PUGET SOUND ENERGY

ELECTRIC VEHICLE CHARGER INCENTIVE PROGRAM REPORT

FINAL
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PUGET SOUND ENERGY

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TABLE OF ACRONYMS

Acronym	Definition
AC	Alternating current
AMI	Advanced metering infrastructure
AMR	Automatic meter reading
BMW	Bavarian Motor Works
California ISO	California Independent System Operator
CRAG	Conservation Resource Advisory Group
DCFC	Direct current fast chargers
DOL	Washington State Department of Licensing
EPRI	Electric Power Research Institute
EV	Electric vehicle
EVCI	Electric vehicle charger incentive
HB	House bill
IRP	Integrated resource plan
kW	Kilowatt
kWh	Kilowatt per hour
MW	Megawatt
OVGIP	Open Vehicle-Grid Integration Platform
PG&E	Pacific Gas and Electric Company
PSE	Puget Sound Energy
RFI	Request for Information
SOC	State of charge
UL	Underwriters Labs
WAC	Washington Administrative Code
WSDOT	Washington State Department of Transportation
WUTC	Washington Utilities and Transportation Commission

EXECUTIVE SUMMARY

Since the introduction of mass-market electric vehicles (EVs) in 2010, Puget Sound Energy (PSE) has been continually engaged with the EV market and EV drivers to understand how EVs may impact the electrical system, including the amount of power needed and when it will be needed. This is part of PSE's role in ensuring that it can provide safe, efficient and affordable power to its customers, regardless of how that power is used.

Customers who are considering or have purchased EVs have been very engaged with PSE, proactively asking for information on EVs and what programs PSE can offer to help them as EV drivers.

Driven by a desire to understand EV charging impacts in its own service area, PSE introduced the first customer-facing electric utility vehicle program in the Pacific Northwest in 2014. The program offered a $500 rebate to residential customers towards the purchase of a residential EV charger. The EV Charger Incentive (EVCI) program ran from 2014 through 2017, and PSE approved 1,993 rebate applications. Customers participating in the program completed surveys about EV driving and charging behavior and allowed PSE to monitor home energy usage. Another primary goal of the program was to evaluate technologies that could be used for smart charging, in order to understand potential options for customers to utilize different charging times so that costs from incremental electric load could be minimized or renewable generation increased.

At the time of this report, there are slightly over 13,000 EVs in PSE's electric service territory[1]. This number is small, representing less than 0.5 percent of the total vehicles estimated on the roadways in PSE's electric service territory[2]. However, the numbers have been growing rapidly since 2010, with EVs estimated to be 4 percent of new car and light truck sales in PSE's electric service territory.

This report's data presents a comprehensive view of how residential customers charge their EVs. In most cases, customers plan to charge their EVs between 5 p.m. and 8 p.m. when they return home from their work day. This results in EV charging peaks coincident with the evening peak load on PSE's electric system. In addition to home charging, customers also indicated that they planned to use public charging locations, as well as workplace charging locations. It is important to note that while customers may indicate that they charge at a specific time, charging is largely driven by need. Charging events are also dependent on battery capacity and daily driving distance. These variables contribute to differing charging behavior.

Another key finding from the program was the size of the additional load that multiple EVs can create. Charging multiple EVs in one home demonstrates a higher peak than the normal peak in the same customer's home. There are some concerns that simply shifting the peak for EVs to charge during an off-peak period may not be sufficient, as high penetration could simply create another peak outside of the normal system peak.

One of the areas of interest in EVs is how they might be used to integrate variable renewable energy resources. The first order analysis in this report examined the coincidence of average normal charging times with average renewable energy generation. Overall, this analysis indicates that changing times of charging will be necessary to align charging times with renewable energy production. At this point, the ability or willingness of customers to align with these different times of charging is unknown, but will be an important area for future work.

The impacts of EV charging in the near and mid-term are expected to be fairly low. The existing distribution system has capacity that can be used to support a significant amount of electrification, though local impacts of concentrated adoption should be monitored. Preventing EV charging at times of peak demand could serve to integrate even more EVs.

