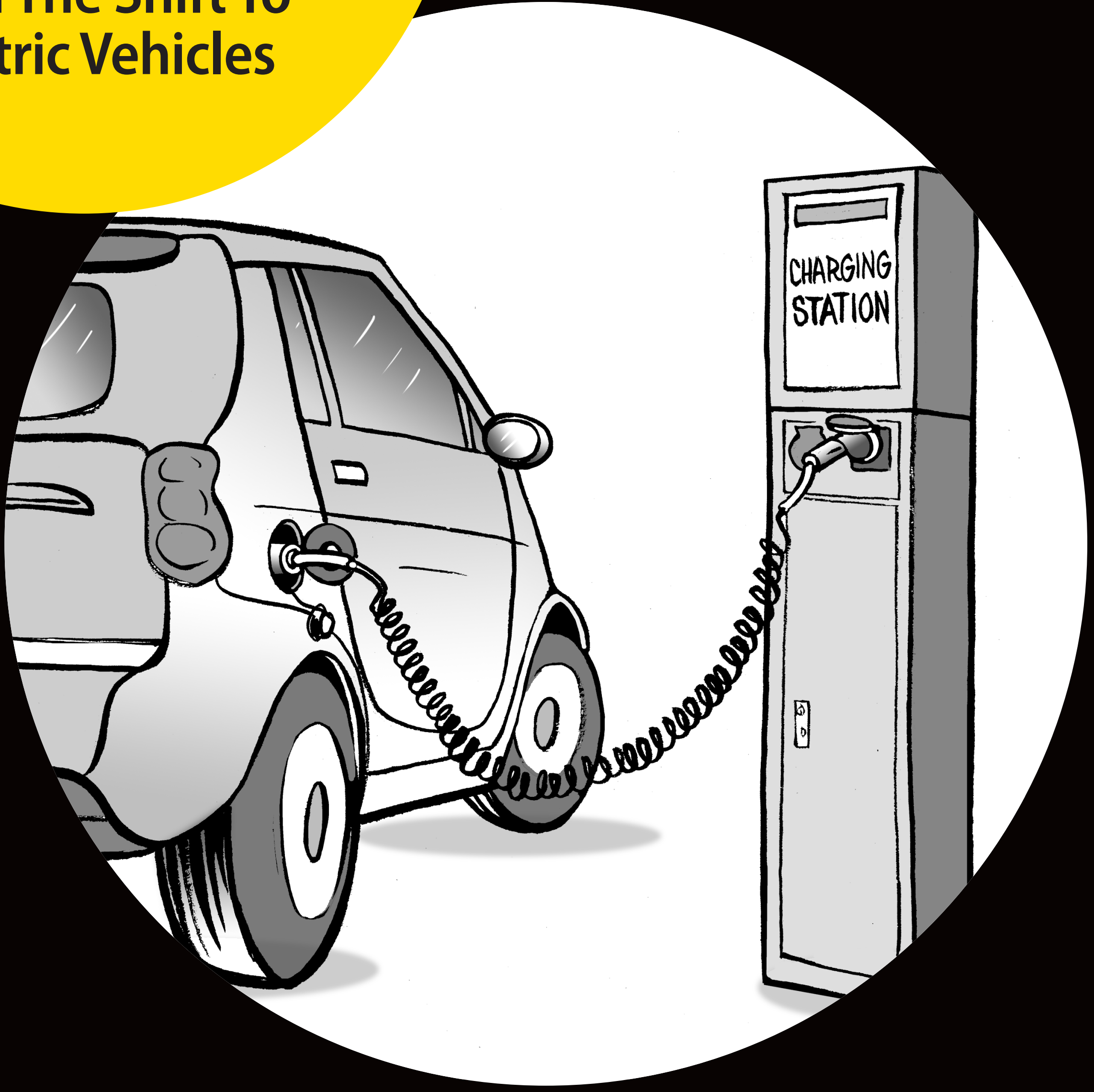
In The Driver's Seat

How Utilities and Consumers Can Benefit From The Shift To Electric Vehicles



Vermont Energy Investment Corporation

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Acronyms

ATR	Alternative Technology Regulation
CAISO	California Independent Service Operator
DOD	(US) Department of Defense
EPA	(US) Environmental Protection Agency
EPRI	Electric Power Research Institute
ESCO	Energy Service Company
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
EVSP	Electric Vehicle Standards Panels
GIV	Grid Integrated Vehicle
ISO	Independent Service Operator
ISO-NE	ISO-New England
kW(h)	Kilowatt (Hour)
MW	Megawatt
NIPSCO	Northern Indiana Public Service Company
OEM	Original Equipment Manufacturers
PG&E	Pacific Gas and Electric
PHEV	Plug-in Hybrid Electric Vehicle
PSE	Puget Sound Electric
RIN	Renewable Identification Number
RFS	Renewable Fuel Standard
RTO	Regional Transmission Organization
SCE	Southern California Edison
SIB	State Infrastructure Bank
TOU	Time-Of-Use
V2G	Vehicle to Grid

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I. Introduction: The Benefits of EVs

The environmental benefits of electric vehicles (EVs) are widely recognized. EVs are seen as a crucial mechanism to reduce North America's dependence on fossil fuels and increase energy security. The large-scale displacement of internal combustion vehicles by EVs would result in sizable public health benefits achieved through improved air quality and reduced noise.

In addition to these often discussed public policy benefits, however, widespread adoption of EVs also represents a source of opportunity for energy utilities. And in a period of rapidly evolving energy systems (increasing amounts of distributed generation, integration of renewables, demand-side resources, and advanced metering infrastructure), it is important to ensure that EVs are part of the discussion. Among the clear benefits for utilities are:

- **Additional revenue for utilities.** EVs are a substantial source of new demand and revenue for utilities. New sources of revenue can lead to increased margins, profitability, and ultimately lower rates. The bulk of EV-induced demand is expected to occur during off-peak hours, filling in nighttime valleys and improving system efficiency.
- **Load management and smoothing net load for cost reduction.** EVs offer new opportunities to implement demand response and peak shaving programs, reducing overall system operating costs.
- **Improved system reliability.** EVs have recognized potential to serve as distributed storage resources during emergency response, as well as the ability to provide ancillary grid services to energy wholesale markets.
- **New business opportunities for utilities and others.** EVs offer new value-added opportunities for the electricity system. System operators and utilities seeking to capture the value added from EVs can engage new or enhanced roles for energy service companies (ESCOs) and aggregators to capture the value.

In addition, displacement of internal combustion vehicles with EVs would result in sizable public health benefits achieved through improved air quality and reduced noise. Proper valuation of the public health factors mentioned previously may also allow them to be incorporated into utility cost-benefit analyses and rate development, and potentially make EVs and/or EV supply equipment (EVSE) eligible for inclusion in utility efficiency programs. It would be through such mechanisms that ratepayer funds could be used to incentivize EVs and EVSE.[1]

Through these considerations, along with the proper rate designs, supporting infrastructure such as charging stations, and support for the development of storage and other new technologies, utilities can help drive the large-scale adoption of EVs — and benefit from it.

1 EVSE, also called charging stations, refers to both residential and away-from-home units that can be used to charge an EV battery. In some cases they may be as simple as a wall outlet. Other units are connected to a broader network with the capability of communicating with the driver, vehicle, and centralized network location.

II. EVs Will Provide Additional Revenue to Utilities

EVs present a substantial new source of demand and revenue for utilities. It is estimated that a comprehensive shift to all EVs would increase average household electricity use by approximately 25 percent. Analysis for the California Public Utilities Commission helps to demonstrate that in that state, EVs will provide new loads and additional revenue for utilities with associated opportunities for increased profitability between periods in which rates are set.[2] Some form of time-of-use (TOU) rate for EVs appears likely to provide the attractive pricing bridge that will encourage greater adoption of the vehicles. The California analysis shows that with TOU rates, both costs to the utility and revenues are expected to be considerably lower than typical uniform usage rates, but under all scenarios, the value of the additional revenue is greater than additional capacity costs. Estimates of the revenue from each EV to utilities by varying rate designs ranged from approximately $2500 to more than $9000.[3] Similarly, Puget Sound Electric (PSE) in Washington State estimates that each EV in its territory will result in a net revenue increase for the utility and is using this increase to help justify the utility's conservation charge for EVSE incentives (discussed further in the next section).

