.

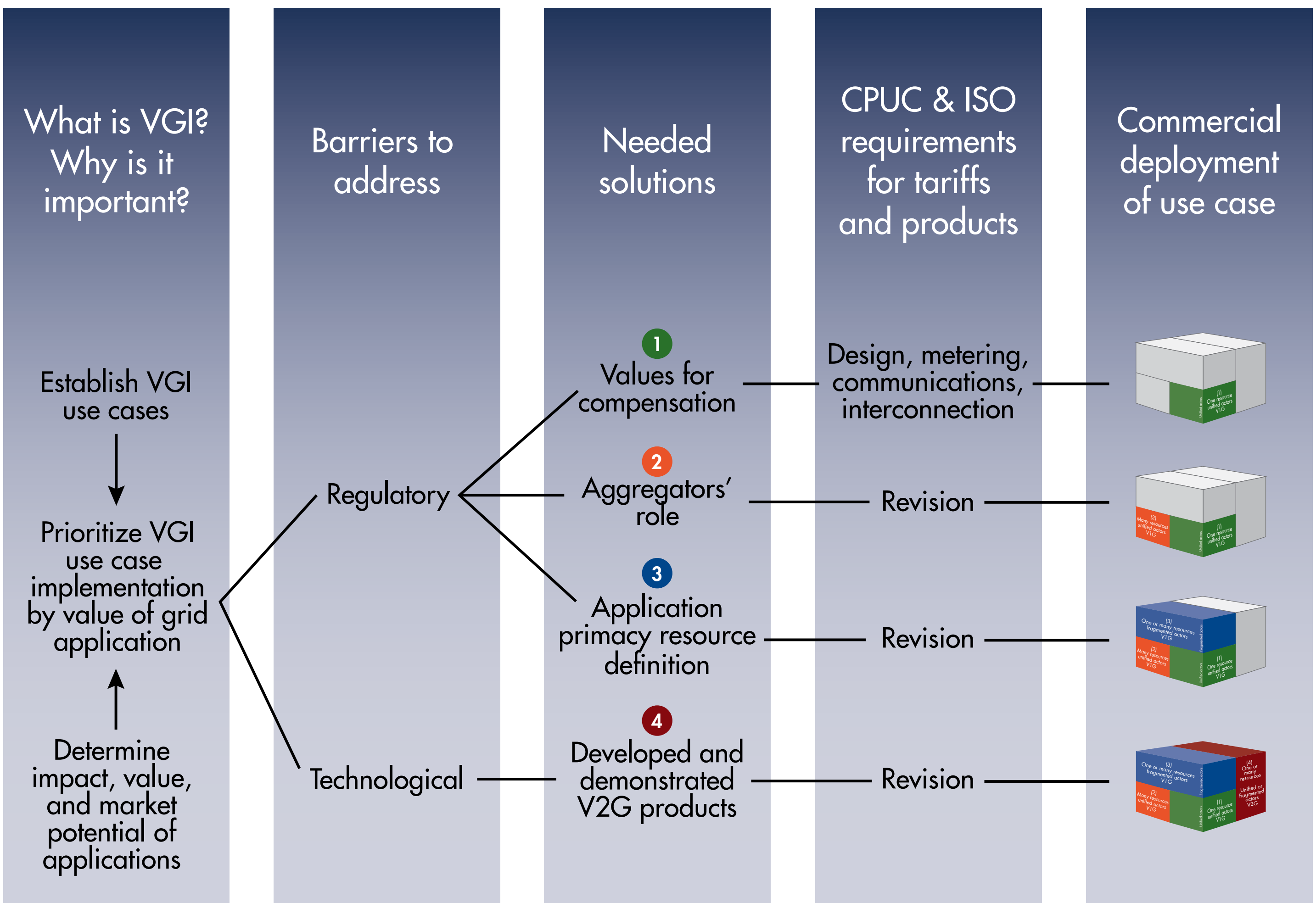
5. CONCLUSION AND NEXT STEPS

Steps to enable EV aggregations to provide grid services are in development in California. Rulemaking proceedings and standards development efforts that will define the future for VGI are in progress. Research, development and demonstrations have begun to explore the potential for VGI services and to enhance enabling technologies. For example, utilities, the ISO, manufacturers, and EV owners are engaged in VGI demonstration projects that range from program trials to impact assessments. Further demonstrations are planned. In addition, relevant policy proceedings involving California stakeholders such as the Energy Commission, CPUC and ISO are planned, completed or in process. Additional detail about policy making activities is available in Appendix B. Alongside policy activities, the Society of Automotive Engineers, the Institute of Electrical and Electronics Engineers, and the National Electrical Manufacturers Association, among others, are developing processes to define standards governing safety, testing and features associated with enabling communications and hardware. Additional detail about standards activities is available in Appendix D.

This roadmap is the first step toward meeting the goal of EV aggregations contributing to grid reliability. Continued outreach is critical to the success of this roadmap and of VGI development in California. The VGI working group expects to hold additional workshops to confirm approaches to prioritizing efforts in the VGI roadmap.

The Energy Commission will schedule annual workshops starting in 2014 to review progress on research and demonstration projects relating to VGI, such as the V2G pilots with the Department of Defense and VGI research under the new Electric Program Investment Charge (EPIC) program. The workshops will also solicit stakeholder feedback on the direction of research, and will help integrate the role of publicly-owned utilities in VGI development. VGI activities will also be discussed in workshops for the Statewide Plug-in Electric Vehicle Infrastructure Plan, and the findings related to VGI will be integrated into the Plan. These workshops will also reach out to the California's publicly-owned utilities (POUs) to ensure the POUs are aware of these VGI activities as they implement their portion of the Governor's ZEV Action Plan.

Additional outreach will be conducted by the CPUC related to its alternative fuel vehicle rulemaking. The CPUC staff has proposed a framework for developing utility regulations that support VGI, illustrated in the graphic below. The CPUC staff white paper prioritized a set of use cases based on the regulatory complexity of each case. During the CPUC workshop, stakeholders identified a need to better understand the values associated with different VGI applications, such as demand response and frequency regulation, to understand the revenue potential of different VGI activities. CPUC staff will work with stakeholders to evaluate the values of different applications. According to the CPUC framework, the prioritization of these applications can be mapped to the prioritization of use cases to determine the sequence of activities in the proceeding. In this process, parties can then begin implementing the simplest use cases testing different applications, starting with high value, high priority applications. According to the CPUC proposed process, the simple use cases validate each of the applications' values before implementing more complex use cases. This will allow stakeholders, via the rulemaking, to begin exploring VGI applications in the near-term with use cases that face fewer barriers, and then address the barriers associated with complex use cases.



APPENDIX A: DETAILED ROADMAP TRACKS

Determine VGI Value

2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022

2013 FERC 784 Final Rule

2013 decision on R.10-12-007 (AB 2514)

Confirm VGI electrical system impacts

Develop tools and methods to assess VGI impacts

Assess VGI impacts

- By VGI type
  - V1G, V2G, B2G, etc.
  - aggregated, individual
  - unified, fragmented
- By approach (e.g., variable pricing, control, etc.)
- By application (distribution, wholesale, etc.)
- By technology (e.g., charger, controls type, etc.)

Assess interaction with other capabilities

Confirm VGI impacts

- Assess and confirm the physical impacts of VGI and the potential responsiveness of VGI to product or program signals (e.g., aggregate kW reduction for a given price signal, kVar change over time due to VGI response, etc.).
- Account for differences in VGI approaches, applications and technologies.
- Account for interactive effects of other distributed resources (e.g., stationary storage, photovoltaic (PV) solar, etc.).
- Account for how VGI, focused on portions of the grid, can simultaneously affect other portions, and how one program might affect the availability of VGI resources for another.
- Develop consistent methodologies & support tool development to assess VGI impacts.

The goal is to provide consistent information about what grid services VGI can provide, by VGI type, and specify how VGI resources change depending on how they are enabled. (e.g., price signals, dispatch signals, etc.)

Refine VGI use cases

- Assess simultaneous effects throughout grid

Refine use cases

- Define high-level use cases specific to California that identify VGI and frames VGI activities across the state according to the objectives (e.g., CPUC framework that is defined by three attributes and eight use cases).

The goal is to create a cohesive framework to organize VGI activities.

Determine VGI value

Develop tools to assess value from impacts

Assess VGI value from VGI impacts

- By VGI type
  - V1G, V2G, B2G, etc.
  - Aggregated, individual
  - Unified, fragmented
- By approach (e.g., time-variant pricing, control, etc.)
- By application (distribution, wholesale, etc.)

Determine VGI value

- Translate VGI impacts into value, including estimates per application and stakeholder type (e.g., consumers, third parties, OEMs, the California ISO and utilities).
- Differentiate by type of VGI.
- Develop consistent methodologies and support tool development to assess value from VGI.

The goal is to assess the likely value of VGI based on its effects, which may differ by VGI type, approach and application.

Confirm VGI potential

Explore market certainty for grid services

Study potential for adoption

- Study potential for market adoption
- Assess potential for substitutes

Confirm VGI market potential

- Assist in the development and sharing of information that helps parties assess the size of the opportunity for VGI services and the longevity of this opportunity. These can be influenced by procurement requirements (such as storage procurement targets which include VGI resources), by potential for market adoption, or both.
- Studies could help explore potential for customer adoption and assess substitutes.

The goal is to provide parties interested in investing in VGI capabilities with information to assess the feasibility of its prospects.

