Electric Transportation - Program 18

Program Overview

Program Description
Plug-in electric vehicles (PEVs) entered the commercial market in late 2010. The early market has been characterized by modest but steadily increasing sales, high vehicle reliability and customer satisfaction, and a rapid evolution of both vehicle and infrastructure technologies. By mid-2013, total U.S. PEV sales exceeded 100,000 vehicles and 15 PEV models were available from 10 manufacturers, including five of the six largest U.S. automotive manufacturers.

Upon introduction, the first mass-produced PEVs charged at relatively low rates (up to 3.5 kW), traveled between 35 and 75 miles (56 to 120 km) per charge, and had little public infrastructure to support them. Within two years, a battery electric vehicle had been introduced with 265 miles of range alongside a plug-in hybrid electric vehicle (PHEV) with 10 miles of electric range. Charging rates in new vehicle models increased dramatically from 3.5 kW to 6.6–19.2 kW. Electric vehicles from sedans to delivery trucks began to see increased usage in fleets, and thousands of public and workplace charging stations were installed. A "fast" charging network began to emerge, using dc electricity at levels of 50 to 90 kW to charge electric vehicles in as little as 20 minutes. In addition, automotive manufacturers developed the first production charging systems that enable electric vehicles to provide power to the grid.

Nearly all major automakers are reaching out to the utility industry to help develop and standardize infrastructure for recharging PEVs. Utility customers, including local governments, are looking to utilities to provide guidance on the design, location, and installation of charging infrastructure. Utilities need to understand the system impacts and customer requirements associated with plug-in vehicles while conducting the necessary preparations to support the rollout and adoption of PEVs by their residential, commercial, and industrial customers. Electricity is the only potential energy source for transportation that addresses the simultaneous need for fuel diversity, energy security, reductions in greenhouse gas emissions, and improvements in air quality that is widely available and produced domestically. Electric utilities must understand the paradigm shift that will occur with an inevitable transition of transportation energy from petroleum to electricity, as well as their new role as a fuel provider for vehicles. In addition, vehicle fleets can offset high fuel costs and meet environmental requirements by incorporating PHEVs or battery electric vehicles (BEVs) into their operations. Adoption of non-road electric vehicles at customer sites can reduce fuel costs and increase customer satisfaction. Emission-constrained sites such as seaports and airports can reduce the cost of environmental compliance.

Research Value
The Electric Transportation program conducts research and development on vehicle and infrastructure technologies that enable the use of electricity as a transportation fuel. The program has played a leading role in the development of PEV technologies that are at the forefront of automotive industry development efforts. The Electric Power Research Institute (EPRI) also serves as a focal point of collaboration between the automotive and utility industries for the development of infrastructure standards, vehicle demonstration programs, and advanced infrastructure technologies. EPRI’s non-road electric transportation efforts have demonstrated the cost-effective use of battery electric vehicles in numerous commercial and industrial applications, and serve as the technical foundation for successful, customer-focused utility non-road electric transportation market expansion programs.

Approach
EPRI research in electric transportation will yield a variety of data and knowledge that will be beneficial to members of the program. This information will be delivered in a number of forms and is expected to include the following:

- Facilitated collaboration between the utility industry and the major automotive manufacturers, PEV infrastructure equipment suppliers, infrastructure operators, and public agencies.
• Analysis of the grid impacts of PEV charging to utility systems.
• Utility-specific analyses on potential PEV market size, load shape and requirements, customer expectations, infrastructure requirements, and other material required to support internal utility PEV readiness or mainstreaming programs.
• Testing and evaluation of PEVs and electric vehicle charging equipment; data collection and analysis of real-world PEV operation in utility fleet and other applications.
• Formation of major vehicle and infrastructure demonstration initiatives to collect and analyze real-world operating data on the latest vehicle and infrastructure technologies.
• Development of advanced charging technologies that enable integration of PEVs into the utility smart grid.
• Development of non-road electric transportation programs through field demonstration and technology development and assessment.
• Validation of the economic and environmental benefits (including greenhouse gas emissions) of PEVs to the utility, utility customers, and their communities.

Accomplishments

The Electric Transportation program has delivered valuable information that has helped its members and the industry in numerous ways. Examples include the following:

Transportation Electrification: A Technology Overview (1021334): This report provides a detailed status on the commercial rollout of plug-in electric vehicles. It describes the key vehicle and infrastructure technologies, and outlines a number of potential roles for electric utilities to consider when developing electric transportation readiness plans. These roles have been formulated with the objectives of enabling utilities to demonstrate regional leadership in planning for transportation electrification, support customer adoption of PEVs and their supporting infrastructure, and understand and minimize the system impacts from vehicle charging.

The Efficacy of Electric Vehicle Time-of-Use Rates in Guiding Plug-In Hybrid Electric Vehicle Charging Behavior (1021741): Time-of-use (TOU) rates can guide PEV charging behavior by economically incentivizing off-peak charging. This EPRI technical update modeled the total cost of fueling a PHEV (gasoline and electricity) under different modeled and real-world TOU and constant rates for different PHEV designs and driver behavior.

Direct Current Fast Charger System Characterization: Standards, Penetration Potential, Testing, and Performance Evaluation (1021743): The importance of direct current (dc) fast charging of plug-in electric vehicles is expected to increase in the near future. This report presents an overview of the standards and protocols in use or under development, a market assessment of dc charging equipment and compatible PEVs, and an analysis of the impact of fast charging given PEV driving patterns. This report also contains test results of a dc fast charger, including charge profiles, power factor, and power quality.

EPRI Lift Truck Calculator Version 1.0 Mobile Application (1023534): EPRI's Lift Truck Calculator is a mobile application for iOS devices (iPhone or iPad) that determines costs and emissions savings for an electric lift truck compared to a combustion version powered by diesel or propane.

Current Year Activities

• Complete codes and standards development activities for the SAE J1772 connector and the SAE J2836/2847 communications recommended practices.
• Conduct an industry-wide demonstration of smart charging technologies and infrastructure utilizing the SAE J2836 standard for utility communications to PEVs.
• Initiate a field demonstration of the medium-voltage dc fast-charging technology at multiple utility locations.
• Expand data collection activities on light-duty passenger vehicles and light- and medium-duty trucks operating in utility fleets and other applications.
• Expand the demonstration of non-road transportation technologies.
• Complete the development of recommendations for residential, workplace, and public charging infrastructure requirements, network design, location, and installation.
- Update PEV adoption and load forecasting models, including the development of climactic and regional models for PEV charging load shapes and grid impacts.
- Initiate a field demonstration of PEVs as distributed energy resources using bi-directional off-board charging appliances.

