United States Senate

Energy and Natural Resources Committee

Testimony of Kenneth Huber,
Senior Technology & Education Principal

PJM Interconnection

December 10, 2009

Executive Summary

In the attached testimony, Kenneth Huber, Senior Technology and Education Principal at PJM Interconnection (PJM) details the activities presently underway within PJM's 13-state footprint regarding the potential of plug-in hybrid electric vehicles (PHEVs) serving as an energy storage resource. PJM is the Federal Energy Regulatory Commission (FERC) approved Regional Transmission Organization (RTO) serving all or parts of the states of Illinois, Michigan, Indiana, Ohio, Kentucky, Tennessee, West Virginia, North Carolina, Virginia, Maryland, Delaware, Pennsylvania and New Jersey as well as the District of Columbia. PJM operates the bulk power grid in this region, plans transmission expansion and operates the largest competitive wholesale electricity market in the world.

The batteries within PHEVs carry with them the promise of serving as a new and highly effective, distributed energy storage resource. If done right, plug-in hybrid vehicles can enhance the efficiency of the grid by shifting load to off-peak nighttime hours — the very time when certain renewable resources, such as wind power, are most available. On the other hand, if customers plug in their cars at 6 p.m. and there are no economic incentives or communication and control technology to drive different customer behavior, then the nation could be worse off both in terms of efficient grid operation and in controlling emissions from fossil generation.

Mr. Huber details PJM's participation in three projects demonstrating and evaluating use of PHEVs for grid storage— the University of Delaware's Mid-Atlantic Grid Interactive Car Consortium (MAGICC), The Ohio State University's SMART@CAR initiative and the North Carolina State Freedom Engineering Research Center. The first MAGICC plug-in electric vehicle has been responding in real-time to the PJM regulation signal since October 2007 and has provided a wealth of data on the use and value of vehicle-to-grid operation. This month, AES, PJM and the University of Delaware will be aggregating three 18 KW vehicles with a 1 MW stationary battery trailer. This is the first demonstration of vehicle-to-grid plug-in electric vehicles actively participating in any regulation market and providing a cash return to the vehicle owners. The three vehicles will be earning between $7-10 each for the 18-20 hours they are plugged in and contributing to the regulation storage needs of the grid. The batteries in plug-in electric vehicles become a source of regulation service that is more distributed and therefore provide the same, and in some cases, superior regulation service to what is today provide by central station generation.

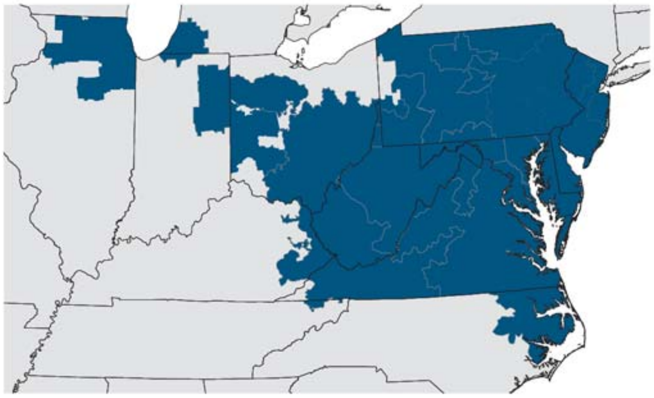
Mr. Huber concludes his testimony by outlining some of the policy challenges associated with wide scale deployment of PHEVs. These include: (1) ensuring coordination between the transportation and electric industries on vehicle design and development; (2) addressing ownership rights associated with infrastructure and the sale of electricity to PHEVs; (3) ensuring seamless "roaming" and ability of back-office billing and settlement systems to match cars with electric customers; and (4) the role of enforcement of interoperability protocols being developed through the National Institute of Standards and Technology (NIST) process. Mr. Huber suggests that continued Committee oversight and focus on these issues will help to underscore the national and international policy benefits of "smart" plug-in hybrid electric vehicle technology.

Testimony of Kenneth Huber, Senior Technology and Education Principal

On behalf of PJM Interconnection, L.L.C. (PJM), I want to thank the Committee for the opportunity to participate in this important discussion of the role of grid-scale energy storage in meeting the energy and climate goals of the United States. My name is Kenneth Huber and I am Senior Technology & Education Principal at PJM. My goal today is to discuss the reliability and economic value of grid-scale storage both for today's grid operation and for forecasting future grid operations. I will also discuss the value of storage as it relates to the anticipated emergence of renewable energy resources.