Formulate VGI business models

Assess stakeholder needs for developing business models

Develop programs to address needs

Formulate VGI business models

- Assess what stakeholders need to develop business models and programs around VGI. Programs might assist with revenue potential, cost-benefit calculations, and sharing information sharing about business requirements.

The goal is to provide parties interested in investing in VGI capabilities with information to assess the feasibility of its prospects.

Additional research, development & demonstration to support determining VGI value (e.g., smart charging/V2G pilots; research; etc.)

Develop Enabling Policy

2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022

2013 finalize Rule 24 for DR direct participation

2014 ISO expands metering and telemetry options

Determine VGI value

Define VGI products and programs

Define VGI eligible utility programs

Define VGI eligible wholesale market products

Define VGI products and programs

- Define products and programs for which VGI resources can provide grid services. This might entail the review and evolution of current products and programs or the development of new products or programs, depending on the ability of VGI capability and on market needs. Additional consideration should be given to the legal or market limitations of provision of service (such as VGI technology patents or monopolies).
- Definitions should account for the different types of VGI (e.g., V1G, V2G, B2G) and the different approaches to VGI (e.g., direct control, voluntary control, etc.).

The goal is to identify those grid services for which VGI can be compensated.

Develop and refine policy

Define program or product eligibility

- Specify definition for VGI resources participating in ISO regulation market accounting for "pay for performance"
- Review DR market rules and define participating VGI resources
- Define other or additional products or programs for VGI

Define program or product technical requirements

- Specify interconnection rules
- Specify telemetry and metering requirements
- Specify communications requirements

Define requirements

- Define eligibility for VGI participating in products and programs (e.g., minimum size requirements).
- Define the technical requirements for VGI resources participating in the products and programs such as interconnection, metering and telemetry, or operation under abnormal conditions, (e.g., stop charging standards under low frequency conditions).

The goal is to define the requirements for VGI participation in state products and programs and to define VGI resources as participants in them.

Support enabling technology development

Clarify settlement

- Define billing processes
- Define enrollment processes and eligibility
- Define penalties and payment mechanisms

Clarify settlement

- Define settlement processes by which VGI resources can get paid (or pay) for services. This might entail the review and evolution of current products and programs or the development of new products or programs, depending on the ability of VGI capability and on VGI-eligible products and programs.
- Define how VGI participants get paid for their services.

The goal is to define settlement associated with VGI including how customers get paid for VGI services and how a customer pays for services associated with VGI.

Define verification and conflict resolution protocols

- Review and define conflict resolution processes specific to VGI
- Review and define verification processes specific to VGI

Define verification and conflict resolution protocol

- Review verification processes (and associated requirements) and conflict resolution processes to assess needs for VGI. Define them as specific to VGI-type resources.

The goal is to define verification and conflict resolution protocols.

Define signals and messaging

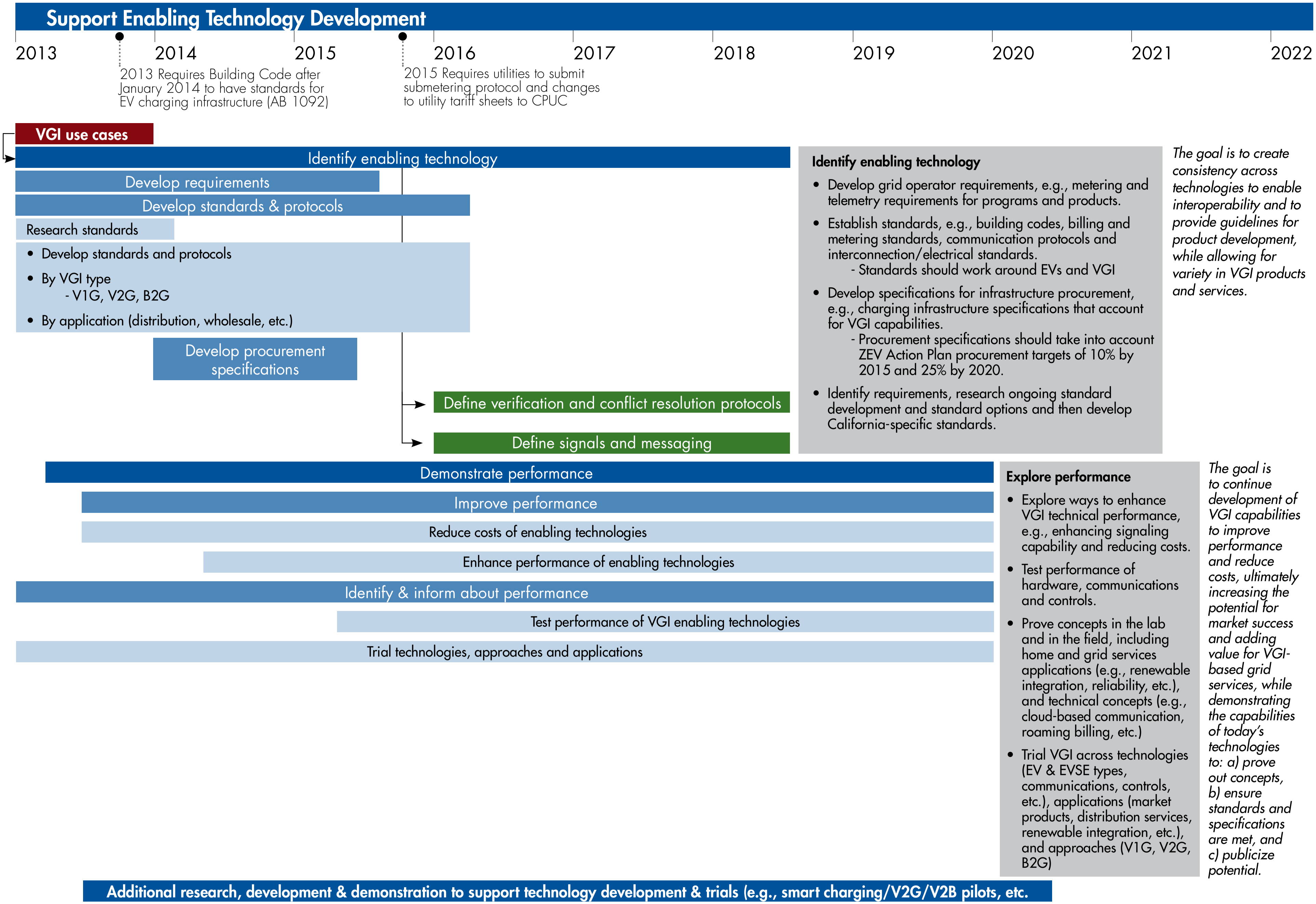
- Define signals for charging and discharging by VGI-eligible product and program

Define signals and messaging

- Explore and define the eligible signaling and messaging processes between VGI participants, and product and program operators.

The goal is to define signals and messaging specific to the programs and products enrolling VGI services.

Additional research, development & demonstration to support trials of proposed products & programs


Support Enabling Technology Development
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2013 Requires Building Code after January 2014 to have standards for EV charging infrastructure (AB 1092)
2015 Requires utilities to submit submetering protocol and changes to utility tariff sheets to CPUC
VGI use cases
Identify enabling technology
Develop requirements
Develop standards & protocols
Research standards
• Develop standards and protocols
• By VGI type
- V1G, V2G, B2G
• By application (distribution, wholesale, etc.)
Develop procurement specifications
Define verification and conflict resolution protocols
Define signals and messaging
Identify enabling technology
• Develop grid operator requirements, e.g., metering and telemetry requirements for programs and products.
• Establish standards, e.g., building codes, billing and metering standards, communication protocols and interconnection/electrical standards.
- Standards should work around EVs and VGI
• Develop specifications for infrastructure procurement, e.g., charging infrastructure specifications that account for VGI capabilities.
- Procurement specifications should take into account ZEV Action Plan procurement targets of 10% by 2015 and 25% by 2020.
• Identify requirements, research ongoing standard development and standard options and then develop California-specific standards.
The goal is to create consistency across technologies to enable interoperability and to provide guidelines for product development, while allowing for variety in VGI products and services.
Demonstrate performance
Improve performance
Reduce costs of enabling technologies
Enhance performance of enabling technologies
Identify & inform about performance
Test performance of VGI enabling technologies
Trial technologies, approaches and applications
Explore performance
• Explore ways to enhance VGI technical performance, e.g., enhancing signaling capability and reducing costs.
• Test performance of hardware, communications and controls.
• Prove concepts in the lab and in the field, including home and grid services applications (e.g., renewable integration, reliability, etc.), and technical concepts (e.g., cloud-based communication, roaming billing, etc.)
• Trial VGI across technologies (EV & EVSE types, communications, controls, etc.), applications (market products, distribution services, renewable integration, etc.), and approaches (V1G, V2G, B2G)
The goal is to continue development of VGI capabilities to improve performance and reduce costs, ultimately increasing the potential for market success and adding value for VGI-based grid services, while demonstrating the capabilities of today's technologies to: a) prove out concepts, b) ensure standards and specifications are met, and c) publicize potential.
Additional research, development & demonstration to support technology development & trials (e.g., smart charging/V2G/V2B pilots, etc.

APPENDIX B: SUMMARY OF RELEVANT POLICY

A number of policy initiatives are underway that will influence the potential demand for VGI services and the means by which they can be implemented, and can influence how entities might be compensated. Initiatives range from creating rules about storage procurement targets that include VGI as a possible resource, to ones concerning mechanisms to access wholesale market programs, and payment for frequency regulation services depending on speed and accuracy in response to market signals. The following highlights some notable policies likely to affect VGI services, issued both at the state and federal levels and the timelines associated with them. It identifies the potential relevance to VGI.