**Estimated 2014 Program Funding**

$5.0M

**Program Manager**

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**Summary of Projects**

**PS18A Plug-In Electric Vehicle Development (056053)**

**Project Set Description**

This project set addresses technologies and products that demonstrate the value of electric-drive systems and components in (PHEV) and battery electric vehicle (BEV) applications.

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<th>Description</th>
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<tr>
<td>P18.001</td>
<td>Plug-in Electric Vehicle Evaluation and Test Data Analysis</td>
<td>This project provides a comprehensive real-world test program for plug-in electric vehicle demonstration fleets using sophisticated systems for collecting and processing detailed vehicle information and reporting the results to members.</td>
</tr>
<tr>
<td>P18.003</td>
<td>Advanced Battery and Powertrain System Development for Plug-In Vehicles</td>
<td>This project will promote the development of Li-ion battery systems technologies and electric-drive powertrain system technologies for PEVs, as well as evaluate their impact on vehicle performance, cost, and life.</td>
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<tr>
<td>P18.027</td>
<td>Consumer Response to Plug-In Electric Vehicles</td>
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**P18.001 Plug-in Electric Vehicle Evaluation and Test Data Analysis (062128)**

**Description**

The first plug-in hybrid and battery electric passenger vehicles—collectively termed plug-in electric vehicles (PEVs)—from large automotive manufacturers entered the U.S. market in late 2010. There are a growing number of active PEV prototype and production vehicle test and demonstration programs in utility and public fleets. These programs provide important opportunities to collect and analyze real-world operating data. This activity will enable members to understand the performance and operation of different types of PEVs, understand customer usage and expectations, and determine benefits and impacts to their systems.

**Approach**

This project provides a comprehensive real-world test program for EPRI and utility PEV demonstration fleets. EPRI has developed a sophisticated system for collecting and processing detailed vehicle systems information and reporting the results to members. This information is valuable for utilities to understand how real-world PEV use impacts their system and business, to guide fleet “greening” and other environmental compliance issues, and to determine the most promising PHEV technological approaches. The scope of data collection and analysis includes
• development of test procedures for field testing of prototype PEV fleets,
• acquisition and analysis of vehicle and system data from demonstration fleets,
• reporting and dissemination of vehicle test data,
• comparison to laboratory battery and component tests and verification of vehicle simulation data, and
• surveys of transportation applications to determine potential PEV candidates and performance profile analyses of these candidates.

Impact

• Increase understanding of PEV product performance.
• Reduce fleet operating costs.
• Facilitate fleet environmental compliance.
• Acquire real-world data to support PEV benefit and impact analysis at the utility.

How to Apply Results

Members can incorporate PEV test results into their internal analyses. Fleet managers can use the test data and vehicle specifications to acquire PEV technology for utility fleet operations. In addition, this project will enable EPRI and its advisors to carefully review the transportation sector and identify transportation operating profiles and specific vehicle platforms as candidates for plug-in hybrid electric vehicle operation.

P18.003 Advanced Battery and Powertrain System Development for Plug-In Vehicles (063272)

Description

The potential for plug-in electric vehicles to achieve widespread market acceptance depends heavily on the cost, performance, and durability of their electric-drive systems and particularly on advanced lithium-ion (Li-ion) battery technology. Early testing by EPRI and utilities of Li-ion battery systems against PHEV duty cycles provided some of the earliest evidence of the capability of the technology to meet PEV requirements. EPRI has also conducted extensive development, demonstration, and evaluation of electric-drive powertrain systems and components. New PEV design requirements and emerging technologies will continue to require additional systems development, technology evaluation, and testing.

Approach

EPRI will continue its industry-leading battery and electric-drive powertrain technology development and evaluation program. This project will identify and address issues of importance to the development and verification of PEV technology, including the following:

• Identification of technical issues related to PEV powertrain and battery systems, including cost, environmental impact, recycling or manufacturing technology
• Evaluation of technical needs and gaps for future PEV powertrain technologies, including electric traction systems, on-board chargers, dc-dc converters and electric accessories
• Development of suitable test procedures and methods for evaluating advanced batteries for PEV applications
• Development of test plans and protocols for long-term life-cycle testing of candidate battery technologies
• Identification of synergies between automotive and stationary battery systems.

Impact

• Evaluate emerging PEV powertrain system and component technologies, including batteries.
• Understand drivers for PEV battery system cost and environmental impact.
• Obtain early identification and testing of promising emerging battery technologies.
• Identify and address issues that affect PEV battery commercialization.
How to Apply Results

The results from this project will provide members with world-class, specific technical and cost information regarding battery and powertrain systems technology for PEVs. Members will gain a thorough understanding of the readiness of Li-ion battery technology for PEVs—the single most substantial technical challenge to the development and commercialization of these vehicles.

P18.027 Consumer Response to Plug-In Electric Vehicles

Description

Customer response and viewpoints with respect to PEVs are an important indicator of the both the likely success of PEV technology and useful data to guide utility programs and interactions with their customers. The attitudes of PEV adopters will naturally change as the technology progresses from the initial early adopters to other customer segments. Understanding the response and expectations of this important and historically vocal customer group will enable utilities to respond appropriately to the needs of their customers.

Approach

This project will collaborate with Program 182, "Understanding the Utility Customer," to identify current knowledge gaps on customer expectations and experiences with PEVs, analyze and understand existing customer research and—where needed—design relevant survey instruments for either EPRI staff or program funders to use in the field.

Impact

- Help members understand customer usage of PEVs and charging infrastructure as the market changes.
- Provide members with concise summaries of the current customer survey research throughout the industry.
- Increase understanding of PEV owners’ expectations of their utilities.

How to Apply Results

Members will have access to survey instruments, summaries, and analyses of existing customer research on a range of topics related to electric vehicles.

PS18B Non-Road and Fleet Applications (056054)

Project Set Description

This project set focuses on the application of electric-drive systems in non-road industrial, commercial, airport and seaport markets whose technology successes will advance the awareness of the value of electric-drive systems.

