Electricity Advisory Committee

MEMORANDUM

TO: **Honorable Steven Chu, Secretary**
Honorable Patricia Hoffman, Assistant Secretary for Electricity Delivery and Energy Reliability

FROM: **Electricity Advisory Committee**
Richard Cowart, Chair

DATE: **November 4, 2011**

RE: **Electric Vehicle Deployment: Policy Questions and Impacts to the U.S. Electric Grid**

Introduction

The U.S. electric grid has served customers for more than 100 years with reliable, affordable electricity service. Most of the existing electric power infrastructure was designed to supply power from large, dispatchable, utility-owned generation sources to end use customers with predictable load shapes. The central dispatch system will continue to serve customers reliably in the upcoming years, but will face new challenges driven by such factors as increasing demands for energy, capacity limitations, environmental constraints, varying load shapes, distributed generation, and new "smart" technologies enabled by the build-out of the Smart Grid. Distribution systems can use Smart Grid concepts to improve efficiency and reliability. However, many challenges are impeding implementation of these technologies and applications, including identifying and understanding rapidly evolving Smart Grid applications, agreeing on appropriate cost allocation for Smart Grid investments, identifying appropriate customer incentives for demand response, establishing standards and protocols, and providing justification for capital investments by utilities. With deployment of the Smart Grid comes a need for a new model for utility and consumer interaction. As these applications and technologies develop, consumers will have more access to data and the ability to understand and

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control their electricity consumption. This increased access and control brings with it the need for utilities to enhance consumer engagement to educate and empower the customer in using new applications to encourage efficiency and diversity in resource use.

One of the newer “smart” demands on the system will come from deployment of plug-in electric vehicles (EVs). Compared to other home “appliances,” EVs can create a significant instantaneous demand for electricity, especially as charging technologies develop that charge the vehicle from the grid quickly (known as fast charging). Estimates of the demand on the system created by EVs have varied with different analyses, but a study by one grid operator concluded that charging a single EV will be comparable to a residential air conditioning load, in the range of 1-6 kW.[1] DC Fast Chargers are also being deployed for commercial installations, capable of 50kW, with standards for fast-charging being created assuming the capability is doubled. Also, the batteries in EVs not only have the potential to store power for transportation, but may eventually have the capability to feed electricity back into the grid (vehicle-to-grid technology). In addition, EV battery storage could have the ability to balance variable renewable generation sources, providing increased stability and operational flexibility for the grid in the long term.

But while this complex new technology is deployed, electric system operators will need to continuously satisfy demand from new EV consumers and all other customers wherever and whenever it arises. As such, even if EVs can be integrated into the larger grid as a routine load, they may necessitate the addition of new local infrastructure, tariffs, and policies to manage localized geographical impacts. Electric infrastructure requirements may change and additional capacity may be needed depending on how electric vehicles are used within the distribution system. The specific needs will change as the interaction and dependency between EVs and the grid becomes more intense and complex.

The U.S. Department of Energy’s (DOE) Electricity Advisory Committee (EAC) has prepared this White Paper to provide background information on potential impacts of EVs on the nation’s electric grid infrastructure. Addressed in this document are impacts to physical infrastructure, charging and discharging schemes, rate design and price impacts, and regional implications of EV deployment. Drawing from this background information, the paper will bring to the forefront critical policy questions and offer recommendations to the DOE for addressing the challenges to future grid operations that will arise from deployment and integration of EVs in the near-term (near term is defined as five years) and mid-term (5 to 15 years). The paper does not include discussion or recommendations on long term (beyond 15 years) grid impacts of EV technology, policies to promote the purchase of EVs, or vehicle-to-grid technology system needs and impacts.

[1] NYISO, “ Alternate Route: Electrifying the Transportation Sector,” 2009

Background

Electric vehicles have become a reality in 2011, with a number of models now commercially available in the U.S. The Center for Automotive Research projects that nearly half a million EVs will be on the road in the U.S. by 2015[2], and the Obama Administration has a goal of reaching 1 million EVs by 2015. However, these projections are offered with a recognition that there are many uncertainties regarding: 1) the rate of deployment of this new technology; 2) questions about technology readiness; 3) the future of fuel and electricity prices; 4) the future of energy and environmental policies and regulations; 5) the future for competing types of vehicles; 6) the interest of government or electric utilities in providing incentives for EVs; and 7) the wide range of possibilities for consumer acceptance.