As EV penetration grows, it will be important in utility infrastructure and customer programs to plan for evolving technology and technology companies. During the course of the program, technology advancements included: the costs of smart chargers falling from more than $4,000 each at the beginning of the program to less than $1,000 each, the introduction of wireless charging, and the announcement from automakers and charging manufacturers of higher-powered charging in the future. Also during the course of the program, changes in technology markets led to the

[1] Washington State Department of Licensing Registry of EVs, June 2017
[2] Washington State Department of Licensing Registry of EVs, June 2017

financial failure of some charging networks, the change of platform technologies for other charging networks, the entry of companies into charging hardware and software, and the exit of some companies from charging hardware and software. What is certain is that there will be continued change in the technology markets.

As PSE prepares for additional EVs in its service territory in the future, this work to develop a current baseline of customer charging behavior and technologies to change charging behavior is foundational. From this baseline, future PSE programs can affect how customers charge their electric vehicles to both meet customer needs for reliable charging, and meet energy systems needs to minimize costs of EV charging and prepare for a future with a high number of variable renewable energy sources.

INTRODUCTION

This report outlines the EVCI program from inception to completion. Driven by the need to better understand EV charging behavior and analyze the specific loads caused by integration of EVs into PSE's electric system, the ultimate goal of this study is to ensure PSE's system is prepared to accommodate future demand for EVs in western Washington.

This report is divided into the following sections:

- Description of the program
- Data collection
- Analysis and presentation of results
- Impacts
- Technology evaluation
- Customer feedback and research
- Options for the future
- Appendices

This report uses the data collected on vehicle charging to evaluate what impact electric vehicles may have on power needs in the future, how these power needs compare to existing power usage, and how the power needs of EVs compare to the output of renewable electricity generators. The report also discusses options and technology to influence the time at which people charge their EVs. These options could be used in future programs to influence when people charge their EV to minimize the cost of the power used to charge the vehicles or to maximize the integration of renewable generation.

DESCRIPTION OF PROGRAM

This section is organized by program goals, regulatory framework, residential charging overview, rebate function and program outreach.

Utility context

When the EVCI program was first proposed in 2013, studies of the impacts of EVs were based on assumptions or only a few types of vehicles – both for PSE and for Washington State. For this reason, PSE pursued the adoption of a program that could assist the company to be responsive and proactive in planning for future load implications of a greater number of electric vehicles.

At the same time, there were relatively few utilities in the industry that were also focused on similar EV research and limited data was available. At the time of program inception, it was thought that the additional load from EVs could have a significant impact on peak demand, which could require new generating resources or traditional utility infrastructure. Through the EVCI program, PSE's aim was to gather data which could inform planning for future programs, and explore potential options to encourage customers to shift their charging load to non-peak times.

Goals

The goals of the EV rebate program were to:

- Collect data on how customers charge their EVs, including when they charge and how much energy they use.
- Understand potential impacts charging patterns could have on the demand for electricity and the costs for supplying electricity for these vehicles.
- Evaluate technologies that could be used for "smart charging", i.e., influencing the time at which customers charge their vehicles so that costs from the incremental electric load from EVs could be minimized or renewable generation increased.

Regulatory background and processes

The EVCI program was originally filed with the Washington Utilities and Transportation Commission (WUTC) on August 23, 2013, under Docket UE-131585. During the course of the proceedings, several changes were made to the original program to increase the amount of data collected and reduce the rebate amount. PSE and other parties agreed to these changes and the filing was updated. In addition, a petition (Docket UE-140626) to grant a waiver to Washington Administrative Code (WAC) 480-100-223 was filed as part of the proceeding.

Order 01 in UE-140626 was issued on April 30, 2014. A copy of the order is included as Appendix C. In the order, the WUTC determined that the waiver of WAC 480-100-223 was unnecessary.

Consistent with Order 01 in UE-140626, PSE provided updates to the Conservation Resource Advisory Group (CRAG) in the Biennial Conservation Plan and in the Annual Compliance Report, as well as during several CRAG meetings. A summary of the requirements of the order is outlined below. These updates to the CRAG are included as Appendix G.