Utility EV and EVSE Incentives

Current federal financial incentives for EVs range from $2500 to $7500, depending on battery size. Additional vehicle incentives are available in 37 states and the District of Columbia.[4] A range of utilities now offer incentives for both EVs and EVSE ranging from $50 to $2500, with new programs launching regularly. Presumably these utilities recognize the enormous financial value that EVs can provide through increased flexible demand: for instance, PSE estimates that each EV will contribute $770 to the utility's margin. In addition, issuing formal incentives provides utilities with the opportunity to track EV and EVSE deployment in their service territories. Although not every vehicle or unit would receive the incentive (and therefore be tracked), the incentive programs should provide an objective gauge of new EV sales and/or EVSE installations. In addition, some utilities require incentive recipients to sign up for TOU rates or permit metering of their EVSE, allowing utilities to gather real-world data on charging behavior. To date, most utility incentives are for EVSE, not EVs. Current utility incentive programs are listed in Table 1 and include:

- PSE is offering incentives for Level 2 home charging stations with the stipulation that recipients allow their charging behavior to be monitored. The incentives and subsequent study are to be funded through a surcharge on the conservation service rider. Use of conservation charges is justified by anticipated efficiency gains of Level 2 charging over Level 1.[5] PSE further justifies this use of ratepayer funds as necessary research to inform planning for EVs. The utility estimates that there are approximately 5000 EVs in PSE territory and is concerned that on-peak charging of these vehicles could drive a need for new generation resources. A clearer understanding of EV charging behavior will determine what mechanisms, if any, are required to ensure that the bulk of EV charging occurs off-peak. As noted previously, PSE analysis indicated that each EV will, at least for the period in which rates are set, contribute $770 to the utility's margin, funds that will ultimately benefit all ratepayers.[6]

2 Of course, increased profitability during periods of load growth will ultimately result in lower rates for price-regulated entities.

3 Energy and Environmental Economics, 2014.

4 NCSL, 2014.

5 Sears et al., 2014.

6 Washington Utilities and Transportation Commission, 2014.

Table 1

Utility EV and EVSE Incentive Programs

Utility or Utility Commission	Incentive for EV or EVSE	Amount
Alabama Power (AL)	Residential EV	$750 (limited to 250 incentives)
Alabama Power (AL)	Commercial EVSE	$500
Austin Energy	EVSE	Up to $1500 (50% cost of equipment and installation)
Central Maine Power (ME)	Commercial EV, Commercial Level 2 EVSE and DC Fast Chargers	$7500 toward EV purchase or lease, $2500 toward EVSE installation
Connexus (MN)	Residential time-of-day meter	$270
Consumers Energy (MI)	Level 2 EVSE	Up to $2500
DTE Energy (MI)	EVSE	Up to $2500
Georgia Power (GA)	Residential Level 2 EVSE	$250
Indiana Michigan Power (MI)	Residential Level 2 EVSE	Up to $2500
JEA (FL)	EV	$500-1000
NIPSCO (IN)	Residential Level 2 EVSE	Up to $1,650
NIPSCO (IN)	Commercial Level 2 EVSE and DC Fast Chargers	Contributions toward equipment, installation, and ChargePoint subscription fees
Orlando Utilities Commission (FL)	Commercial EVSE	Up to $1000
PECO (PA)	EV	$50
Public Service Electric and Gas (NJ)	"Smart" EVSE units supplied to employers with at least five employees committed to commuting via EV	
PSE (WA)	Residential Level 2 EVSE	$500

- Northern Indiana Public Service Company (NIPSCO), an investor-owned utility in Indiana, offers customers the IN-Charge Electric Vehicle Program. IN-Charge works to accelerate EV adoption by reducing the complexity and costs of charging. NIPSCO provides incentives for residential customers to purchase and install Level 2 home charging stations, as well as incentives for businesses and organizations for Level 2 and DC Fast Charging.
- Central Maine Power offers an EV Matching Grant Program, available to local businesses and organizations for EV purchase or lease, or installation of EVSE. Similar to PSE, recipients must provide Central Maine Power with information on charging behavior.
- Two utilities in Michigan (Indiana Michigan Power and DTE Power) offer incentives for EVSE but require that recipients install a separate meter and sign up for an EV-specific TOU rate.
- Georgia Power is investing $12 million in a pilot program to increase the number of EVSEs in the state: a $250 incentive will be available to customers for residential EVSE installation, and the utility will be installing 50 public EVSE in Georgia, both Level 2 and DC Fast Chargers.

In addition, the Edison Electric Institute, the association representing all US investor-owned utilities, has requested that its member utilities commit five percent of annual fleet purchase plans to plug-in vehicles. As of November 2014, more than 70 utilities have committed.[7]

7 Newsroom America, 2014.

III. EVs Will Help Utilities Manage Load and Smooth Net Load for Cost Reduction

EVs present utilities with a relatively flexible and manageable load. If managed properly, they can contribute to reduced system load factors and improved system performance, reducing the average costs of the system by smoothing and shifting loads toward lowest-cost production periods. Among the most important tools to achieve improved performance are EV-specific TOU rates and "smart charging" programs. Smart charging refers collectively to a family of approaches and algorithms that minimize EV charging impact on the grid through controlled and coordinated charging, which stops and starts in response to signals from the grid operator.

Rate Design

Rate design is one mechanism that can be used to mitigate EV impacts on the electric grid and improve utility financial performance. TOU rates can encourage desired load shifts, avoiding increases in peak demand and pushing charging into off-peak hours, filling nighttime valleys, and increasing overall system efficiency. There is also the potential for controlled charging: EV drivers would have the option of signing up for a reduced rate that would give the utility the ability to control the flow of power to the vehicle. This controlled charging could be used not only at the system level, to better manage load variation, but also at the transformer level, to mitigate issues that may arise from clustering of vehicles.

A number of utilities across the nation are implementing EV-specific rates and EV rate pilot projects, including Georgia Power and Light, Pacific Gas and Electric (California), San Diego Gas and Electric, and NV Energy (Nevada). These rates are typically TOU rates that are especially low during off-peak hours. Currently, many utilities offer residential TOU rates but do little to market them, and as a result relatively few customers take advantage of them.[8] But buying an EV means a large load increase for a residential customer, which may create a more compelling financial incentive. Some utilities require customers who access EV incentives to sign up for TOU rates. Dominion North Carolina Power and Dominion Virginia Power are offering residential customers the option to participate in an EV pricing pilot project. This project offers discounted TOU rates and will track what impact the availability of such rates has on charging behavior. Dominion anticipates that growth of the EV market will result in up to 86,000 EVs charging in Virginia by 2020.

The bulk of EV charging takes place at home charging stations, and there is potential that this charging could be clustered during peak hours, to the detriment of the utility's load shape, if drivers plug in immediately upon returning home at the end of the day (between 4 PM and 7 PM). But the implementation of TOU rates has the potential to induce customers to shift this behavior, to the benefit of the grid. The most complete data on charging behavior are available through the EV Project, a US Department of Energy-funded project that has been tracking travel and charging behavior of thousands of EVs in nine states since 2011. Data from this project have shown that in areas with TOU rates, the majority of EV charging occurs during off-peak hours. This was not the case in areas without TOU rates, where EV demand generally peaked in the early evening.[9] Figure 1 shows how TOU rates in San Diego and San Francisco encourage nighttime charging, in contrast to Los Angeles and Washington State, which lack TOU rates.

TOU rates are one way that utilities can encourage EV charging at times when demand on the grid is low.[10] Analyses of the projected impacts of EV charging on regional utilities across the United States have concluded that by having EVs charging during off-peak evening hours, utilities can increase profitability and/or potentially lower electricity average usage costs for customers.[11]

8 Berst, 2014.

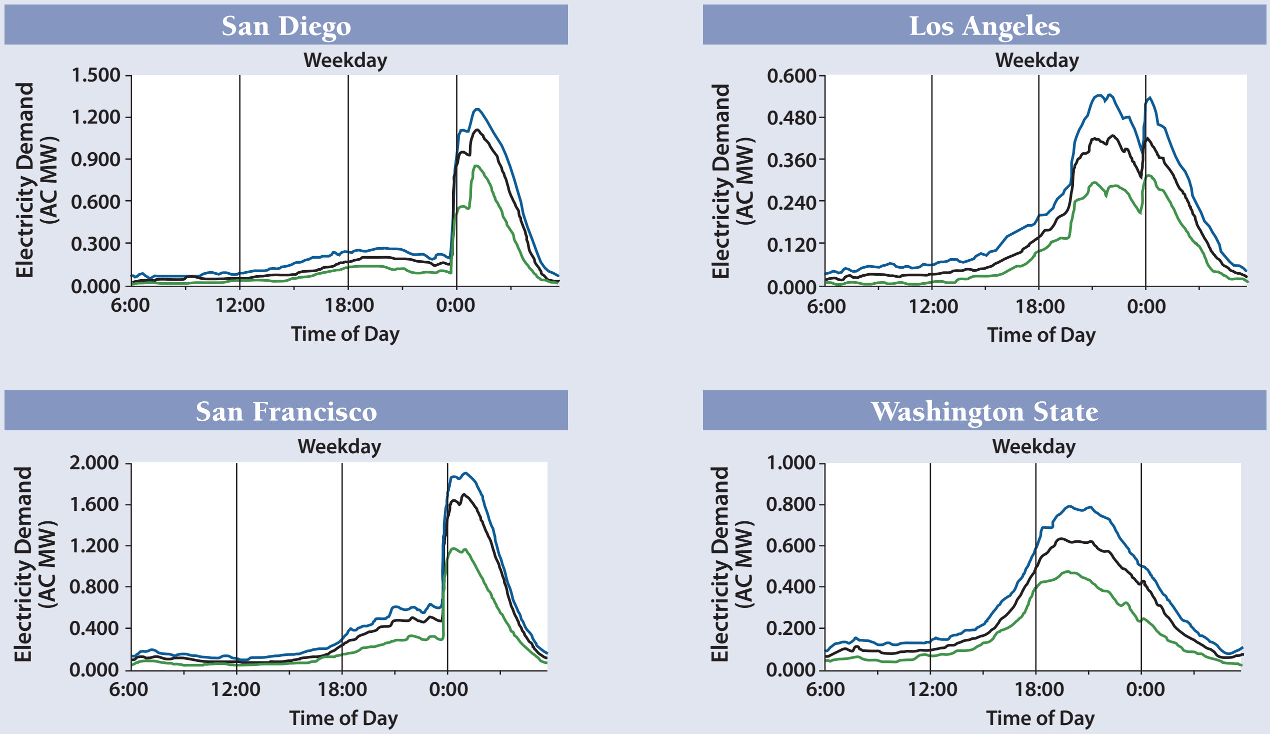
9 Schey et al., 2012. EV Project, 2013.