In the early years of deployment, EVs are likely to remain significantly more expensive in terms of purchase price but the operating cost is much less expensive on a cost per mile basis as compared to conventional motor vehicles. Although early adopters of EVs are likely to have reasons other than economics for purchasing the vehicles, more widespread adoption will likely be governed by the economics of EVs relative to conventional motor vehicles.

As EV adoption increases, it is likely that electric power companies and grid operators will face integration challenges with respect to installing public charging stations and supporting individual customers who wish to charge their vehicles at home. These challenges will be inconsequential in 2011, but could become quite significant as deployment of EVs increases.

Most early research suggests that the existing bulk power system (i.e. generation and transmission assets and operational procedures) can accommodate a relatively significant level of EV deployment, *if vehicle charging is not coincident with times of peak demand.* For example, a study by the Pacific Northwest National Laboratory concluded that the power demands of 73% of U.S. light duty vehicles could theoretically be supported by electricity from the existing bulk power system, though the percentage would vary by region. This ability to provide service with no change to the bulk power system is despite the fact that this level of EV penetration would add 910 billion kWh to annual U.S. generation, an increase of over 20%.[3] One study of local impacts found that 500,000 EVs could be added to the Xcel Colorado service territory alone, without adding to peak demand, if the vehicles were all charged off peak.[4] Similarly, a University of Vermont study found that 100,000 EVs could be accommodated in Vermont without adding to

[2] See http://www.cargroup.org/pdfs/deployment.pdf

[3] PNNL "Impacts Assessment of Plug-In Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids: Part 1," 2007.

[4] "Costs and Emissions Associated with Plug-In Hybrid Electric Vehicle Charging in the Xcel Energy Colorado Service Territory," 2007.

system peaks if the vehicles were charged at night.[5] Several other studies have reached similar conclusions.

Given the relatively modest expectation for EV deployment in the next five years (500,000 to 1 million vehicles), the aggregate load will be relatively small and the bulk power system is unlikely to be negatively affected regardless of when charging occurs. As EV adoption increases with time, there may be localized bulk power system problems which could include resource adequacy and wholesale pricing effects. However, aggregated EV customers (through wholesale demand response providers) also have the potential to provide *benefits* to the bulk power system and receive payments for their services. In the near term, the ability of EVs to provide demand response services can be demonstrated in small but potentially meaningful ways.

The biggest impact on the electric power system in the medium term (5 to 15 years) of widespread EV deployment is likely to be at the electric distribution system level. The effects at the local distribution level are magnified by the fact that EVs will likely be "clustered" assuming the purchasing patterns are similar to hybrid EVs. One area of concern with widespread deployment is the potential impact of many EV owners charging their vehicles in a relatively short period of time (e.g. 30 minutes or less), and in a manner and time of day that is convenient for them, including doing so during periods when there is heavy demand on the power system. In addition, even if the EVs aren't charged during peak times, overnight, off-peak charging could prevent distribution assets, such as transformers from cooling down overnight, resulting in reduced lifetimes for these components. Also, as options for fast charging become available to the consumer, that will increase the instantaneous electric demand that is placed on the distribution system. As a result, the coincident demand from EV charging in the midterm may cause distribution equipment to operate in excess of its design rating.

This operational challenge may place stress on the distribution system (and eventually in the long run, the bulk power system), ultimately requiring larger capacity components (such as distribution transformers) in order to operate the system reliably during peak demand periods. The cost allocation for associated equipment upgrades presents a policy challenge in the short to medium term for state utility regulators and electric distribution companies.

