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FINAL PROJECT REPORT

Charging Infrastructure for Plug-in Hybrids and Electric Vehicles Demonstration with General Motors

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PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program, formerly known as the Alternative and Renewable Fuel and Vehicle Technology Program. The statute authorizes the California Energy Commission (CEC) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorizes the Clean Transportation Program through January 1, 2024, and specifies that the CEC allocate up to $20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The Clean Transportation Program has an annual budget of about $100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and nonroad vehicle fleets to alternative technologies or fuel use.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce-training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued solicitation PON-08-010 to provide funding opportunities under the ARFVT Program for projects which have been awarded funding from the U.S. Department of Energy under a federal funding opportunity announcement for specified transportation projects. In response to PON-08-010, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards August 28, 2009 and the agreement was executed as ARV-10-034 on May 31, 2011.

ABSTRACT

Sacramento Municipal Utility District (SMUD) partnered with General Motors to accelerate the transition to electric vehicles in the United States. This program is being conducted under contract with the U.S. Department of Energy's Recovery Act- Transportation Electrification DE-FOA 0000028. The primary effort of this program were in 5 categories, which included deployment and demonstration of the Chevrolet Volt Extended Range Electric Vehicle, installation and maintenance of the supporting charging infrastructure, utility readiness, regional readiness and planning and new technology opportunities.

Keywords: electric vehicles, Chevrolet Volt, Sacramento Municipal Utility District, charging infrastructure, electrical vehicle supply unit, permitting, codes, regional readiness, multi-dwelling unit, grid impacts

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EXECUTIVE SUMMARY

The Sacramento Municipal Utility District in conjunction with other utilities working with General Motors worked to develop and implement a program that promotes its strategy to accelerate the transition to electric vehicles in the United States.

This program is being conducted under contract with the US Department of Energy's Recovery Act - Transportation Electrification DE-FOA 0000028. A portion of this project effort by SMUD was supported by CEC grant ARV-10-034.

SMUD administered and monitored the use and performance of the Chevrolet Volts and installed fleet charging infrastructure. Other research tasks helped advance the understanding of driver experience, charging infrastructure installation best practices, utility readiness, regional readiness, and future utility-vehicle technologies.

CHAPTER 1: Project Purpose

1.0. Introduction

SMUD concurrently worked together with General Motors to promote a strategy to accelerate the transition to electric vehicles in the United States. SMUD is a publicly owned electric utility that operates independently of other local government and functions as a non-profit entity. They provides electric power to the majority of the Sacramento County as well as a portion of Placer County in Northern California. In total, SMUD service region covers approximately 900 square miles and serves around 550,000 residential customers and 50,000 commercial accounts.

The program is being conducted under contract with the U.S. Department of Energy's Recovery Act - Transportation Electrification DE-FOA 0000028. The CEC grant ARV-10-034 supported a portion of SMUD's project effort. The primary focus of the project is the deployment and demonstration of the Chevrolet Volt Extended Range Electric Vehicle, and the installation and maintenance of the supporting charging infrastructure.

The key initiative of the project is the demonstration of the Chevrolet Volt Extended Range Electric Vehicles in real world conditions with real customers. SMUD administered and monitored the use and performance of the Chevrolet Volts and installed fleet charging infrastructure. Other research tasks helped advance knowledge of driver experience, developing infrastructure best practices, utility readiness, regional readiness, and future utility-vehicle technologies.

1.1. Vehicle Demonstration

The vehicle demonstration task's goal was to understand the environmental and cost benefits by capturing real world experience of plug-in hybrid electric vehicles (PEV) in fleet applications. The 2011 Model Year Chevrolet Volt was used for demonstration in this project. Vehicle data was logged in real time through OnStar and sub-meters on some charger installations. Additionally, driver surveys and interviews were conducted to gather experience related to PEV usage and charging in fleet applications.

1.2. Infrastructure

Charging infrastructure installations' goal was to capture the experience and cost for installation, operation, and maintenance for fleet-oriented charging applications. Level 2 Electric Vehicle Supply Equipment (EVSE) was the focus of charging infrastructure. Level 2 EVSE are chargers that operate on 208/240V AC supply power, which are usually preferred for fleet applications. All Level 2 EVSE installations were intended to support Chevrolet Volts that were registered with this Department of Energy sponsored grant where remote data collection was enabled via OnStar.

1.3. Utility Readiness

A key component to utility readiness is the ability to respond to PEV customer needs. Specifically, new or prospective PEV customers may have questions about the technology, special rates, incentives, charging infrastructure, and permitting requirements. This customer support requires dedicated program considerations for this new market segment. A customer service and program process flow was developed to address this need.

The differences between residents of single family dwellings versus multi-family dwellings are a unique aspect to PEV customer needs. There are a number of issues that property managers and Electric Vehicle (EV) owners must take into consideration regarding the installation of EVSE in multi-family or multi-unit residences. With parking amenities ranging from assigned spaces to on-street parking, configurations for chargers at multi-family residences fall in between those of home chargers and public chargers. The installation, ownership, and maintenance of multi-family residence chargers will vary on a case-by-case basis.

Utility infrastructure is an important consideration given that plug-in electric vehicles are a relatively new product in the market and customers are just beginning to gain familiarity. Furthermore, PEVs are a unique load in comparison to many other existing loads from a utility perspective. At the residential level, a PEV can provide a sustained load of 1.4 – 19.2 kW depending on the vehicle model and charger type.

1.4. Regional Readiness

The goal of this effort was to facilitate the roll out of PEVs in a coherent, cohesive manner that promotes wise planning with a consumer-friendly focus. Several critical components to regional readiness include regional coordination among planning authorities and harmonization of permitting and codes across local jurisdictions. The Sacramento Area Council of Governments' (SACOG) plays a key role in land use and transportation planning to prepare the Sacramento region. SACOG worked to educate local Authorities Having Jurisdiction about new technologies, streamline the EVSE installation permitting processes across the SMUD service territory, work with building officials and planning staffs in local jurisdictions to harmonize these processes, and identify training opportunities for first responders.

1.5. Future Technologies

Vehicle to Grid (V2G) services have been under research as a new value proposition for plug-in electric vehicles (PEV). V2G services can be provided using unidirectional or bidirectional power flow and also through centralized control or autonomous control. The specific services are often bundled as ancillary services which may include one or a combination of regulation up, regulation down, or spinning reserves. The goal was of this task was to demonstrate two V2G technologies on an individual vehicle:

- Demand response with the aid of OnStar was demonstrated on a single Chevrolet Volt with prototype firmware and hosted network system.
- Primary frequency control was demonstrated with a prototype charger by Aerovironment on a single Chevrolet Volt.

CHAPTER 2:
Project Activities and Results

2.1. Vehicle Demonstration

2.1.1. Vehicles

SMUD received ten Chevrolet Volts from the 2011 model year on August 2, 2011. The City of Sacramento purchased two of the vehicles on their own as part of the overall demonstration program. Four of the ten Chevrolet Volts were assigned to project partners as following: two were provided to California State University, Sacramento, one was provided to University of California, Davis, and one was provided to Los Rios Community College District. Four Chevrolet Volts were assigned to SMUD departments and the last two Chevrolet Volts were assigned to SMUD's general pool fleet.

The Chevrolet Volt is an Extended Range Electric Vehicle, which is an electric vehicle that provides for extended range through an on board gasoline engine with generator. The Chevrolet Volt charges with the SAE J1772™ charging standard connector to provide an electric range of approximately 35 miles. The extended range gasoline engine allows for an additional 300 miles of range after the battery is discharged to a sustained minimum state of charge.

2.1.2. Vehicle Management

Accessibility

Project partners (California State University Sacramento, University of California Davis, and Los Rios Community College District) had assigned drivers for the vehicles, who managed sharing and access to the vehicles as needed. Usage of vehicles assigned to SMUD Departments was managed through locally designed systems, such as by Outlook calendar or hand-written calendar. Vehicles in SMUD's general pool fleet were administered through a web-based pool vehicle management system called Fleet Commander.

Training

SMUD developed laminated graphical cards tethered inside vehicles on how to use the Chevrolet Volt for the vehicles assigned to SMUD. SMUD also offered 1-hour training classes open to employees on how to use the Volt through a company-wide email. SMUD also posted a 4-minute video on how to use a Chevrolet Volt on Fleet Commander. Drivers at partner sites were personally trained as needed.

Maintenance

Most vehicle maintenance was routine and related to oil, tires, and brakes. An update to the vehicle structure and battery coolant system was a unique maintenance item that affected all vehicles. This update was offered by General Motors as a voluntary customer satisfaction update in response to a National Highway Traffic Safety Administration Chevy Volt

Investigation, which concluded that the Chevrolet Volts were no less safe than conventional vehicles.

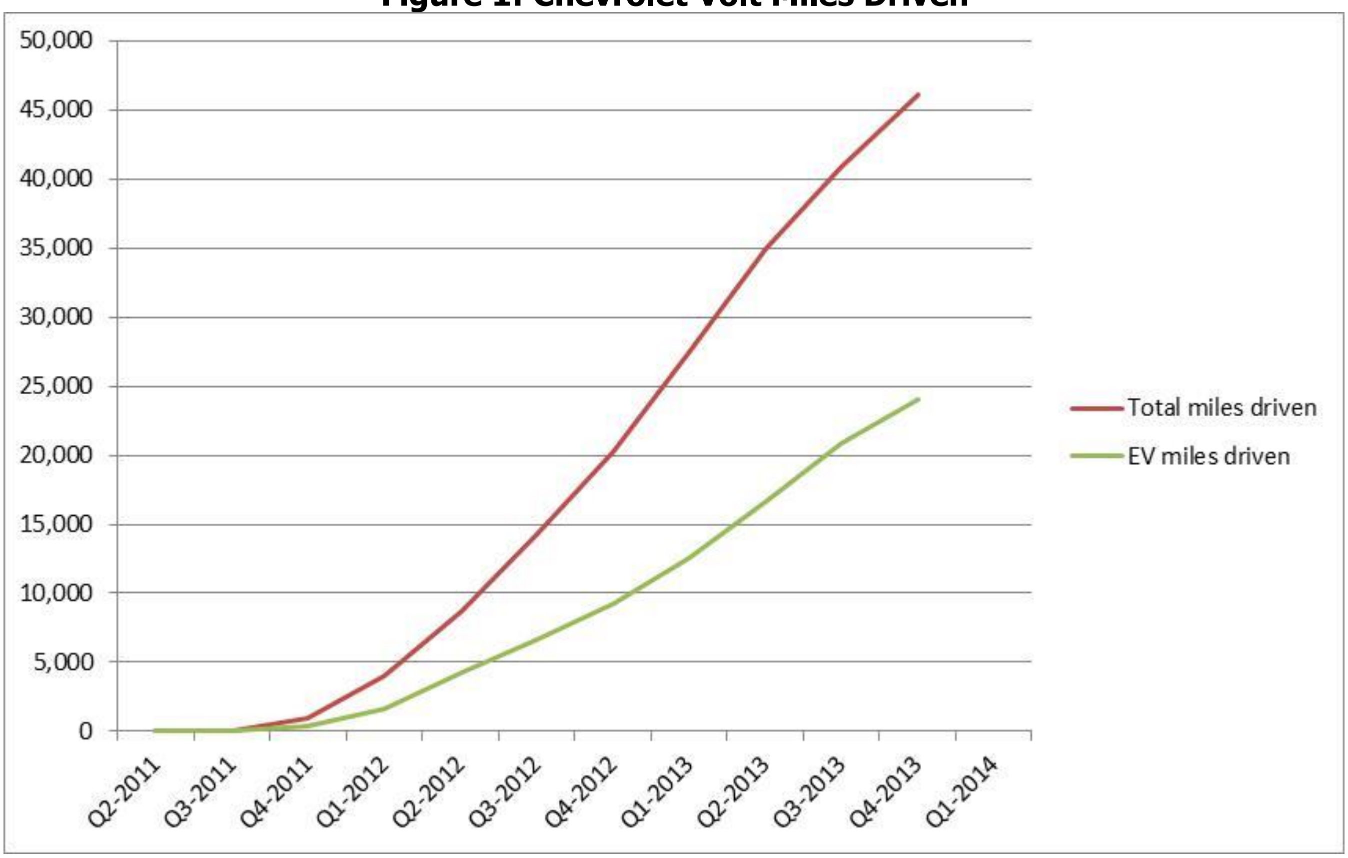
Other unique maintenance items were not consistent across the vehicles. The only moderate repair items that occurred was replacement of the drive motor relay on one vehicle. Aside from that, some minor repairs were done for cracks in the shifter lever, wear of on the front air dam, and tight operation of charger cover door. There were also 3 minor vehicle accidents with no injuries which required minor body work for repair.