Policy	Entity	Description & Relevance
Federal Energy Regulatory Commission Order No. 784 *(Issued July 18, 2013)*	FERC	• Expands FERC 755 pay-for-performance requirements to account for speed and accuracy • Potentially affects payment for VGI services, depending on VGI capabilities
Federal Energy Regulatory Commission Order No. 792 *(Issued November 22, 2013)*	FERC	• Adjusts the Small Generator Interconnection Procedures (SGIP) and Small Generator Interconnection Agreement (SGIA) for generating facilities no larger than 20 MW • Will shape interconnection associated with storage devices
Standard ISO/IEC 15118 *(Stage 60.60: International Standard published os of April 16, 2013)*	ISO/ IEC	• Creates a global standardization of communication interface • Will likely shape VGI enabling technologies
Standard SAE J1772 *(Most recent revision is October 15, 2012)*	SAE	• Establishes a recommended practice for EVSE • Will likely shape VGI enabling technologies
Assembly Bill (AB) 2514 and CPUC Storage Proceeding Docket No. R. 10-12-007	CPUC	• Sets targets for the procurement of storage • States that EV capacity can contribute to the storage procurement targets • Potentially creates demand for VGI services, depending on how VGI compares to other options
Resource Adequacy (RA) Proceeding	CPUC	• Guides the resource procurement process and promotes infrastructure investment by requiring LSEs to provide capacity as needed by California ISO • Potentially influences demand for VGI services, depending on VGI capability to meet RA needs.
Demand Response (DR) Proceedings Docket No. R.07-01-041	CPUC	• Reviews and analyzes demand response to assess its potential role in meeting the state's energy needs • Potentially serves as a platform for clarifying rules about how EV may participate in DR
Rule 24 DR Direct Participation	CPUC	• Determines how customers might "directly participate" in, or bid services directly into, the wholesale market. • Potentially influences the process by which VGI services can offer wholesale market services.
Rule 21 Interconnection and Net-metering (Docket No. R.11-09-011)	CPUC	• Describes the interconnection, operating and metering requirements for generation facilities of various sizes to be connected to a utility's distribution system, over which the CPUC has jurisdiction. • May influence the interconnection requirements around VGI, where two-way power flows are possible
Wholesale Distribution Access Tariff (Docket No. ER11-2977-000)	CPUC	• Defines the tariffs architecture of energy transfer between California ISO and utilities or customers • Guides a portion of VGI payment processes
EV Proceedings	CPUC	• Addresses barriers to widespread EV adoption, on which the VGI market is dependent • Promotes communication among EV stakeholders, including those involved in VGI • Addresses EV sub-metering issues, which could influence VGI payment processes
Smart Grid Proceeding (Docket No. R.08-12-009)	CPUC	• Establishes standards, protocols, and policies which will affect Smart Grid programs and strategies, such as VGI

Federal Energy Regulatory Commission (FERC) Order No. 792

Issued in November 2013, the Order adjusts the SGIP and SGIA for generating facilities no larger than 20 MW. In particular, the Order revised the SGIP and SGIA to specifically include energy storage devices and to change the 2 megawatt threshold for participation in the fast track process. In addition, the Order provides ways for the interconnection customers to request a pre-application report for information about system conditions at a point of possible interconnection, revises the supplemental review process, and allows interconnection customers to provide comment regarding upgrade requirements for interconnection. It also clarifies sections of the SGIP and SGIA pro forma. The intent of the revisions was to help ensure that the time and costs for interconnection customers and transmission providers are just and reasonable.

FERC Order No. 784

This Order was issued to promote competition and transparency in ancillary services (AS) markets. It requires utilities to amend their open-access transmission tariff (OATT) Schedule 3 to take into account the speed and accuracy of energy resources providing frequency regulation services when determining their reserve requirements. The final rule requires transmission providers to publish area control error (ACE) data. FERC is currently reviewing reporting and accounting practices to promote record-keeping of transactions associated with public utilities' use of energy storage.

Assembly Bill (AB) 2514 and CPUC Storage Proceeding Docket No. R. 10-12-007

Assembly bill 2514 established the policies and mechanisms associated with procuring energy storage. As stated in the law, the program includes the following major clauses:

- procurement targets for each of the investor-owned utilities
- procurement requirements for other load serving entities
- mechanisms facilitating the procurement of storage
- methods to alter procurement targets
- program evaluation criteria.

On October 17, 2013, the CPUC issued a final decision which establishes the following:

1. procurement targets for each of the investor-owned utilities and procurement requirements for other load serving entities;
2. mechanisms to procure storage and means to adjust the targets, as necessary; and
3. program evaluation criteria.

The procurement targets and requirements are as follows:

- PGE, SCE, and SDGE are required to add an aggregated total of 1,325 megawatts (MW) of energy storage to their portfolio by 2020 and begin soliciting by January 1, 2020; and
- Community choice aggregators and electric service providers are required to procure 1 percent of their annual peak load by 2020 and provide compliance proof on a bi-yearly basis starting January 1, 2016.

According to the decision, EV charging may qualify for behind-the-meter applications.

Demand Response (DR) Proceedings Docket No. R.07-01-041

The CPUC initiated this rulemaking to determine whether and how to bifurcate current utility-administered, ratepayer-funded DR programs into demand-side resources, and supply-side resources. The intent is to prioritize DR as a utility-procured resource to competitively bid into the ISO wholesale electricity market.

The ultimate goal is to enhance the role of DR programs in meeting the state's long-term clean energy targets while maintaining reliability system wide and locally. Thus, the purpose of this proceeding is to do the following:

- review and analyze current DR programs to determine whether they are demand-side or supply-side resources
- create an appropriate competitive procurement mechanism for supply-side DR resources
- determine the program approval and funding cycle
- provide guidance for transition years and
- develop and adopt a roadmap with the intent to collaborate and coordinate with other Commission proceedings and state agencies to strategize the development of DR capabilities.

Rule 24 DR Direct Participation

This decision is intended to allow retail customers to participate in ISO's wholesale market under peak demand reduction and reliability DR products marketed directly or through aggregators.

EV Proceedings

The CPUC initiated an Alternative-Fueled Vehicle Rulemaking in August 2009 in response to the Senate Bill 626 that seeks to ensure that utilities are prepared for the projected statewide market growth of plug-in electric vehicles (PEV).

After reviewing legal briefings on the matter in an open regulatory process, the CPUC in August 2010 ordered that providers of EV charging services should not be regulated as public utilities.

The CPUC issued a proposed Decision on July 6, 2011 that addresses issues in the proceeding that help overcome barriers to EV deployment and compliance with PU Code 740.2. This decision addresses the following:

- directs electric utilities, automakers and other stakeholders to communicate through the adoption of a notification process;
- affirms that most electric utilities' existing residential, commercial and industrial EV rates are sufficient for early EV market development;
- establishes a process to re-examine EV rates;
- considers opportunities to adopt new and more affordable metering technologies for EV charging;
- establishes a process to develop an EV metering protocol to accommodate increased EV metering options, such as submetering;
- determines that until June 30, 2013, the costs of distribution or service facility upgrades necessary to accommodate basic residential EV charging will be treated as shared cost on an interim basis;
- defines the role that utilities may play in education and outreach efforts related to EV;
- requires utilities to perform load research to inform future Commission policy; and
- addresses utility ownership of EV service equipment.

The utilities submitted in October 2012 a strawman proposal that proposed rules and requirements for different types of customer-owned submetering technology and configurations that they use for separately billing their PEV load. Subsequently, the Commission's Energy Division staff submitted a proposal for Development of Electric Vehicle Submetering. In a proposed decision issued in October 2013 the CPUC adopted the roadmap for a two-phase pilot project.

On November 14, 2013 the CPUC approved an Order Instituting Rulemaking on Alternative-Fueled Vehicle Programs, Tariffs, and Policies. The Rulemaking, R.13-11-007, was issued on November 22, 2013. The OIR will continue the CPUC's work in R.09-08-009, supporting Executive Order B-16-2012, and working towards action items identified in the Zero-Emission Vehicles Action Plan. The proceeding has two tracks: one on the value of VGI and the other on the development of new alternative fuel vehicle tariffs.

Rule 21 Interconnection and Net-Metering (Docket No. R.11-09-011)

This is a tariff describing the interconnection, operating and metering requirements for generation facilities to be connected to a utility's distribution system, over which the CPUC has jurisdiction.

Wholesale Distribution Access Tariff (Docket No. ER11-2977-000)

This tariff is applicable to the transmission of electricity that is generated or purchased by a distribution customer or the distribution provider and transported to the ISO grid or customer service area using the distribution provider's system. The distribution customer is also required to pay for transmission services for energy transfer to or from the ISO grid.

Smart Grid Proceeding (Docket No. R.08.-12-009)

The CPUC initiated this rulemaking to consider policies promoting the development of an electric grid that is more automated and efficient in the state of California. It will consider establishing policies, standards and protocols to guide the development of a smart grid system and promote the adoption of new technologies and strategies.

Resource Adequacy (RA) Proceeding

In 2004 the CPUC adopted an RA policy framework (PU Code section 380) to ensure safe and reliable operation of the electricity grid. This program is intended to provide the ISO with adequate existing resources by establishing siting and construction incentives for new resources. This framework guides the resource procurement process and promotes infrastructure investment by requiring LSEs to provide capacity as needed by the ISO. Annual filings are the mechanism LSEs use to prove compliance with their RA obligations.