This also presents a potential reliability challenge for transmission owners and bulk power system operators (including ISOs/RTOs). While the bulk power system is designed to operate reliably at these levels during peak periods, sustained operation at these levels may reveal new constraints. For example, there may be intra-regional transmission

[5] "Effects of Plug-In Hybrid Electric Vehicles on the Vermont Electric Transmission System," 2009.

constraints that come into place when transmission lines are heavily loaded for extended periods. To assure reliability, new technology that is able to respond more quickly to changes in electrical properties of the line might be required. Subject to review by state utility regulators, distribution utilities will need to determine if, when, and where location-specific upgrades should be undertaken. Utilities and regulators must also establish appropriate methods to allocate and recover the costs of such upgrades from consumers. A notification process to inform utilities where EVs will be charged (and thus where upgrades may be needed) will assist utilities in identifying the costs of location-specific upgrades as they become necessary. Aggregators can play an increasingly important role in the mid-term by helping to smooth expected peaks in demand resulting from increased EV deployment. An aggregator would coordinate the use of multiple vehicles to meet commitments to the grid operator while also limiting the impacts of peak demand on the grid and achieving targeted charge levels for the vehicles. Scheduled charging may also be complementary to planned time-of-use (TOU) programs offered by some retail utilities.

Policy Challenges

1. Near to Mid Term Deployment Challenges

Policy challenges to deployment of first generation EVs center on whether owners of EVs will drive the need for expensive upgrades to the distribution system (and in the long-term place sufficient additional demand on the bulk power system so as to increase infrastructure needs and prices at the wholesale level). It is expected that EV charging units will be located at places most convenient for the consumer, which are usually in the densest population centers, such as residences, hotels, parking lots, service stations, employer parking lots for employees, utility sites, and other publicly accessible locations. Early indications are that most charging will be done at the residential level, rather than public charging, and a bottleneck may be providing residential charging for apartments and condominiums that do not have a garage.

The extent of needed distribution upgrades (and potential effects on prices) will be affected by the timing of the aggregate demand on the system, volume of vehicles being charged, and location specific charging. If EV charging demand coincides with generic system peak demand, it will tend to amplify the need for upgrades. Typically, the costs of upgrading the distribution system are allocated to all distribution system customers through retail wires charges on a per-customer or per-kilowatt hour basis. Retail distribution rates for commercial and industrial customers may also include demand charges that are recovered on a per kilowatt basis. However, cost allocation on distribution system upgrades needed to support EV deployment may become a controversial policy question.. Consumers who do not drive EVs and do not expect to invest in EVs may not want to have the additional costs to the system allocated to them. However, utilities and regulators have faced similar questions with respect to large, distributed loads such as electric heating and air conditioning, and have found ways to moderate those costs (via load management plans and tariffs) and allocate those costs under universal service principles. This experience and these principles are likely to guide cost allocation practice for EVs as well.

2. Regulatory and Policy Challenges

Introduction to Regulatory and Policy Challenges

All of the likely challenges for distribution systems, as well as the potential problems for the bulk power system, can almost certainly be solved – but not overnight. Planners and policy makers need to know *in advance* where and when the impacts of EVs on the electric grid are most likely to be felt. This means regulators need to understand the near term as well as the medium term implications, so that potential near term and medium term solutions can be tested and proven solutions can be implemented for the longer term. All of the parties need better information about how consumers are likely to drive and charge their EVs and use smart grid technologies to participate in demand response programs. It will be difficult, if not impossible, for regulators to establish appropriate rate designs without such specific information. DOE can provide such information from the EV deployment project that is underway where data is being gathered and analyzed through 2013.

Discussion of Regulatory and Policy Challenges

Deciding how state regulators and electric distribution companies might best allocate costs and design retail rates for EV charging to accomplish the desired consumer behavior (i.e., off-peak charging of EVs) is a policy challenge that must be addressed in the near term. Retail rate designs that do not account for the specific attributes of EV charging may inhibit the adoption of EVs, or may unfairly burden retail customers that do not choose to purchase EVs, and in the worst case, may have unfavorable reliability and economic effects at the wholesale level.

Regulators, system operators and EV owners must address the following technical and policy challenges to ensure the successful widespread deployment of EVs.

A. Cost Allocation and Rate Design

The issue of EV metering is relevant to cost allocation issues. EV charging stations may be metered separately, counted as part of the total amount of electricity consumed by a household, or placed under another "master" meter. Given the expected relatively lower costs of operating EVs (relative to conventional gasoline-powered vehicles), an essential question to evaluate will be: What retail rate designs will be necessary and sufficient to incent the desired consumer behavior (i.e. off peak charging) and appropriately allocate infrastructure costs associated with supporting EVs?