2.1.3. Vehicle Data Collection

Energy consumption and usage data was collected from the OnStar telematics system and SMUD smart meters beginning with Q4-2011. A summary of this data is shown in Figure 1.

Of 46,000 total miles driven from the electrified fleet of Chevrolet Volts, 24,000 miles were driven in a pure electric mode. This equates to approximately 52 percent reduction in tailpipe emissions. The observed fuel economy was 359 watt-hour per mile in electric mode and 29.7 miles per gallon in extended range hybrid mode. For 24,000 miles driven in electric mode, approximately 808 gallons of gasoline consumption was avoided in exchange for 8,961 kWh. Considering SMUD's low carbon generation mix of 30 percent hydro, 24 percent renewable, and 46 percent high efficiency natural gas combustion, this much electrical energy yields approximately 1/3 of the carbon emission associated with the displaced gasoline consumption.

Figure 1: Chevrolet Volt Miles Driven



Source: Aswani, D. (2013). *OnStar Smart Charging Demonstration.* Sacramento: Sacramento Municipal Utility District.

Driver Data Collection

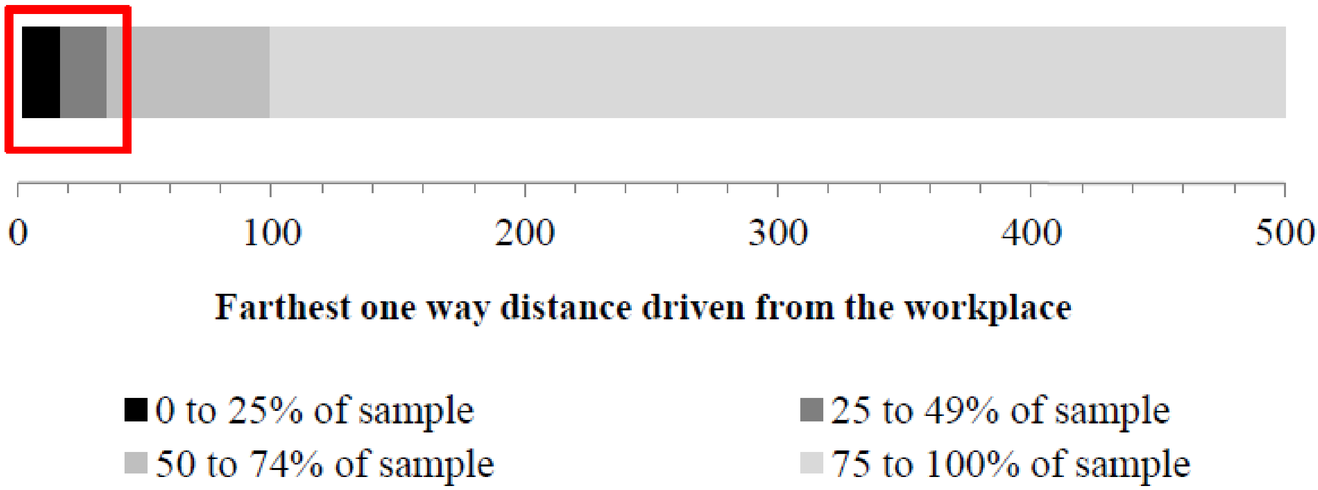
On December 24, 2013 a contract was approved with the University Of California, Davis Institute of Transportation Studies to survey and interview participating drivers regarding their vehicle and charging infrastructure experiences for the task final report. Over 50 drivers were estimated to have used the Chevrolet Volts during the course of this project. Of these drivers, 27 drivers were surveyed and 12 were interviewed.

The fleet drivers found the Chevrolet Volt adequate for 82 percent of their fleet needs, while at other times there was a need for passenger or cargo space of SUVs/trucks. About 71 percent of the driving was perceived to be electric, which exceeded the 52 percent measured amount of electric driving according to data collected through OnStar. About a quarter of the drivers used the Volt daily, another quarter of the drivers used the Volt weekly, and half of the drivers, as shown in Figure 2, used the Volt monthly. In Figure 3, about half of the trips were less than 40 miles, which can typically be covered within all electric mode.

Figure 2: Chevrolet Volt Regularity of Use

Source: Davies, J., & Nesbitt, K. A. (2014). Results and lessons learned from a Plug-in Electric Vehicle (PEV) demonstration project. Davis: University of California Davis.

Figure 3: Chevrolet Volt Trip Distances



Source: Davies, J., & Nesbitt, K. A. (2014). Results and lessons learned from a Plug-in Electric Vehicle (PEV) demonstration project. Davis: University of California Davis.

The 50 drivers talked with an estimated 850 individuals about the Volt. Of these conversations, about 70 percent were favorable. Of the drivers with favorable perceptions, 37 percent recommended a Volt purchase to somebody else. Three drivers purchased PEVs partly as a result of Volt experience. Of the drivers with an unfavorable perception, 17 percent of drivers discouraged a Volt purchase to someone else.

The most positive attributes used by drivers to describe the vehicle were: environment, commuting, appearance, acceleration, comfort, and reliable. The most negative attributes used by drivers to describe the vehicle were: limited seating & cargo capacity, EV range, and visibility.

2.2. Infrastructure

2.2.1. Hardware

Charging equipment was procured after competitive bid in July 2011. Charging equipment was required to be in compliance with the SAE J1772™ standard and Level 2 with a 240V/20A or greater branch breaker. The AeroVironment EVSE-RS unit was selected as primary EVSE, and subsequently, the ClipperCreek CS40 units were approved as a secondary option. The ClipperCreek units with a higher water resistance rating, as described by NEMA 4[1], were used in landscaped areas that could be exposed to watering sprinklers. The Aerovironment units with a lower water resistance rating, as described by NEMA 3R[1], were used in all other areas.

2.2.2. Installation Locations

A total of 29 Level 2 EVSE installations were made to support twelve Chevrolet Volts that were part of vehicle fleets spread among multiple buildings and locations. Installations were made

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1 National Electrical Manufacturers Association (NEMA) https://www.nema.org

in compliance with National Electric Code Article 625. The installation sites included facilities for SMUD; City of Sacramento; California State University, Sacramento; American River College, Los Rios Community College District; and the University of California, Davis. During the process of Level 2 installations, vehicles were supported by Level 1 charging with the portable cord sets included with each vehicle until relevant Level 2 charging was in place. Table 1 summarizes the number of installation per sites.

Table 1: Number of EVSE Installations Grouped by Location

# of EVSE	Date Complete	Location	Brand
1	9/22/2011	SMUD Headquarter Mezzanine Parking Deck 6201 S St Sacramento, CA 95817	AeroVironment
2	10/19/2011	SMUD Main Campus Warehouse 1708 59th St Sacramento, CA 95819	AeroVironment
7	2/17/2012	SMUD Fitness Center 6301 S St Sacramento, CA 95817	ClipperCreek
2	6/27/2013	SMUD East Campus Office Building 9750 Kiefer Blvd Sacramento, CA 95827	ClipperCreek
1	8/15/2013	SMUD East Campus Fleet Garage 9750 Kiefer Blvd Sacramento, CA 95827	AeroVironment
4	12/18/2013	SMUD Solar Port Parking Lot 6077 S St Sacramento, CA 95817	AeroVironment
2	5/15/2012	City of Sacramento, Corporate Yard 5730 24th St, Building 20 Sacramento, CA 95822	AeroVironment
2	11/27/2012	City of Sacramento, Public Safety Building 5770 Freeport Blvd Sacramento, CA 95822	AeroVironment
2	1/15/2013	City of Sacramento, City Hall Fleet Parking Garage 915 I St Sacramento, CA 95814	AeroVironment

