

## Electric Transportation - Program 18

### Program Overview

#### Program Description

The commercial rollout of plug-in electric vehicles (PEVs) began in late 2010, and by the end of 2014, over 30 new models representing nearly all of the major automotive manufacturers are expected to have entered the market. This rapid introduction of PEVs presents electric utilities with many different challenges and opportunities. Aggregate projections of market adoption indicate that PEVs could exceed 5% of new vehicle sales by 2020, and large utilities could have hundreds of thousands of vehicles connected to their system for recharging, representing hundreds of megawatts of new demand. At the same time, transportation electrification will deliver annual carbon dioxide (CO<sub>2</sub>) reductions that could exceed 100 million tons by 2025 and 500 million tons by 2050.

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.

Nearly all of the major automakers are reaching out to the utility industry to 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.

Fleets can offset high fuel costs and meet environmental requirements by incorporating plug-in hybrid electric vehicles (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 like 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 charging 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 come in a number of forms and is expected to include the following:

- Facilitate 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, 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—Product ID # 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, to support customer adoption of PEVs and their supporting infrastructure, and to 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—Product ID # 1021741**

Time-of-use (TOU) rates can guide PEV charging behavior by economically incentivizing off-peak charging. This 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—Product ID # 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—Product ID # 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 as 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 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 2013 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 the technologies and products that demonstrate the value of electric-drive systems and components in (PHEV) and battery electric vehicle (BEV) applications.

Project Number	Project Title	Description
P18.001	Plug-in Electric Vehicle Evaluation and Test Data Analysis	This project provides a comprehensive real-world test program for plug-in electric vehicle (PEV) demonstration fleets using sophisticated systems for collecting and processing detailed vehicle information and reporting the results to members.
P18.003	Advanced Battery and Powertrain System Development for Plug-In Vehicles	This project will promote the development of Li-ion battery systems technologies and electric-drive powertrain systems technologies for PEVs, as well as evaluate their impact on vehicle performance, cost, and life.
P18.018	Advanced Vehicle Technologies for PEVs	This project will demonstrate the state-of-the art in bidirectional-communications capable, grid-integrated smart PEVs that enable dynamic load management, price signaling, and demand response applications.

**P18.001 Plug-in Electric Vehicle Evaluation and Test Data Analysis (062128)**

**Key Research Question**

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 are important opportunities to collect and analyze real-world operating data. This activity will enable utilities to understand the performance and operation of different types of PEVs, to understand customer usage and expectations, and to determine benefits and impacts to their systems.

## Approach

This project provides a comprehensive real-world test program for the Electric Power Research Institute (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
- surveying transportation applications to determine potential PEV candidates and performing performance profile analyses on these candidates.

## Impact

This project may have the following impacts:

- Increased understanding of PEV product performance
- Reduced fleet operating costs
- Facilitation of fleet environmental compliance
- Real-world data to support PEV benefit and impact analysis at the utility

## How to Apply Results

Utilities 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 to identify transportation operating profiles and specific vehicle platforms as candidates for plug-in hybrid electric vehicle (PHEV) operation.

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

### Key Research Question

The potential for plug-in electric vehicles (PEVs) to achieve widespread market acceptance depends heavily on the cost, performance, and durability of the electric-drive systems and particularly on advanced lithium-ion (Li-ion) battery technology. Early testing by the Electric Power Research Institute (EPRI) and utilities of Li-ion battery systems against plug-in hybrid electric vehicle (PHEV) duty cycles provided some of the earliest evidence of the capability of the technology to meet PEV requirements. EPRI also has 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 evaluation of 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

This project may have the following impacts:

- 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 member utilities with world-class, specific technical and cost information regarding battery and powertrain systems technology for PEVs. Member utilities 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.

## P18.018 Advanced Vehicle Technologies for PEVs (071989)

### Key Research Question

As plug-in electric vehicles (PEVs) enter the marketplace in conjunction with smart grid technologies, there are a disparate and diverse set of technologies emerging on both the vehicle and smart grid side. PEVs constitute a significant new household load—sometimes doubling the household consumption, 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 the 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, requiring communications. There are currently a number of approaches to achieve this, many of which are proprietary or closed systems.

### Approach

EPRI will utilize its ongoing collaborative efforts between 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 should be implemented
- Design and develop technologies that can be deployed on-board any PEV
- Implement standards-based requirements into intelligent vehicle connectivity solutions
- Demonstrate cost-effectiveness, robustness, reliability, and security of intelligent vehicle connectivity

### Impact

- Verify 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 to smart grid integrated systems with and without intermediaries

### How to Apply Results

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

## 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, and airport and seaport markets whose technology successes will advance the awareness of the value of electric-drive systems.