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<tr>
<td>P18.015</td>
<td>Non-Road Electric Vehicle Technology Assessment</td>
<td>This project will assess the performance, energy consumption, and emissions benefits of non-road electric vehicles.</td>
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<tr>
<td>P18.016</td>
<td>Fleet Applications for Plug-In Hybrid and Electric Vehicles</td>
<td>This project provides utility and customer fleet managers with guidelines and calculation tools to assist in planning fleet electrification.</td>
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<tr>
<td>P18.019</td>
<td>Non-Road and Fleet Vehicle Demonstration and Evaluation</td>
<td>This project investigates the application of electric-drive systems in non-road industrial, commercial, airport and seaport markets.</td>
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P18.015 Non-Road Electric Vehicle Technology Assessment (070588)

Description
The adoption of non-road electric vehicles depends upon accurately understanding their benefits, real-world performance, life-cycle costs, and emissions reduction potential. Expanding non-road electric-drive technology into new applications requires a detailed technical understanding of the performance requirements of the vehicles in those applications.

Approach
This project will use a combination of test data from EPRI Project 18.006, other available test data, and existing literature to conduct technology assessments of non-road electric vehicles. This work will quantify the following aspects of non-road electric vehicle operation relative to combustion-powered equipment:

- Charging requirements and electricity consumption
- Fossil fuel consumption reductions
- Greenhouse gas and criteria emissions reductions
- Life-cycle operating costs
- Vehicle performance and capabilities

Impact
This project may have these impacts:

- Understand the life-cycle performance, energy consumption, and emissions of non-road equipment.
- Improve the adoption of non-road electric vehicles by utility customers.
- Inform environmental managers, policymakers, and other stakeholders of the emissions benefits of non-road EVs.

How to Apply Results
Utility managers and account executives will use technical reports and other project data to inform customers and design non-road adoption or market expansion programs.

P18.016 Fleet Applications for Plug-In Hybrid and Electric Vehicles (070589)

Description
In addition to currently available non-road electric vehicles, commercial fleets will face an increasing range of choices for electric and plug-in hybrid electric light-, medium- and heavy-duty vehicles for their on-road fleets. Most fleet managers lack unbiased, accurate information to help them plan the acquisition of plug-in electric vehicles and the supporting infrastructure. Commercial fleets may represent a significant share of total PEV adoption in a community or region; however, lack of information and the risk of making poor initial decisions is an obstacle to adoption.

Approach
This project will utilize results from Projects 18.006 and 18.015 to develop guidelines and analytical tools to help fleet managers understand the technical capabilities of PEVs, accurately predict the performance of PEVs in their fleet applications, determine life-cycle costs, and calculate emissions and energy consumption benefits. The project also will develop an infrastructure planning tool that will help fleets develop preliminary electrical designs and understand charging equipment installation costs.
Impact
This project may have these impacts:

- Increase adoption of PEVs by the utility fleet and by commercial fleets owned by utility customers.
- Provide unbiased, accurate PEV technical and performance data.
- Enable accurate planning and understanding of infrastructure installations.
- Enable fleets to determine optimum compliance pathways to meet environmental requirements.

How to Apply Results
Utility fleet managers will use project guidelines and calculators to plan fleet electrification. Utility account executives and electric transportation staff will use project results to help utility customers electrify their fleets and plan charging infrastructure.

P18.019 Non-Road and Fleet Vehicle Demonstration and Evaluation (071990)

Description
This research focuses on the application of electric-drive systems in non-road industrial, commercial, airport and seaport market segments whose technology successes will advance the awareness of the value of electric-drive systems.

Increased success of non-road electric vehicle market penetration has most often resulted from actual product demonstrations spanning a diverse industry base that includes airports, food processing plants, and automotive manufacturers. Continued efforts in this area will enable ongoing market expansion.

Approach
This project will continue to seek and execute non-road EV demonstration projects across the United States. The scope of work is as follows:

- Review past demonstrations to identify types, locations, and level of success.
- Define criteria that resulted in successful demonstrations.
- Identify potential future demonstration projects across the United States and develop a scope of work for these projects.

Impact
This project may have these impacts:

- Increase penetration of EVs in the non-road market.
- Expand the market for utility products while enhancing customer satisfaction.
- Achieve greater carbon dioxide (CO₂) emissions reductions.
- Demonstrate EV technology validation in increasingly diverse applications.
- Provide valuable market information to a national audience.

How to Apply Results
Utility account executives will use case studies and reports that document the value of EV applications to establish interest in electric transportation among customers in their service territories as part of a non-road EV campaign.
PS18D Electric Transportation Systems, Infrastructure, and Utility Readiness (056057)

Project Set Description
This project set addresses issues surrounding the design, performance, and deployment of plug-in electric vehicle (PEV) charging infrastructure and impacts on the utility grid, with a focus on utility issues such as tracking PEV adoption, load forecasting, and the environmental and economic benefits of electric transportation.

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<td>P18.010</td>
<td>Infrastructure Working Council</td>
<td>This project will provide support to the Infrastructure Working Council (IWC) for the execution of infrastructure analysis that affects the commercialization of plug-in hybrid electric vehicles and battery electric vehicles in the automotive and truck industries.</td>
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<tr>
<td>P18.020</td>
<td>PEV Charging Infrastructure - Evaluation, Planning and Business Models</td>
<td>This project will evaluate electric vehicle supply equipment (EVSE) and infrastructure, as well as develop planning and business models for deploying EVSE in utility services territories.</td>
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<tr>
<td>P18.021</td>
<td>Grid Integration of PEVs</td>
<td>This project will develop models and framework to provide members with integrated, detailed, and localized estimates of electric vehicle adoption and its associated impacts in the electric system.</td>
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<tr>
<td>P18.022</td>
<td>Utility PEV Readiness</td>
<td>This project will develop best practices for internal planning and management practices for utility PEV readiness programs.</td>
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<tr>
<td>P18.023</td>
<td>PEV Adoption and Load Forecasting</td>
<td>With plug-in electric vehicles poised to grow in the mainstream automotive market, electricity providers are working to account for the new electrical load in their planning process. Seamless integration of PEVs into the grid is a key concern of utilities. While technological barriers to the commercialization of PEVs continue to fall, the expected influence of PEVs on the electrical system has not been completely evaluated. Understanding the relationships between this new load type and the utility system will help members augment their planning processes to manage any additional stresses to their systems.</td>
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<tr>
<td>P18.024</td>
<td>Environmental and Economic Assessment of Electric Transportation</td>
<td>This project develops research methods for estimating electric vehicle adoption rates, and incorporates that information into electric vehicle readiness planning.</td>
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<tr>
<td>P18.028</td>
<td>Evaluation of Near-Term PEV Charging Technologies</td>
<td>This project will create an up-to-date listing of vendors and their capabilities that provide EVSE and related charging infrastructure.</td>
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P18.010 Infrastructure Working Council (065239)