Anticipating how consumer EV charge behavior might change in response to pricing signals may be difficult prior to large scale deployment of EVs, but the economic assumptions of rate design require answers sooner rather than later to ensure effective load control. In addition, it is often difficult to change consumer expectations about service and rate conditions once they are in place (for example, if mandatory time-of-use pricing is contemplated for EV charging, it will be important for consumers to know this is the case before thousands of vehicles are already on the system). Consumer price sensitivity is predicated on consumer knowledge of options, the signal being large enough to impact consumer decision-making, and the ability of the consumer to respond to price signals. Consumer demand is only marginally impacted by motor fuel prices because consumers have no choice other than to travel, consumers become accustomed to price ranges, and other factors. Given expected lower costs of operating EVs (relative to conventional gasoline-powered vehicles), and uncertainty around consumer behavior and load control techniques, some essential questions to evaluate will be:

- What retail rate designs will be necessary and sufficient to incent the desired consumer behavior (i.e., off-peak charging)?
- What is the forecasted rate of adoption of EVs, by region and major metropolitan area?
- What are the expected demands that will be placed on the distribution system due to these additional regional demands?

B. Interoperability

EVs will have significant electronic capability to recognize the type of charge units to which they are connected (e.g., fast or slow). It will be important for the charge unit/meter to have standardized communication capabilities to interact with the EV to recognize the type of vehicle, recognize whether the EV is charging or discharging, calculate and display the economic impact of the charge/discharge to the consumer, respond to consumer directives to the vehicle, and monitor or provide other information to the consumer and utility. DOE has opportunities to guide these discussions by encouraging the development of standards to achieve interoperability between the EV, the charging station, and the meter or device containing the pricing signals. In addition, to maximize the potential grid-related benefits that EVs can offer over the long timer, it will be important for DOE to continue coordination efforts with the automotive industry as EV functionality is defined and implemented.

Cyber security is frequently discussed in terms of maintaining the operational integrity of the grid. EV owners will have security concerns in terms of the private data on their energy use and utilities will have concerns about the two-way communications between EVs and charge units/meters/distribution system assets. Addressing how such data will be protected will be an issue of importance. Given these concerns, an essential question to evaluate will be:

- What standards need to be developed to ensure both interoperability and data security between the EV, the charging unit, and the meter or device containing the price signals?

C. Infrastructure Improvements

When investing in additional infrastructure it will be important to identify maturing tools that can be used to plan for near to mid-term investment in adequate grid capacity. Public recharging centers (i.e., hotels, service stations, parking lots) have the potential to create additional infrastructure requirements to sustain local distribution systems. The use of energy storage devices, one such tool, in conjunction with such public recharging facilities may allow off-peak energy to be stored and subsequently to charge EVs during peak hours without adversely impacting local infrastructure needs. Essential questions to evaluate will be:

- What are grid-friendly charging characteristics and the trade-offs associated with charging times, consumer acceptance and distribution upgrades?
- What conditions would necessitate community-based storage as the preferred alternative to integrate EV charging with the grid?

3. International Lessons Learned

It is possible that lessons can be learned from EV deployment already undertaken globally that would help guide U.S. policy makers in answering such challenges. For example, the Energy Technologies Institute and a consortium of participants in the United Kingdom (UK) have developed a comprehensive study which will propose an overall architecture for integrating electric vehicles considering electricity infrastructure such as networks, charging points, payment systems, and business models. Key points examined in the UK study include:

- Design concepts for the “intelligent architecture” of interconnected data and systems needed to enable local networks of EV charging points linked to the distribution networks;

- Analysis of how growth in EV recharging could impact electricity distribution networks, and what steps energy companies could take to overcome any barriers to supplying demand; and
- Assessment of current issues and likely future developments involving regulatory, legislative and commercial matters related to the recharging infrastructure.

Demonstration projects are also underway to examine the most effective ways to coordinate consumer charging of EVs so as to discourage on-peak charging. One North East, the regional development agency in the North East of England, is leading an initiative to deploy 1300 public access charge posts in an effort determine the appropriate policies and business models as well as the requisite systems needed to support public charging and ensure that user convenience is maximized. The effort revolves around the following principles:

- Deployment of quick charging capabilities to analyze impact on the distribution grid;
- Determine the optimum location of charging stations based on anticipated usage patterns, distribution network capabilities, and other factors; and
- Encourage the development of information technology systems needed for communications between charge posts for interoperability**.**