PJM is a Regional Transmission Organization (RTO) and one of the seven Independent System Operators (ISOs) and RTOs located throughout the country. PJM is responsible for the reliability of the bulk power grid in a 13-state region which encompasses over 51 million Americans. PJM operates the bulk power grid in this region, plans transmission expansion and operates the largest competitive wholesale electricity market in the world. Over two thirds of the nation is served by RTOs and ISOs. As an independent entity, we are dedicated to ensuring open access to the grid and embracing many new and sometimes competing technologies. PJM was privileged recently to be a recipient of one of the Department of Energy's Smart Grid grants — a grant for the installation of phasor measurement units to enhance the overall visibility of grid conditions on a minute-by-minute basis and to improve the overall efficiency of the grid operations.

Figure 1: PJM's service territory



To keep the lights on, PJM must perform the real-time balancing of the electrical grid — every second of every minute of every day, PJM matches electricity demand with the 'least-cost group' of electricity generation and demand response resources. The dispatch of over 1,200 generators on our system must be undertaken with recognition of the physical constraints of the electric transmission system and the need to ensure adequate reserves available to keep the lights on in the event of a sudden loss of generation or transmission. This challenging balancing of the grid is complicated by the unique physics of electricity. Electricity is not like oil which can be refined and stored easily for long periods until the time it is needed. Electricity must be generated at the near moment that it is required. I will discuss how grid storage, with a particular focus on plug-in electric vehicles, can and is being used to assist in this system balancing requirement. I will also highlight the specific activities PJM is undertaking to jump start the deployment of "smart" plug-in hybrid vehicles in our footprint, as well as, briefly address some of the policy challenges that will affect further deployment of plug in hybrid electric vehicles.

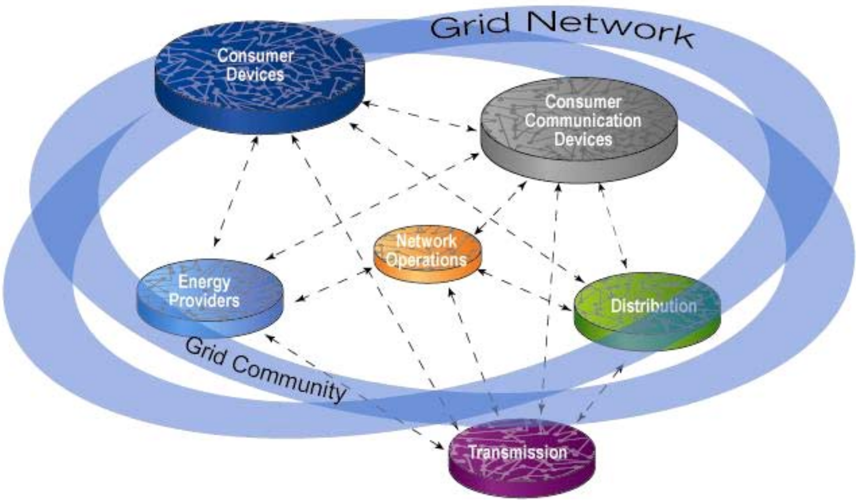
The State of the Grid Today

Figure 2: PJM's control room

Contrary to the beliefs of some, the bulk power grid already is very interactive and “smart”. Today, we have more sophisticated operations and market-based tools to manage flows on the grid than ever before. These tools include our state estimator which monitors and reports on the state of the system every two minutes. They include our ability to redispatch generation to proactively clear congestion before reliability is threatened by overloads on a given transmission line or set of lines. In short, we have been able to utilize technology to help manage power flow more efficiently than in years past.

New Opportunities – A Smarter Grid

Figure 3: Relationships in a smart grid



Although the bulk power grid can be considered “smart” today, emerging technologies and enhanced communication will put in place an even more robust grid. Advanced technology will open a new frontier for the grid in many ways. A grid that is based on smart grid technology, when coupled with electrification of transportation and the delivery of more real-time information, will provide new opportunities to better manage the grid and control both for price and environmental externalities. PJM is actively working on the agreement of and the eventual creation of the capabilities and role of the RTO/ISOs that will deliver that smarter grid. We are accomplishing this goal through active participation in the National Institute of Standards and Technology (NIST) Smart Grid Interoperability

Panel, the North American Electric Reliability Council (NERC) Smart Grid Standards Task Force and the North American Energy Standards Board (NAESB) Smart Grid Standards Task Force. I have been focusing my participation in the NIST Priority Action Plans for Storage and Electric Transportation and am a voting member of the Society of Automotive Engineers (SAE) standards process.