Description
The Infrastructure Working Council (IWC) was established to provide a forum for utilities, automotive manufacturers, suppliers, and other stakeholders to address issues regarding electric infrastructure for plug-in hybrid and electric vehicles. The IWC focuses on interoperability, safety, and simplicity of grid infrastructure as electrically powered vehicles enter the marketplace. EPRI is well positioned to represent its members through support of the IWC and its activities to foster continued adoption of electric transportation technologies.
Approach
The IWC will continue to serve the industry as the facilitator of infrastructure review, analysis, and standardization. This project will provide support to IWC for the execution of infrastructure analysis that positively affects the commercialization of plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) in the automotive and truck industries. This project also will conduct a representative sample audit of airports and seaports across the United States and prepare a report with recommendations on airport and seaport infrastructure issues that should be addressed by the IWC. The scope of work is as follows:

- Lead utility industry participation in Society of Automotive Engineers plug-in electric standards development.
- Lead or participate in relevant U.S. and international standards (IEEE 1547, NEC 625 and others) development.
- Continue to identify and execute infrastructure projects that address issues, concerns, and standards that impact PHEV and BEV commercialization.

Impact
- Standardize vehicle and stationary charging connection, equipment, and infrastructure for the interoperability and safety of vehicle recharging.
- Confirm that new standards facilitate communication between vehicle and grid to support industry needs for off-peak charging as well as electricity billing and tracking.
- Minimize connectivity costs from both the grid and vehicle perspectives.

How to Apply Results
Results from the IWC analysis will enable members’ clean vehicle technology management teams and their customers to implement connectivity between the grid and electric vehicle systems. Members will use the reports developed through this project to confirm that connections are achievable and cost-effective.

P18.020 PEV Charging Infrastructure - Evaluation, Planning and Business Models (071991)

Description
PEV infrastructure planning is an important aspect of a successful PEV market. Utilities will both deploy PEV infrastructure (either for their own fleet vehicles or as part of customer programs) and serve as a valuable advisor to customers and other local stakeholders in regional planning and implementation activities. Understanding the best practices for both the design and deployment of PEV charging infrastructure will minimize costs and result in charging infrastructure that is both appropriate in scale and capable of meeting the needs of PEV owners and utility customers.

Approach
This project will use analytical tools developed by EPRI to:

- Calculate the number of charging locations needed as the number of PEVs in a utility’s service territory increases over time.
- Quantify the costs and help identify low-cost, practical alternatives for deploying charging equipment.
- Model and quantify the economics of widespread plug-in vehicle charging infrastructure. Several potential business models will be considered and analyzed as part of the project.

Impact
- Provide members with a clear understanding of best practices for PEV infrastructure deployment.
- Support utility learning for deployment of plug-in electric vehicle infrastructure.
- Help members understand the economics of widespread deployment of plug-in vehicle infrastructure.
**How to Apply Results**

Members will be able to use study results in infrastructure planning, field installation, and building both economic models of charging and shaping the regulatory climate needed to facilitate PEV infrastructure.

**P18.021 Grid Integration of PEVs (071992)**

**Description**

As technologies and demands continue to evolve on electric distribution networks, the ability of distribution utilities to continuously provide safe and reliable service requires operating and planning practices capable of accounting for these system changes. One of the changes that may dramatically influence distribution system design and operation include integration of plug-in electric vehicles (PEVs) to the grid. Incorporation of electric vehicles has led to a variety of questions related to grid impacts (loading and power quality), optimization, smart-charging strategies, and ancillary services capabilities. From a distribution planning perspective, the spatial and temporal variations associated with PEV charging make it difficult to predict using existing methods and tools. Further, the risk is exacerbated by the fact that the key source of the uncertainty and risk lies at a very local level (e.g., at the service transformer levels, small sections of the circuit).

Seamless integration of PEVs to the grid is a critical step to encourage utility support for PEV commercialization. Understanding the causes and relationships between this new load type and the distribution system will give utilities the ability to augment their planning process to account for any additional stresses to their systems. Assessing the extent of the impacts of PEV adoption requires the development of detailed load models for PEVs, detailed models of existing distribution feeders for many different configurations and operating philosophies, and subsequently advancing the state of the art for distribution system planning, operations, and modeling processes.

**Approach**

This project builds on multi-year research conducted by EPRI to develop research methods and frameworks for understanding the distribution impacts of PEVs across 20 utilities. EPRI’s PEV Distribution Assessment initiative was a multi-year collaborative project to understand PEV grid impacts with several utilities in the United States and Europe. The initiative was launched mid-2008 with more than 20 participants, including one international funder. This project lays the platform for model-based management of the smart distribution system to integrate PEVs within the planning and operation of the system.

Methods, tools and frameworks will be developed to understand the operational impacts of PEVs on the distribution system. New planning tools will be developed that will help manage the adoption of PEVs within the power grid.

**Understanding the Operational Impacts to the Distribution System**

- Improve understanding of how PEV charging (ac as well as dc) will affect the grid.
- Understand how PEV growth and charging patterns influence the electrical network.
- Develop a consistent methodology to assess the "likely hourly impact" of adding PEV fleets on a utility’s distribution system.
- Assess interactions between the grid, PEVs, renewable resources, and energy storage systems while qualifying the benefits through demonstration and detailed modeling.
- Assess PEV charging effects on specific circuits within a utility’s distribution system, and ensure distribution reliability in the face of increasing deployment of PEV and smart-charging applications to the grid.