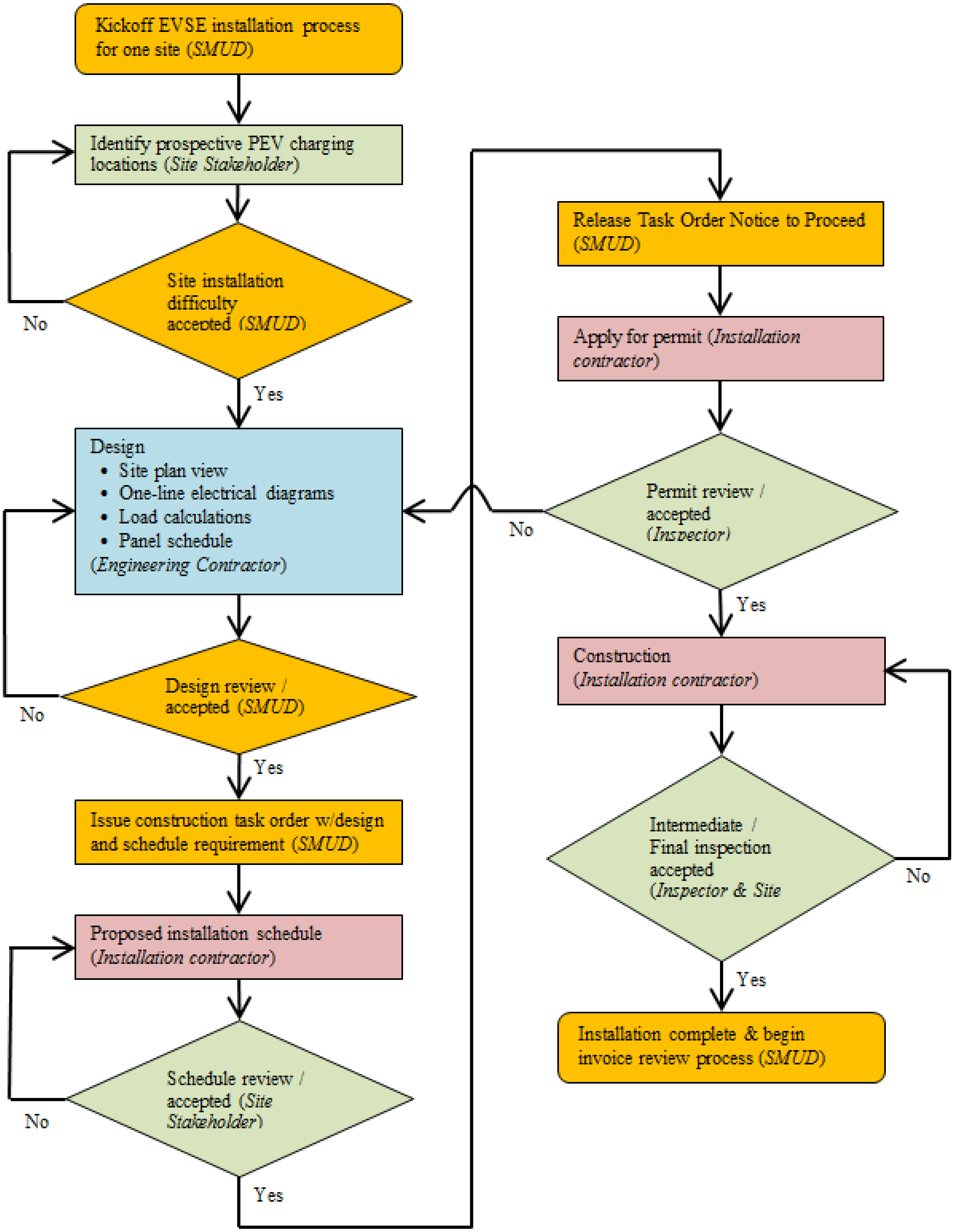
# of EVSE	Date Complete	Location	Brand
2	3/22/2013	City of Sacramento, Richards Police Facility 300 Richards Blvd Sacramento, CA	AeroVironment
1	7/13/2012	American River College Automotive Technology Building 4700 College Oak Drive Sacramento, CA 95841	AeroVironment
1	8/24/2012	California State University of Sacramento, Sacramento Hall 6000 J St Sacramento, CA 95819	ClipperCreek
1	8/21/2012	California State University of Sacramento, Parking Structure 1 6000 J St Sacramento, CA 95819	ClipperCreek
1	12/12/2012	U.C. Davis, Institute of Transportation Studies PH&EV Center 1605 Tilia Street, Suite #100 Davis, CA 95616	ClipperCreek

Source: Aswani, D., & Hatfield, D. (2014). *Electric Vehicle Supply Equipment Infrastructure.* Sacramento: Sacramento Municipal Utility District.

2.2.3. Installation Process

Figure 4 details the process that SMUD followed in conjunction with site stakeholders, engineering contractors, installation contractors, and inspection authorities to install the 29 EVSE for this project.

Figure 4: Installation Process Flow Chart



Source: Aswani, D., & Hatfield, D. (2014). *Electric Vehicle Supply Equipment Infrastructure.* Sacramento: Sacramento Municipal Utility District.

2.2.4. Costs

The costs per EVSE installation site are detailed below in Table 2 categorized by: engineering; EVSE hardware; materials, tools, & other; permit; construction labor; and independent inspection labor. In Table 2, the sites will be represented by their corresponding numbers as follows: SMUD will be 1, City of Sacramento will be 2, American River College will be 3, California State University, Sacramento will be 4 and University of California, Davis will be 5.

Table 2: Summary of Installation Costs

Site #	Location	# of EVSE	Engineer-ing	EVSE Hardware	Materials, Tools, & Other	Permit	Construct-ion Labor	Inspect-ion Labor
1	Headquarter Parking Deck	1	$4,689	$1,172	$1,440	x	$2,453	$742
1	Main Campus Warehouse	2	$8,185	$2,344	$717	x	$2,910	$881
1	Fitness Center	7	$20,927	$18,190	$10,869	x	$26,002	$7,872
1	East Campus Office Building	2	ǂ	$5,898	ǂ	x	$3,248	x
1	East Campus Fleet Garage	1	ǂ	$1,172	ǂ	x	$537	x
1	Solar Port Parking Lot	4	$2,143 ǂ	$10,936	$11,471	$758	$16,417 ǂ	$4,970
2	Corporate Yard	2	ǂ	$2,344	ǂ	ǂ	ǂ	x
2	Public Safety Building	2	$9,063	$5,468	$8,493	$494	$17,583	$5,323
2	City Hall Garage	2	$16,278	$2,344	$8,157	$493	$12,412	$3,758
2	Richards Police Facility	2	$11,444	$5,468	$1,552	$596	$7,433	$2,250

Site #	Location	# of EVSE	Engineer-ing	EVSE Hardware	Materials, Tools, & Other	Permit	Construct-ion Labor	Inspect-ion Labor
3	Automotive Tech Building	1	$3,524	$1,172	$2,264	x	$5,573	$1,687
4	Sacramento Hall	1	$3,524	$2,243	$1,643	x	$6,551	$1,983
4	Parking Structure 1	1	$3,524	$2,243	$2,003	x	$9,116	$2,760
5	ITS PH&EV Center	1	$0	$2,243	*	*	$5,000	x

KEY: * indicates the cost is not available in disaggregated form
ǂ indicates that a portion or all of the cost was covered by a third party
x indicates a cost that is not applicable

Source: Aswani, D., & Hatfield, D. (2014). *Electric Vehicle Supply Equipment Infrastructure.* Sacramento: Sacramento Municipal Utility District.

From the detailed cost data, the following cost model in Table 3 is proposed for workplace fleet installations.

Table 3: Level 2 EVSE Cost Model

Cost Category	Per Site	Additional Per EVSE	Additional Per Pedestal
Engineering	$5,900	-	-
Inspection & coordination	$2,300	-	-
Permitting	$600	-	-
Construction	$4,100	$1,000	$1,000
Trenching	+$200/ft.	-	-
EVSE hardware	-	$1,500	$700
Installation hardware & other	-	$1,600	-

Source: Aswani, D., & Hatfield, D. (2014). *Electric Vehicle Supply Equipment Infrastructure.* Sacramento: Sacramento Municipal Utility District.

2.3. Utility Readiness

2.3.1. Market Readiness

In support of market readiness, SMUD created a customer program around an existing PEV electricity billing rate called the Residential Time-of-Use Electric Vehicle rate. This rate provides incentives to customers to charge off-peak, prevents customers from going into a higher costlier tier rate due to vehicle charging, and protects infrastructure. This rate is provided through sub-metering, where a secondary meter that is downstream of the whole house meter is dedicated to a PEV charging circuit. SMUD provides the second meter with installation if the customer has an intermediate meter socket installed. This option is depicted in Figure 5.

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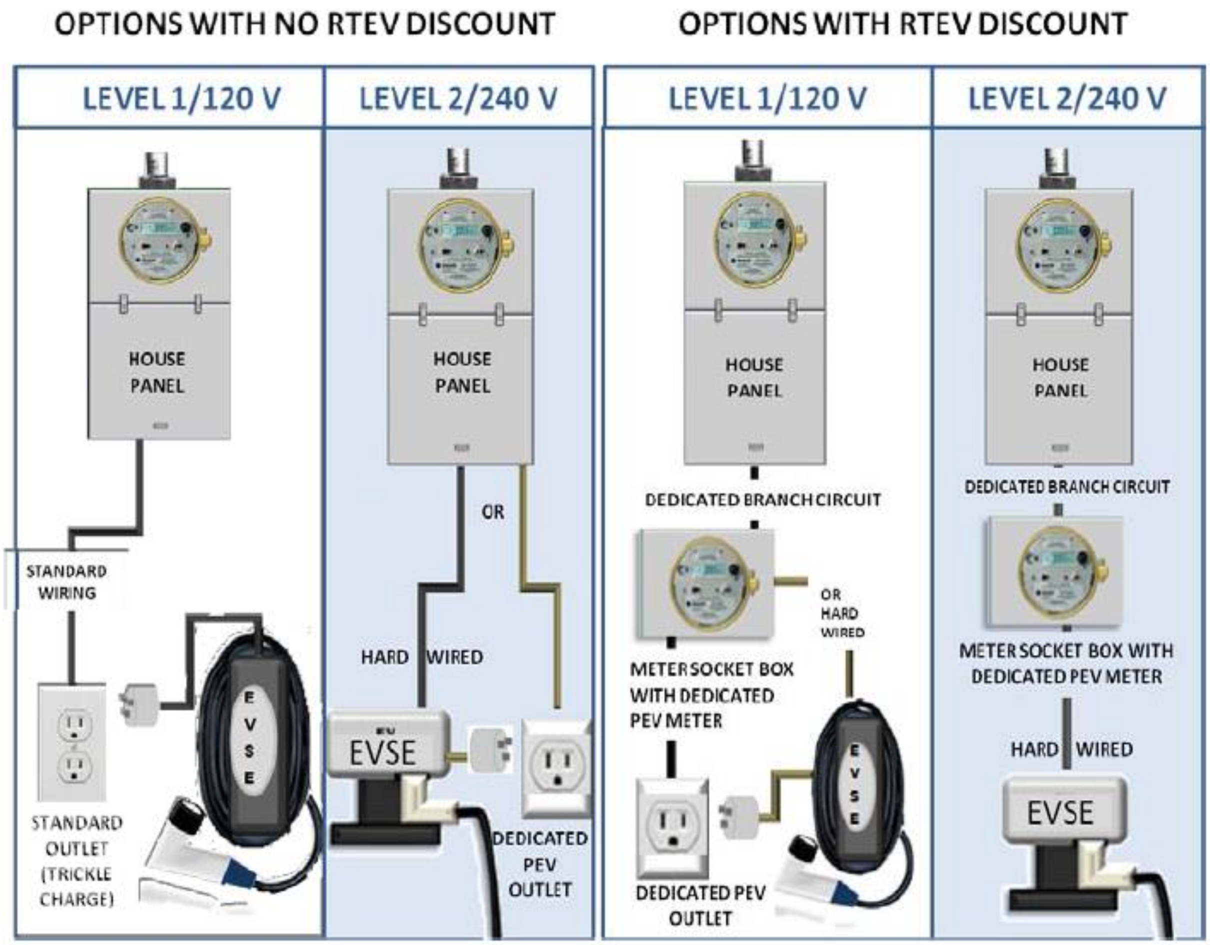
Figure 5: SMUD PEV Metering and Billing Options



Source: Gehringer, D., & Vargas, T. (2011). *Plug-in Electric Vehicle Market Readiness.* Sacramento: Sacramento Municipal Utility District.

The specific details of the Residential Time-of-Use EV rate are depicted in Figure 6.