4. U.S. Demonstration Projects Lessons Learned

Demonstration projects of EV integration in the U.S. have also provided valuable lessons learned. These projects are addressing the system challenges:

- Austin Energy is deploying Level 1[6] and Level 2[7] stations throughout the city so that no EV owner is more than 5 miles away from a charging station. Austin Energy is also implementing a reimbursement program to motivate homeowners with an EV to install Level 2 chargers.
- Highway I5, running from the Mexican border to the Canadian border, is slated to become a "Green Highway." The states of Washington, Oregon and California are in the process of installing charging stations (Level 2 and Fast Charge[8]) at 40-50 mile spacing along the Highway.
- The American Automobile Association (AAA) has established a program of mobile charging in several cities for its customers. AAA will provide a mobile EV charger if the customer runs out of charge before they can reach a charging station.

[6] Level 1 charging: 120 volts (http://www.austinenergy.com/About%20Us/Environmental%20Initiatives/plug-in%20Partners/faq.htm)

[7] Level 2 charging: 220/240 volts (http://www.evcarco.com/evcarco/2011/08/08/plug-in-program-austin-texas-103-public-ev-charging-stations/)

[8] Also known as Level 3 charging. Requires high levels of voltage and current. There is no common standard for this charging, and most likely additional equipment will be required to be installed at the station. The advantage is speed; some vehicles can charge in as little as 15 minutes. (http://www.mass.gov/Eoca/docs/doer/charger1.pdf)

The lessons learned from these efforts can provide empirical data and other verifiable data for the nation's policy makers and will provide important insights into the challenges currently facing the integration of EVs.

5. U.S. Regulatory Experience with EV Deployment

State and federal policy makers, regulators, and electric companies are beginning to grapple with the issue of how the electric system will be affected in the near and mid-term by the integration of electric vehicles. For example, the California Public Utilities Commission (CPUC) has an ongoing docket (Rulemaking 09-08-009) which addresses EV deployment for the three large investor-owned utilities it regulates in California. The CPUC conclusions are the following: 1) A system whereby utilities are notified when EV charging systems are installed would be very helpful for ensuring safety and efficiently managing the grid; 2) With limited exceptions, existing residential TOU rates are sufficient for the early EV market; 3) Collecting more load and behavioral data is necessary before making a number of longer-term policy decisions regarding the integration of large numbers of EVs onto the electric grid. Consequently, the CPUC ordered utilities to undertake research and report by 2013 on infrastructure upgrade costs associated with EVs, how metering arrangements and rate design impact EV charging behavior, whether participation in demand response programs impacts EV charging behavior, and whether distribution costs are increased by different charging levels and quick charging in public locations.

The CPUC docket is one of several examples where policy makers are beginning to address EV challenges and opportunities. Several entities have performed initial analyses, and further research is underway. Such examples have already and will continue to inform U.S. state regulators in tackling these policy challenges. However, there has not been an authoritative, comprehensive, industry-wide and nation-wide study of the impacts to the grid on EV deployment.

Electricity Advisory Committee Recommendations:

1. ***DOE should provide state utility regulators and stakeholder information on options for EV charging policies and retail rate designs and develop guidelines outlining best practices.*** DOE can help to enhance the nationwide visibility of successful state level policies. DOE should facilitate the gathering of best practices and act as a conduit for the distribution of this information among federal, regional, state and local policy makers.

2. ***DOE should analyze the impacts that EV deployment may have on the electric power system (particularly the distribution system) and make recommendations,***

or provide guidelines, on appropriate infrastructure investments. In doing this analysis, the DOE could create a forum for discussion that will allow the various parties in the industry to bring forward proposals for consideration, so that both the DOE and other federal and state policy makers can be informed on the issues, and the best practices for addressing the issues, arising from EV deployment.

3. ***DOE should, to the extent that it is needed, consider promoting the standardization of the physical and information technology/communications interface between EVs and EV charging stations.*** There are a number of forums, including the National Institute of Standards and Technology (NIST), that are addressing this issue but it is of national importance that we achieve standardization in this area as quickly as possible. If, in the assessment of the DOE, the industry is not reaching consensus in this area, the DOE could act as a facilitator to ensure that the appropriate standards emerge.

These recommendations were approved by the Electricity Advisory Committee via electronic voting completed on November 3, 2011.