10 Glazner, 2012; Kintner-Meyer et al, 2007; Parks et al., 2007.

11 Galus et al, 2012; Scott et al., 2007.

Figure 1

EV Project EV Charging Patterns With and Without TOU Rates[12]



Smart Charging

Another option is for the utility to implement technology that allows it to control the charge to an EV. Although EV-specific TOU rates are available in utility service areas throughout the country, smart charging remains largely theoretical. It would require the advanced metering infrastructure (or "smart grid") and a submeter on the EVSE or the vehicle to allow communication between the charger and the power grid. A range of modeling exercises have explored potential charging management schemes to minimize power losses and voltage deviation, while still meeting EV drivers' charging needs.[13] It is through this managed charging that many of the benefits of EVs can be realized — filling in valleys of demand and improving overall system efficiency. One study estimates that smart charging techniques could allow the grid to accommodate EVs in up to 50 percent of households with no grid upgrades needed.[14]

12 EV Project, 2013.

13 For example, Rezaei et al, 2014; Deilami et al., 2011; Kiviluoma & Meibom, 2010.

14 De Hoog et al., 2013.

IV. EVs Can Help System Reliability

At a broad geographic scale, modeling efforts by Pacific Northwest National Laboratory have found current grid infrastructure to be capable of accommodating relatively high penetration rates of plug-in vehicles,[15] although there is some concern around localized clustering of EVs and potential impacts on the electric grid's distribution system.[16] A recent review of utility Integrated Resource Plans found that at most, EVs were predicted to increase load by one to four percent. More commonly, the additional load was assumed to be small enough that it was not quantified but was implicitly captured in the utility's "high demand" Integrated Resource Plan modeling scenario.[17] EVs do, however, have enormous potential to improve system reliability, as distributed generation resources and through provision of ancillary grid services. During emergencies, EV batteries can serve as backup power sources, powering small appliances and lighting via equipment that converts the vehicle's DC power to AC. EV batteries could prove to be an important component of grid resilience, especially for microgrids: grids with the capability of being islanded or functioning independently of the larger power grid.

As EV adoption increases and interaction with the utilities evolves, potential arises to aggregate EVs to serve as energy storage resources, improving system reliability. The charging and discharging of vehicle batteries can be adjusted quickly, making EVs an attractive resource in regulation markets through bidirectional charging of their battery system. Through bidirectional charging, EVs are able to quickly inject and withdraw small amounts of power to and from the grid. EV batteries have a comparative advantage in the ramp rate relative to generation. Batteries can respond almost instantaneously and potentially command a higher value than other resources relied upon for reliability needs.[18]

This same function can also be accomplished to some extent through unidirectional charging by modulating the charge of EVs. Curtailing load (reducing charging) provides the same services as ramping up generation: it provides balance when electricity demand exceeds supply. Vehicles are typically driven fewer than two hours a day, and so are available for recharge and the provision of grid services the remaining 22 hours. The vehicle is in some form of passive parking roughly 16 hours a day, usually at the home or workplace, and available for charging and/or service provision.[19] EVs have the potential to participate in ancillary services markets when they are aggregated as flexible storage devices. Most research to date has focused on EVs serving as resources in the regulation market and most likely this opportunity will have fewer near-term barriers than EV participation in other ancillary services markets.

There are six independent service operators (ISOs) and regional transmission organizations (RTOs) that operate ancillary service markets: California ISO (CAISO), Electric Reliability Council of Texas, Midcontinent ISO, Pennsylvania-New Jersey-Maryland (PJM) Interconnection, New York ISO, and ISO-New England (ISO-NE). There are a number of rules and regulations specific to each ISO/RTO that may facilitate or limit EV participation in regulation markets.[20] For instance, where the minimum resource size

15 Pacific Northwest National Laboratory, 2009.

16 Evidence suggests that the distribution of EVs in communities will not be random but may occur in clusters, correlating with political views, socio-demographic factors, and the presence of other EVs (Aultman-Hall, 2012; Zhu & Liu, 2013). There is some question as to how well the current electricity distribution network will be able to accommodate potential clustering of the additional load resulting from EV charging. Hilshey et al., 2013; Shao et al., 2009; Sullivan, 2009.

17 Sears & Glitman, 2013.

18 MJ Bradley, 2013.

19 MJ Bradley, 2013.

20 Macdonald et al., 2012.

Table 2

Estimated Number of EVs Required to Provide 1-MW Resource Size[23]

Vehicles	Connection Level	Power Level (kW)	Number of EVs Needed
Average EVs currently on the road	Level 1	1.4	715
Average EVs currently on the road	Level 2	3.6	278
Higher power EVs becoming available	Level 2	6.6	152
EVs retrofitted with more powerful charger	Level 2	15	67
Electric school buses (or other large vehicles) retrofitted with high power charger	DC Fast Charging	60	17

required by a market is small, there will be fewer logistical challenges to aggregating the required number of EVs to participate as a single resource. Minimum resource sizes for the reserves and regulation markets range among the ISOs and RTOs from 0.1 megawatt (MW) to 1 MW.[21] A number of pilot projects on EV regulation service are underway across the country and internationally and are described below.

ISO-NE Alternative Technology Regulation Pilot Program

Traditionally, regulation services have been provided by natural gas generators and storage hydro resources. In 2007, ISO-NE established an Alternative Technology Regulation (ATR) Pilot Program to allow alternative technologies (such as batteries, flywheels, and demand response) to provide regulation services. A primary goal of the pilot was to evaluate the economic feasibility of alternative technologies in the regulation market. Under the pilot program, the minimum resource size required of participants bidding into the regulation market was reduced from 1 MW to 0.1 MW.[22]

The minimum resource size for participation in the ISO-NE regulation markets requires aggregation of multiple EVs, even at the reduced minimum size required under the ATR Pilot. For example, at an average power rating for the Chevrolet Volt of 3.3 kilowatts (kW), it would take more than 30 vehicles to provide the minimum resource size under this pilot, and an aggregation of more than 300 in the regular ISO-NE regulation market. The number of vehicles needed to aggregate a 0.1- or 1-MW resource varies by numerous factors, but the most important is the power level. The power level is determined by either the charger (onboard or offboard) or the EVSE connection, whichever is weaker. Table 2 illustrates this variation by multiple vehicle types and connection levels.

Because many factors (such as vehicle availability and state of charge) impact the number of vehicles needed, this table is only intended to show the magnitude and variation of aggregation needs. The number of vehicles needed to meet a 1-MW minimum resource size is an important determinant of the value of the service: it determines the number of vehicles splitting the benefits. Additionally, the level of participation of each vehicle is important. If vehicles are not participating in the market 24 hours per day, either more vehicles are needed to maintain a constant bid, or the resource cannot be bid into the market 24 hours per day. ISO-NE is in the process of redesigning aspects of their regulation market, so the feasibility of EV participation in this market may change in coming years.

ISO-NE Demand Response Pilot Program

Alongside the ATR Pilot Program, ISO-NE implemented a Demand Response Pilot Program to assess the participation of demand response in the regulation and spinning reserves market. The purpose of this pilot was to evaluate the feasibility of including resources less than 5 MW in the reserves market (outside of this pilot, ISO-NE does not allow demand response resources to participate in the reserves market). This pilot was conducted between 2006 and 2010. Overall, the reliability of the Demand Response Pilot Program resources was found to be less than that of generation resources.[24]

21 Macdonald et al., 2012.

22 ISO-NE, 2008.

23 Morse and Glitman, 2014.

24 KEMA, 2010.

EVs have the potential to participate in demand response programs through one-way controlled charging; however, their ability to participate in wholesale markets will be limited by minimum resource sizes. For instance, CAISO requires that demand response resources be at least 0.1 MW for participation in wholesale markets,[25] but participation in the CAISO spinning reserves market requires a minimum resource size of 0.5 MW.