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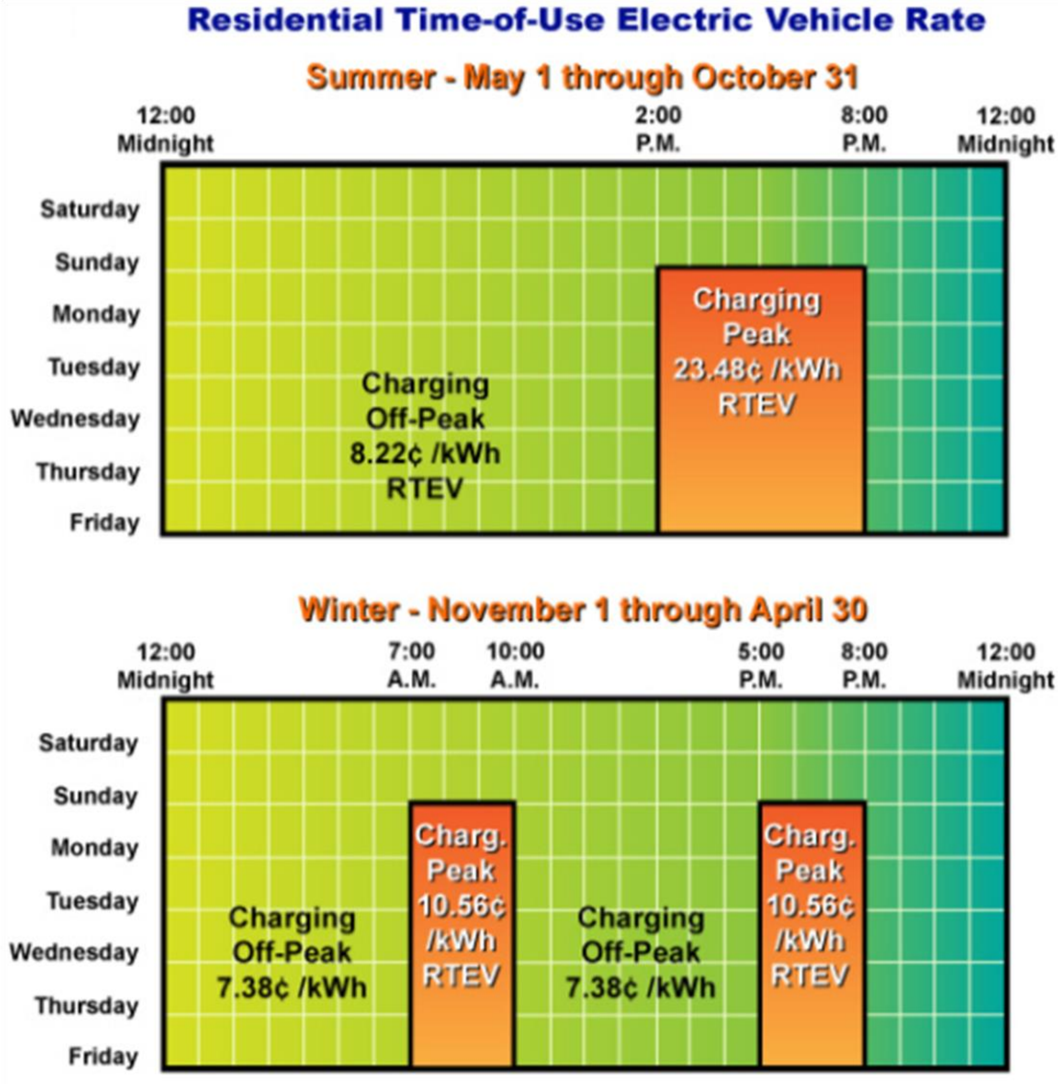
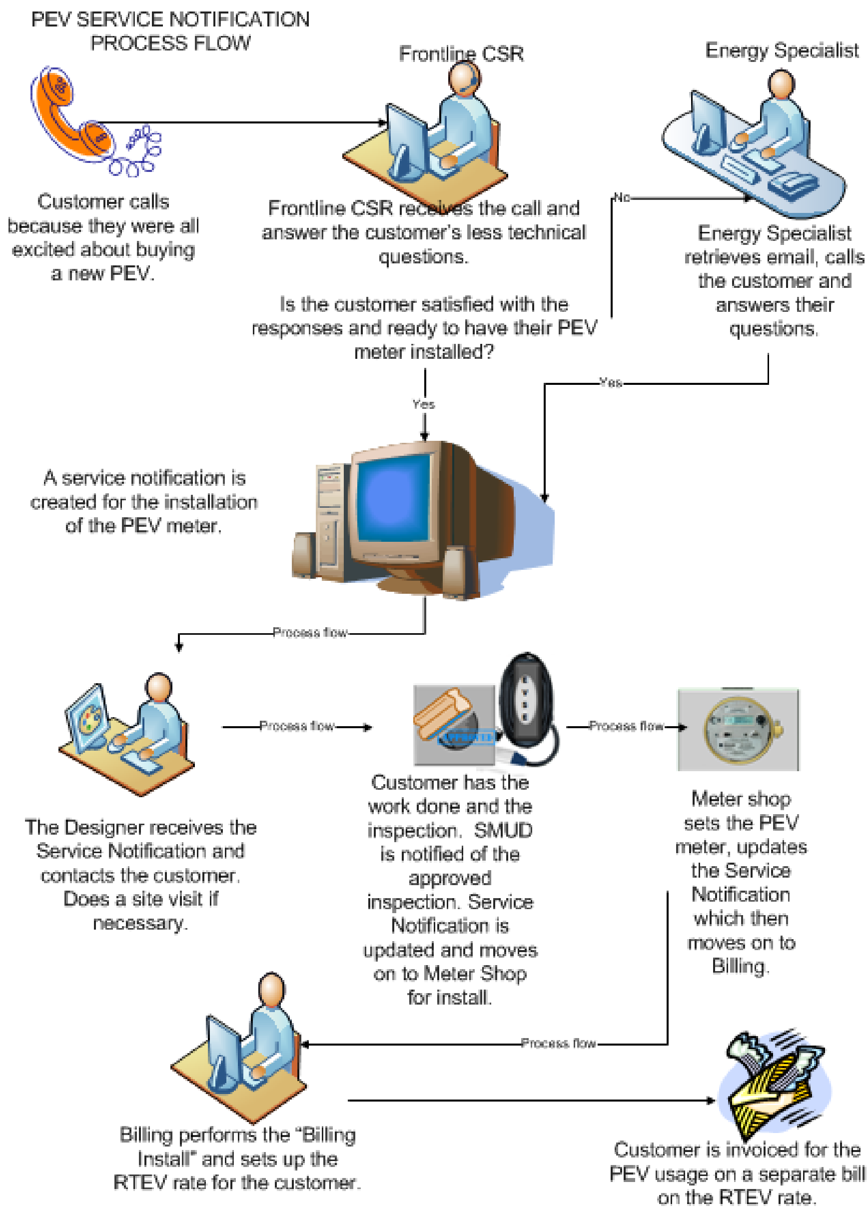
Figure 6: SMUD's Residential Time-of-Use Rate for Summer and Winter



Source: Gehringer, D., & Vargas, T. (2011). *Plug-in Electric Vehicle Market Readiness.* Sacramento: Sacramento Municipal Utility District.

In 2010, SMUD launched its PEV customer support program. Through this ongoing program, SMUD is supporting customers by phone, including an Integrated Voice Response System, e-mail, and via the SMUD PEV website[2]. SMUD's Integrated Voice Response System routes PEV calls to our contact center, where a Customer Service Representative answers basic questions and creates Contact Logs and Service Notifications for any of three SMUD-recommended charging installation methods. If the Customer Service Representative is unable to answer the customer's questions, an Energy Specialist will contact them within two business days. If the customer needs immediate assistance, the phone call is routed directly to a program specialist, who has over 10 years of electric vehicle experience. All pertinent customer residence information is logged and the Distribution Services is notified to ensure that the customer has adequate electrical service, to assess transformer loads, and to provide additional customer service. The customer coordinates purchase, installation, and inspection of EVSE, commonly known as charging stations. SMUD will install a PEV dedicated meter if the customer has decided to take advantage of SMUD's Residential Time-of-Use EV off-peak discount rate. All customers on this rate receive an integrated SMUD bill specifically for PEV charging electrical use. SMUD's Billing group has automated 'subtractive-billing' in order to separate the home electrical use from the PEV charging station/EVSE electrical use. Figure 7 depicts this customer service process flow.

Figure 7: SMUD PEV Service Notification Process



Source: Gehringer, D., & Vargas, T. (2011). *Plug-in Electric Vehicle Market Readiness.* Sacramento: Sacramento Municipal Utility District.

Currently SMUD's program has grown into a cross functional team with additional support from the Electric Transportation Research and Development group. SMUD monitors customer contacts to help improve staff's knowledge and improve the ability to support customers on this topic as the program progresses. SMUD's PEV website[2] is a significant tool for internal customer support, as well as for direct contact with the customer. SMUD's website is continually updated to support the increased PEV manufacturing for the 2012 model year. SMUD has also provided brochures to the local auto dealerships explaining the PEV market. SMUD has developed detailed training for the Customer Service Representatives, Energy Specialists, and Contractors. SMUD has created an independent customer support process for preparing customer's homes for PEV charging and also created standards for how the electrical sub meters should be installed for the Residential Time-of-Use EV rate.

2.3.2. Multi-family Considerations

Property owners and managers of 30 apartment and condominium complexes were surveyed to get perspectives on different configurations for installation, ownership and maintenance of multi-family residence chargers. Different neighborhoods in Sacramento County were selected for the survey to provide a diverse sampling of demographics and multi-unit building characteristics. All the rent statistics included in this report are from the 2000 U.S Census.

The site survey looked at each location's existing capacity to install chargers and the opportunities to upgrade the existing infrastructure, including the following questions:

1. Is there a need for charging infrastructure among tenants?
2. Who will manage the decision, installation, and permitting process for each EVSE installation?
3. Who will own and maintain the equipment?
4. How will the installation be financed and the cost recovered?
5. Will the equipment be shared or assigned/dedicated?

The survey results are summarized in Table 4, Table 5, and Figure 8.

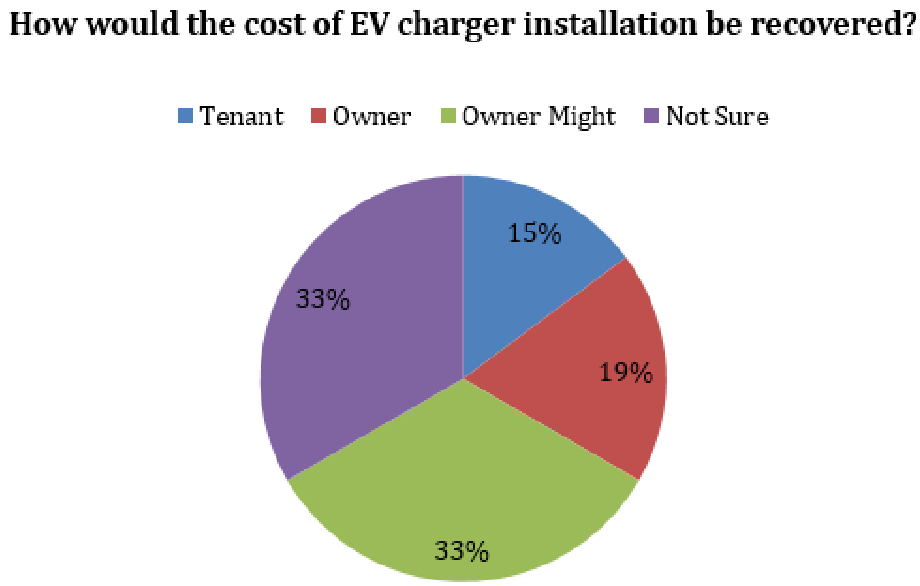
Table 4: Charging Infrastructure Interest Survey Results

Survey Questions	Survey Results (in percentage)
Have any tenants asked about EV charging?	5%
If tenants pay for EV chargers, can they remove them if they move?	10%
Are there any tenants currently charging EVs?	0%
Do you plan to install EV chargers within the next two years?	3%

Source: Vargas, T., Durkin, M., Tang, J., Oto, S., & Aswani, D. (2013). *EVSE Considerations for Multi-Family Dwellings in Sacramento California.* Sacramento: Sacramento Municipal Utility District.