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

## P18.015 Non-Road Electric Vehicle Technology Assessment (070588)

### Key Research Question

The adoption of non-road electric vehicles depends upon accurately understanding their benefits—real-world performance, lifecycle costs, and emissions reductions. 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 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 life-cycle performance, energy consumption, and emissions of non-road equipment
- Improve 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)**

### **Key Research Question**

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 fleet. Most fleet managers lack unbiased, accurate information to help them plan the acquisition of plug-in electric vehicles (PEVs) 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 enable fleet managers to understand the technical capabilities of PEVs, accurately predict the performance of PEVs in their fleet applications, determine lifecycle 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)**

### **Key Research Question**

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

Increased success of non-road electric vehicle (EV) 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 (CO<sub>2</sub>) 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 from 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.

Project Number	Project Title	Description
P18.010	Infrastructure Working Council	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 (PHEVs) and battery electric vehicles (BEVs) in the automotive and truck industries.
P18.020	PEV Charging Infrastructure - Evaluation, Planning and Business Models	This project will evaluate electric vehicle supply equipment (EVSE) and infrastructure, as well as develop planning and business models for deployment of EVSE in utility services territories.
P18.021	Grid Integration of PEVs	Development of models and framework to provide utilities with integrated, detailed, and localized estimates of electric vehicle adoption and associated impacts in the electric system.
P18.022	Utility PEV Readiness	This project will develop best practices for internal planning and management practices for utility PEV readiness programs.
P18.023	PEV Adoption and Load Forecasting	With plug-in electric vehicles (PEVs) 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 the 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 the utilities augment their planning processes to manage any additional stresses to their systems.
P18.024	Environmental and Economic Assessment of Electric Transportation	This project develops research methods for estimating electric vehicle adoption rates, and flow that information into electric vehicle readiness planning.

## **P18.010 Infrastructure Working Council (065239)**

### **Key Research Question**

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. The Electric Power Research Institute (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. Project 18.010 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 utility industry participation in Society of Automotive Engineers plug-in electric standards development
- Lead or participate in relevant U.S. and international standards (Institute of Electrical and Electronics Engineers [IEEE] 1547, National Electrical Code [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**

This project may have the following impacts:

- Standardization of vehicle and stationary charging connection, equipment, and infrastructure for the interoperability and the safety of vehicle recharging
- Confirm that new standards facilitate communication between vehicle and grid to support industry needs for off-peak charging and 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 clean vehicle technology management teams at funding utilities and their customers to implement connectivity between the grid and electric vehicle (EV) systems. The reports developed will be used by members to confirm that connections are achievable and cost-effective.

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

### **Key Research Question**

For plug-in electric vehicles (PEVs) to proliferate, there must be sufficient charging infrastructure to make consumers confident that PEVs are a viable 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 utilities 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 evaluation of electric vehicle supply equipment and infrastructure:

- Perform laboratory evaluation of hardware, including compatibility, power quality and reliability evaluation.
- Lead utility industry efforts to develop infrastructure standards where such standards will enhance PEV acceptance and deployment.
- Develop deployment planning tools for utilities and other stakeholders.
- 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 funders with a clear understanding of available EVSE hardware
- Support utility learning for deployment of plug-in electric vehicle infrastructure
- Help utilities understand the economics of widespread deployment of plug-in vehicle infrastructure

### How to Apply Results

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

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

### Key Research Question

As technologies and demands continue to evolve on electric distribution networks, the ability of distribution utilities to continue to 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 provide the ability for utilities to augment the planning process to account for any additional stresses to their systems. Assessing the extent of the impacts from of PEV adoption requires the development of detailed load models of PEVs, detailed models of existing distribution feeders of many different configurations and operating philosophies, and subsequently advancing the state of the art for distribution system planning, operations, and modeling.

### Approach

This project builds on multi-year research conducted by the Electric Power Research Institute (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 over 20 funders, 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 to 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

- Improved understanding of how PEV charging (ac as well as dc) will affect the grid, through the following activities:
  - Understand how the PEV growth and charging patterns influence the electrical network
  - Develop a consistent methodology to assess the "likely hourly impact" of adding PEV fleets on utility's distribution system
  - Understand the characteristics and features of the fast charger systems available commercially and under demonstration
  - Evaluate the impact of on-board and fast dc charging systems on PEV range extension and on utility infrastructure
  - Assess interactions between the grid, PEVs, renewable resources, and energy storage systems, and qualify the benefits through demonstration and detailed modeling
- Improved understanding on the impact of distribution system power quality on battery charger operation (on-board as well as off-board chargers)
- 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