APPENDIX C: ACTIVITIES REFERENCE INFORMATION

Apart from policy and standards-related initiatives, several other activities around VGI have been occurring over the past several years and many more are planned. Details about some VGI-related activities were provided by stakeholders through the VGI roadmap development process. This list is not comprehensive, but rather an aggregation of those projects identified by stakeholders. This list and project descriptions are based on stakeholder comments. Associated or relevant tracks were identified based on project descriptions in stakeholder comments. Copies of the full comments are available on the ISO, CPUC and CEC websites via the stakeholder comment documents.

- California Public Utilities Commission: http://www.cpuc.ca.gov/PUC/energy/altvehicles/
- California ISO: http://www.caiso.com/informed/Pages/CleanGrid/VehicletoGridRoadmap.aspx
- California Energy Commission: http://www.energy.ca.gov/research/notices/#10082013

In addition, information about research supported by California, such as the Electric Program Investment Charge Program administered by the Energy Commission, can be found at: http://www.energy.ca.gov/research.

Los Angeles Air Force Base Vehicle-to-Grid Demonstration, 2011-2015 — Tracks 1, 2, 3

Los Angeles Air Force Base, Southern California Edison, Lawrence Berkeley National Labs, California Energy Commission, U.S. Department of Defense

The Air Force is focused on two major objectives: a) to demonstrate a 100% all-electric non-tactical fleet at a base, and b) to explore the V2G capability of such a fleet by participating as fully as possible in the California ISO ancillary services markets. LBNL was awarded funding from the Environmental Security Technology Certification Program (ESTCP) of the DOD for this effort. LBNL is managing the project to develop: a) a fleet management platform, b) charging and grid services optimization, c) real-time charging control and communication, and d) grid operator systems integration and communication. This effort will result in the largest V2G demonstration in the DOD and California. Additionally, this project will address all the issues associated with V2G vehicles bidding into the California ISO ancillary services market and also being used as a grid resource to manage the base grid during times of peak demand. The CPUC has approved a pilot tariff governing direct participation of V2G load into the California ISO's wholesale market in SCE's territory. SCE will be inspecting the bidirectional hardware in its labs before deployment.

U.S. Navy China Lake V2G EV Charging Infrastructure Project, Announced November 2012 — Tracks 1, 2, 3

U.S. Department of the Navy, Southern California Edison and other partners

V2G EV charging infrastructure project located at China Lake, California and developed by the U.S. Department of the Navy. The project involves 75 EV charging points. The CPUC has approved a pilot tariff governing direct participation of V2G load into the California ISO's wholesale market in SCE's territory. SCE will be inspecting the bidirectional hardware in its labs before deployment.

PJM V2G Demonstration, 2012-2015 — Tracks 1, 2, 3

BMW, NRG, AutoPort, Inc., University of Delaware, PJM Interconnect, Milbank Manufacturing, Honda

The demonstration project sought to show how wholesale electricity pricing signals can be communicated to EVs and how EVs can provide response to these signals. The demonstration used V2G technology. In addition, the pilot explored the capability of EVs to earn revenues. Initial demonstrations were conducted with BMW Mini E vehicles. Additional demonstrations will be conducted with Honda Accord Plug-In Hybrid with added V2G capabilities. NRG is in the process of measuring the cost for the battery chemistry in the MINI Es in use in the pilot.

Launching the Market for Electric School Buses, 2013 – TBD — Tracks 1, 2, 3

Clinton Global Initiative, National Strategies LLC, NRG Energy, PJM Interconnection, Ernst & Young; California efforts include: California ISO, SCAQMD, SJVAPCD, BAAPCD, Torrance Unified School District, Kings Canyon USD, Napa Valley USD and other parties

The project seeks to establish the economic viability of electric, vehicle-to-grid connected zero emissions school buses. The project will demonstrate EV school buses with V2G technology in a variety of school districts around the country, including ones in California. The buses will be used to collect and disseminate data on operation, performance, cost saving, and revenue generation so that a financial model can be developed to support rapid commercialization. The data generated will be provided to all interested parties, allowing the creation of economic and financing models that can enable widespread adoption of EV V2G school buses and other heavy-duty vehicles in the U.S. and abroad.

U.S. Air Force Fort Carson Microgrid Project, Announced 2012 — Tracks 1, 2, 3

Fort Carson, U.S. Department of Defense, U.S. Army Corps of Engineers, Boulder Electric and other partners

The demonstration is implementing bidirectional charging and discharging and an aggregation control system as part of the SPIDERs microgrid project funded by the Department of Defense at Fort Carson Colorado. Boulder Electric vehicles have been performing V2G along with Coritech EVSE and South West Research Institute as the aggregator since July of 2013. It is the first demonstration of all-electric trucks charging and discharging at 60 kW.

DR EV Pilot, 2013-2014 — Tracks 1, 2, 3

Pacific Gas and Electric (PG&E)

- Determine the technical requirements needed to provide DR through EVs
- Determine the business models required to ensure fair and reasonable treatment of payments for mobile loads
- Examine different engagement models with customers that achieves the highest level of customer adoption and satisfaction
- Create a demand response program for EVs and their owners
- Encourage a robust third party market for EVSPs, OEMs and aggregators to provide DR via EVs

Electric Vehicle Service Provider (EVSP) Smart Grid Development Project — Tracks 1, 2, 3

San Diego Gas and Electric (SDG&E) and partners

- Partnering with an EVSP
- Investigating distribution grid impacts associated with PEV charging
- Development of standardized communication protocols used to control EVSE charging power based on demand response signals and/or varying price
- May include integration with more broadly-applied Home Energy Management systems within homes of PEV customers participating in the project
- SDG&E and its industry partners will gain better understanding of how PEV charging and other household loads can be seamlessly influenced (from the customers' point of view) and controlled in order to minimize impacts on the distribution grid
- Results of this work will be used to help utilities minimize incremental costs resulting from new PEV charging load. Field-tested communications protocols will be used to implement new DR and pricing tariff designs and will be made available to all EVSPs. Observations of behavior-change will be applied to development of new DR programs and tariff designs.

Cloud-based PEV Communication Pilot, 2012-2013 — Tracks 1, 2, 3

Pacific Gas and Electric (PG&E), Honda, IBM

The pilot project explored an EV's ability to receive and send information and respond to charge instructions based on grid conditions. The goal was to determine if a "cloud-to-cloud" interaction from an aggregator that interfaces with utility needs and an OEM that has communication structures with EVs can provide reasonable charging schedules that meet the needs of the grid. The demonstration explored the development of a DR program for EVs and their owners. It worked towards encouraging a robust third party market for EVSPs, OEMs and aggregators to provide demand response via EVs.

EV Subtractive Billing EPIC Pilot, 2013-2016 — Tracks 1, 2, 3

Pacific Gas and Electric (PG&E)

- Determine what the technical and operational requirements are to allow EV subtractive billing through engagement with real customers
- Determine the market demand for EV subtractive billing from customers
- Support reduction in costs to implement any EV subtractive billing based on actual experiences and lessons learned
- Allow EV subtractive billing at the appropriate scale to meet customer demand

ESMart EV Charging Demonstration Project, 2013 — Tracks 1, 2, 3

BMW and partners

- EV charging demonstration project for time-of-use and demand response with U.S. utility partners.
- Establish data communication between utility, aggregator, BMW backend and vehicle using IEC 15118 protocol.
- We aggregate TOU tariffs and demand-response signals and create vehicle specific charge profiles based on these data and customer mobility needs.
- Promote industry-wide adoption of EV-to-utility communication architecture.

ESMart EV Charging Demonstration Project, 2013 — Tracks 1, 2

Plug-in Hybrid and Electric Vehicle Research Center, California Energy Commission, Wireless Glue

- Identify and evaluate the costs and benefits of HESA B2G with V2G systems on California's electrical grid
- Model battery storage energy systems in the ancillary services market, using ISO and applicable IOU tariff structures
- Using a probable early market penetration for Plug-in Vehicles, consider aggregated fleet energy capacity to determine V2G impacts on California's grid
- Evaluate HESA B2G device in single family home, commercial and community level energy storage context and evaluate potential impacts in the ancillary services market
- Evaluate and model V2G potential for providing ancillary and demand response services on local and regional levels

PHEV Research Center University of California, Davis, 2013 — Tracks 1, 2

University of California, Davis (UC Davis), California Energy Commission

With Energy Commission funding, and under its PHEV Research Center, UC Davis conducted 11 stakeholder interviews from the EV and utility sectors and submitted a final report to the Energy Commission titled "Optimal PEV-Grid Interactions' in September 2013. The study analyzed technical, regulatory and market issues. Interviews covered four topics: the technical and economic value of PEV-DSM; preferences on technology and policy; relations with other stakeholders; and visions on consumer engagement.

Irvine Smart Grid Demonstration — Tracks 1, 3

Southern California Edison

PEVs, stationary storage, and advanced controls are studied as part of a microgrid in SCE's Irvine smart grid demonstration. Here, system impacts of charging PEVs are measured and controls are used to adapt to the state of the microgrid in real time.