Grid Storage – A Key Element of a Smarter Grid

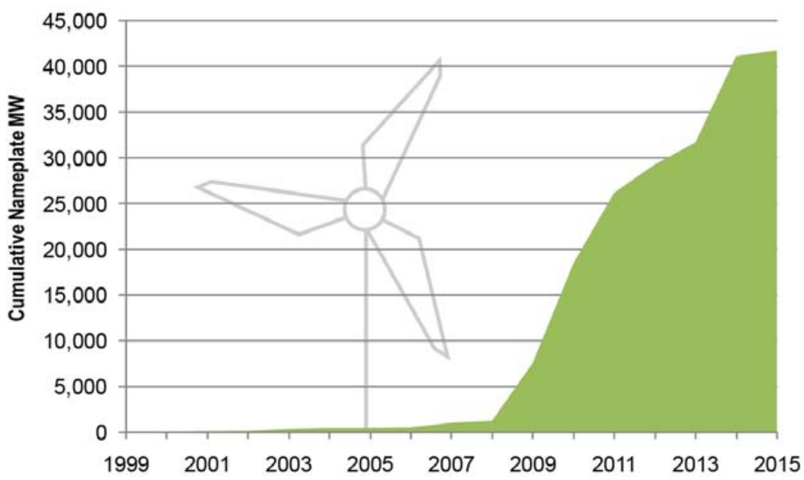
PJM Interconnection supports projects of all types to expand the electricity storage capability of the electric grid. More storage capacity will be needed to deal with the forecasted major expansion of intermittent renewable energy sources and their potential impact on system reliability.

One of the challenges facing grid operators like PJM is the inability to "store" electricity for use at times of high demand or when certain generation may be operationally or environmentally constrained. However, new technologies are being developed and tested that offer the promise of more widespread storage options for grid operators and utilities. These technologies will become even more important as intermittent renewable energy sources play a greater role in the nation's electricity supply.

Today, additional options for storing electricity are emerging and are being tested. These technologies – such things as battery arrays, flywheels, compressed air energy storage and even PHEVs[1] – may give grid operators additional flexibility in their efforts to ensure the reliability of the electric system. After outlining the general storage needs of the grid, I will be concentrating the bulk of my testimony on the grid storage applications afforded by PHEVs.

There are a number of reasons why additional storage capacity is needed on the grid. The dramatic expected increase in the penetration of renewable generation resources is the primary driver. These sources typically are intermittent – their production isn't available all the time, for example, when the wind isn't blowing or the sun isn't shining – and their output may not be available at times of peak demand when it is needed most.

Figure 4: Nameplate capacity value of wind in PJM Interconnection Queues



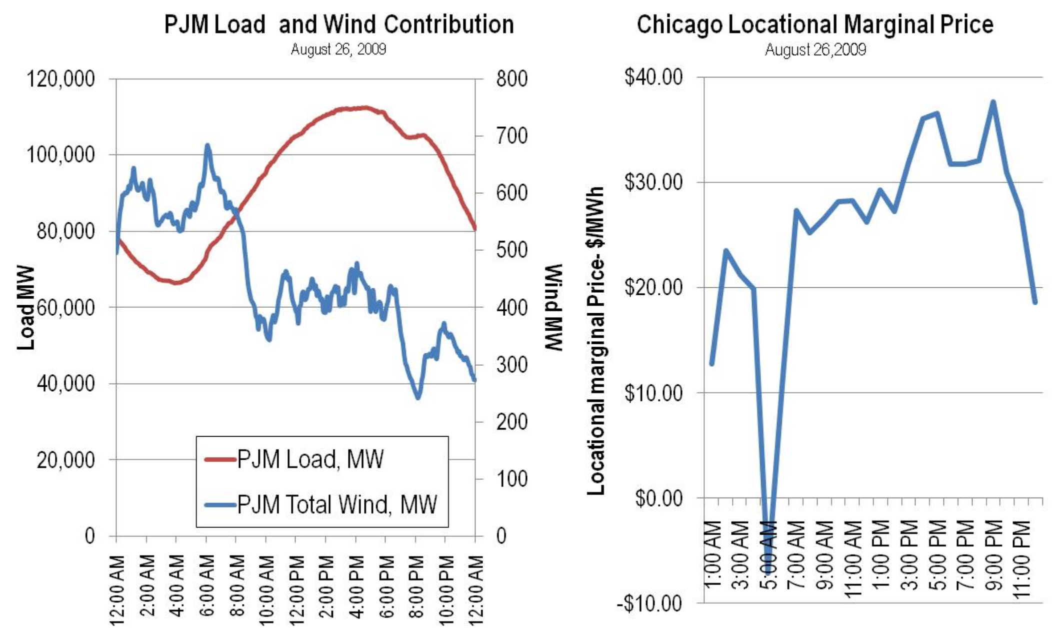
[1] The term PHEV used in this testimony refers to different types of plug in electric vehicles including plug-in hybrid vehicles, extended range electric vehicles and battery extended vehicles.