PJM Advanced Technology Pilot Program

PJM's program allows new resources to participate in wholesale markets, regardless of capacity size. There are three EV initiatives underway in the pilot:

1. **Smart Charging Demonstration.** A collaboration between BMW and North American utilities, this demonstration project will explore TOU rates and EV demand response capabilities.
2. **General Motors OnStar.** OnStar is piloting technology to integrate renewable energy supply and EV charging demand. OnStar receives a signal from PJM indicating availability of renewable energy on the grid, and then uses that signal to manage EV charging to match availability.
3. **NRG, University of Delaware Partnership eV2g.** Under this project, NRG and the University of Delaware are aggregating EVs and bidding into the PJM regulation market (described further in the section on Grid-Interactive Vehicle Demonstration Projects).

EV Demand Response Demonstration Program, Victoria, Australia

In 2013 the Australian province of Victoria implemented a four-week EV demand response program with eight households. The trial used advanced metering infrastructure in conjunction with a device attached to each household's EVSE that allowed communication between the driver's smartphone and computer, the EVSE unit, and the utility network, as well as remote control of the flow of energy from the utility to the EVSE units. Participants were notified when a demand response event was occurring and received $5 for each time they opted to allow the utility to halt charging duration of the event. Overall the trial has been touted as a success — communications between the EVSE, the utility, and the customer were generally smooth and participants were satisfied with the program overall.

In addition, the AMI and EVSE metering facilitated off-peak charging such that 56 percent of charging occurred off-peak. Although this project does not address the cost-effectiveness of EV demand response programs, it does demonstrate that EVs can be valuable participants in such a program. DiUS, the technology company that designed the EVSE device used in the project estimates that Victorian EV drivers could save approximately $250 annually through participation in a demand response program (about half of their annual charging costs). A post-study survey found that generally customers were accepting of external charge management, assuming it was accompanied by adequate information and financial benefit, and they were able to maintain some level of control over vehicle charging.

California Vehicle to Grid Roadmap

CAISO led the completion of a Vehicle to Grid Roadmap for California, in partnership with the California Public Utilities Commission, the California Air Resources Board, the California Energy Commission, and the Governor's Office. Broadly, the plan is working toward a mutually beneficial system between EVs and the state's power grid. As part of this roadmap, stakeholders are identifying grid-integrated vehicle (GIV) eligible utility programs and wholesale markets, as well as development of required policies and technology.[26]

GIV Regulation and Policy Needs

To enable a grid-interactive vehicle system to move forward in which EVs are serving as resources in wholesale markets, regulators, ISO/RTOs, utilities, and other stakeholders will need to make decisions about how these systems should be structured to clarify ownership and participation. A clearly defined program in which customers understand what they are signing up for and how they benefit from participating will be necessary. To date, no GIV or demand response pilot projects have explicitly addressed consumer protections to ensure that the asset (the vehicle, owned by the customer) is adequately compensated for its use and that the consumer is adequately informed about program details. Research and

25 CAISO, 2011.

26 A primary goal of the GIV roadmap is to better define how EVs can provide grid services and how these services will be valued and compensated. Additionally, the roadmap aims to work toward standardization of EV and GIV technologies in order to facilitate widespread vehicle connectivity. Addressing these questions will reduce uncertainty for market players and assist stakeholders in development of business models.

pilot testing will also be critical in determining interest and level of participation. Many of the regulation and policy needs for EVs to provide regulation services are similar to those needed for demand-side management and utility-level vehicle integration.

Other Opportunities - Forward Capacity Markets

Both PJM and ISO-NE allow efficiency and demand resources to participate in their capacity markets, also called forward capacity markets.[27] In these markets, resources (either generating or demand-side) are procured for future use. There may be opportunities for EVs to sell their storage resources in these markets. Guarantees are auctioned for the provision of grid resources to meet peak demand anticipated up to three years in advance. Future income is then assured, providing investment security so that these grid resources can be constructed in time to meet the need. Demand-side resources, including energy efficiency, demand response, and distributed generation, are eligible to participate in forward capacity markets, along with generation.[28] In these cases, guarantees are bid into the forward capacity market to reduce peak demand at a given point in the future. It is feasible that a third-party aggregator could coordinate the use of EVs as storage for distributed renewable resources and enter bids for the guarantee of EV storage in the form of distributed generation. Under such a scenario, a guarantee of future revenues could support the establishment of the aggregation system and the necessary technology, and any incremental revenue from the market can be passed on to subscribers as compensation.

In a period of rapidly evolving energy systems (increasing amounts of distributed generation, integration of renewables, demand-side resources, advanced metering infrastructure), it is important to ensure that EVs are part of the discussion. During this time of rapid change, it is difficult to determine how energy market structures may shift, but it is likely that increasing renewable penetration of the system will increase demand for storage technologies. As EV penetration rates increase, an aggregated system of EV battery storage could have significant value and benefit. Technology, standards, and regulation are all needed to enable and encourage the widespread adoption of EVs, but a vision for a sustainable, renewably sourced electric grid in which EVs serve as valuable storage resources fully integrated into the grid's wholesale markets is possible. Demonstration and pilot projects around the country are beginning to show the first steps in this direction.

Grid-Interactive Vehicle Demonstration Projects

As described earlier, the potential grid services that EVs can provide is enormous, although largely untapped to date. There are, however, a variety of vehicle to grid (V2G) demonstration projects underway across the country.

University of Delaware

The University of Delaware pioneered one of the nation's first V2G demonstration projects in 2007. In 2013 the project became a participant in the PJM regulation market. The vehicles began providing regulation services by participating in the hour-ahead regulation market with a 100-kW resource of 15 vehicles aggregated together. They participated for the month of March, and received approximately $5 per day per car.[29] The additional vehicle electronics required for V2G costs approximately $400 per vehicle, considerably less than the $1800 per year regulation payment.[30] Both BMW and Honda have produced EVs with bidirectional chargers.[31]

Department of Defense

As one of the country's largest consumers of energy, the US Department of Defense (DOD) has been tasked with reducing dependence on foreign oil and greenhouse gas emissions. The DOD is investing $17 million into EV research toward this goal, including pilot projects to evaluate the economic benefits of providing ancillary services to the grid.[32]

V2G Demonstrations at Four Air Force and Army Bases

The DOD will be testing 72 V2G-equipped vehicles at four pilot locations: LA Air Force Base (CA), Joint Base Andrews (MD), Fort Hood Army Base (TX), and Joint Base McGuire-Dix-Lakehurst (NJ).[33]

LA Air Force Base will focus specifically on serving as a

27 Fetter et al, 2012.

28 Gottstein and Schwartz, 2010.

29 Showtimes, 2013.

30 Wald, 2013.

31 Gage, 2013; Lienert, 2013.

32 Marnary, 2013; Kenner, 2014.

33 Gorguinpour, 2013.

resource in CAISO Regulation Up and Regulation Down markets. In November 2014, the base unveiled an all plug-in fleet of 42 vehicles.[34] Three technologies have been developed and are being tested to form the Plug-in EV (PEV) Fleet Optimization Model:

1. A software suite is providing aggregation and fleet management of charging and discharging;
2. OpenADR is the technology being used for communication between CAISO and the base; and
3. A near real-time optimization tool is being used to evaluate energy and ancillary service prices to ideally schedule services.

These technologies will be used to coordinate the complex task of optimally scheduling vehicles, taking into account vehicle needs for transportation, energy costs, and ancillary service market prices simultaneously.

The LA Air Force Base has faced challenges being a retail customer in Southern California Edison (SCE) territory while simultaneously serving as a resource in the CAISO wholesale market, highlighting the need for regulatory and policy coordination enabling GIV systems. This pilot project, while laying the groundwork for future projects in CAISO, identifies the need for pilot projects in other regional grids to work through similar issues.[35]

Fort Carson Army Post Pilot Project

The DOD is also participating in a pilot project at Fort Carson Army Post in Colorado Springs, CO, integrating V2G technology, renewables, and microgrid technology. This project is part of the Smart Power Infrastructure Demonstration for Energy Reliability and Security project, led by the US Army Corps of Engineers Omaha District.[36] A goal of the project is to increase security by developing a microgrid capable of being completely disconnected from the local grid.[37] Safety throughout the system, including for electric repair crews, is critical when connecting and disconnecting from the utility grid.[38] Lessons learned from grid islanding, especially with regard to safety, will be applicable to vehicle-to-building systems.