During the course of the EVCI program, several other proceedings regarding EVs occurred. First, the Washington Legislature passed House Bill (HB) 1853 during the 2015 legislative session, which Governor Inslee signed into law on May 11, 2015. This law established a public purpose and financial incentive for utilities to pursue EV infrastructure. Second, Avista filed and received approval in April 2016 (Docket UE-160082) for a pilot program that includes residential, workplace and public charging.

On June 24, 2016, the WUTC opened UE-160799 to discuss issues related to utility participation in EV charging programs, which had been raised in the Washington Legislature under HB 1853 during the 2015 legislative session. PSE filed comments in this Docket on August 16, 2016, and November 23, 2016. Numerous other parties also commented.

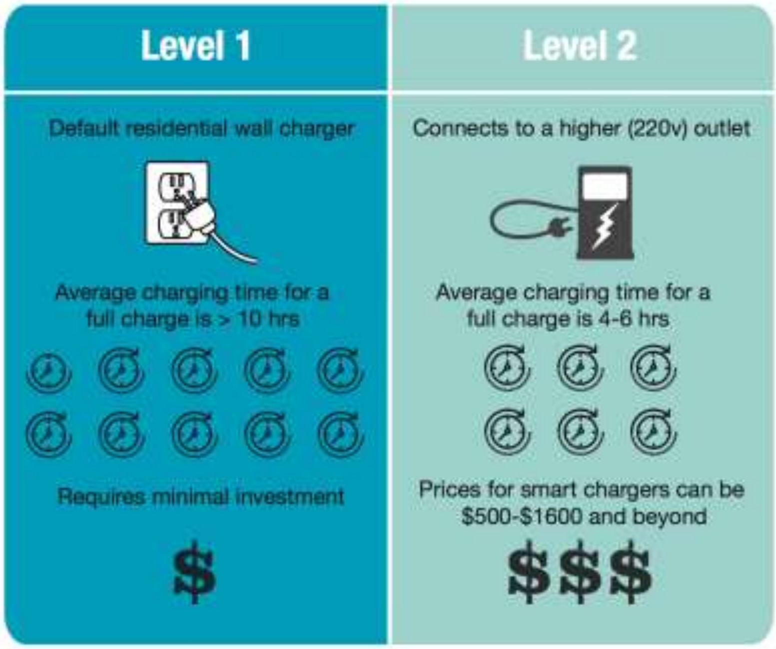
On November 21, 2016, PSE filed to extend the EVCI program through April 1, 2017, in cooperation with WUTC staff. This prevented any interruption to the EVCI program while UE-160799 was being resolved. This case was assigned Docket UE-161156 and was heard on the consent agenda, thus extending the program at the November 10, 2016, Open Meeting.

The WUTC issued a draft policy statement and opportunity to comment on January 17, 2017. PSE filed comments on the draft policy statement on March 31, 2017. The WUTC issued a final policy statement on June 14, 2017.

Residential charging overview

Charging in residential settings typically consists of two options.

Figure 1: EV charging options



Level 1 (110V) is the standard residential wall outlet. All new vehicles are sold with a charger that can connect to a standard wall outlet. Dependent on battery capacity, the vehicle's battery is typically replenished over 10 hours.

Level 2 (220/240V) is connected to a higher voltage outlet typically used for conventional residential washers and dryers or hard-wired into a home. If a 220V outlet is located in the garage, the Level 2 vehicle charger can be connected directly to the outlet. If no higher voltage outlet exists in the garage, an electrician may be required to run additional wiring to support the charging. Level 2 chargers greatly reduce charging time; a vehicle is typically fully charged within four to six hours.

For PSE's EVCI program, customers were provided a $500 rebate after purchase of a Level 2 home charger.

Outreach

PSE connected with potential customers in several ways to encourage customer enrollment and participation in the rebate program. This section discusses customer communications, dealership outreach and online advertising.

Customer communications

PSE provided program updates to customers during the program via email. The 65 to 75 percent open rate for these emails was exceptionally high when compared to the PSE average, indicating the emails were well received by our customers. EV customers in general showed high engagement and interest, with more than 75 percent of rebate customers indicating they would like to receive regular newsletters about EVs[3] from PSE.