**Tools to Help Manage the System**

- Make desired improvements in planning and modeling tools to design distribution systems that support and accelerate the deployment of efficient end-use technologies such as plug-in hybrid electric vehicles.
- Develop asset management and screening tools and techniques that are capable of performing system-wide evaluations of individual asset capacity against projected PEV per-capita demands.
• Develop tools capable of projecting and quantifying potential impacts due to PEV adoption across entire service territories, and determine optimal distribution investment plans.
• Apply proactive methodologies to identify which assets, or circuit sections, are likely to be at risk sooner than others, to forecast how EV load additions cluster into "hotspots" of localized risk, and to determine whether this additional clustered risk is consequential to the circuit, given the existing asset configurations.
• Detect PEV charging from advanced metering infrastructure (AMI) data.
• Develop secondary models from AMI data and investigate voltage drop impacts on secondaries.

Impact
• Understand how PEV growth and charging patterns influence the electrical network.
• Accurately capture PEV load potential across the distribution system at a regional or census-block level.
• Provide for integration into asset management programs and/or system investment budgeting applications.

How to Apply Results
Employ the models and methods developed into:

• Utility distribution planning tools for near-term implementation and assessment
• Utility electric vehicle readiness planning activities
• Utility asset management programs and/or system investment budgeting applications

P18.022 Utility PEV Readiness (071993)

Description
As electric utilities become fuel providers for a growing fleet of plug-in electric vehicles, they must develop internal planning and management processes to address this new paradigm. Not only will this affect load-growth planning activities, it will open new avenues for utility-customer interaction. Utilities developing internal programs to support PEV readiness will be a key factor in the growing use of plug-in electric vehicles.

Approach
EPRI will work with members to develop best practices and guidelines for utility PEV-readiness programs.

• Identify customer education opportunities and tools.
• Help members identify internal bottlenecks in their infrastructure deployment processes.
• Study staffing and internal team structures used by utilities that have established successful PEV-support deployment strategies.
• Develop best practices for PEV-readiness programs.

Impact
• Position members to proactively address issues and opportunities in the PEV arena.
• Help members understand the internal structural changes that may required to adequately address PEV readiness.

How to Apply Results
Members will be able to use the project results to develop internal PEV readiness tools, teaming strategies, and support systems for successful deployment of PEV infrastructure.
P18.023 PEV Adoption and Load Forecasting (071994)

Description
The commercialization of plug-in hybrid and pure electric vehicles has created a need for utilities to prepare for the installation of charging infrastructure in their service territories and manage the impact of these new loads on the electric distribution system. As with any load, PEV demand exhibits its own unique set of diversity characteristics. Given the particular spatial and temporal uncertainties associated with charger locations and usage, traditional methods of load forecasting and distribution system analysis methods only provide a limited understanding of the true impacts of PEVs on the system.

To characterize the effects, it is necessary to forecast the size of the PEV fleet and its electricity consumption, and evaluate a range of potential PEV adoption scenarios. The market for these vehicles is essentially new, and the trajectory of sales is highly uncertain. Electricity use must be analyzed over long (e.g., annual) and short (e.g., hourly) time frames to understand the system impacts. The expected size of the PEV fleet over time is a direct factor in the calculation of the different types of impacts on the electric utility system. The size of the total PEV fleet is based primarily on the addition of vehicles due to annual new PEV sales. Using the fleet size and consumption forecasts, analysts can estimate their influence on grid operations, infrastructure, air quality and greenhouse gas emissions, and other areas of the electricity business.

Approach
This project builds on research conducted by EPRI to develop tools for PEV adoption forecasts (EPRI 1021635, 1019921, 1019727), distribution impact analysis, and a consumer survey framework to gauge PEV awareness and perceptions (EPRI 1021285, 1022729, 1022728). Additional refinements and approaches will be developed to better improve vehicle adoption estimates, including the ability to tie to distribution planning tools.

This project will incorporate the results of surveys and the associated generalized adoption models implemented by EPRI and utilities to further refine Load Estimator algorithms and forecasts for utility service territories, regions or rather specified geographic areas. Among the additional refinements planned:

- Permit evaluating impacts of time-varying utility rates on passenger vehicle charging scenarios.
- Extend the tool to include multiple vehicle types, including commercial vehicle driving patterns and load forecasts.
- Expand NHTS analysis to differentiate residential/commercial/industrial locations, charging scenarios, and vehicle types.
- Develop methods, tools, and frameworks to integrate the Load Estimator within the EPRI Phase II Impact Assessment Screening tool.
- Provide customized EV adoption forecasts across the service territory based on substation-defined regions and geographic information systems (GIS) mapping framework.
- Allow the user to customize known or expected PEV market characteristics or adoption centers at specific points in the system.
- Permit multiple PEV market forecast scenarios (e.g., home only, work only, all locations).
- Enable user-defined inputs from customer market surveys, customers with fleets, customer segment demographics, and parking garages.

Impact
- Understand how PEV growth and charging patterns influence the electrical network.
- Accurately capture PEV load potential across the distribution system at a regional or census-block level.
- Generate forecasts of new plug-in vehicle sales in a specific geographical area and calculate relevant data including cumulative PEV market penetration, electricity demand of PEVs, and gasoline saved.
- Overlap the revised Load Estimator tool in the Distribution Screening tool for performing system-wide evaluations of individual asset capacity against projected PEV per-capita demands.
• Use the Load Estimator and Screening tool to reassess the risks as system conditions and PEV projections change over time or across multiple scenario evaluations.
• Use the PEV Adoption tool to drive revaluation of system design practices such as component sizing in future years.

**How to Apply Results**

Incorporate the models and methods developed into

• utility distribution planning tools for near-term implementation and assessment,
• utility electric vehicle readiness planning activities, and
• utility asset management programs and/or system investment-budgeting applications.

In addition, utility planners can utilize a forecast of PEV fleet sizes to determine the most fundamental impact of PEVs, which include the following:

• Number of residential accounts that may potentially affect the utility system due to vehicles charging at home
• Extent of the need for public or commercial charging infrastructure
• Number of utility staff required to administer PEV-related programs and manage the various impacts of PEVs.