In recent years, the nameplate capacity value of wind generation projects entering the PJM interconnection queues has steeply increased. There are currently 3,300 MW of nameplate wind capacity in operation, 1,500 MW under construction and approximately 42,000 MW nameplate capacity of wind generation in the interconnection queue in PJM.

Taking full advantage of renewable sources while dealing with the reliability challenges of the sources' power fluctuations will require a significant increase in storage on the grid.

Although the PJM system is one of the nation's largest and thus able to absorb a greater degree of intermittency than smaller systems, the lack of sufficient storage already is causing issues for PJM. In some areas, abundant wind production in the off-peak (night-time) hours has forced electricity prices into the negative range. During low load periods, storage will become critical to prevent curtailment of this wind generation. Figure 5 is illustrative of a common occurrence in PJM in which the wind output is rapidly declining just at the time (5:00 a.m. in this example) when the grid load is beginning its morning period of rapid load increase. Negative prices for wholesale electricity frequently result from these conditions. In this example the Locational Marginal Price of electricity in Chicago fell to minus $8. On this day at this hour, in order to maintain the system's load to generation balance, a storage facility would have been paid to store energy. From a PHEV perspective, the vehicle owner would be paid to charge their car during that hour.

Figure 5: PJM Load and Wind Resources as of August 2009



Given the states' requirements for renewable energy and economic incentives for the development of renewable projects, the expected expansion of renewable power will magnify this situation, along with the challenges for grid operators to maintain reliability during such periods of fluctuations in the output of these power sources.

New Battery and Vehicle Grid Storage Technologies

Battery storage – A one-megawatt (MW) array of lithium-ion batteries began offering regulation service in the PJM market in May of this year. The batteries, housed in a trailer on the PJM campus, are owned by AES Energy Services LLC, a subsidiary of The AES Corp., a PJM member. The facility can help PJM quickly balance variations in load to regulate frequency as an alternative to adjusting the output of fossil-fuel generators; it is capable of changing its output in less than one second. In response to PJM requests to balance the grid, the battery unit can supply power into the grid by discharging its batteries or store excess electricity from the grid to charge its batteries. Thirty four MWs of battery storage have been put in the PJM generation queues for 2010.

Figure 6: AES one megawatt lithium-ion battery trailer

PHEVs – The dual use of PHEV batteries to support both transportation (when the vehicle is being driven) and the grid (when the vehicle is parked and plugged in) is particularly attractive. Most vehicles are driven only several hours per day and are plugged in and available to provide grid support for the remaining time in the day. Fleet vehicles, while driven 8-12 hours per day, are typically returned to the same location and available for grid services the remaining 12-16 hours of the day.

Figure 7: MAGICC cash back plug in electric vehicle

Off-peak electricity from the grid could charge PHEVs, shifting load to the night-time hours. In addition, PHEVs also could provide regulation services to the grid whenever parked.

Regulation service, provided today principally by central station generators, matches generation and load and adjusts generation output to maintain the desired 60 Hz frequency. Regulation service corrects for short-term changes in electricity use that might affect the stability of the power system. Regulation is needed throughout the day and night to ensure system frequency despite constant fluctuation in demand and generation. Grid operators must continuously match the generation of power to the consumption. Regulation requires a generating facility that can ramp power up or down under real time control of the grid operator.