In addition to microgrid support and providing backup power, at Fort Carson a fleet of bidirectional EVs and EVSE are being used for regulation and peak shaving when not in use for transportation. At 60-kW charge and discharge, the Smart Power Infrastructure Demonstration for Energy Reliability and Security installation is the most powerful V2G demonstration to date using five bidirectional DC fast chargers.[39] At Fort Carson, the EVSE are aggregated, rather than the vehicles. Aggregation provides a single point of contact to the grid and receives signals from the grid operator. The control intelligence and the inverter (charger) are located in the supply equipment. The aggregation software manages the schedules of the vehicles, ensures they are ready when needed, but sends dispatch instructions to the EVSE rather than to the vehicles. Software developed by MIT Lincoln Labs determines optimal times for using renewables and EVs for peak shaving and sends instructions to the microgrid controller to be coordinated with the aggregator.[40]

US Navy V2G Project at China Lake, CA

The US Navy has implemented a V2G project in China Lake, CA. The California Public Utility Commission has approved a pilot tariff for participation of V2G load in the CAISO wholesale market in SCE territory.[41] Other planned or in-progress V2G pilot projects are listed in Table 3.

EPRI Utility-Automotive OEM Smart Charging Collaborative

The Electric Power Research Institute (EPRI) is leading the Utility-Automotive OEM Smart Charging Collaborative, in collaboration with nine automakers[42] and a growing number of utilities.[43] The goal of this collaborative is

34 Military.com, 2014.

35 Marnay et al., 2013.

36 Crowe, 2013.

37 Mitchem, 2013.

38 Massie et al., 2013.

39 Crowe, 2013; Mitchem, 2013a.

40 Southwest Research Institute, 2013.

41 CA V2G Roadmap.

42 Auto manufacturers participating in this project include Honda, BMW, Chrysler, Ford, General Motors, Mercedes-Benz, Mitsubishi, and Toyota.

43 Utilities and RTOs participating in this project include Austin Energy, CenterPoint Energy, Commonwealth Edison, Con Edison, CPS Energy, DTE Energy, Duke Energy, Manitoba Hydro, Northeast Utilities, Pacific Gas & Electric Company, PJM, Sacramento Municipal Utility District, San Diego Gas & Electric, Southern Company, Southern California Edison, and the Tennessee Valley Authority.

Table 3

Other Planned or In-Progress V2G Pilot Projects[44]

Partners	Timeframe	Project
Pacific Gas and Electric (PG&E), Honda IBM	2012—2013	Cloud-based PEV Communication Pilot: explore EVs' ability to respond to charging instructions based on grid conditions
PG&E	2013—2014	Demand response EV pilot project: determine optimal business models and customer engagement tactics for EV demand response program; encourage a market where electric vehicle standards panels (EVSPs), original equipment manufacturers (OEMs), and aggregators to provide EV demand response programs
Plug-in Hybrid and Electric Vehicle Research Center, California Energy Commission	2013	ESmart EV Charging Demonstration Project: assess value of V2G systems to California's electric grid
PG&E	2013—2015	Fleet V2G EPIC Pilot — explore use of plug-in hybrid electric vehicles (PHEVs) to improve grid reliability
SCE	—	Workplace Charging Demand Response Pilot — SCE is installing charging stations at its facilities for commuting employees and using demand response to manage loads

to develop an open platform that integrates EVs with smart grid technology and facilitates "demand charging." Demand charging (also referred to as controlled charging) allows communication between utilities and EVs so that charging can be cut back or turned off during times of peak electricity demand, when prices (and often environmental costs) are highest. Charging can then be ramped up when demand is low. Demand charging would allow the utility to control the flow of energy to vehicles. In addition, a goal of this platform is to eventually allow bidirectional flow of energy between vehicles and the grid.

EPRI anticipates that this open platform will eventually allow EVs to participate in not only demand response programs (one way flow of energy, utility-controlled flow of electricity), but also in wholesale markets such as the ancillary services market (delivery of bidirectional services, EVs serving as energy storage devices). Standardization and coordination among automakers, utilities, and RTOs in development of the software should increase flexibility and ease for EV drivers to participate in smart charging efforts. The first demonstration of the software platform occurred in October 2014, at the Sacramento Municipal Utility District, involving eight vehicles and demonstrating demand response and load curtailment capabilities.[45]

GIV Facilitates Greater Renewable Power Generation

An electric grid with high levels of renewable resources will require significant storage assets for balancing, shifting, and stabilization: EVs can play this role through technology. When EVs are fully integrated into the power system and acting as flexible storage resources, they can contribute to a more reliable, resilient, and sustainable grid in which generation and demand are increasingly decoupled or free to move with some freedom and kept in balance by available EV battery storage. The intermittent nature of renewable energy resources like wind or solar photovoltaic power present obstacles to full displacement of conventional energy generation sources like coal- or gas-fired turbine generators.[46] A proposed solution to the intermittency problem has been provision of energy storage such as pumped hydroelectricity, flywheels, thermal storage, and electrochemical batteries. Regardless of the method, when renewable energy production surpasses demand at a given moment, excess electricity is stored and made available later when renewable energy generation is lower than demand, effectively decoupling demand and generation.[47]

As battery technology evolves and EVs' market share grows, there is an opportunity to overcome energy storage

44 CA V2G Roadmap.

45 EPRI, 2014.

46 Kempton & Tomic, 2005.

47 Borneo, 2013.

barriers of high capital and operational costs.[48] Currently the primary use of an EV is as a mobility resource, but their batteries could serve a secondary role as electrical storage. It may be possible at a later date to consider the electrical storage as the primary use and the mobility resources of an EV as a secondary role. When aggregated at scale, a fleet or community of EVs while plugged in and not in use for mobility may serve as a balancing resource, compensating for the intermittency of renewable energy sources. In fact, when controlled charging is used to manage EV charging schedules, the estimated cost of integrating these vehicles is cut in half and the magnitude of savings is higher with a higher penetration of wind in the system.[49]

48 Denholm et al., 2013.

49 Weis et al, 2014.

V. EVs Will Give Rise to New Business Opportunities

Utility-Deployed EVSE

Electric utilities have begun deploying their own EVSE units. There is a strong business case to be made for such deployment: over time, EVSE revenues are expected to exceed costs that will flow back to customers to reduce rates. In 2014, Green Mountain Power, Vermont's largest utility, deployed DC Fast Chargers and Level 2 EVSE throughout the state. In 2015 and 2016, these efforts will be expanded in partnership with the eVgo NRG initiative, which is a subscription EV charging plan currently available in California, Georgia, Illinois, Maryland, Tennessee, Texas, Virginia, and the District of Columbia. Austin Energy also offers a subscription service at the 170 public charging stations the utility operates in central Texas.

Analysis by Silver Spring Networks, a smart grid technology company, estimates that utility-owned EVSE can yield substantial benefits to utilities and may ultimately be more cost-effective than a customer-owned model. Utility-deployed EVSE allows customers to assign charging preferences but permits the utility some control over load scheduling in exchange for lower EV-specific rates. In the absence of such controls, utilities will have more difficulty tracking EVSE units as they are deployed and managing additional load.[50]

The California Public Utility Commission is currently considering whether or not the state's utilities will be permitted to deploy their own charging stations. They were banned from doing so in 2011 to ensure competition in the young EV charging market. SCE and San Diego Gas and Electric have proposed investing a combined $500 million in 30,000 charging stations.[51]

It's estimated that about 2000 of the 8000+ public EVSE are free to use (Plugincars.com 2014).[52] Many others are linked into networks such as ChargePoint, eVgo, and the Aerovironment AV Subscription Network. eVgo and Aerovironment networks offer unlimited charging plans with upfront monthly fees as well as other pay-as-you-go options. ChargePoint has no fees associated with subscription, and use fees are set by each charging station owner independently. In order to charge users a fee, a station generally needs to be linked into a larger network.

Initially many public charging stations were free to users, such as the stations available to EV project participants. Fees are becoming increasingly common, often based on the amount of time a vehicle is plugged in (or drawing power), rather than the actual amount of power used. The subscription services available through the eVgo network are generally based on time rather than power drawn. Ultimately the amount of power drawn from the grid will depend on not just the amount of time that a vehicle is plugged in and drawing power, but the size of the vehicle charger. In many states, only utilities are permitted to sell electricity, but a fee structure based on time works around such limitations. A recent ruling by the Pennsylvania Public Utility Commission stated that non-utilities could charge consumers for electricity on a per-kWh basis at EVSE, as long as the price of the electricity is not marked up. Consumer protections are needed at public EVSE to ensure that the cost of charging is prominently displayed and easily understood. Along similar lines, there may eventually be a role for government weights and measures offices to verify the products being sold at public EVSE (generally electricity with the potential to contain grid service components) to ensure standardization among units and clarity of communication with customers.