**P18.024 Environmental and Economic Assessment of Electric Transportation (071995)**

**Description**

Electric vehicles are just now being made available by auto manufacturers. It will be four to five years before sales achieve more than 5% of new car sales, but the number of cars on the road and using charging stations at a variety of locations may accelerate quickly thereafter. The slow initial build-up in vehicles on the road, which places increasing demands on electricity infrastructure, provides the electricity sector time to develop the organizational processes and functional organizations required to understand and forecast the implications of electric vehicles. That reprieve is important because of the time utilities require to make infrastructure investments to extend facilities and make existing facilities capable of meeting new utilization demands.

At the center of this transition process is credible and reliable forecasting tools to:

• anticipate the rate of adoption of electric vehicles;
• identify their home base (where they are parked in the evening) and other locations where charging services may be required or desired, and when they will be used;
• predict the corresponding use-of-system implications; and
• incorporate the results into utility and regional capacity and energy supply forecasting models.

**Approach**

This project builds on foundational research conducted by EPRI to develop research methods for implementing consumer surveys to gauge electric vehicle awareness and perceptions (EPRI 1021285, 1022729, 1022728), and to specify a framework for estimating electric vehicle adoption rates and incorporate that information into a electric vehicle readiness planning (EPRI 1019727).

This project will develop methods and protocols to use the results of surveys implemented by EPRI and utilities to forecast electric vehicle adoption rates in utility service territories, regions, or other specified geographic areas. An adoption model forecasts the rate at which electric vehicles are purchased and produces the corresponding estimate of the cumulative number of vehicles in the fleet. Typically, new technology adoption is characterized by replacement as starting slowly, gaining momentum, and then eventually reaching a ceiling level. This time-indexed conversion to a new technology typically results in the iconic "S" adoption curve. Initially, EPRI will develop the adoption curve using localized or regional consumer survey data; over time, as electric vehicles become more prominent, EPRI will incorporate electric vehicle sales data. The regional focus
allows members to conduct consumer research when they determine it is appropriate and produce results that are directly applicable to their circumstances.

Vehicle adoption estimates will provide inputs to EPRI readiness processes and models that convert vehicle ownership (differentiated by survey data to characterize driving and charging behaviors) into producing estimates of time-differentiated charging energy requirements and feeder-level energy demands to help identify where local capacity reinforcements are most likely to be needed for reliability purposes.

The aggregate annual forecast of charging demands will be configured so that it can be incorporated into utility capacity-planning processes to direct capacity investments, and into operational and dispatch models to characterize consequences of electric vehicle charging demands. Adoption rates will be prepared using geospatial mapping to indicate clustering of the home bases of electric vehicles and where they are likely to spend sufficient time to accommodate charging. This will inform distribution planning models so that utilities can anticipate and take action so that the added charging loads can benefit all stakeholders. Localized estimates of adoption can be shared with community organizations and businesses that seek to promote and support electric vehicle adoption—for example, local governments providing charging facilities and businesses considering doing the same.

**Impact**

Electric vehicle readiness initiatives will need adoption and impact forecasting tools to direct when and what infrastructure investments are most supportive of electric vehicle adoption and conducive to a positive ownership experience.

Utility planners will be able to explore the consequences of alternative adoption rates and consequential vehicle-charging energy demand on capacity requirements.

**How to Apply Results**

Conduct electric vehicle readiness-planning activities by employing the models and methods developed for utility or larger geographic areas.

**P18.028 Evaluation of Near-Term PEV Charging Technologies (NEW)**

**Description**

Electric vehicle charging equipment products are entering the market at a rapid pace. For plug-in electric vehicles to proliferate, there must be sufficient charging infrastructure to make consumers confident that PEVs are a viable and convenient alternative to liquid-petroleum-fueled vehicles. In addition, this infrastructure must provide reliable and consistent performance from the consumer’s perspective and do so in a cost-effective manner. EPRI will collaborate with members and infrastructure providers to assess the state of electric vehicle supply equipment (EVSE) technology, from the hardware to deployment and operation.

**Approach**

The project will take a holistic approach to evaluating electric vehicle supply equipment and infrastructure:

- Track the development, certification, and market entry of EV-charging equipment and related products, including electric vehicle supply equipment, billing and authentication systems, networking and communications technologies, cable-handling and auto-docking devices, and other accessories.
- Perform laboratory evaluation of hardware, including compatibility and reliability evaluation.
- Lead utility industry efforts to develop infrastructure standards where such standards will enhance PEV acceptance and deployment.
- Understand equipment costs, performance, reliability and safety.
Impact

- Provide members a clear understanding of available EVSE hardware.
- Provide feedback to the supplier and stakeholder communities on the performance and functionality of EVSE and related products.
- Provide up-to-date electrical load and other test data on EVSE hardware.

How to Apply Results

Members will have access to up-to-date databases of EVSE hardware and test results.

PS18E Advanced PEV Infrastructure and Smart Charging (071998)

Project Set Description

This project set addresses the advanced infrastructure requirements to integrate smart charging into the grid while meeting consumer expectations for vehicle availability. This may include closed-loop control and bi-directional communications for both smart-charging and vehicle-to-grid to operations. This collaborative effort with the automotive industry will help develop functional communications and physical media standards.

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<td>P18.025</td>
<td>Smart Grid Technologies for PEV Grid Integration</td>
<td>This project will demonstrate the state of the art in bidirectional-communications-capable, grid-integrated smart plug-in electric vehicles that enable dynamic load management, price signaling, and demand-response applications.</td>
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<td>P18.026</td>
<td>Advanced Infrastructure Development and Testing</td>
<td>This project will provide the technical analysis and development work to support a clear understanding of the implications and mitigation techniques for high-density charging infrastructure installations, such as when vehicle charging occurs at clusters of homes sharing common grid resources or at public charging facilities.</td>
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<td>P18.029</td>
<td>PEVs as Distributed Energy Resources</td>
<td>This project will combine a mix of laboratory equipment evaluation and modeling-based technology assessments to evaluate bi-directional &quot;charging appliances&quot; for applications of emergency backup power and vehicle-to-grid (V2G) delivery of frequency regulation and other ancillary services.</td>
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P18.025 Smart Grid Technologies for PEV Grid Integration (071996)