2 SMUD Plug-in Electric Vehicle https://www.smud.org/PEV

Figure 8: Proposed Sources for SMUD Infrastructure Capital



Source: Vargas, T., Durkin, M., Tang, J., Oto, S., & Aswani, D. (2013). *EVSE Considerations for Multi-Family Dwellings in Sacramento California.* Sacramento: Sacramento Municipal Utility District.

Table 5: Multi-family Dwelling Parameters in the Region

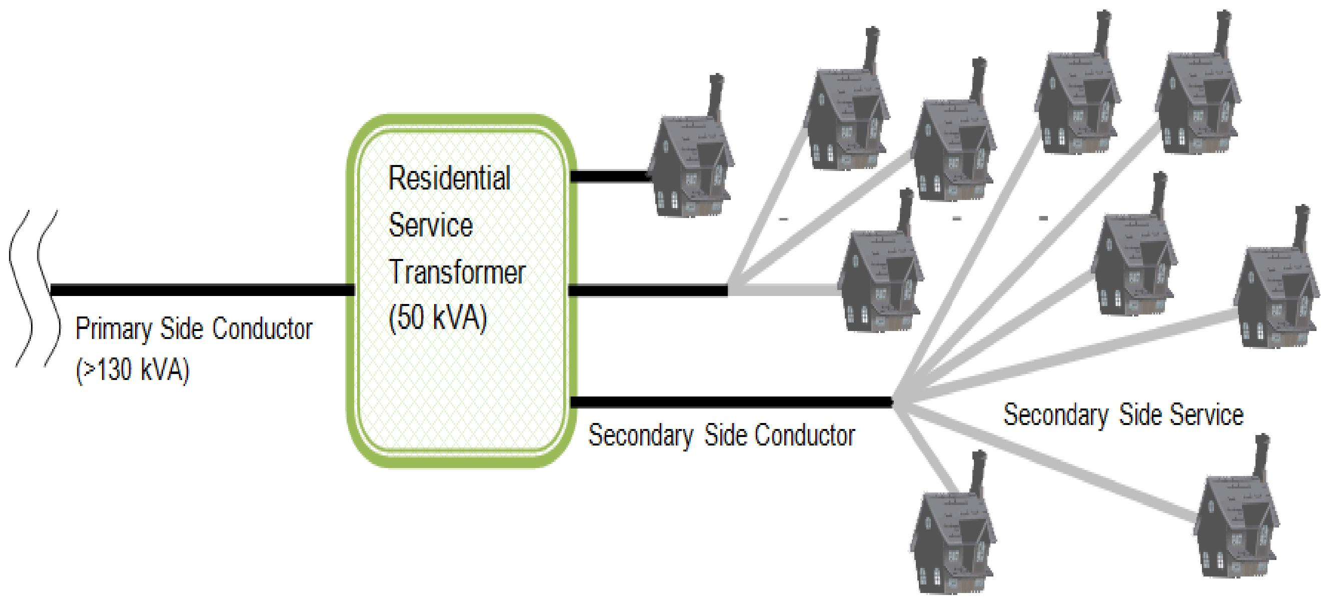
	Average Overall	**Folsom**	**Pocket**	**Watt/ Howe**	**Down-town & Midtown**
Average number of units for rent	202	202	213	226	149
Average number of tenant parking spaces	226	226	219	232	131
Average number of visitor spaces	86	86	57	89	14
Average number of total parking spaces	311	312	272	321	145
Common electricity allocated to tenants?	13%	10%	28%	0%	14%
Tenants have assigned parking?	86%	80%	72%	100%	71%
Tenants have garages?	59%	80%	58%	20%	86%
CC&Rs exist that impact the installation of EV chargers?	14%	10%	42%	0%	0%

Source: Vargas, T., Durkin, M., Tang, J., Oto, S., & Aswani, D. (2013). *EVSE Considerations for Multi-Family Dwellings in Sacramento California.* Sacramento: Sacramento Municipal Utility District.

2.3.3. Grid Infrastructure

Grid infrastructure may be impacted by the unique and sustained loading of PEVs, especially at the Level 2 rate of 3.3 – 19.2 kW. Power generation and transmission form the backbone of the electric utility infrastructure and are scaled to handle an expansion or reduction in both load and distribution infrastructure. However, the distribution side of the system is significantly impacted by the increased sustained loading of PEVs. At the residential end of the distribution infrastructure, capacity is sized on a per home basis. The residential transformer and associated secondary side and service conductor is usually the bottleneck for residential distribution, as the primary side conductor is often sized for quite high capacity. Sometimes the secondary side conductor and / or the service line between the transformer and the house meter, requires being upgraded to a higher rated conductor depending on the age of the home and secondary side distribution system. Figure 9 is an example of typical capacity ratings for a single residential transformer.

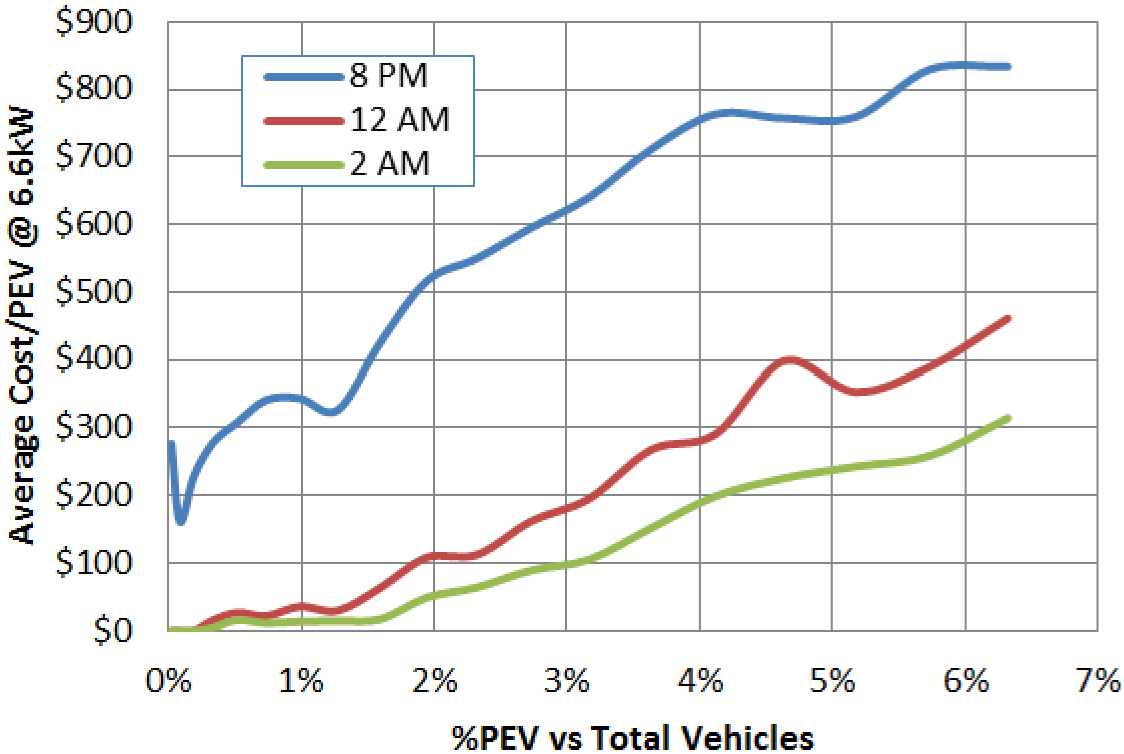
Figure 9: Typical Residential Service Transformer Network



Source: Berkheimer, J., Tang, J., Boyce, B., & Aswani, D. (2013). *Electric Grid Integration Costs for Plug-In Electric Vehicles.* Sacramento: Sacramento Municipal Utility District.

A residential distribution infrastructure model of SMUD's service region was developed and used to project the impact of PEV market growth in terms of system upgrade costs. Figure 10 shows that the charge start time has a significant effect on the cost of infrastructure upgrade costs. Beginning to charge a PEV at 8 PM has almost twice the marginal infrastructure cost as beginning to charge after midnight.

Figure 10: Infrastructure Cost Impact of Charge Start Time

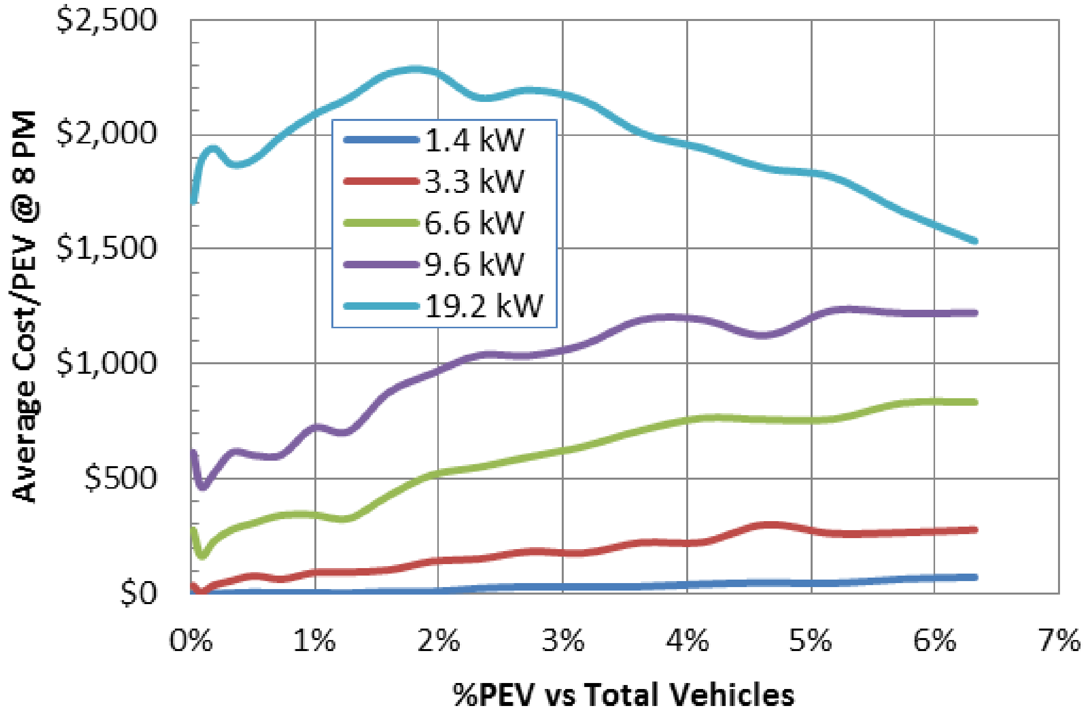


Source: Berkheimer, J., Tang, J., Boyce, B., & Aswani, D. (2013). *Electric Grid Integration Costs for Plug-In Electric Vehicles.* Sacramento: Sacramento Municipal Utility District.