PJM is part of three initiatives — the University of Delaware's Mid-Atlantic Grid Interactive Car Consortium (MAGICC), The Ohio State University's SMART@CAR initiative and the North Carolina State Freedom Engineering Research Center – each of which is analyzing, demonstrating and evaluating use of PHEVs for grid storage. The MAGICC vehicle has been responding to the PJM regulation signal since October 2007 and has been evaluating the vehicle-to-grid (V2G) approach, which enables PHEVs to discharge their stored power to the grid based on regulation signals from PJM. This month AES, PJM and the University of Delaware will be aggregating three 18 KW vehicles with the 1 MW stationary battery trailer (Figure 6). This is the first realization of the 'cash-back' vehicle[2] as the three vehicles will be actively participating in the PJM regulation market and earning between $7 - $10 each for the 18-20 hours they are plugged in and contributing to the regulation storage needs of the grid. The annual payment for each of these vehicles will be in the order of $2,500 to $3,500.

Figure 8: OSU SMART@CAR

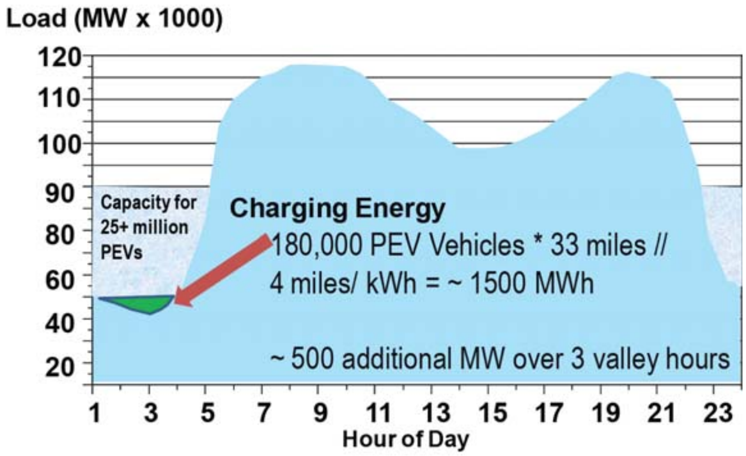
Of particular interest is the opportunity for automotive fleets to become an early adopter of PHEVs and showcase the direct economic and environmental value for both transportation and grid support. Local delivery fleets suffer from low fuel mileage, idle a large percentage of their time and are economically impacted by any increase in price of gasoline. As PHEVs, these fleet vehicles would charge at night with inexpensive electric, be available for regulation services and market revenues and would deliver green transportation while serving our neighborhoods.

Plug-in hybrid vehicles represent an exciting new opportunity to provide both ancillary services to the grid and utilize the power system assets more efficiently. If done right, plug-in hybrid vehicles can enhance the efficiency of the grid by shifting load to off-peak nighttime hours. On the other hand, if everyone plugs in their car at 5 p.m. and there are no economic incentives or communication and control technology to drive different customer behavior, a much higher peak load would have to be supported by high cost generation.

2 "*How To Improve The Efficiency Of The World's Biggest Machine - While Solving A Few Other Problems Along The Way,*" Jon Wellinghoff, Commissioner, Federal Energy Regulatory Commission, May 7, 2007.

Figure 9 shows the minimal impact of 180,000 PHEVs (1,000,000 vehicles times the 18% of the nation's population that resides in the PJM territory). It also illustrates the potential for supporting 25 million PHEVs if the charging is done at off peak times.

Figure 9: Minimal impact of 180,000 PHEVs with smart charging



The auto industry and the electric industry also must work together to make the future PHEVs deliver on their potential to reduce oil imports, to reduce carbon dioxide and to reduce the cost of transportation. The automobile manufactures, the local utilities, the RTO/ISOs and the Electric Power Research Institute (EPRI) are meeting regularly to discuss and work through the needs of our industries and of the end-use consumer to provide reliable, clean and economic transportation and electricity use.

A mixture of all of these storage technologies will help grid operators and utilities address the impact of a large-scale addition of renewable energy sources to the electricity system, including the intermittent nature of renewables, the off-peak timing of much wind energy output and the potential impact on the loading levels of baseload coal and nuclear plants.