Renewable Fuel Standard Biogas to Electricity Pathway

The federal Renewable Fuel Standard (RFS) ensures that a minimum amount of renewable transportation fuel is in use in the United States, and requires distributors and refiners of petroleum-based fuels to purchase renewable

50 Silver Spring Networks, 2010.

51 Smart Grid News, 2014.

52 Plugincars.com, 2014?

fuel credits. Traditionally the RFS has applied to liquid fuels, such as ethanol and biodiesel, and biogas. In July 2014, the US Environmental Protection Agency (EPA) approved the first renewable electricity pathway under the RFS. Under this pathway, electricity that is generated from approved sources of biogas (landfill methane, agricultural anaerobic digestion, and municipal wastewater treatment facilities) and used to power EVs is eligible to generate renewable fuel credits.[53] These credits are referred to as Renewable Identification Numbers, or RINs, and are a tradable commodity. At the close of 2013, the RINs market was valued at just under $1 billion.[54]

The biogas to electricity pathway provides utilities and biogas producers with a new revenue stream: production and sale of RINs. In the United States, biogas production from agricultural digesters alone was estimated be more than 300 million kWh annually in 2009,[55] enough to power approximately 100,000 all-electric vehicles. Estimated biogas potential in the United States is 41 billion kWh annually,[56] enough to power more than 13.5 million all-electric vehicles.[57] The nature and variety of revenue-sharing agreements that will develop among utilities, EV owners, and biogas producers are yet to be determined. Generally it is assumed that the utility supplying the electricity to EVs will own the RINs, although this may not always be the case. There is potential that the RINs could also be owned by charging station owners. These ownership models will develop with time. At present there is work to be done informing utility and biogas producers about this opportunity.

Sale of RINs would require registration with the EPA and subsequent verification that the electricity being produced meets the criteria set under the RFS and that the electricity is ultimately being used in transportation. In cases where the biogas-generated electricity is linked in with the greater electric grid, metering can be used to determine the proportion of electricity that is RFS-eligible (i.e., what proportion is renewably generated, and of that, what proportion is used to power transportation). The additional revenue stream provided by RFS credits will help to make EVs more profitable to utilities and charging station owners, providing market incentives to grow EV adoption and available charging infrastructure. At current rates of EV adoption in most of the country, sale of RINs is most likely not a cost-effective option after considering administration and verification fees, but as EV penetration grows, so does the potential for utilities to generate RINs in bulk and participate in this market.

Innovative Financing for EV and EVSE Deployment: State Infrastructure Banks and Social Impact Bonds

Financing EVSE deployment may be available through state infrastructure banks (SIBs). Since 1995, 33 states have established such banks, and their total capital is more than $661 million. A SIB, much like a private bank, can offer a range of loans and credit assistance enhancement products to public and private sponsors of eligible projects. Public EVSE is recognized as a SIB-eligible project type in federal transportation legislation, although few states, with the exception of Vermont, are promoting this use of SIB financing.[58,59] In Washington, establishment of an EV infrastructure bank has been proposed. Under this model, EV registration fees would be used to fund EVSE deployment throughout the state.[60]

Another source of financing for EVs may be available through social impact bonds. Under these bond agreements, a government agency (or in theory, any entity) sets a clear and measurable goal and agrees to pay an outside organization (the intermediary) only if the organization achieves the desired outcome. Working capital is provided by outside investors and a third-party evaluator determines success of the project. If the project is successful, the government pays the intermediary, who in

53 EPA, 2014a.

54 Irwin, 2013.

55 EPA, 2010.

56 EPA, 2014b.

57 Assumes each EV uses approximately 2700 kWh annually.

58 Federal Highway Administration Innovative Program Delivery: State Infrastructure Banks. Available at: http://www.fhwa.dot.gov/ipd/finance/tools_programs/federal_credit_assistance/sibs/qualified_projects.aspx. See also discussion of CMAQ funds. Available at: https://www.law.cornell.edu/uscode/text/23/149

59 See VEDA Financing Options. Available at: http://www.veda.org/financing-options/other-financing-option/state-infrastructure-bank-program/

60 State of Washington Senate Bill 5444. Available at: http://app.leg.wa.gov/documents/billdocs/2015-16/Htm/Bills/Senate%20Bills/5444.htm

turn pays back the project investors, with a return. If the goal is not achieved, the investors are not repaid. Generally, social impact bonds are considered best suited for projects in which outcomes and benefits can be clearly defined and measured and ample evidence exists demonstrating the success of previous similar initiatives. To date, social impact bonds have been used to fund early childhood education programs and programs to reduce recidivism among nonviolent and juvenile offenders.

With regard to EVs, there is a large body of research demonstrating the health impacts and costs of exposure to the tailpipe emissions of conventional internal combustion engine vehicles (ranging from respiratory ailments to developmental neurologic damage).[61] There is the potential for this research to form the basis of a social impact bond to promote deployment of EVs and EVSE, especially in areas plagued by poor air quality, such as parts of southern California, Salt Lake City, and New York City. Achieving markedly improved air quality and the associated health benefits through EV and EVSE deployment may require additional research and data collection owing to the relative novelty of EV technology. A grant-to-social-impact-bond model is underway in Fresno, California, to demonstrate the value of preventive health care in reducing asthma-related emergencies among children. The grant portion will be used to fund data collection efforts before the effort is scaled up to a social impact bond. A similar model could work for EVs.

New Business Opportunities for Utilities, Aggregators, ESCOS, and Others

EVs offer considerable potential to provide new, or substantially more, value-added services to the distribution network and to the bulk transmission system. The storage capabilities in batteries and driving patterns of owners mean that the batteries will typically be available for 22 hours out of each day (when the vehicle is parked at home or near work). The batteries in EVs offer the potential to deliver a wide range of demand-side services capable of delivering load shifting, capacity services, and balancing services. Because they are relatively small loads spread through the distribution system, they offer considerable potential for a targeted distribution system (e.g., stressed distribution transformers, circuits, or substations), or to be aggregated to deliver upstream grid services to system operators en masse to provide energy, reserves, or balancing services.

The utilities in these circumstances can play the role of the market maker, or central buyer of needed distributed storage and working with ESCOs or third-party aggregators to purchase services, or they can play the role of the market agent or actor that aggregates customer EV loads and sells the services on a bilateral or bid-in basis to the grid operators, potentially in competition with other utilities and third-party aggregators.

The role that third-parties could play could even extend to a role for EV manufacturers.[62] Vehicle manufacturers assuming the role of third-party agents or aggregators of value-added services could provide sizable discounts on EVs at the time of sale or lease in exchange for some measure of control over the vehicle recharging. Recharging could then not only meet the customer's needs to have a fully charged vehicle in a timely manner, but could address concerns associated with the manufacturer's own warranty specifications. The new business model for EV manufacturers could find welcome partners in utilities and system operators that would benefit from the aggregated delivery of local distribution capacity and ancillary services, among others.

Another category of services that is emerging is associated with public charging. Today only about three-quarters of public EV charging stations require a fee for service, usually based on the amount of time used for the charge. But the business model for these situations will vary. In the near term, many of these involve the commitment of government and utilities to help move the market and reduce range anxiety — drivers' fear that all-electric vehicles will run out of charge before they can get to a station. Over time, there will likely evolve a diversity of models, including free charging at restaurants and retail stores as a way of attracting desired customers; situations involving some form of payment for service; and the model of automotive manufacturers such as Tesla, which uses its network of charging stations both to reduce range anxiety and as a marketing tool to encourage the sale of vehicles. Utilities will find that widespread availability of stations can reduce range anxiety, and so encourage growth of electricity loads associated with new vehicle sales. Utilities might also find that these stations provide complementary sales of electricity, allowing customers the flexibility to recharge their vehicles at home or work, whether or not the workplace exists in the same service territory as their home.

61 Calderon-Garciduenas et al, 2014; Volk et al., 2013.

62 Moskovitz, 2014.

Encouraging a diversity of market actors may help grow the market for EVs and improve the sales and financial performance of electric utilities.

Public charging stations may also provide a mechanism for providing services upstream to the utility itself, to the grid operator, or through appropriate use of middlemen (assuming customers accept these arrangements and assuming the delivery can be done in ways that do not adversely affect the warranties and performance of vehicle batteries.) As noted earlier, the vehicle recharging, whether at home or through a public recharging station, can be used in conjunction with federal RFS to create renewable fuel credits.