- Desired improvements in planning and modeling tools to design distribution systems that support and accelerate deployment of efficient end-use technologies such as plug-in hybrid electric vehicles.
- Development of 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
- Development of tools capable of projecting and quantifying potential impacts due to PEV adoption across entire service territories, and determination of optimal distribution investment plans
- 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

**Impact**

With this information, utilities may be able to:

- 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)****Key Research Question**

As electric utilities become the fuel provider for a growing fleet of plug-in electric vehicles, they must develop the 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. Utility development of internal programs to support plug-in electric vehicle (PEV) readiness will be a key factor to the growth in the use of plug-in electric vehicles.

### Approach

The Electric Power Research Institute (EPRI) will work with member utilities to develop best practices and guidelines for utility PEV- readiness programs.

- Identify customer education opportunities and tools
- Help utilities identify internal bottlenecks in the infrastructure deployment process
- 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 member utilities to proactively address issues and opportunities in the PEV arena
- Help utilities understand the internal structural changes that may need to be made to adequately address PEV readiness

### How to Apply Results

Member utilities 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)**

### Key Research Question

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, plug-in electric vehicle (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 1) forecast the size of the PEV fleet and its electricity consumption, and 2) evaluate a range of potential PEV adoption scenarios because the market for these vehicles is essentially new, and the trajectory of sales is highly uncertain. The electricity use must be analyzed over long (for example, annual) and short (for example, hourly) timeframes in order 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 the influence on grid operation, infrastructure, air quality and greenhouse gas emissions, and other areas of the electricity business.

### Approach

This project builds on research conducted by the Electric Power Research Institute (EPRI) to develop tools for PEV adoption forecasts (EPRI 1021635, 1019921, 1019727), distribution impact analysis, and 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.

- Incorporate 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

- Additional refinements to include:
  - 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
- 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

With this information, utilities may be able to achieve the following:

- 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 reevaluation of system design practices such as component sizing in future years

### 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, 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 vehicle 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)**

### **Key Research Question**

Electric vehicles are just now being made available by auto manufacturers. It will be four to five years before they 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 required for utilities 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: 1) anticipate the rate of adoption of electric vehicles, 2) identify their home base (the residence where they are parked in the evening,) and other locations where charging services may be required or desired and when they will be used, 3) predict the corresponding use of system implications, and 4) incorporate the results into utility and regional capacity and energy supply forecasting models.

### **Approach**

This project builds on foundation research conducted by the Electric Power Research Institute (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).

Methods and protocols will be developed to use the results of surveys implemented by EPRI and utilities to develop forecasts of the rates of adoption of electric vehicles for utility service territories, regions, or rather 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 conversation to a new technology typically results in the iconic "S" adoption curve. EPRI will develop the adoption curve to produce estimates using localized or regional consumer survey data initially, and over time as electric vehicles become more prominent, incorporate electric vehicle sales data. The regional focus allows utilities 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) to produce estimates of 1) time-differentiated requirements for energy for charging, and 2) feeder-level energy demands to support identification of where local capacity reinforcements are most likely to be needed to support reliability.

The aggregate annual forecast of charging demands will be configured so that it be incorporated into utility capacity-planning processes to direct capacity investments, and into operational and dispatch models to understand the 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 loads from charging can result in benefits to all stakeholders. Localized estimates of adoption can be shared with community organizations and businesses that seek 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 impart 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 energy demand for charging on capacity requirements.

## How to Apply Results

Employ the models and methods developed for utility or larger geographic areas, for electric vehicle readiness-planning activities

## PS18E Advanced PEV Infrastructure and Smart Charging (071998)

### Project Set Description

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

Project Number	Project Title	Description
P18.025	Smart Grid Technologies for PEV Grid Integration	This project will demonstrate the state of the art in bidirectional-communications capable, grid-integrated smart plug-in electric vehicles (PEVs) that enable dynamic load management, price signaling, and demand-response applications.
P18.026	Advanced Infrastructure Development and Testing	This project will provide the technical analysis and development work to support a single standard communication protocol and physical media for vehicle-to-grid communications.

## P18.025 Smart Grid Technologies for PEV Grid Integration (071996)

### Key Research Question

As plug-in electric vehicles (PEVs) enter the marketplace in conjunction with smart grid technologies, there are a disparate and diverse set of technologies emerging on both the vehicle and smart grid side. PEVs constitute a significant new household load—sometimes doubling the household consumption, 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 the 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, requiring communications. There are currently a number of approaches to achieve this, many of which are proprietary or closed systems.