Also the rate of charge has a significant impact on the marginal cost of infrastructure upgrade per vehicle. Figure 11 shows that charging at 19.2 kW can cost about $1900 in incremental distribution infrastructure upgrades versus about $200 at 3.3 kW charging rate.

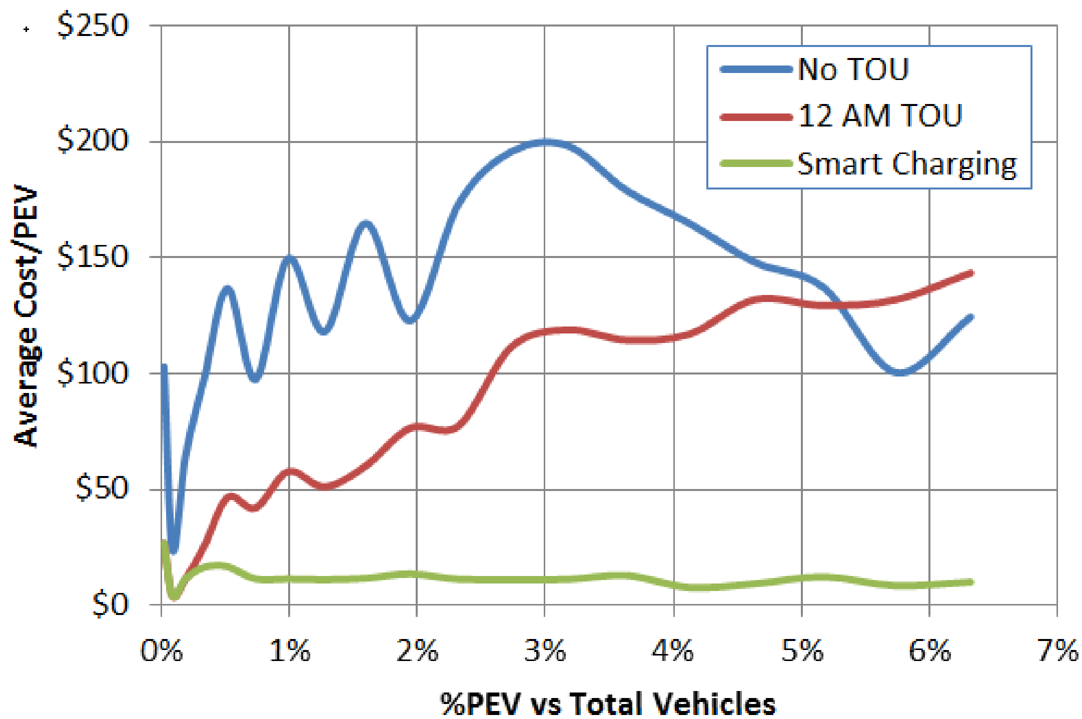
In the cost modeling effort, simultaneous geographic, temporal, and charging rate diversity were considered for a nominal flat rate case (replicating Tennessee load profile), 12 AM off-peak incentive (PG&E San Francisco load profile), and a smart charging optimized charging start time. Figure 12 shows that order of magnitude of cost per vehicle for a diversified case is at a magnitude close to $150.

Figure 11: Infrastructure Cost Impact of Charge Rate



Source: Berkheimer, J., Tang, J., Boyce, B., & Aswani, D. (2013). *Electric Grid Integration Costs for Plug-In Electric Vehicles.* Sacramento: Sacramento Municipal Utility District.

Figure 12: Infrastructure Cost for Diversified Time and Rates



Source: Berkheimer, J., Tang, J., Boyce, B., & Aswani, D. (2013). *Electric Grid Integration Costs for Plug-In Electric Vehicles.* Sacramento: Sacramento Municipal Utility District.

2.4. Regional Readiness

2.4.1. Local Coordinating Council

In order to promote regional readiness efforts, SMUD helped form the Capital Area Plug-in Electric Vehicle Coordinating Council, rebranded as TakeChargeSAC. The council has been meeting on a bi-monthly basis since September 2011. To form the council, SMUD had several meetings with the other founding members: SACOG, Sacramento Clean Cities, Sacramento Metropolitan Air Quality Management District, and a nonprofit Valley Vision. SMUD also facilitated infrastructure coordination by building awareness between local jurisdictions interested in participating in grant-supported publicly accessible EVSE charging stations and grant recipients such as ClipperCreek and Coulomb Technologies.

2.4.2. Permitting and Ordinances

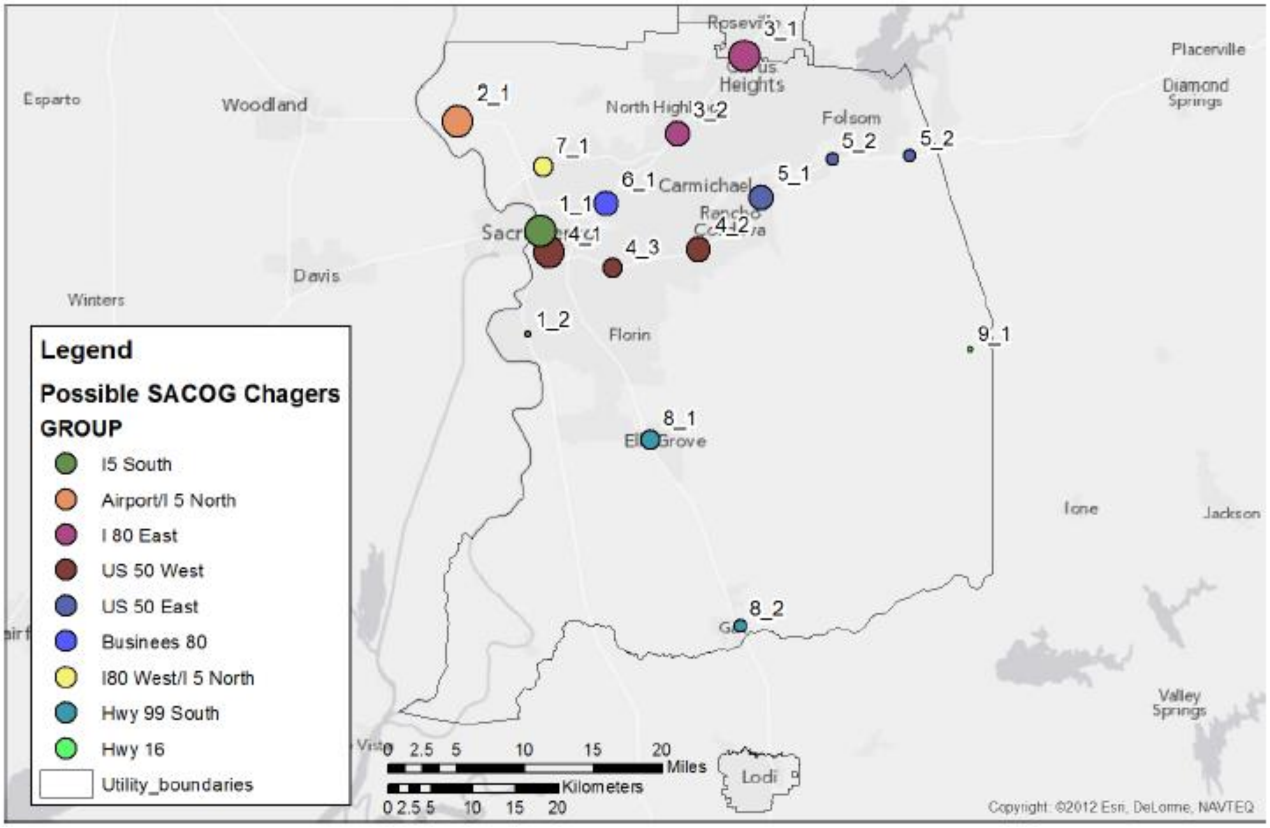
SACOG provided regional stakeholders with draft planning guidelines on best practices and models for planning, building codes, and permitting processes. This was accomplished by disseminating PEV Planning Guidelines to all Regional Stakeholders in electronic and paper copies. SACOG also conducted workshops to promote discussion for final best practice guidelines for consideration of adoption by local jurisdictions.

SACOG also provided staff from local government agencies within the SACOG service area with detailed information on draft Regional Planning Guidelines and background on best practices in PEV planning, building construction codes, permitting processes, and public infrastructure planning. This included one-on-one meetings which had been identified as one of the key best practices by the successful readiness teams to date.

2.4.3. Infrastructure Planning

With the help of U.C. Davis, SACOG studied the most favorable types of public charging locations in our region. U.C. Davis Institute of Transportation Studies was identified as a strategic partner given its role in PEV market research and participation in the California PEV Collaborative. Specific sites evaluated for public EVSE infrastructure included Interstate 80, Interstate 5, Highway 99 and Highway 50 corridors in Sacramento County. SACOG developed region-specific guidelines for PEV infrastructure deployment for multi-unit dwellings, workplaces and fleets including surveys, education and outreach. Figure 13 highlights some of the recommended charging infrastructure clusters for Sacramento County. SACOG also conducted workshops in Sacramento County for building and property owners to educate them on PEV infrastructure and highlight aspects of the plan that could be implemented in the county, as a special session at the 2013 Sacramento Regional Technology Alliance CleanStart showcase.

Figure 13: Recommended Charging Infrastructure Clusters



Source: SACOG. (2014). *Sacramento Area Regional Coordination for EV Readiness.* Sacramento: Sacramento Council of Governments.

2.4.4. Readiness Plan

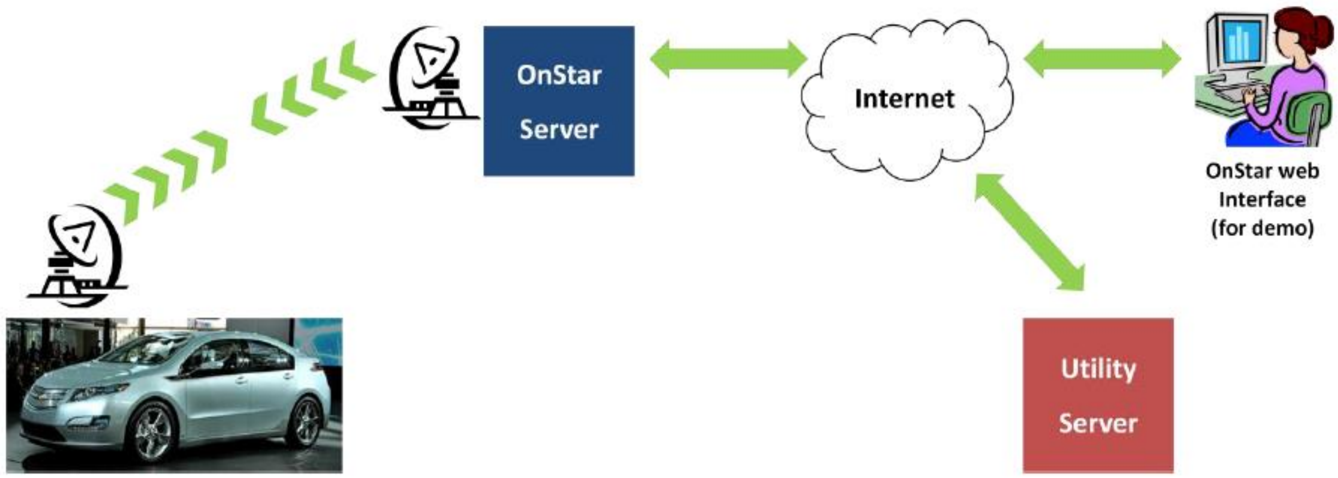
SACOG drafted a Regional Readiness Plan as a public document and resource. The intention of this document was to provide a public view of regional coordination activities conducted, resources available, and challenges faced by the region. This readiness plan was also presented by SACOG to the SMUD Board of Directors and to local elected officials.