Fast Charging Plaza — Tracks 1, 3

Fast-Charging Plaza Working Group, Clinton Climate Initiative

The Project will embody two concepts that have particular relevance to the topic of vehicle-grid integration. The first is the use of newly developed technology that can streamline, in physical and financial senses, the link between the electrical distribution system and an EV's battery. The second is the use of energy storage. Energy storage may be deployed to 1) take advantage of time-of-use tariffs to shape the daily profile of electricity consumption; 2) avoid spikes in power demand and thereby minimize the demand charge per kWh dispensed; and/or 3) provide ancillary services to wholesale power markets. A 12-head plaza could involve as much as 1 MWh of energy storage. Activities include:

- Design a fast-charging plaza with potential integration of energy storage
- Build and operate the facility with the intention of demonstrating proof of the plaza concept
- Document and disseminate the project's results

The goals of the proposed project are to:

- Optimize the design according to financial criteria
- Generate favorable results from the operation of the facility
- Influence the course of investment in charging infrastructure

Integrating Used Batteries from EVs — Tracks 1, 3

BMW

- Integrating used batteries from EVs in a grid-tied energy storage system with bidirectional power flow capability.
- Determine energy cost savings due to building demand reduction, value of solar energy storage from a PV array, longitudinal study of battery performance degradation under different load profiles and use cases, direct DC charging of electric vehicles, investigation of ancillary services market participation.
- Supports BMW internal business and product strategy decisions, policy engagement activities and outreach (LESR and non-generator products and markets).

Fleet V2G EPIC Pilot, 2013-2015 — Tracks 1, 3

Pacific Gas and Electric (PG&E)

- Determine whether hybridized PG&E fleet vehicles can be used to reduce customer average interruption duration index (CAIDI). CAIDI is one of several ways utilities measure reliability for their customers.
- Create a robust business case for hybridizing PG&E's fleet
- Purchase hybridized vehicles and reduce operating costs and CAIDI

Plug-in Electric Vehicle Load Simulator, Completion in 2014 — Track 1

San Diego Gas & Electric (SDG&E), California Energy Commission

- Develop simulator that allows utility companies to estimate PEV charging impacts to their distribution grid including increased load information and power quality effects needed to upgrade the grid infrastructure to prepare for PEV adoption
- Demonstrate an integrated approach to PEV charging that incorporates renewable generation, battery energy storage, and smart charging, further facilitating PEV market adoption.

Vehicle to Grid Simulator — Track 1

Lawrence Berkeley National Laboratory

LBNL has recently begun development of V2G-Sim based on high level recognition in the 2014 DOE Congressional Budget request of the need for tools and models to characterize the many complex opportunities and impacts from VGI. V2G-Sim is being developed to generate temporally and spatially resolved predictions of grid impacts and opportunities from increased PEV deployment. Currently in the prototype stage, V2G-Sim provides bottom up modeling from individual vehicle dynamics all the way up to aggregate grid impacts and opportunities. The model is targeted to be able to simulate impacts and opportunities for a number of vehicles (from 1 to 1 million or more PEVs). As a prototype, V2GSim is being designed to provide planning and scenario analysis capabilities. In the long term, V2G-Sim is being developed to provide an aggregator or integrator the tools and information needed to bid PEV services onto an electricity market (i.e., operations). V2G-Sim is being developed with Laboratory Directed Research and Development (LDRD) funding at LBNL.

EV Driver Panel Study, 2014 Results — Track 1

Recargo

Recargo will undertake a robust panel study with EV drivers to determine driver attitudes towards VGI and potential costs/benefits. The goal is to better understand how drivers perceive VGI costs and benefits.

Managed Charging Pilots, 2013-2014 — Track 1

Recargo, California fleet owners and utilities (unspecified)

Recargo is currently involved in several managed charging pilots with California fleet owners and utilities. The goal of these pilots is to demonstrate the potential for VGI both as revenue stream for fleets/managers/owners and value to grid.

Workplace Charging Demand Response Pilot — Track 1

Southern California Edison

SCE is implementing charging stations at its facilities for commuting employees and using demand response controls to understand grid impacts and manage loads.

CalCharge — Track 3

Lawrence Berkeley National Laboratory (LBNL), CALCEF

LBNL is partnering with CALCEF Catalyst to launch CalCharge, an energy storage innovation accelerator, composed of emerging and established California companies, research institutions, and related organizations developing energy storage technologies for the electric/hybrid vehicle, grid, and consumer electronics markets. CalCharge is intended to create a "center of gravity" that enables California's energy storage stakeholders to collaborate, identify barriers to emerging technology, develop solutions, and provide access to resources that clear the path to commercialization.

Zero Net Energy Home of the Future, 2013-2014 — Track 3

University of California, Davis (UC Davis), Pacific Gas and Electric (PG&E), Honda

PG&E, Honda and UC Davis are exploring approaches to zero net energy (ZNE) homes. The project seeks to establish best practices for new ZNE homes and ZNE communities to integrate in the most beneficial way with the grid. The project will explore multiple technologies for managing home energy use, including direct solar PV-to-vehicle charging. The project is making use of UC Davis' zero energy campus facility at West Village.

Vehicle-to-Grid Pilots: Stationary Battery Aggregation and Control, 2013 — Track 3

San Diego Gas and Electric (SDG&E) and partners

During 2012, site plans were developed for an EV public access charging site, owned and managed by an independent third party, combined with a solar PV parking canopy and energy storage assets, as part of SDG&E's Sustainable Communities Program. The facility was planned to be equipped to provide utility grid support, as well as PEV charging support, and to be operational in 2013.

Vehicle-to-Grid Pilots: Stationary Battery Aggregation and Control – DC Fast Charging Stations, 2013 — Track 3

San Diego Gas and Electric (SDG&E) and partners

In late 2011, SDG&E purchased and installed a 50 kW DC fast charging system with integrated storage to test with SDG&E EV fleet vehicles.

When owned by utility customers, this charging system reduces distribution system load impacts—and associated demand charges—resulting from fast charging, by maintaining a continuous 20-kW-or-less load by utilizing the energy storage as a buffer. The equipment Battery Assisted Fast Charger ('RAPIDAS') was provided by JFE Japan, and was safety certified in the field by a Nationally Recognized Test Laboratory (NRTL). The system is operational and data acquisition is underway. The next phase of testing included exploring how to deploy the stationary battery to provide utility grid support.

Cloud Computing Platform for Smart Home, 2012-2013 Track 3

BMW

- Cloud computing platform for smart home with EV charging, home energy storage and renewable energy generation.
- Orchestrating appliance loads to reduce peak loads behind the meter, establish communication between home energy management system and the EV. Integrate home solar, HEMS and HESS. Learn from a customer smart home field trial.
- Supports BMW internal business and product strategy decisions, policy and utility engagement activities and outreach.

Technology Deployment: VGI Telemetry Solution, 2013 Track 3

Recargo

In the fourth quarter of 2013, Recargo deployed telemetry solutions for VGI control. The goal was to demonstrate the potential for VGI independent of charging stations or charging station operators.

Develop & Demonstrate High-Power Vehicle-to-Grid Energy Module (V2GEM), 2011-2015 Track 3

TransPower, California Energy Commission, South Coast AQMD, EPC Power Corp

TransPower is working to develop and demonstrate a high-power V2GEM compatible with a broad range of medium and heavy-duty vehicles. The work entails designing, developing and testing:

- High-power onboard Inverter-Charger Unit (ICU) with bidirectional capability to recharge batteries and export power to grid
- Modular battery subsystem capable of storing tens to hundreds of kilowatt-hours of energy on board various vehicles and will install ICU and battery subsystems on various medium and heavy-duty EVs and test system capabilities

Goals of the work are to:

- Reduce EV pars counts by combining the functions of the inverter and battery charger
- Enable medium and heavy duty EVs to recharge their batteries with minimal external charging infrastructure
- Provide significantly higher energy capacity and export power levels than offered by light-duty vehicles used for V2G applications
- Drive down costs by using common inverter-charger and battery modules for electric vehicle and stationary applications

APPENDIX D: STANDARDS OVERVIEW

In the U.S. and internationally, several organizations have been working to develop standards, codes and regulations that define the characteristics and use of EV-related equipment. Sample U.S. organizations include:

- Society of Automotive Engineers (SAE),
- Underwriters Laboratories, Inc. (UL),
- National Fire Protection Association,
- Institute of Electrical and Electronics Engineers (IEEE),
- International Code Council (ICC),
- National Electrical Contractors Association (NECC),
- National Electrical Manufacturers Association (NEMA), and
- Alliance for Telecommunications Industry Solutions.

International groups, among others, include:

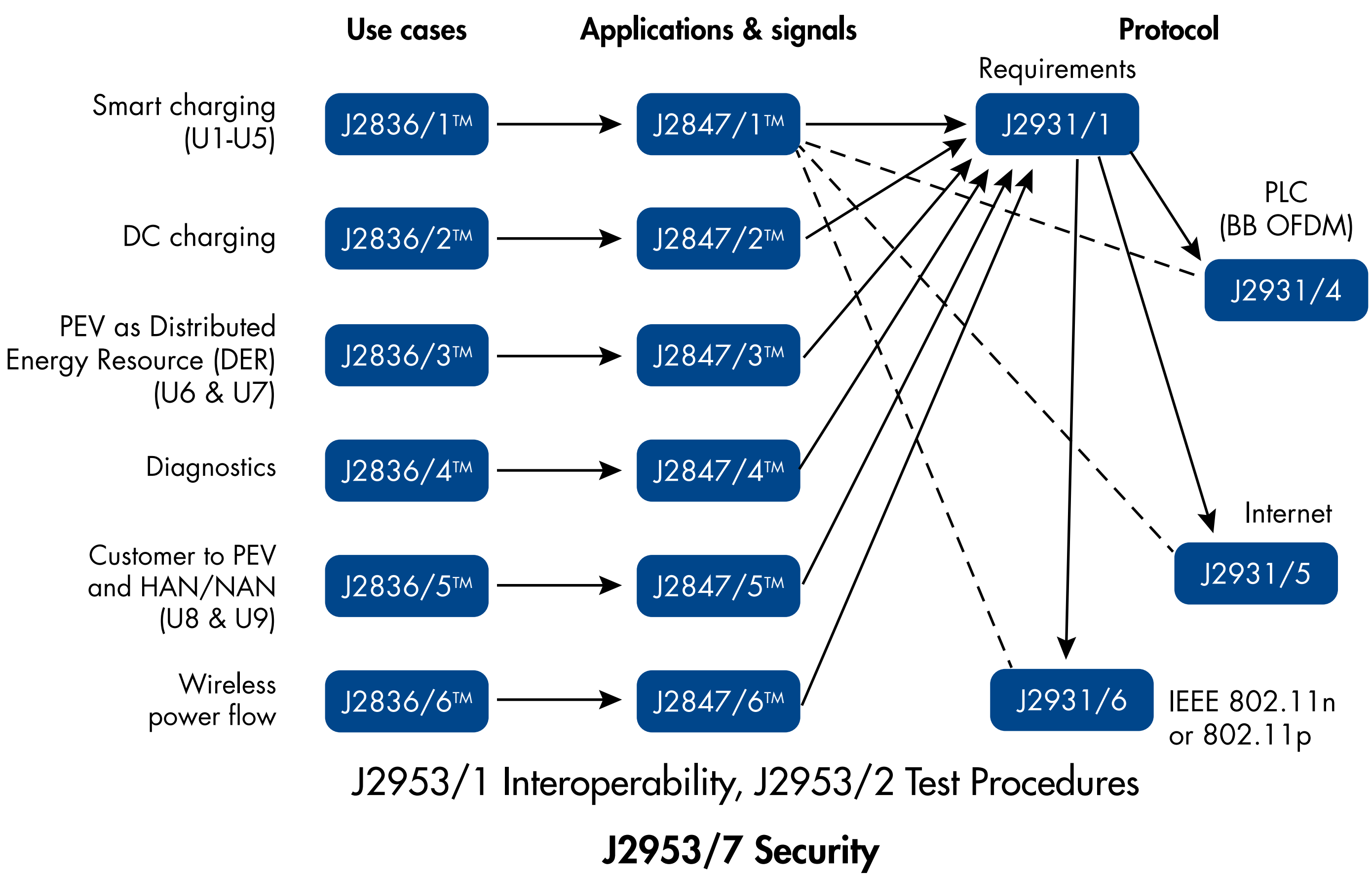
- International Electrotechnical Commission,
- International Organization for Standardization (IOS),
- European Standards Organizations (ESOs),
- European Committee for Standardization,
- European Committee for Electrotechnical Standardization, and
- CHAdeMO Association.

In May 2013, the Electric Vehicle Standards Panel of the American National Standards Institute (ANSI) published a roadmap for standards development related to EVs, entitled, Standardization Roadmap for Electric Vehicles: Version 2.0. The roadmap is available online at: http://publicaa.ansi.org/sites/apdl/evsp/ANSI_EVSP_Roadmap_May_2013.pdf. It provides a comprehensive overview of standard-making activities in the U.S. and also identifies relevant international activities. Details regarding the standards, codes, regulations, and conformance programs described in the ANSI roadmap are available via an "ANSI EVSP Roadmap Standards Compendium" at: www.ansi.org/evsp.

The following section provides an update, as of December 2013, of a sample of standards maintained by the Society of Automotive Engineers (SAE). Information comes directly from the SAE website at http://www.sae.org, from stakeholder comment, and from Rick Scholer, Chair of the PEV/EVSE Communication SAE Task Force. For updates or additional detail about other standards, and reference to the citations for standard descriptions, please refer to the SAE website.

SAE Communications Standards

The SAE maintains a series of standards around communication that pertain to VGI. Standards referencing J2836 define use cases which establish the requirements referenced by other standards. These are harmonized with ISO/IEC 15118-1. Using the use cases, J2847 standards define applications, messaging approaches and sequence diagrams. These are harmonized with ISO/IEC 15118-2. J2931 standards identify the communication requirements and protocols. These are harmonized with ISO/IEC 15118-3. J2953 standards define interoperability and test procedures. J2931/7 defines security. These are harmonized with ISO/IEC 15118-4. The following figure visualizes the relationship and roles of the different communication-focused standards.



Source: R. Scholer, PEV/EVSE Communication SAE Task Force Status, presented at IWC Meeting, December 5, 2013

The following sections outline the status of each standard and provide a brief overview of the standards functions.

SAE J2847/1™ Communication for Smart Charging of Plug-in Electric Vehicles using Smart Energy Profile 2.0

SAE J2847/1™ was first published on 6-16-2010. The latest revision, version 4, was published on 11-5-2013.

This document describes the details of the Smart Energy Profile 2.0 (SEP2.0) communication used to implement the functionality described in the SAE J2836/1™ use cases. Each use case subsection includes a description of the function provided, client device requirements, and sequence diagrams with description of the steps. Implementers are encouraged to consult the SEP2.0 Schema and Application Specification for further details. Where relevant, this document notes, but does not formally specify, interactions between the vehicle and vehicle operator.

SAE J2847/2™ Communication Between Plug-in Vehicles and Off-Board DC Chargers

SAE J2847/2™ was first published on 10-21-2011. The latest revision was published on 8-20-2012. Meetings were restarted in October 2013 and a pilot is planned to start in the first quarter of 2014. Version 3 is expected to be completed in 2014.

This SAE Recommended Practice SAE J2847/2™ establishes requirements and specifications for communication between plug-in electric vehicle and the DC off-board charger. Where relevant, this document notes, but does not formally specify, interactions between the vehicle and vehicle operator. This document applies to the off-board DC charger for conductive charging, which supplies DC current to the RESS of the electric vehicle through a SAE J1772™ coupler. Communications will be on the J1772™ Pilot line for PLC communication. The details of PLC communications are found in SAE J2931/4™. The specification supports DC energy transfer via Forward Power Flow (FPF) from source to vehicle.

SAE J2847/3™ Communication for Plug-in Vehicles as a Distributed Energy Resource

SAE J2847/3™ was published on 12-10-2013.

This document applies to a Plug-in Electric Vehicle (PEV), which is equipped with an onboard inverter and communicates using the Smart Energy Profile 2.0 Application Protocol (SEP2). It is a supplement to the SEP2 Standard, which supports the use cases defined by J2836/3™. It provides guidance for the use of the SEP2 Distributed Energy Resource Function Set with a PEV. It also provides guidance for the use of the SEP2 Flow Reservation Function Set, when used for discharging. It is not intended to be a comprehensive guide to the use of SEP2 in a PEV.

SAE J2847/4 Diagnostic Communication for Plug-in Vehicles

SAE J2847/4 is started but waiting for J2836/4™ and J2953/1 & /2.

This SAE Recommended Practice J2847/4 establishes the communication requirements for diagnostics between plug-in electric vehicles and the EVSE for charge or discharge sessions. It takes the use case and general information identified in J2836/4™ and provides the detail messages and diagrams to implement the communication.

SAE J2847/5 Communication between Plug-in Vehicles and their Customers

SAE J2847/5 is waiting for J2836/5™ use cases.

This SAE Recommended Practice J2847/5 establishes the communication requirements between plug-in electric vehicles and their customers for charge or discharge sessions. It takes the use case and general information identified in J2836/5™ and provides the detail messages and diagrams to implement the communication.

SAE J2847/6 Wireless Charging Communication between Plug-in Electric Vehicles and the Utility Grid

SAE J2847/6 was started on 3-21-2013. The SAE Task Force expects to finish version 1 in 2014.

This SAE Recommended Practice J2847/6 establishes signals and messages for communication between plug-in electric vehicles and the electric power grid, for wireless energy transfer. This is the first version of this document and completes the step 1 effort that captures the initial objectives of the SAE task force. The intent of step 1 was to record as much information on "what we think works" and publish. The effort continues however, to step 2, which allows public review for additional comments and viewpoints, while the task force also continues additional testing and early implementation. Results of step 2 efforts will then be incorporated into updates of this document and lead to a republished version.

SAE J2836/1™ Use Cases for Communication Between Plug-in Vehicles and the Utility Grid

SAE J2836/1™ was published on 4-8-2010.

This SAE Information Report J2836 establishes use cases for communication between plug-in electric vehicles and the electric power grid, for energy transfer and other applications.

SAE J2836/2™ Use Cases for Communication between Plug-in Vehicles and Off-Board DC Charger

SAE J2836/2™ was published on 9-15-2011.

This SAE Information Report SAE J2836/2™ establishes use cases and general information for communication between plug-in electric vehicles and the DC off-board charger. Where relevant, this document notes, but does not formally specify, interactions between the vehicle and vehicle operator. This applies to the off-board DC charger for conductive charging, which supplies DC current to the vehicle battery of the electric vehicle. This is done through an SAE J1772™ Hybrid coupler or SAE J1772™ AC Level 2 type coupler on DC power lines by using the AC power lines or the pilot line for PLC communication, or dedicated communication lines as further described in SAE J2847/2™. The specification supports DC energy transfer via Forward Power Flow (FPF) from grid-to-vehicle.

SAE J2836/3™ Use Cases for Plug-in Vehicle Communication as a Distributed Energy Resource

SAE J2836/3™ was published on 1-3-2013.

This SAE Information Report establishes use cases for a Plug-in Electric Vehicle (PEV) communicating with an Energy Management System (EMS) as a Distributed Energy Resource (DER). The primary purpose of SAE J2836/3™ is to define use cases which must be supported by SAE J2847/3™. This document also provides guidance for updates to SAE J2847/2™ to allow an inverter in an EVSE to use the PEV battery when operating together as a distributed energy resource (DER).