The Role of Government and Other Non-Utility EV and EVSE Incentives

The most widely available EV incentive program is the federal tax credit available for purchase and lease of new EVs. There are clear environmental, energy security, and public health benefits of EVs, however, they remain financially out of reach for many consumers, despite competitive leasing deals. An aggressive campaign to incentivize these vehicles will be crucial to overcoming the initial financial hurdle (that will eventually give way to much cheaper operating and fuel expenses). In addition, EVs will become accessible to a wider range of people once they enter the used-car market. In 2014, 42 million used cars were sold compared to 16.5 million new cars. The costs and benefits of EVs can be divided into costs to the consumer, the utility, and society. Cost-benefit analysis suggests that in many cases, EVs are the cheapest option overall when accounting for all of these costs.[63] However, many of the benefits that show that EVs are less costly to society than a conventional vehicle, such as climate and health impacts of emissions, are not felt by individual consumers. Thus, there is a case to be made to incentivize EVs to promote this technology that ultimately benefits all of us through improved health and reduced climate impacts.

Research by the International Council on Clean Transportation[64] concludes that state EV incentives have had significant impacts on EV sales. States with some of the largest available incentives (California, Georgia, Hawaii, and Washington) also have EV sales shares two to four times the national average. However, this study was not able to account for how availability of EVs in given locations impacts adoption. No entity is tasked with tracking EV availability at dealerships nationwide and the lack of availability is presumably a serious impediment to adoption in some areas.

A survey of Norwegian EV owners found that incentives were an "important" or "very important" consideration for 65 percent of respondents when they decided to purchase an EV. In Norway, incentives may include purchase incentives, tax exemptions, free tolls and parking, and reduced ferry fares. Non-purchase and tax exemption incentives are estimated to be worth more than $1000 annually.[65] In contrast, another study[66] found only a weak relationship between incentive policies and hybrid vehicle (non-plug-in) sales. Hybrid sales *were* strongly correlated with high gasoline prices. Presumably the effectiveness of incentives will vary (depending on vehicle purchase price, incentive size, and gasoline prices, among other factors), but given the relatively high purchase price of EVs, generous incentive programs for new and used vehicles will be crucial to the widespread adoption among middle and lower income households.

The Vermont coalition Drive Electric Vermont piloted the nation's first upstream EV incentives program in the summer of 2014. Under this program, participating dealerships received a $200 incentive from Drive Electric Vermont for each plug-in vehicle sold. In addition, $500 purchase incentives were available to customers at time of purchase rather than as a rebate or tax credit. This incentive

Table 4

Financial and Non-Financial EV Incentives

Financial Incentives	Non-Financial Incentives
Tax credits	High-occupancy vehicle lane access
Purchase incentives	Free tolls
Tax exemptions	Reduced parking fees
Reduced EV-specific electricity rates	Reduced ferry fares
Upstream incentives for auto dealers	

63 Sears & Glitman, 2014.

64 ICCT, 2014.

65 Figenbaum & Kolbenstvedt, 2013.

66 Diamond, 2009

reduced the monthly lease price by $20 in many cases.

An alternative approach to incentivizing vehicles is to incentivize EV charging stations. The efficacy of this approach has not yet been rigorously assessed, although lack of away-from-home charging stations is a commonly cited barrier to EV adoption.[67] For instance, a survey of EV awareness among Vermonters found that more than 90 percent of respondents found the lack of public charging stations to be a "very important" or "important" barrier to their own decision whether to purchase an EV.[68] Incentive programs for public/commercial charging stations may thus be an important strategy to increasing rates of EV adoption and increasing range confidence among consumers. There are a variety of such incentives already available across the country, including from utilities (see Table 2). Future research may consider evaluating the effectiveness of these incentives through survey techniques and local trends in EV adoption.

Conclusions

Widespread deployment of EVs offers a wide range of benefits to electric energy utilities. As EV adoption grows and more EVSE are installed, these benefits will become more tangible and easily quantified; however, there will also be an increased need for planning dedicated to accommodating EV demand so that these benefits are maximized. There are clear policy and regulatory gaps in the EV landscape that will need to be addressed before many of the grid reliability benefits of EV demand response and vehicle-grid integration can be realized on a large scale. Utilities can play a vital role facilitating uptake of EVs through spearheading and incentivizing EVSE deployment and integrating EVs and EV grid services into utility planning processes.

67 Axsen & Kurani, 2013; Traut et al., 2012.

68 VEIC, 2014.

References

Aultman-Hall, et al. (2012). *Travel Demand and Charging Capacity for Electric Vehicles in Rural States.* Transportation Research Record.

Axsen & Kurani. (2013). *Hybrid, Plug-In or Electric — What Kind of Electric Vehicles Do Consumers Want?* Energy Policy.

Berst. (2014). *The Tipping Point for Time-Of-Use Rates?* Available at: http://www.smartgridnews.com/artman/publish/Business_Consumer_Engagement/The-tipping-point-for-time-of-use-rates-6406.html/?fpt#.VGoHxPnF9qU

Borneo. (2013). *Energy Storage: An Overview.* Presented at the Vermont Energy Storage Meeting, June 2013.

CAISO. (2014). *California Vehicle-Grid Integration (VGI) Roadmap: Enabling Vehicle-Based Grid Services.*

CAISO (2011). *Demand Response & Proxy Demand Response Resource — Frequently Asked Questions.* Available at: http://www.caiso.com/Documents/DemandResponseandProxyDemandResourcesFrequentlyAskedQuestions.pdf

Calderon-Garciduenas, et al. (2014). *Air Pollution and Detrimental Effects on Children's Brain. The Need for a Multidisciplinary Approach to the Issue of Complexity and Challenges.* Frontiers in Human Neuroscience.

Crowe. (2013, September 3). *First-of-a-Kind Bi-Directional Electric Vehicle Chargers At Fort Carson, Colorado.* HybridCars.com. Available at: http://www.hybridcars.com/first-of-a-kind-bi-directional-electric-vehicle-chargers-at-fort-carson-colorado/

Deilami, et al. (2011). *Real-Time Coordination of Plug-In Electric Vehicle Charging in Smart Grids to Minimize Power Losses and Improve Voltage Profile.* IEEE Transactions on Smart Grid.

De Hoog, et al. (2013). *Demonstrating Demand Management: How Intelligent EV Charging Can Benefit Everyone.* EVS27 Conference Paper.

Diamond. (2009). *The Impact of Government Incentives for Hybrid-Electric Vehicles: Evidence From US States.* Energy Policy.

DiUS. (2013). *Demand Management of Electric Vehicle Charging Using Victoria's Smart Grid.* Available at: http://dius.com.au/wp-content/uploads/sites/2/2012/05/Demand-management-of-EV-charging-using-Victorias-Smart-Grid_May-2013.pdf

US Energy Information Administration. (2011). *Residential Energy Consumption.* Available at: http://www.eia.gov/tools/faqs/faq.cfm?id=97&t=3

Energy and Environmental Economics. (2014). *California Transportation Electrification Assessment, Phase 2: Grid Implications.*

US EPA. (2014a). *EPA Issues Final Rule for Renewable Fuel Standard (RFS) Pathways II and Modifications to the RFS Program, Ultra Low Sulfur Diesel Requirements, and E15 Misfueling Mitigation Requirements.* EPA-420-F-14-045. Available at: http://www.epa.gov/otaq/fuels/renewablefuels/documents/420f14045.pdf

US EPA. (2014b). *Biogas Opportunities Roadmap.* Available at: http://www.epa.gov/climatechange/Downloads/Biogas-Roadmap.pdf

US EPA. (2010). *US Anaerobic Digester Status Report.* Available at: http://www.epa.gov/agstar/documents/digester_status_report2010.pdf

EPRI. (2014). *EPRI, Utilities, Automakers to Demonstrate Technology Enabling Plug-in Electric Vehicles to Support Grid Reliability.* Available at: http://www.epri.com/Press-Releases/Pages/EPRI,-Utilities,-Automakers-to-Demonstrate-Technology-Enabling.aspx

EV Project. (2013). *EV Project EVSE and Vehicle Usage Quarter 1 2013 Report.* Available at: http://www.theevproject.com/cms-assets/documents/113177-646795.q1-2013-rpt.pdf

Fetter et al. (2012). *Energy Efficiency in the Forward Capacity Market: Evaluating the Business Case for Building Energy Efficiency as a Resource for the Electric Grid.* ACEEE Summer Study on Energy Efficiency in Buildings. Available at: http://www.aceee.org/files/proceedings/2012/data/papers/0193-000167.pdf

Figenbaum & Kolbenstvedt. (2013). *Electromobility in Norway — Experiences And Opportunities With Electric Vehicles.* Institute of Transportation Economics, Norwegian Centre for Transport Research.

Gage. (2013). *V2G: Energy Storage with EVs.* Presented at the Electric Auto Association, Palo Alto, CA, June 15, 2013. Available at: http://www.eaasv.org/files/TGage-EVgrid_130615.pdf

Galus et al. (2012). *The Role of Electric Vehicles in Smart Grids.* WIREs Energy Environ 2012. Doi:10.1002/wene.56

Glazner. (2012, February). *Electric Mobility and Smart Grids: Cost Effective Integration of Electric Vehicles With the Power Grid.* Symposium Energieinnovation.