Dealer outreach

Automotive dealers are one channel for customers to receive information about EVs and requirements for ownership, although customers are becoming more research-savvy and relying more heavily on online information channels (see Customer Feedback & Research section). PSE's outreach team developed a comprehensive list of all dealerships throughout PSE's service territory and surrounding geography. The organization contacted a total of 71 dealers during spring 2015 and 2016, with most dealers being contacted twice, at a yearly interval. Each dealer was provided background on the charger rebate program and printed materials about the program they could provide to their customers.

Some dealers were very enthusiastic about the program and contacted PSE to request program updates and additional materials, whereas other dealers did not offer EVs for sale at their locations. PSE communicated with dealers via email throughout the program to ensure they were updated regarding the status of the program and any relevant updates.

Advertising

PSE ran several online advertising campaigns throughout 2015, 2016 and 2017. These advertising campaigns were primarily display ads that were shown within PSE's electric service territory, and keywords that would prioritize those advertisements when internet users in PSE's electric service territory searched common words associated with EVs.

In addition, PSE distributed informative flyers at corporate events and to dealerships. Examples of marketing collateral are shown in Figure 2.

Figure 2: PSE EVCI program advertisements

[3] PSE customer research with rebate customers, 2017

Rebate program operations

Applications for the $500 rebate were accepted online and through paper applications. Customers were required to submit a completed application form, a copy of their EV registration and a copy of the receipt for the purchase and/or installation of their Level 2 charger. A third party was used to verify the customers' qualifications, process their rebates and dispense customer payments.

PSE received 2,502 applications for the program; however, not all applicants were eligible for the rebate. The most common reasons for applicants not meeting the program qualifications were:

1. The customer did not apply within one year of initial vehicle registration. In many cases, customers applied for rebates on used vehicles that were outside the one year age qualification for vehicles.

2. The customer purchased a charger not certified by Underwriters Labs (UL) or an equivalent testing agency, which is a requirement typically required by electrical inspectors.

3. The customer did not reside in PSE's electric service territory and/or was a PSE gas-only customer

PSE approved 1,993 rebates for the program.

At the time of PSE's filing with the WUTC in 2014, there were approximately eight vehicle models available to consumers, and by the end of the rebate program there were more than 25 models available. Customer applications were received for a variety of vehicle makes and models, and dispersed by brand and model. In addition, some vehicles were full battery electric, while others were a plug-in hybrid electric model. A summary of the approved vehicle models are shown in Figure 3 and Table 1. Almost 90 percent of the approved vehicles were in the top six types of approved vehicle makes and model.