SAE J2836/4 Use Cases for Diagnostic Communication for Plug-in Vehicles

SAE J2836/4 V1 started for failures on control pilot and proximity circuits, but waiting for J2953/1 and /2 for more data.

This SAE Information Report J2836/4 establishes diagnostic use cases between plug-in electric vehicles and the EV Supply Equipment (EVSE). As Plug-In Vehicles (PEV) are deployed and include both Plug-In Hybrid Electric (PHEV) and Battery Electric (BEV) variations, failures of the charging session between the EVSE and PEV may include diagnostics particular to the vehicle variations. This document will describe the general information required for diagnostics and J2847/4 will include the detail messages to provide accurate information to the customer and/or service personnel to identify the source of the issue and assist in resolution. Existing vehicle diagnostics can also be added and included during this charging session regarding issues that have occurred or are imminent to the EVSE or PEV, to assist in resolution of these items.

SAE J2836/5™ Use Cases for Communication between Plug-in Vehicles and their Customers

SAE J2836/5 version 1 is developing use cases U8 and U9. The Task Force is planning to complete U8 and publish Version 1 in 2014.

This SAE Information Report J2836/5™ establishes use cases between Plug-In Vehicles (PEV) and their customer. The customer will be able to interact with the PEV as it charges/discharges. Information and control for each session, including status, updates and potential changes are identified in this document as they use private or public scenarios to connect their vehicles to the utility grid.

SAE J2836/6™ Use Cases for Wireless Charging Communication for Plug-in Electric Vehicles

SAE J2836/6™ was published on 5-3-2013.

This SAE Information Report SAE J2836/6™ establishes use cases for communication between plug-in electric vehicles and the EVSE, for wireless energy transfer as specified in SAE J2954. It addresses the requirements for communications between the on-board charging system and the Wireless EV Supply Equipment (WEVSE) in support of detection of the WEVSE, the charging process and monitoring of the charging process. Since the communication to the charging infrastructure and the power grid for smart charging will also be communicated by the WEVSE to the EV over the wireless interface, these requirements are also covered. However, the processes and procedures are expected to be identical to those specified for V2G communications in SAE J2836/1.

SAE J2931/1™ Digital Communications for Plug-in Electric Vehicles

SAE J2931/1™ was first published on 1-24-2012. The latest revision was published on 9-7-2012.

This SAE Information Report SAE J2931 establishes the requirements for digital communication between Plug-In Vehicles (PEV), the Electric Vehicle Supply Equipment (EVSE) and the utility or service provider, Energy Services Interface (ESI), Advanced Metering Infrastructure (AMI) and Home Area Network (HAN). This is the second version of this document and completes the step 2 effort that specifies the digital communication protocol stack between Plug-in Electric Vehicles (PEV) and the Electric Vehicle Supply Equipment (EVSE).

SAE J2931/4™ Broadband PLC Communication for Plug-in Electric Vehicles

SAE J2931/4™ version 1 was published on 7-26-2012 and version 2 on 11-14-2013. Version 3 was reopened in November 2013 for updates to match ISO/IEC 15118.

This SAE Technical Information Report SAE J2931/4 establishes the specifications for physical and data-link layer communications using broadband Power Line Communications (PLC) between the Plug-In Vehicle (PEV) and the Electric Vehicle Supply Equipment (EVSE) DC off-board-charger. This document deals with the specific modifications or selection of optional features in HomePlug Green PHY v1.1 necessary to support the automotive charging application over Control Pilot lines as described in SAE J1772™. PLC may also be used to connect directly to the Utility smart meter or Home Area Network (HAN), and may technically be applied to the AC mains, both of which are outside the scope of this document.

SAE J2931/5 Telematics Smart Grid Communications between Customers, Plug-In Electric Vehicles (PEV), Energy Service Providers (ESP) and Home Area Networks (HAN)

SAE J2931/5 is waiting for J2847/5.

This SAE Recommended Practice J2931/5 establishes the security requirements for digital communication between Plug-In Electric Vehicles (PEV), the Electric Vehicle Supply Equipment (EVSE) and the utility, ESI, Advanced Metering Infrastructure (AMI) and/or Home Area Network (HAN). This is the first version of this document and completes the step 1 effort that captures the initial objectives of the SAE task force. The intent of step 1 was to record as much information on "what we think works" and publish. The effort continues however, to step 2, which allows public review for additional comments and viewpoints, while the task force also continues additional testing and early implementation. Results of step 2 efforts will then be incorporated into updates of this document and lead to a republished version.

SAE J2931/6 Digital Communication for Wireless Charging Plug-in Electric Vehicles

SAE J2931/6 is waiting for J2847/6.

This SAE Recommended Practice J2931/6 establishes the digital communication protocol requirements for wireless charging between Plug-In Vehicles (PEV), the Electric Vehicle Supply Equipment (EVSE) and the utility, ESI, Advanced Metering Infrastructure (AMI) and/or Home Area Network (HAN). This is the first version of this document and completes the step 1 effort that captures the initial objectives of the SAE task force. The intent of step 1 was to record as much information on "what we think works" and publish. The effort continues however, to step 2, which allows public review for additional comments and viewpoints, while the task force also continues additional testing and early implementation. Results of step 2 effort will then be incorporated into updates of this document and lead to a republished version.

SAE J2931/7 Security for Plug-in Electric Vehicle Communications

SAE J2931/7 will restart in January 2014.

Develop and document the functional and technical requirements for a standard telematics application programming interface that facilitates two way communications between the PEV telematics service provider and the Energy Services Provider. The telematics interface will provide access to consumer specific usage data e.g., instantaneous usage, consumption usage, volts, amps, VAR, power factor, etc. The telematics common interface solution will encompass, at minimum, four key interfaces: Aggregation, Control, TOU Rates, and Vehicle Information inclusive of interconnectivity with utility energy management systems, utility back office networks, ISOs, RTOs, and consumer home area networks. Use cases are to be developed to define the attributes of key interface requirements and functionality. Requirements for implementation shall include compliance and/or interoperability with J2847 series of recommended practices, and with Smart Energy Profile 2.0 and/or OpenADR/OpenADE application standards.

SAE J2953/1™ Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)

SAE J2953/1™ version 1 was published on 10-7-2013. In November, it was reopened for version 2. The SAE Task Force expects to update version 2 with DC charging interoperability in 2014.

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

SAE J2953/2 Test Procedures for the Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)

SAE J2953/2 started SAE formatting on 11-21-2013. It will be re-opened once published. The SAE Task Force expects to update version 2 with DC charging interoperability in 2014.

This SAE Recommended Practice J2953/2 establishes the test procedures to ensure the interoperability of Plug-In Vehicles (PEV) and Electric Vehicle Supply Equipment (EVSE) for multiple suppliers.

SAE Hybrid-Electric Vehicle Standards

Additional standards from SAE define details relevant to hybrid-electric vehicles (HEV). The following sections outline the status of sample HEV standards and provide a brief overview of the standards functions.

SAE J2841™ Utility Factor Definitions for Plug-In Hybrid Electric Vehicles Using Travel Survey Data

SAE J2841™ was first published on 3-27-2009. The latest revision was published on 9-21-2010.

The total fuel and energy consumption rates of a Plug-In Hybrid Electric Vehicle (PHEV) vary depending upon the distance driven. For PHEVs, the assumption is that operation starts in battery charge-depleting mode and eventually changes to battery charge-sustaining mode. Total distance between charge events determines how much of the driving is performed in each of the two fundamental modes. An equation describing the portion of driving in each mode is defined. Driving statistics from the National Highway Transportation Survey are used as inputs to the equation to provide an aggregate "Utility Factor" (UF) applied to the charge-depleting mode results.

SAE J1711™ Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid-Electric Vehicles, Including Plug-in Hybrid Vehicles

SAE J1711™ was first published on 3-1-1999. The latest revision was published on 6-8-2010.

This SAE Recommended Practice establishes uniform chassis dynamometer test procedures for hybrid-electric vehicles (HEVs) that are designed to be driven on public roads. The procedure provides instructions for measuring and calculating the exhaust emissions and fuel economy of HEVs driven on the Urban Dynamometer Driving Schedule (UDDS) and the Highway Fuel Economy Driving Schedule (HFEDS), as well as the exhaust emissions of HEVs driven on the US06 Driving Schedule (US06) and the SC03 Driving Schedule (SC03).

SAE J1772™ SAE Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler

SAE J1772™ was first published on 1-15-2010. The latest revision was published on 10-15-2012.

This SAE Recommended Practice covers the general physical, electrical, functional and performance requirements to facilitate conductive charging of EV/PHEV vehicles in North America. This document defines a common EV/PHEV and supply equipment vehicle conductive charging method including operational requirements and the functional and dimensional requirements for the vehicle inlet and mating connector.

SAE J1773™ SAE Electric Vehicle Inductively Coupled Charging

SAE J1773™ was first published on 1-1-1995. The latest revision was published on 5-28-2009.

This SAE Recommended Practice establishes the minimum interface compatibility requirements for electric vehicle (EV) inductively coupled charging for North America. This part of the specification is applicable to manually connected inductive charging for Levels 1 and 2 power transfer. Requirements for Level 3 compatibility are contained in Appendix B. Recommended software interface messaging requirements are contained in Appendix A.

SAE J2344™ Guidelines for Electric Vehicle Safety

SAE J2344™ was first published on 6-1-1998. The latest revision was published on 3-5-2010.