Policy Challenges

While today we are seeing aftermarket conversions of plug-in hybrid electric vehicles (e.g. the BMW Mini) production vehicles from original equipment manufacturers will begin with the deployment of plug in hybrid electric vehicles in 2010, such as the Chevrolet Volt. As I mentioned previously, to truly realize the full benefit of PHEVs rather than simply swapping one set of increased emissions for another, we will need to ensure that there is smart charging of the vehicle with two way communications available between the vehicle and the grid. The customer remains in control. However, through appropriate price and control signals, parked plug-in hybrid electric vehicle, can provide a source of distributed generation that can better help us to manage the grid than we can today with large central station generators distant from the loads. And by using price signals to incent vehicle owners to charge their cars in off-peak times, we can avoid creating a whole new set of system peaks at the very time we are seeking to reduce carbon emissions and otherwise smooth out fluctuations in peak demand.

To achieve this vision, we will need to address a number of policy issues, some of which are well on their way to resolution and others which are only first being identified. Let me outline a few for the Committee's consideration:

Cooperation and coordination between the electric and transportation industries —These industries have traditionally not had to adjust their product to meet the needs of the other. However, both industries have now recognized the need to collaborate on infrastructure requirements, data exchange and ensuring a positive, holistic experience for the PHEV customer. The industries are working together in many forums, including the Society of Automotive Engineers standards activities, the EPRI PHEV collaboration programs and many local deployment projects. To truly realize the benefits of PHEVs, these collaborations will need to result in agreements on the minimal information that must be exchanged, the ownership of the data and how usage and revenue will be measured and verified.

Infrastructure Deployment — As part of the deployment of the smart grid, we will need to tackle issues such as who owns the infrastructure down to the outlet and what constitutes a permissible vs. impermissible sale for resale of electricity. For example, would the outlets deployed at a Walmart sm [3] parking lot be owned by Walmart, a separate aggregator or the local utility? Would Walmart serve as the intermediary between the utility and the customer and aggregate the purchase of electricity to vehicles on its lots during the day. For residential uses, can a landlord of an apartment building insist that he or she own the infrastructure? Does a customer have a "right" to connect in order to charge their battery (so long as they are financially in good standing with the electric company) just as customers have a right to electric service under state law today? The industry is beginning to consider these regulatory and policy issues. Let me give an example of a working system today; AES has aggregated its 1 MW stationary battery system with the three 18 KW plug-in electric vehicles in the University of Delaware. The total energy of 1.054 MW participates in the PJM Regulation Market. AES allocates approximately 5% of the PJM market payment to the University of Delaware and AES is allocated 95%. The University vehicles are plugged in at home and at the university and the net usage of the vehicle is measured on standard utility meters and usage payments are made to the local utility (Delmarva Power and Light). A retail net metering tariff completes the picture allowing the customer to participate in the service he or she is providing to the grid.

To tackle these questions more broadly, we will all need to look at the typical utility tariff in a new light and determine what is the best legal relationship that is fair to the utility, the vehicle owner and the owner of the garage or parking lot itself.

Roaming— Although the plethora of different electricity rates by geography is often cited as an impediment to properly linking mobile cars to customer accounts, I do believe that technology development from the transportation and telecommunication industries has provided us clear guidance in this area. Today, states still have a variety of different toll rates on their highways just as different cellular companies have different rates and plans. The advent of the *E-Z Pass* demonstrates that these different state and utility requirements can be harmonized and a system of billing and collection can be managed for vehicles. We will need the "smart" grid to be able to identify vehicles and their location

[3] Walmart is a service mark of Wal-Mart Stores, Inc

and match them to utility customers. We will further need to develop new inter-utility billing and settlement systems to manage this mobile fleet. But, at least from a technology viewpoint, the path forward on this issue has already been demonstrated.

Need for Comprehensive Interoperability Standards — The Smart Grid Interoperability Panel work of the NIST with cooperation of the automotive companies, utilities and the RTO/ISO is actively addressing and coordinating this need in the NIST Electric Transportation Priority Action Plan. Of critical importance is the need for deployment that conforms to the NIST interoperability agreements and for appropriate enforcement at the state and federal level.

Need to Retain Policy Focus — The future of PHEVs as an energy storage resource is highly dependent on close coordination between the electricity and transportation industries — two industries that have had limited interaction in the past. Moreover, the infrastructure needed to be deployed potentially spans the traditional jurisdictional reach of both federal and state regulators and policymakers. As a result, continued Congressional oversight on this issue and the progress being made would be helpful to underscore the importance of PHEV deployment to meet national (and even international) policy goals We at PJM look forward to working with this Committee and the Congress as a whole as we move forward in this important area.