### Approach

The Electric Power Research Institute (EPRI) will draw on its ongoing collaborative efforts between 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 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 to smart grid integrated systems with and without intermediaries

### How to Apply Results

Member utilities will get 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. Member utilities also will 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)**

### Key Research Question

Communication between plug-in hybrid electric vehicles (PHEVs) and grid infrastructure is the key element to maximizing the value of PHEVs as a connected load. As the market adopts PHEVs, utilities will need a means of communicating with these vehicles to incentivize off-peak charging, tracking, and billing the consumption of electricity as a transportation fuel and to optimize their use as distributed storage devices. There are a number of communication protocols and physical media—both wired and wireless—and their integration in advanced metering and other Smart Grid applications must be understood.

### Approach

This project will provide the technical analysis and development work to support a single communication protocol and physical media that can be adopted as a standard by the automotive industry for vehicle-to-grid communication. The technical results of this project will support ongoing standards efforts in Project 18.010 and physical demonstrations in Project 18.017.

### Impact

- Understanding of technical issues regarding vehicles communicating to grid infrastructure
- Development of a viable approach to create a single communication methodology applicable to plug-in hybrid vehicles from all automotive manufacturers
- Testing and validation of power line carrier (PLC), ZigBee wireless, Smart Energy Profile (SEP 2.0), and other communication media and protocols applicable to electric vehicles
- Development of technical requirements and specifications for vehicle-to-grid communication

## How to Apply Results

Results will be used in advanced planning for the integration of PHEVs into distribution systems. Member utilities will receive a technical specification document that can be used to clearly designate requirements to advanced metering infrastructure suppliers, regulators, and other stakeholders.

## Supplemental Projects

### Demonstration and Evaluation of Advanced PEV Infrastructure (072003)

#### Background, Objectives, and New Learnings

The plug-in electric vehicle (PEV) market is growing, and many emerging communications and control technologies are being utilized. As the number of PEVs in the market increases, there will be increasing interest in managing charging assets to minimize the impact on utility infrastructure. Creating charging methodologies and practices may help to minimize the cost of service to society through optimum use of existing grid assets. This project will assess new technologies through field demonstrations.

Funding members will be able to use the new knowledge from this project in planning and implementing advanced PEV infrastructure, gain firsthand experience with the technologies, and better understand the issues related to operating of new types of PEV support hardware. The funder will also gain insight in planning and implementation strategies for deploying advanced PEV support infrastructure.

#### Project Approach and Summary

The Electric Power Research Institute (EPRI) will survey new and emerging technologies in the PEV infrastructure market. A limited number of the new technologies will be selected for field demonstration at participant sites. Technology areas to be surveyed will include novel electric vehicle supply equipment features, cable handling for charge stations, communications hardware, energy measurement devices, and charging control technologies.

The project will:

- survey new, innovative technologies in the PEV infrastructure space,
- deploy a selection of these advanced technical solutions in field demonstrations, and
- monitor the performance and quantify the benefits of the selected technologies.

#### Benefits

This project offers a number of benefits to participants that could also serve the general public. These include:

- identifying new, innovative technologies in the PEV infrastructure arena;
- providing hands on experience in field application and testing of the hardware; and
- identifying promising technologies that may allow utilities to deliver charging energy to vehicles while minimizing system impacts.

## **Demonstration of Non-road Electric Transportation Technologies (073653)**

### **Background, Objectives, and New Learnings**

Previous EPRI studies have revealed opportunities for reducing emissions and fuel consumption of non-road vehicles and stationary goods-moving equipment by converting them to electric drive. The studies have shown that electric drive non-road equipment can lessen the environmental impact of user operations and reduce end-user life cycle costs by cutting fuel costs, improving operating efficiencies, and lowering maintenance expense. The advantages of electric drive have been verified in various locations: at seaport loading docks, on airport runways, and in warehouses and manufacturing plants.

This project will apply the lessons from these studies and will synthesize existing case-based knowledge to quantify the environmental and economic impact to the energy provider of their end-use customers converting to electric drive. It will estimate the reduction in fossil fuel consumption and the resulting additional load and electric energy supply requirements. Transitioning non-road goods-moving equipment from using fossil fuel to electric energy may reduce environmental impact and carbon emissions enough to enable energy providers to comply with regulatory-mandated energy-efficiency programs. Presently, however, an energy efficiency program's effectiveness is evaluated only by considering total reduction of electric energy consumption. This project will model the reductions in environmental impact resulting from an electric-drive conversion program for comparison with a traditional energy-efficiency improvement program, providing a basis for demonstrating that an electric-drive conversion program can provide comparable benefits.