2.5. Future Technologies

With the focus on V2G services through unidirectional power flow, two cases were evaluated. The first case was coordinated unidirectional power flow, which in aggregated form is analogous to Automated Demand Response. Gaps between power supply and demand can be accommodated by regulating the charging load up or down from some intermediate level.

In spring of 2013, SMUD and OnStar demonstrated this capability with the Chevrolet Volt on a single vehicle. Figure 14 depicts the control mechanism for this Automated Demand Response demonstration. A web demonstration interface or utility server communicates through the cloud with the OnStar back office server, which then uses the OnStar cellular network to communicate with individual vehicles. The server to server communication implemented by OnStar is a Simple Object Access Protocol based Web Service Definition Language.

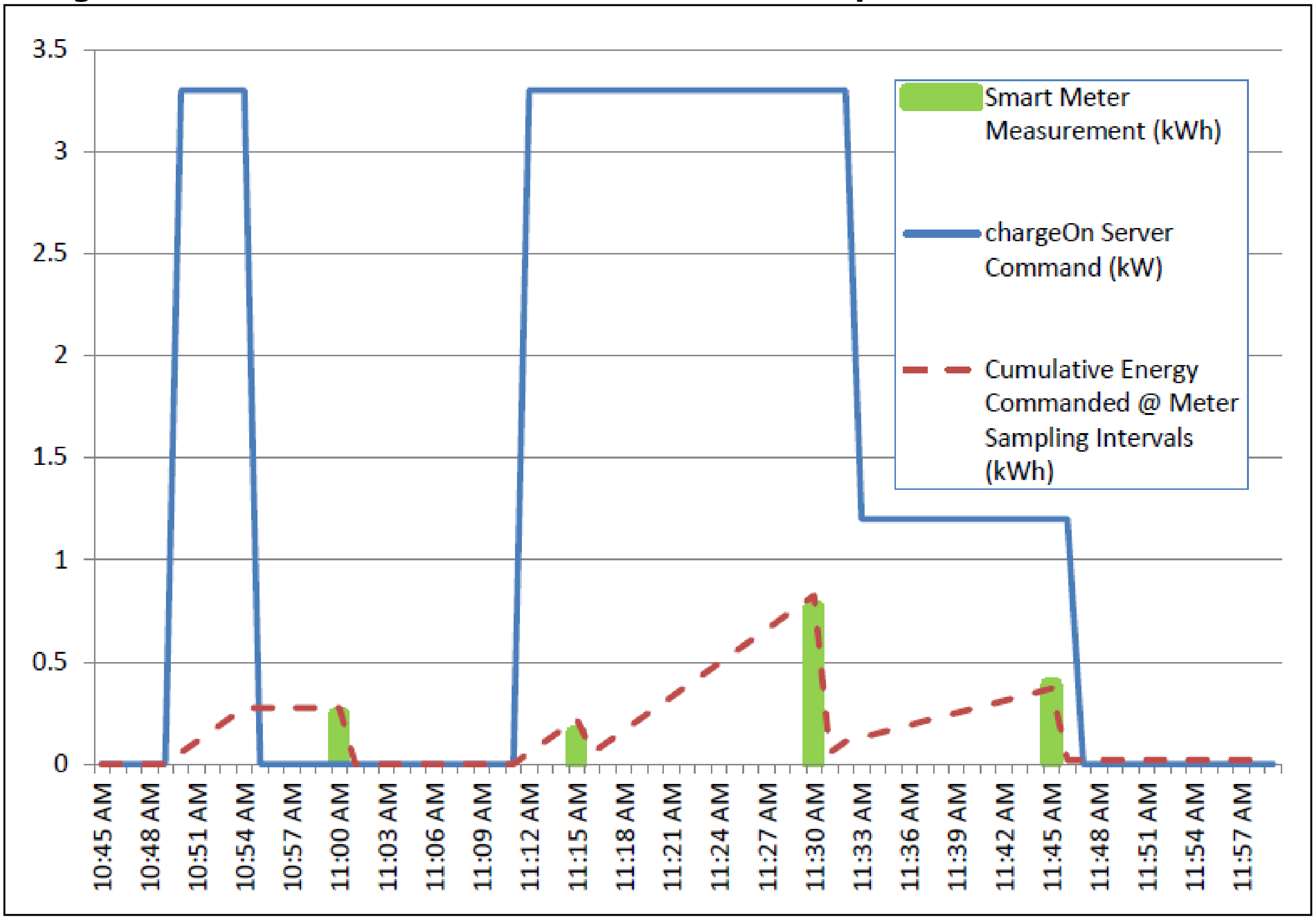
Figure 14: OnStar Demand Response Network Communication Diagram



Source: Aswani, D. (2013). *OnStar Smart Charging Demonstration.* Sacramento: Sacramento Municipal Utilty District.

Figure 15 shows the results from a Demand Response demonstration test with a Chevrolet Volt. This figure shows a plot which compares the smart meter measurements with the calculated cumulative energy resulting from the command, reset at the meter sampling interval. The smart meter measurements are close to what is expected based on the command, demonstrating a successful Demand Response according to command.

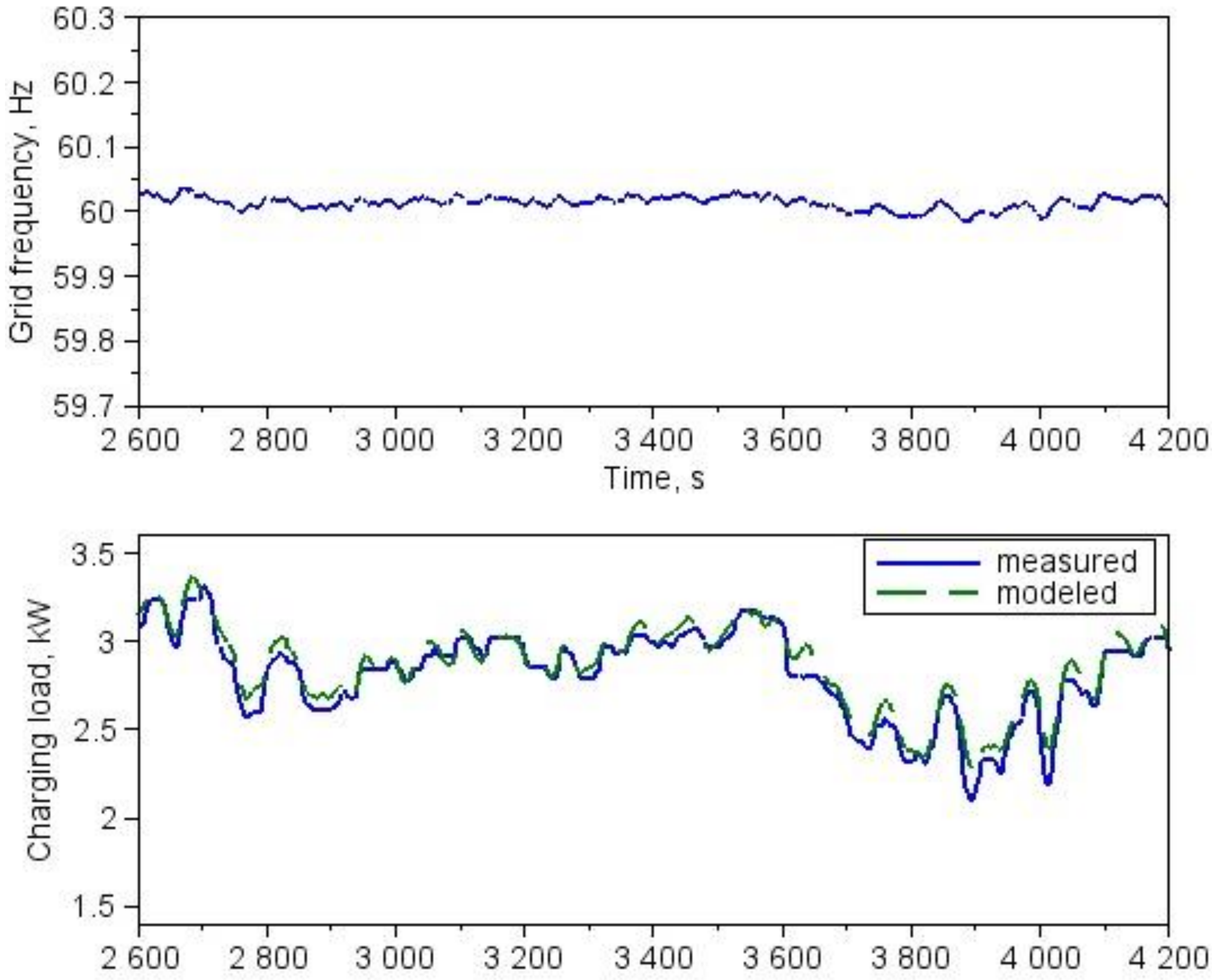
Figure 15: Data Recorded from OnStar Demand Response Demonstration Test



Source: Aswani, D. (2013). *OnStar Smart Charging Demonstration.* Sacramento: Sacramento Municipal Utilty District.

In fall of 2013, SMUD demonstrated a prototype EVSE by Aerovironment that provides (autonomous) primary frequency control V2G services. This type of V2G service works toward meeting WECC requirements for spinning reserve capacity, as required according to generation dispatch and load. This service benefits short term immediate power supply and demand gaps on an overall synchronous grid. This is different from the regulation services (regulation up or regulation down) that are necessary to fill gaps in power supply and demand within a balancing area. However, autonomous frequency control is a simpler alternative to aggregated Automated Demand Response which requires network connectivity with each vehicle. Figure 16 shows how the charging rate varies with grid frequency.