Description

As plug-in electric vehicles enter the marketplace in conjunction with smart-grid technologies, disparate and diverse technologies are emerging on both the vehicle and smart-grid sides. PEVs constitute a significant new household load—sometimes more than doubling the electrical energy demand for a single household—that is likely non-seasonal (i.e., people drive every day and will recharge their PEVs every night). Therefore, its integration into the distribution infrastructure will need to be managed through closed-loop control facilitated by bi-directional communications. There is a need for intelligence on self-managing the vehicle’s grid-connected behavior to reside on the vehicle itself. In addition, this intelligence needs to be a part of the bigger, utility/automotive energy system that is coordinated at the utility end, which requires communications. There are currently a number of approaches to achieve this, many of which are proprietary or closed systems.
Approach

EPRI will draw on its ongoing collaborative efforts with utility and automotive industries to help develop technologies and demonstrate them as products as well as integrated systems. These efforts will enable PEVs to communicate with smart-grid elements whether they are smart meters, advanced distribution automation systems, meter data management systems, or utility back-ends, as follows:

- Identify open-standards-based technologies that could be implemented.
- Implement standards-based requirements into intelligent vehicle connectivity solutions.
- Demonstrate cost-effectiveness, robustness, reliability, and security of intelligent vehicle connectivity.

Impact

- Verify the maturity and readiness of standards’ applicability to grid-connected vehicles.
- Demonstrate a viable set of technologies and suppliers that enable automotive-grade connectivity solutions.
- Demonstrate cost-effectiveness, scalability, robustness, reliability, and security of smart PEVs and smart-grid integrated systems with and without intermediaries.

How to Apply Results

Members will have access to case studies in developing their own roadmaps for preparing the grid for intelligent grid-connected vehicles through hands-on demonstrations of these technologies on select PEVs. Members will also have access to all of the demonstration-related insights and data to help inform their own decisions on infrastructure investments and rate cases if applicable.

P18.026 Advanced Infrastructure Development and Testing (071997)

Description

The number of plug-in electric vehicles is expected to continue to increase. What began as a relatively low power load has quickly expanded to include high-power ac and dc charging. AC charging rates in new vehicle models has increased from 3.3 kW to 6.6–19.2 kW. It is expected that the density of charger installations and potential for clustering of charging locations will also increase. Installations that include multiple charging stations that share common grid resources, such as at a multi-family dwelling or a public charging facility with multiple high-power dc fast-charge systems, are likely to become more commonplace over time. As the density of charging locations increases, the likelihood of negative interactions within this infrastructure also increases. In addition, this equipment will be exposed to the electric grid 24/7, operating mostly unattended, and therefore must be able to ride through typical off-normal grid conditions while providing for self-recovery from such events.

This project set will explore the impact of higher-density charging and the long-term operational reliability of such systems when exposed to real-world grid conditions. The project will evaluate new and more advanced technologies that can be used to mitigate the cost of infrastructure and grid impacts as well as improve reliability of the charging infrastructure, such as using local energy storage or integrating charging functions into a medium-voltage solid-state transformer to provide high-density dc fast charging.

Approach

This project will focus on evaluating existing technologies and developing new technologies to support members' understanding and integration of PEV infrastructure where multiple charging locations share a common grid interconnection. Results will be used to develop utility requirements for safely integrating high-density charging installations, and to work with the supplier and stakeholder communities to incorporate new learnings into product designs while developing relevant standards. The project will focus on the following topics:

- Development and testing of the intelligent universal transformer (IUT) for dc fast charging and the integration of PEVs, renewable energy, and storage at charging sites
• Impacts at the transformer and neighborhood levels, with aggregation of multiple vehicle loads (harmonics, load profiles, resonance, NEV, and secondary voltage impacts)
• Behavior of PEV and charging equipment (such as EVSE) during power quality events
• Interaction of PEVs and charging infrastructure during off-normal grid events (PEV and charging infrastructure acting as a system)
• Development of an application guide for PEV and charging equipment for power quality events.

**Impact**

• Understand integration issues related to dense PEV infrastructure installations, demand charges, and installation costs.
• Investigate the merits of connecting IUT technology—a utility asset—directly to the medium voltages, providing multi-head charging options and cost implications during installation.
• Influence product development cycles to help ensure safe, standards-compliant outcomes and understanding of utility requirements for high-power charging installations.
• Understand potential power quality impacts at the feeder and neighborhood levels, with aggregation of on-board and off-board vehicle battery charging systems.

**How to Apply Results**

Members will have access to test results and case studies to understand real-world applications and operation of high-density ac and dc charging infrastructure installations. Results will inform utility interaction with the supplier community at the Infrastructure Working Council (Project 18.010) and with the Society of Automotive Engineers in setting standards and practices.

**P18.029 PEVs as Distributed Energy Resources (NEW)**

**Description**

The interface between plug-in electric vehicles and the electric grid is evolving rapidly. What began as a relatively low-power, load-only connection is quickly expanding to include potential applications of PEVs as distributed energy resources (DER) using fully bi-directional power systems that enable two-way power flow between PEVs and grid. With such systems, PEVs could be used as local resources to provide distribution-level benefits such as peak shifting and preventing local overloads. In addition, when intelligently aggregated with proper control and coordination, the same devices can act as a vast bulk system resource, capable of providing demand response, frequency regulation, and other system-wide functions.

PEVs acting as an opportunity power source may also have a potential role to play in grid resiliency—in particular, load curtailment during recovery and customer survivability measures. PEVs, both all-electric and hybrid, could be used to supply energy to a home during an outage when power is lost for an extended period of time. Hybrid electric vehicles could also operate as gasoline-fueled generators to provide additional standby power. A comprehensive understanding of the needs, requirements, and existing service level standards for connecting on-board versus off-board bi-directional systems during storm events does not exist. Automakers are interested in the concept, but the technologies require further development. Current grid resiliency and storm-hardening efforts typically do not address the needs of PEVs. Microgrids and some other hardening measures focus on commercial zones, whereas the bulk of PEV charging occurs at home.

**Approach**

EPRI will work with members and automotive industries to conduct preliminary evaluations of PEVs with bi-directional power capability to provide emergency backup power to residential premises for extended periods of time. This project set will combine a mix of laboratory equipment evaluation and modeling-based technology assessments to support utility understanding and ensure that integrating PEVs as export power devices is robust and reliable. Initial testing will be performed based on three configurations: a PEV providing short-term ac power for critical but low-power appliances; a PEV linked with grid-independent solar; and a PHEV providing direct power to a premise for an indefinite period of time. Results will be used to develop utility requirements for
safe integration of these devices, and to work with the supplier and stakeholder communities to incorporate them into product designs while developing relevant standards.