Gorguinpour. (2013, July 17). *DoD Plug-in Electric Vehicle Program: V2G Overview.* Presented at the V2G Overview State Regulatory Agency Briefing.

Gottstein & Schwartz. (2010). *The Role of Forward Capacity Markets in Increasing Demand-Side and Other Low-Carbon Resources: Experience and Prospects.* Montpelier, VT: The Regulatory Assistance Project. Available at: www.raponline.org/docs/RAP_Gottstein_Schwartz_RoleofFCM_ExperienceandProspects2_2010_05_04.pdf

Hilshey, et al. (2013). *Estimating the Impact of Electric Vehicle Smart Charging on Distribution Transformer Aging.* Institute of Electrical and Electronics Engineers.

ICCT. (2014). *Evaluation of State-Level US Electric Vehicle Incentives.* Available at: http://www.theicct.org/evaluation-state-level-us-electric-vehicle-incentives

Irwin. (2013). *What's Behind the Plunge in RINs Prices?* Farmdoc Daily, Department of Agriculture and Consumer Economics, University of Illinois. Available at: http://farmdocdaily.illinois.edu/2013/10/whats-behind-the-plunge-in-rin.html

ISO-NE. (2008). *Alternative Technologies Regulation Pilot Program.*

Jenkins, Neme, & Enterline. (2010). *Energy Efficiency as a Resource in the ISO New England Forward Capacity Market.* Energy Efficiency.

Kema. (2010). *Demand Response Reserve Pilot Evaluation.* Available at: http://www.isone.com/staticassets/documents/committees/comm_wkgrps/mrkts_comm/mrkts/mtrls/2010/dec782010/a15_dr_reserve_pilot_final_report_11_30_10.pdf

Kempton & Tomić. (2005). *Vehicle-to-Grid Power Implementation: From Stabilizing the Grid to Supporting Large-Scale Renewable Energy.* Journal of Power Sources. doi:10.1016/j.jpowsour.2004.12.022.

Kenner. (2014, March 31). Concurrent Technologies Corporation (CTC), Document Review Process.

Kintner-Meyer, et al. (2007). *Impacts Assessment of Plug-In Hybrid Vehicles on Electric Utilities and Regional US Power Grids, Part 1: Technical Analysis.* Pacific Northwest National Laboratory.

Kiviluoma & Meibom. (2010). *Methodology for Modeling Plug-In Electric Vehicles in the Power System and Cost Estimates for a System With Either Smart or Dumb Electric Vehicles.* Energy.

Lienert. (2013, December 5). *2014 Honda Accord Plug-In Hybrid Previews Vehicle-to-Grid Future.* Edmunds. Available at: http://www.edmunds.com/car-news/2014-honda-accord-plug-in-hybrid-previews-vehicle-to-grid-future.html

NCSL. (2014). *States' Efforts to Promote Hybrid and Electric Vehicles.* Available at: http://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx

Newsroom America. (2014). *Fact Sheet: Growing in the United Stated Electric Vehicle Market.* Available at: http://www.newsroomamerica.com/story/458531/fact_sheet_growing_the_united_states_electric_vehicle_market.html

Marnay, et al. (2013). *Los Angeles Air Force Base Vehicle To Grid Pilot Project.* Lawrence Berkeley National Laboratory. Available at: http://drrc.lbl.gov/sites/all/files/lbnl-6154e.pdf

Massie et al. (2013, August). *Application of Bi-Directional Electric Vehicle Aggregation in a Cyber Secure Microgrid Controller.* Presented at the 2013 NDIA Ground Vehicle Systems Engineering and Technology Symposium, Troy, MI.

Military.com. (2014). *Air Force Tests First All-Electric Vehicle Fleet.* Available at: http://www.military.com/daily-news/2014/11/17/air-force-tests-first-all-electric-vehicle-fleet.html

MJ Bradley. (2013). *Electric Vehicle Grid Integration in the U.S., Europe, and China.* Available at: http://www.theicct.org/sites/default/files/publications/EVpolicies_final_July11.pdf

Mitchem. (2013, October 8). *Fleet PEVs as Grid Resources.* Presented at the Plug-In 2013, San Diego, CA.

Morse & Glitman. (2014). *Electric Vehicles as Grid Resources in ISO-NE and Vermont.* Available at: http://www.veic.org/documents/default-source/resources/reports/evt-rd-electric-vehicles-grid-resource-final-report.pdf

Moskovitz. (2014). *An Electrifying New Business Model.* Featured Work. Montpelier, VT: The Regulatory Assistance Project. Available at: http://www.raponline.org/featured-work/an-electrifying-new-business-model

Pacific Northwest National Laboratory. (2009). *The Smart Grid and its Role in a Carbon-Constrained World.* Available at: http://www.smartgridinformation.info/pdf/2309_doc_1.pdf

Parks, et al. (2007). *Costs and Emissions Associated With Plug-In Hybrid Electric Vehicle Charging in the Xcel Energy Colorado Service Territory.* Golden, CO: National Renewable Energy Laboratory.

Plugincars.com. (2014). Available at: http://www.plugincars.com/ultimate-guide-electric-car-charging-networks-126530.html

Rezaei, et al. (2014). *Packetized Plug-in Electric Vehicle Charge Management.* IEEE Transactions on Smart Grid.

Schey, et al. (2012). *A First Look at the Impact of Electric Vehicle Charging on the Electric Grid in the EV Project.* EVSE 26 Conference, Los Angeles, CA.

Sears & Glitman. (2014). *Transportation Technical Reference Manual.* Available at: http://www.veic.org/resource-library/transportation-technical-reference-manual

Sears & Glitman. (2014, July). *Using a Transportation Technical Reference Manual in the Transportation Sector.* NASEO Webinar. Available at: http://www.naseo.org/event?EventID=457

Sears & Glitman. (2013). *Review of Utility Integrated Resource Plans and Electric Vehicle Load Forecasting.* Available at: http://www.veic.org/resource-library/plugging-electric-vehicles-into-utility-integrated-resource-plans

Sears, J., Forward, E., Mallia, E., and Glitman, K.. (2014). *An Assessment of Level 1 and Level 2 Electric Vehicle Charging Efficiency.* Transportation Research Record. Available at: http://trb.metapress.com/content/121n1434u2vx0m58/

Shao et al. (2009). *Challenges of PHEV Penetration to the Residential Distribution Network.* Power & Energy Society General Meeting, Institute of Electrical and Electronics Engineers.

Showtimes. (2013, June 25). *'We Got a Check,' Says EV Grid.* ShowTimes Clean Fuel & Vehicle News. Available at: http://www.showtimesdaily.com/act-expo-2013/we-got-a-check-says-ev-grid

Silver Spring Networks. (2010). *The Dollars and Sense of EV Smart Charging.* Available at: http://www.rmi.org/Content/Files/DollarsandSense.pdf

Smart Grid News. (2014). *Will They or Won't They? CPUC to Decide If Utilities Can Deploy EV Charging Stations.* Available at: http://www.smartgridnews.com/artman/publish/End_Use_Electric_Transportation/Will-they-or-won-t-they-CPUC-to-decide-if-utilities-can-deploy-EV-charging-stations-6869.html/#.VGoK6fnF9qU

Sullivan. (2009). *Will Electric Cars Wreck the Grid?* Scientific American. Available at: http://www.scientificamerican.com/article.cfm?id=will-electric-cars-wreck-the-grid

Southwest Research Institute. (2013, October 23). *Staff Interview With Sean Mitchem.*

Traut, et al. (2012). *Optimal Design and Allocation of Electrified Vehicles and Dedicated Charging Infrastructure for a Minimum of Greenhouse Gas Emissions and Cost.* Energy Policy.

US DOE. (2014). *Database of State Incentives for Renewables and Efficiency.* Available at: http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=DE02R&re=0&ee=0

VEIC. (2014). *A Survey of Electric Vehicle Awareness and Preferences in Vermont.* Final Report.

Volk, et al. (2013). *Traffic-Related Air Pollution, Particulate Matter, and Autism.* Journal of American Medical Association, Psychiatry.

Wald. (2013, April 25). *Electric Vehicles Begin to Earn Money from the Grid.* The New York Times. Sec. Business Day/Energy & Environment. Available at: http://www.nytimes.com/2013/04/26/business/energy-environment/electric-vehicles-begin-to-earn-money-from-the-grid.html

Washington Utilities and Transportation Commission. (2014). Docket UE-140626.

Weis, et al. (2014). *Estimating the Potential of Controlled Plug-in Hybrid Electric Vehicle Charging to Reduce Operational and Capacity Expansion Costs for Electric Power Systems with High Wind Penetration.* Applied Energy. doi:10.1016/j.apenergy.2013.10.017.

Zhu & Liu. (2013). *Investigating the Neighborhood Effect on Hybrid Vehicle Adoption.* Transportation Research Board Annual Meeting.