Quantifying the environmental and economic benefit of these technologies can give energy providers the tools and information they need to create programs to motivate their customers to convert their non-road vehicles and goods-moving equipment to electric drive. At the national level, results of the project may be used by EPRI Electric Transportation to evaluate the emissions reduction potential of electrifying non-road vehicles.

### **Project Approach and Summary**

This project will utilize results from work completed in 2010 that defined the operational and load characteristics of 36 non-road electric technologies. The technology assessment will be used to design a model to help energy providers to assess potential environmental and economic benefits of implementing a non-road electric transportation program.

### **Benefits**

The anticipated benefits include:

- Identifying opportunities to reduce carbon emissions and environmental impacts
- Effectively apply investments to achieve lower energy costs for commercial and industrial customers
- Understanding the environmental impact of new technologies, and their potential for meeting environmental and efficiency policies and standards
- Quantify the economic impact to the energy provider of implementation of a non-road electric-drive conversion program
- Development of a regionally specific non-road electric transportation program
- Better operating efficiencies and lower maintenance expenses could lead to potential savings for consumers

## Characterizing Plug-in Electric Vehicle Adoption and Charging Demand (073652)

### Background, Objectives, and New Learnings

Plug-in Electric Vehicles (PEV), including Plug-in hybrid Electric Vehicles (PHEV) and Battery Electric Vehicles (BEV), are available in the market and new models continue to be developed. All major automakers are selling PEVs or have announced PEV models which will be available in the next 2-3 years. The PEV is advancing rapidly from a concept or hypothetical travel mode to a viable option for new car buyers.

The conversion of the fleet to PEVs can contribute substantially to reducing carbon dioxide and other harmful emissions associated with internal combustion engine-power vehicles, while providing consumers the reliable and cost-effective transportation services they expect. The adoption of PEVs may result in more efficient use of the electric system to the benefit of utilities and the customers that they serve. Finally, the switch to electric vehicles may serve as an important element to the revitalization of the U.S. automotive manufacturing sector, which would benefit all consumers. However, there are challenges to achieving these benefits.

The timing and amount of electricity used to charge PEVs will affect the electric system in many ways. Recharging opportunities may be extended beyond the household so that EV owners can charge at work, at public outlets (like parking garages and street parking meters), and at facilities built expressly for that purpose, but that offer much faster charging. However, the extent to which such infrastructure is essential or contributory depends on the relative adoption rate by vehicle type (PHEV or BEV), the cost of the various charging options, and many other factors that will be heavily influenced, if not largely determined, by consumers.

Preparing for this transformational technology requires building new infrastructure and developing commercial and institutional arrangements to support even a low level of PEV adoption. In order to identify the barriers and opportunities, and address them, a more comprehensive characterization of consumer preferences and needs relative to PEV adoption and utilization must be developed. Consumer preferences must be constructed by asking consumers about preferences for vehicles that are so new that most have never seen one, no less driven or ridden in one.

### Project Approach and Summary

The objective will be accomplished by implementing a survey to solicit data from a representative sample of households in the utility market or other population of interest to characterize and portray:

- expectations and preferences regarding electric vehicle ownership and operation;
- where consumers expect to get information about PEVs;
- demographic attributes and driving behaviors; and
- willingness to pay for alternative levels of electric vehicle charging and PEV ownership

The survey response data will provide a detailed and localized characterization of the consumers that will support developing actions to meet immediate and local needs, including developing readiness plans for responding to customer wants and needs related to PEV ownership.

### Benefits

The benefits of a more complete characterization of consumer needs and expectations will be widespread, including:

- The development of survey methods that can be employed throughout North America to reduce the costs and speed up the collection of essential data on consumer preferences and the readiness of households for PEVs.
- Implementing a consumer expectations survey will provide EPRI with the opportunity to further refine the survey instrument and add new data to more robustly characterize customer expectations to better address important considerations.
- Better characterizations of consumer behavior will promote and direct attention to a wide range of technical direct research efforts.

- The database on consumer preferences provides the basis for developing more credible portrayals of PEV adoption that are the foundation of several EPRI research tools.
- The findings will help utilities and other affected stakeholders forecast adoption rates for PEVs and to undertake PEV infrastructure and support system readiness activities that are aligned with what consumers want and expect.

The area-focused findings will support testing for differences among customers that are due to factors such as: driving behaviors; housing circumstances, electricity and gas prices; social influences; and access to information about PEVs.

These expected benefits will help utilities to meet the expectation of the public safety, and plan for additional infrastructure if necessary.

These expected benefits will help utilities to meet expectations of the public and plan for additional infrastructure if necessary.