This project set will be structured into the following areas of investigation:

- System/technology/product (export power devices) testing and evaluation
- Grid integration and deployment (power quality and system compatibility, modeling and evaluation)
- Applications/guides (use case and requirements, islanding, protection features, reliability, safety)
- Communications and standards
- Testing and evaluation of bi-directional "charging appliances" for applications of emergency backup power and vehicle-to-grid (V2G) delivery of frequency regulation and other ancillary services
- Development of utility requirements for safe design, installation, and operation of export power and bi-directional charging equipment
- Testing and evaluation of export power devices in utility fleet settings.

**Impact**

- Understand integration issues of PEVs and distributed energy resources.
- Understand applications of export power in utility field operations.
- Develop preliminary requirements for U.S. certified commercial equipment design and installation for customer resiliency.
- Influence product development cycles to help ensure safe, standards-compliant outcomes and understanding of utility requirements.

**How to Apply Results**

Results will be used in advanced planning for the integration of PEVs into distribution systems. Members will have access to test results and case studies to understand real-world applications and the operation of export power and charging appliances. Results will inform utility interaction with the supplier community at the Infrastructure Working Council (Project 18.010) and with the Society of Automotive Engineers (SAE) in setting standards and practices.
Supplemental Projects

PEV Distribution Impacts Analysis - Phase 2 GIS-Based Screening Tool (072002)

**Background, Objectives, and New Learning**

The rapidly approaching commercialization of plug-in hybrid and electric vehicles has created an urgent need for utilities to support customer adoption of electric vehicles, prepare for the installation of charging infrastructure in their service territories, and manage the impact of these new loads on the electric distribution system. EPRI proposes the creation of a screening tool capable of performing system wide evaluations of individual asset capacity against projected Plug-in Electric Vehicle (PEV) demands.

In prior research, EPRI conducted a comprehensive study assessing PEV charging effects on specific circuits within a utility’s distribution system. This Phase I effort used very detailed simulations to develop summaries of general concerns, assets that are likely to be at most risk, conditions that could require additional monitoring to avoid problems, and the impacts of different charging profiles (including controlled charging) on these results.

The results of the research effort concluded that the short term impacts for most utilities should be minimal and localized. However, there is a need for the development of tools ongoing assessment of wider areas and identify locations and equipment most likely to be impacted than the general conclusions from the completed research.

This project is designed to establish proactive methodologies to identify which assets, or circuit sections, are likely to be at risk sooner than others, to forecast how EV load additions cluster into “hotspots” of localized risk, and to determine whether or not this additional clustered risk is consequential to the circuit, given the existing asset configurations.

**Project Approach and Summary**

The Phase II effort is focused on developing a screening tool capable of projecting and quantifying potential impacts due to PEV adoption across entire service territories. The screening tool will build on the results from Phase 1 but will incorporate the ability to integrate with databases of actual asset characteristics, customer load characteristics, distribution system loading characteristics, as well as projected penetration of electric vehicles as a function of customer characteristics. EPRI believes the screening tool’s ability to identify the risk assigned to each asset as well as identify geographic “hot spots” will provide for more effective asset management and reliability practices. Additionally, the screening tool can be used to reassess the risks as system conditions and PEV projections change over time or across multiple scenario evaluations.

**Benefits**

The screening tool will provide utilities with a more complete understanding of grid impacts associated with various PEV adoptions. Features include:

- Understand how the PEV growth and charging patterns influence the electrical network,
- Accurately capture PEV load potential across the distribution system at a regional or census block level. Accuracy of prediction at the service transformer level depends on the accuracy of market research forecasting, combined with the accuracy of the utility’s transformer ratings database and customer data from the billing system.
- Develop a consistent methodology to assess the “likely hourly impact” of adding PEV fleets on utility’s distribution system, and
- Ascertain levels of penetration and charging behaviors which result in excess demand requiring remediation or asset upgrades.
The developed framework considers the following principle factors that define PEV loading on distribution systems:

- Different PEV charging patterns (battery type, charger efficiency) and profiles
- PEV market penetration levels per utility customer class (residential, commercial)
- Time profiles and likely customer charging habits by season

The benefits to the public from this project are better utilization of the grid, increased opportunities for additional resources, and reduction of CO2 emissions in the production and delivery of electric power for the use in vehicles. These benefits are derived from a more effective planning process of PEV and improved practices for planning and operation of the public power supply.

PEV Data Analysis and Insights (105322)

Background, Objectives, and New Learning

Plug-in Electric Vehicles (PEVs) are rapidly gaining customer acceptance and are available across all 50 states and Canada for retail sales. To-date, 80,000 of these have been sold and they remain popular.

Plug-in Electric Vehicles have several operational peculiarities which require deeper understanding to maximize the energy savings by using them. This requires operational and charging data under widely varying, day-to-day typical operating conditions and driving patterns. Further, they have batteries that need recharging which, if done optimally, can both save money and reduce grid stress. Again, this requires getting operational data during charging events.

The objectives of this project are to enable data monitoring of the PEVs using commercial, off-the-shelf tools in a secure private manner and provide analysis that compares the vehicle’s performance to its peers as well as provides a composite picture of its driving and charging behavior.

The new learnings of this project are in the form of insights generated that educate and inform the individuals, grid planners or fleet managers as to the applicability of the PEVs as an alternate-fuel technology as well as their impact on the grid.

Project Approach and Summary

EPRI has implemented an end-to-end system comprising of commercial, off-the-shelf tools and EPRI-owned intellectual property that forms the ‘glue’ of this system that uses two identical commercially available data monitoring devices on the vehicle in conjunction with an iPhone or an Android phone running an EPRI-designed App that collects operational data while the vehicle is driving and charging. This data is then sent over cellular data network from the smart phone to EPRI server securely. The data is further analyzed by the EPRI staff and combined with data from the entire fleet to create individualized and fleet-specific profiles of energy use while driving and charging the PEVs.

Benefits

This is a low-cost way for anyone to gather data using commercial, off-the-shelf and touch-less tools that are entirely managed by EPRI and its’ providers to create on demand analysis that has strong scientific and technical foundation and uniformity to compare vehicles across the geographic, weather, driving pattern as well as driver classes.