This SAE Information Report identifies and defines the preferred technical guidelines relating to safety for Electric Vehicles (EVs) during normal operation and charging. Guidelines in this document do not necessarily address maintenance, repair or assembly safety issues. The purpose of this SAE Information Report is to provide introductory safety guidelines information that should be considered when designing electric vehicles for use on public roadways.

SAE J2293/1™ Energy Transfer System for Electric Vehicles—Part 1: Functional Requirements and System Architectures

SAE J2293/1™ was first published on 3-1-1997. The latest revision was published on 7-7-2008.

SAE J2293/2™ Energy Transfer System for Electric Vehicles—Part 2: Communication Requirements and Network Architecture

SAE J2293/2™ was first published on 6-1-1997. The latest revision was published on 7-8-2008.

SAE J2293 establishes requirements for Electric Vehicles (EV) and the off-board Electric Vehicle Supply Equipment (EVSE) used to transfer electrical energy to an EV from an Electric Utility Power System (Utility) in North America. This document defines, either directly or by reference, all characteristics of the total EV Energy Transfer System (EV-ETS) necessary to ensure the functional interoperability of an EV and EVSE of the same physical system architecture.

SAE J2758™ Determination of the Maximum Available Power from a Rechargeable Energy Storage System on a Hybrid Electric Vehicle

SAE J2758TM was published on 4-30-2007.

This document describes a test procedure for rating peak power of the Rechargeable Energy Storage System (RESS) used in a combustion engine Hybrid Electric Vehicle (HEV). Other types of vehicles with non-fossil fuel primary engines, such as fuel cells, are not intended to use this test procedure.

SAE Battery Standards

Additional standards from SAE define details relevant to vehicle batteries. The following sections outline the status of sample battery standards and provide a brief overview of the standards functions.

SAE J2380™ Vibration Testing of Electric Vehicle Batteries

SAE J2380™ was first published on 1-1-1998. The latest revision was published on 12-10-2013.

This SAE Recommended Practice describes the vibration durability testing of a single battery (test unit) consisting of either an electric vehicle battery module or an electric vehicle battery pack. For statistical purposes, multiple samples would normally be subjected to such testing. Additionally, some test units may be subjected to life cycle testing (either after or during vibration testing) to determine the effects of vibration on battery life. Such life testing is not described in this procedure; SAE J2288 may be used for this purpose as applicable. Finally, impact testing, such as crash and pothole, is not included in this procedure.

SAE J2464™ Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing

SAE J2464™ was first published on 3-11-1999. The latest revision was published on 11-6-2009.

This SAE Recommended Practice is intended as a guide toward standard practice and is subject to change to keep pace with experience and technical advances. It describes a body of tests which may be used as needed for abuse testing of electric or hybrid electric vehicle batteries to determine the response of such batteries to conditions or events which are beyond their normal operating range.

SAE J1797™ Recommended Practice for Packaging of Electric Vehicle Battery Modules

SAE J1797™ was first published on 1-1-1997. The latest revision was published on 6-30-2008.

This SAE 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. The document does not provide for performance standards. Performance will be addressed by SAE J1798. This document does provide for guidelines in proper packaging of battery modules to meet performance criteria detailed in J1766.

SAE J1798™ Recommended Practice for Performance Rating of Electric Vehicle Battery Modules

SAE J1798™ was first published on 1-1-1997. The latest revision was published on 7-8-2008.

This SAE Recommended Practice provides for common test and verification methods to determine Electric Vehicle battery module performance. The document creates the necessary performance standards to determine (a) what the basic performance of EV battery modules is; and (b) whether battery modules meet minimum performance specifications established by vehicle manufacturers or other purchasers.

SAE J2288™ Life Cycle Testing of Electric Vehicle Battery Modules

SAE J2288™ was first published on 1-1-1997. The latest revision was published on 6-30-2008.

This SAE Recommended Practice defines a standardized test method to determine the expected service life, in cycles, of electric vehicle battery modules. It is based on a set of nominal or baseline operating conditions in order to characterize the expected degradation in electrical performance as a function of life and to identify relevant failure mechanisms where possible. Accelerated aging is not included in the scope of this procedure, although the time compression resulting from continuous testing may unintentionally accelerate battery degradation unless test conditions are carefully controlled. The process used to define a test matrix of accelerated aging conditions based on failure mechanisms, and to establish statistical confidence levels for the results, is considered beyond the scope of this document. Because the intent is to use standard testing conditions whenever possible, results from the evaluation of different technologies should be comparable. End-of-life is determined based on module capacity and power ratings. This may result in a measured cycle life different than that which would be determined based on actual capacity; however, this approach permits a battery manufacturer to make necessary tradeoffs between power and energy in establishing ratings for a battery module. This approach is considered appropriate for a mature design or production battery. It should be noted that the procedure defined in this document is functionally identical to the USABC Baseline Life Cycle Test Procedure.

SAE J2289™ Electric-Drive Battery Pack System: Functional Guidelines

SAE J2289™ was first published on 11-15-2000. The latest revision was published on 7-29-2008.

This SAE Information Report describes common practices for design of battery systems for vehicles that utilize a rechargeable battery to provide or recover all or some traction energy for an electric drive system. It includes product description, physical requirements, electrical requirements, environmental requirements, safety requirements, storage and shipment characteristics, and labeling requirements. It also covers termination, retention, venting system, thermal management, and other features. This document does describe guidelines in proper packaging of the battery to meet the crash performance criteria detailed in SAE J1766. Also described are the normal and abnormal conditions that may be encountered in operation of a battery pack system.

APPENDIX E: INDEX OF TERMS

BEV	Battery electric vehicles run only on electric motors powered by batteries, which are recharged by plugging in. Because electricity is the only source of fuel for these vehicles, all BEVs are plug-in vehicles.
CHAdeMO	CHAdeMO is the name of a fast charging protocol that specifies charging which can deliver up to a maximum of 62.5 kW of high-voltage direct current. The standard is being proposed as a global standard by the CHAdeMO Association.
Electric Drive Vehicle	Vehicles converting stored electrical energy to kinetic energy through the use of one or more electric motors.
EV Rate	Electricity tariffs that apply to customers with electric drive vehicles.
EVSE	The term "Electric Vehicle Supply Equipment" refers to the equipment associated with charging electric drive vehicles. It encompasses all of the conductors, plugs, fittings, and other hardware purposed to deliver energy from the electric grid to the vehicle.
IEC 62196	An international standard addressing electrical connector types and EV charging modes. The standard is maintained by the International Electrotechnical Commission (IEC).
Interconnection Agreement	A contract between a utility and a power developer that formally approves connecting a facility to the distribution system; or a contract between the ISO and a resource owner formally approving the interconnection of a resource to the ISO-controlled grid.
Managed Charging	The control of EV charging, either through modulated charging rates or on-off charging. Often, it refers to the centralized control and dispatch of charging signals to multiple EV chargers or vehicles for coordinated grid service.
Peak Shaving	The reduction in magnitude of peak demand. Strategies such as load reduction or load shifting are often used to achieve peak shaving.
Peak Shifting	The shifting of load from one moment in time to another moment in time.
PHEV	Plug-in hybrid electric vehicles (PHEVs) can be charged with electricity as well as operate with a combustion engine. PHEV describes both parallel hybrids and series hybrids. Parallel hybrids are PHEVs where both the electric motor and the combustion engine are mechanically coupled to the wheels through a transmission. Series hybrid describes PHEVs where the electric motor is directly coupled to the wheels and the combustion engine is used to charge the batteries.

Power Inverter	A device used to transform direct current (DC) to alternating current (AC).
Regulation Services	The service provided by generating units certified by the ISO capable of responding to the ISO's direct digital control (AGC) signals, or by system resources that have been ISO certified as capable of delivering in an upward and downward direction on a real-time basis matching demand and resources consistent with North American Electric Reliability Corporation and Western Electricity Coordinating Council reliability standards, including any Nuclear Regulatory Commission requirements. Regulation is used to control the power output of electric generators within a prescribed area in response to a change in system frequency, tie line loading, or the relation of these to each other so as to maintain the target system frequency and the established interchange with other balancing authority areas within the predetermined regulation limits. Regulation includes both the increase of output by a generating unit or system resource (regulation up) and the decrease in output by a generating unit or system resource (regulation down). Regulation up and regulation down are distinct capacity products, with separately stated requirements and ancillary service marginal prices in each settlement period.
SAE J1772	A North American standard addressing general physical, electrical, communication protocol and performance requirements for EVSE. The standard is maintained by the Society of Automotive Engineers (SAE).
Sub-Meter	A meter dedicated to measuring loads independently from the overall facility load. In the context used here, it represents meters dedicated to measuring EV loads.
V1G	The term refers to the unidirectional flow of power enabling EVs to charge from the grid. (V2G refers to two-way power flows).
V2G	The term refers to the bidirectional flow of power enabling EVs to charge from the grid and to discharge back to the grid. (V1G refers to one-way power flow).
VGI	The term vehicle-grid integration (VGI), as used in this roadmap, encompasses the many ways in which an electric vehicle can provide grid services. This may be through the managed charging of a vehicle or the two-way interaction between a vehicle and the grid.
V2B	The term refers to the bidirectional flow of power enabling EVs to charge from a building and to discharge back to a building.
WDAT	The Wholesale Distribution Access Tariff (WDAT) defines the rates, terms and conditions associated with small and large generator interconnections to the grid. These tariffs are regulated by the Federal Energy Regulatory Commission (FERC).