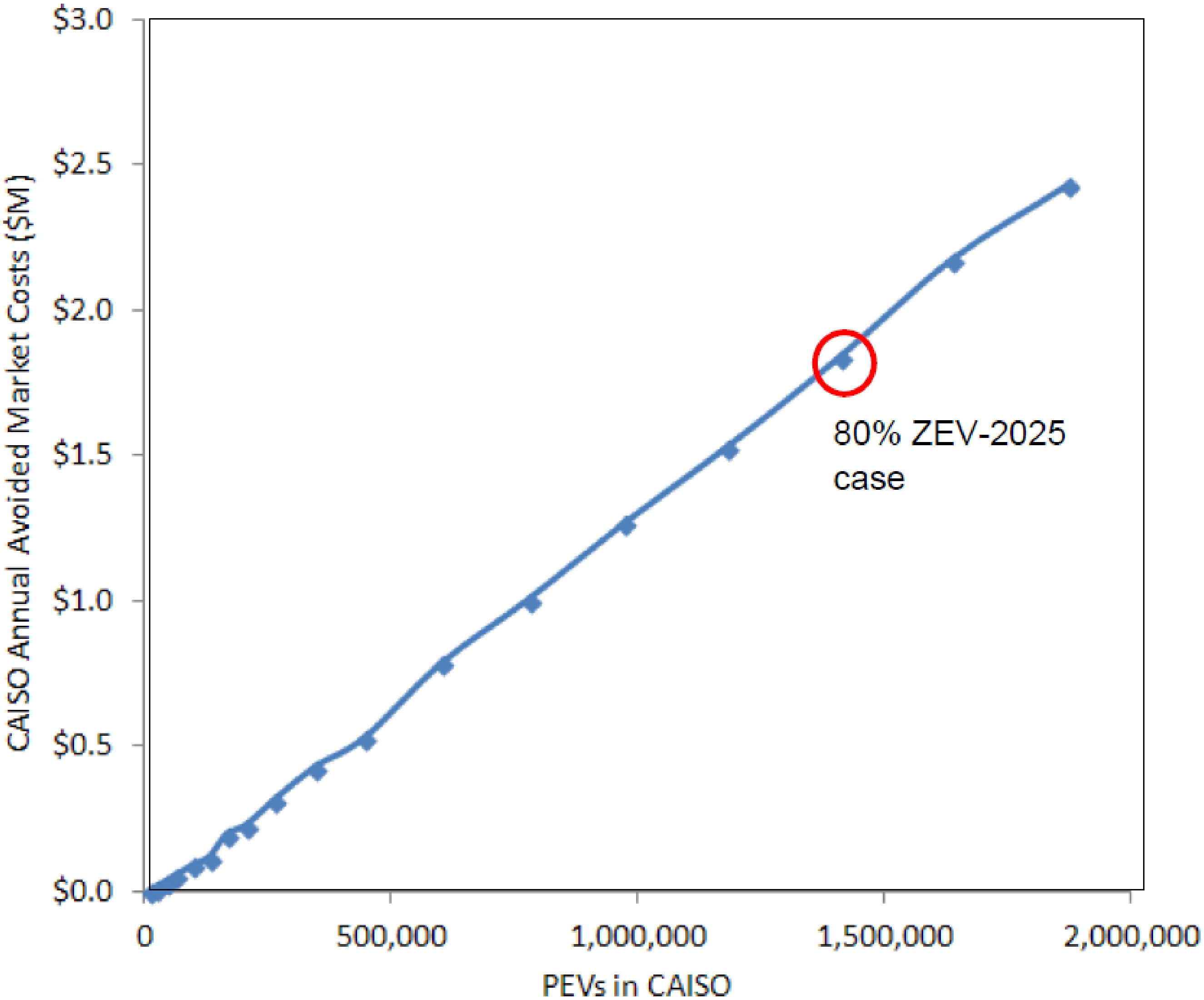
Figure 16: Frequency Responsive EVSE Recorded Data



Source: Aswani, D., & Boyce, B. (2014). *Autonomous Grid Services through Plug-in Electric Vehicle Charging.* Sacramento: Sacramento Municipal Utility District.

For the overall California Independent System Operator (CAISO) market, the increased supply of spinning reserves leads to an overall avoided cost benefit for ratepayers due to reduced cost to procure spinning reserves as shown in Figure 17.

Figure 17: CAISO Market Avoided Cost Benefit of Spinning Reserves



Source: Aswani, D., & Boyce, B. (2014). *Autonomous Grid Services through Plug-in Electric Vehicle Charging.* Sacramento: Sacramento Municipal Utility District.

CHAPTER 3: Advancements & Conclusion

3.1. Vehicle Demonstration

This study helped identify PEV awareness as an area of need to benefit PEV adoption. Understanding PEVs from a consumer perspective and a commercial perspective (fleet) is essential to recognize the value and benefits these new vehicles provide. Fleet experiences can shape residential vehicle purchase decisions, as seen in this project. The majority of drivers had a positive experience which led to positive purchase recommendations and 3 recorded personal purchases. Some drivers had a negative experience, of which some drivers discouraged others from purchasing PEVs. Electrified fleets should be accompanied with awareness activities such as lunch and learn events, ride and drive events, and providing workplace charging for employee personal vehicles.

3.2. Infrastructure

Through the 29 Level 2 EVSE installations across fourteen sites, SMUD gained valuable experience in the installation of fleet-oriented charging infrastructure. All Level 2 EVSE installations were intended to support Chevrolet Volts that were registered with this Department of Energy sponsored grant where remote data collection was enabled via OnStar. The average cost per fleet EVSE installation was higher than expected and estimated to be $11,800. Some recommendations to manage installation cost are:

- Ensure that contractors have the appropriate experience.
- Sharing installation cost with site stakeholders to help set cost controls and accountability.
- Use engineer support only when necessary.
- Avoid installation at sites that require trenching or significant equipment upgrades such as transformer additions. If unavoidable, budget additional time and money for uncertainty.
- Select a parking layout where a single EVSE can serve multiple spots so a conventional vehicle occupying one spot does not eliminate access to the EVSE.

In addition to gaining installation experience, SMUD gained experience in the operation and maintenance for fleet-oriented charging applications. Some recommendations to improve the operation and maintenance of fleet-oriented EVSE are:

- Select EVSE quantity and type (Level 1, Level 2, or a mix) with sharing in mind to maximize utilization and minimize capital costs.
- Have policies and etiquette that supports EVSE sharing (disable any charger disconnect alarms)
- Incorporate some form of cord management to avoid tripping hazards and cord disorder.

3.3. Utility Readiness

SMUD has implemented special rates to encourage PEV adoption and has customer service representatives trained to support PEV customers, in relation to questions about vehicles, charging infrastructure, and special PEV rates offered by SMUD. Although this program support has been received positively by customers, it needs to be continually updated and adjusted as technology evolves and the market needs changes due to maturity.

The challenges to PEV growth for multi-unit dwellings are complex. This seems to be one of the gaps in the electrified transportation industry. In order to address these unique needs, a series of pilot evaluations may help establish several models to provide a mechanism for infrastructure accessibility for multi-unit dwelling residents that may be interested in purchasing PEVs.

SMUD has estimated the order of magnitude of grid integration costs per PEV to be $100-200 per vehicle on average. Better understanding the marginal costs of PEVs can help better define the next generation of PEV energy products for customers. These products could be a combination of programs or rates specialized for customers.

3.4. Regional Readiness

The progress of regional readiness activities for the Sacramento area was apparent in SACOG's regional readiness presentation to local elected officials in March 2014. The infrastructure planning efforts supported through this project directly benefited the AB32-funded fast charger location planning by SMUD. Furthermore, many local elected officials and building officials seem to be well versed on the challenges facing electric vehicles such as infrastructure needs, workplace charging, and multi-dwelling unit support. The interest from SACOG and local jurisdictions is helping continue the momentum and activity of TakeCharge. Supplementary funding is currently being sought to further charging infrastructure development projects as well as continue the regional coordination and harmonization efforts.

3.5. Future Technologies

The successful demonstration tests provide encouragement for V2G technology. It should be noted that primary frequency control is not a competing service to secondary frequency control. They are complementary functions. In fact, primary frequency control by EVSE can serve as a stepping stone to secondary frequency control by EVSE, if the latter reaches technology maturity for a sustainable business model. With both primary and secondary frequency control, PEV V2G services would more closely represent traditional frequency regulating generation resources.

Several questions remain in two main categories before V2G services may be adopted in a large scale implementation:

3.5.1 Technology Maturity

In the case of the OnStar demonstration, considerable software customization was required in the vehicle as well as manual over-ride of services. This suggests that the Smart Charging services are not production-ready with the 2011 MY Chevrolet Volt and further product development may be required. Another requirement for scalability is demonstration of how to aggregate many vehicles under the constraints of utility load requirements and customer expectations for energy delivered by the time of morning departure. Also testing with the Aerovironment prototype EVSE was not exhaustive, and thereby may not have considered all test conditions for a mainstream product.

3.5.2 Market Feasibility

The market feasibility for a V2G service requires consideration. Two elements of market feasibility are customer acceptance of V2G services such as demand response and whether the value added can be split in way that all parties can recover the initial cost of implementation and ongoing services. Also V2G services need to be proven and accepted by RTOs, ISOs, and balancing authorities in order to be recognized as legitimate services.

GLOSSARY

ALTERNATING CURRENT (AC) – Flow of electricity that constantly changes direction between positive and negative sides. Almost all power produced by electric utilities in the United States moves in current that shifts direction at a rate of 60 times per second.

CALIFORNIA ENERGY COMMISSION (CEC) – The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The Energy Commission's five major areas of responsibilities are:

- Forecasting future statewide energy needs
- Licensing power plants sufficient to meet those needs
- Promoting energy conservation and efficiency measures
- Developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels
- Planning for and directing state response to energy emergencies

Funding for the Commission's activities comes from the Energy Resources Program Account, Federal Petroleum Violation Escrow Account and other sources.

CALIFORNIA INDEPENDENT SYSTEM OPERATOR (CAISO) – The California ISO maintains reliability on one of the largest and most modern power grids in the world, and operates a transparent, accessible wholesale energy market.

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE) – Infrastructure designed to supply power to EVs. EVSE can charge a wide variety of EVs including BEVs and PHEVs.

ELECTRIC VEHICLES (EV) -- A broad category that includes all vehicles that are fully powered by Electricity or an Electric Motor.

PLUG-IN ELECTRIC VEHICLE (PEV) - is a general term for any car that runs at least partially on battery power and is recharged from the electricity grid. There are two different types of PEVs to choose from - pure battery electric and plug-in hybrid vehicles.

PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV) - PHEVs are powered by an internal combustion engine and an electric motor that uses energy stored in a battery. The vehicle can be plugged in to an electric power source to charge the battery. Some can travel nearly 100 miles on electricity alone, and all can operate solely on gasoline (similar to a conventional hybrid).

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA) - This organization sets standards for some non-electronic products like junction boxes.

SACRAMENTO AREA COUNCIL OF GOVERNMENTS (SACOG) – An association of local governments in the six-county Sacramento region.[3]

SACRAMENTO MUNICIPAL UTILITY DISTRICT (SMUD) - The acronym for the Sacramento Municipal Utility District, an electric utility serving the greater Sacramento, California, region.

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) – A global association of more than 128,000 engineers and related technical experts in the aerospace, automotive, and commercial-vehicle industries. The leader in connecting and educating mobility professionals to enable safe, clean, and accessible mobility solutions.[4]

VEHICLE-TO-GRID (V2G) – A system in which there is a capable of controllable, bi-directional electrical energy flow between a vehicle and the electric grid. The electrical energy flows from the grid to the vehicle in order to charge the battery; it flows in the reverse direction when the grid requires energy.[5]

3 Sacramento Area Council of Governments (https://www.sacog.org/about-sacog)
4 Society of Automotive Engineers (https://www.sae.org/about/)
5 U.S. Department of Energy (https://www.energy.gov/sites/prod/files/2014/02/f8/v2g_power_flow_rpt.pdf)