Figure 3: Top approved vehicle make and model

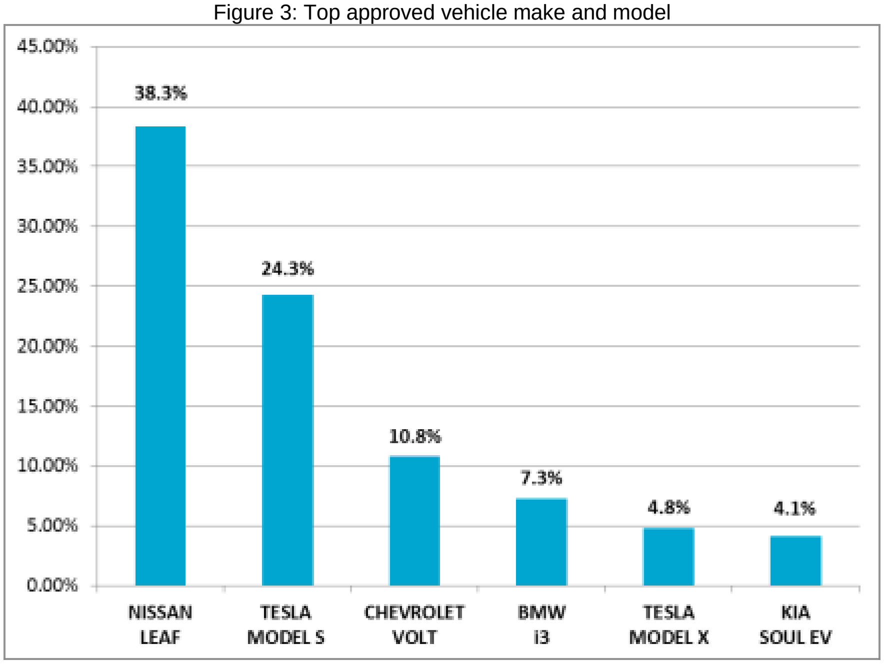
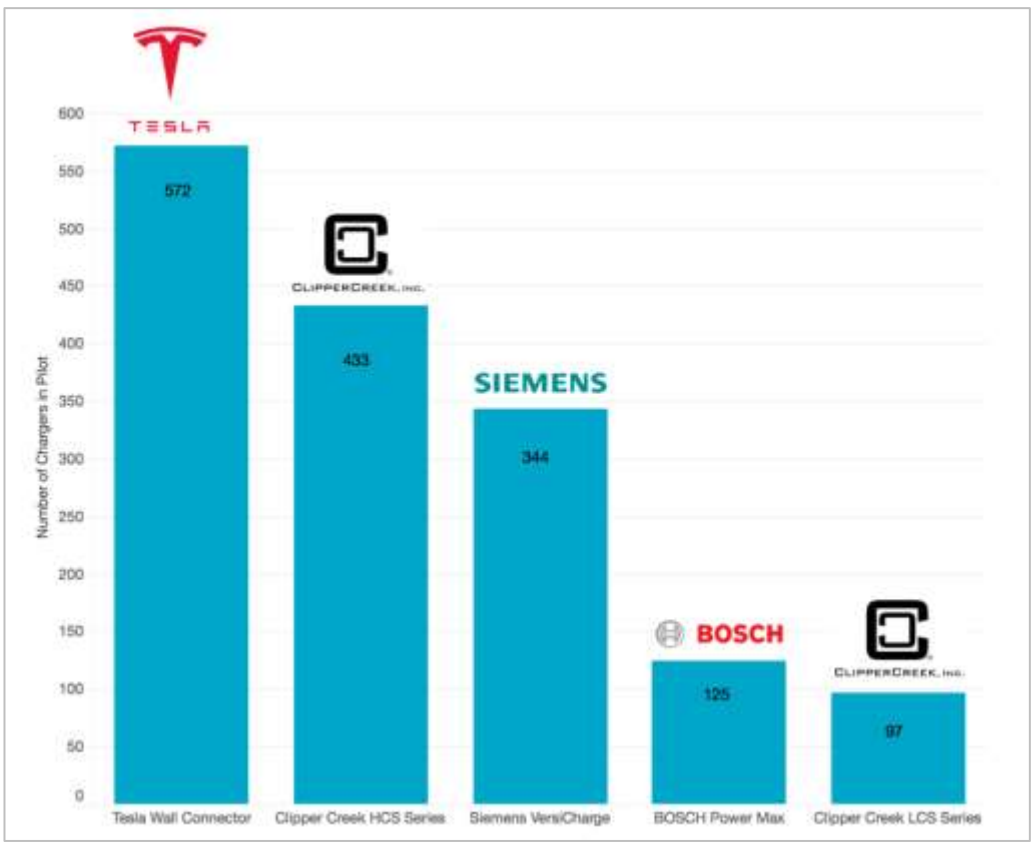


Table 1: Additional approved vehicle make and models

Vehicle Make	Vehicle Model	Vehicle Make	Vehicle Model
Audi	A3 E-Tron	Hyundai	Sonata
BMW	330E	Mercedes	B-Class Electric
BMW	X5	Mitsubishi	i-MiEV
BMW	i8	Porsche	Cayenne
Cadillac	ELR	Smart	ForTwo
Chevrolet	Bolt	Tesla	Model S & Model X
Chevrolet	Spark	Toyota	Prius Prime
Fiat	500E	Toyota	Rav4 EV
Ford	Fusion	Volkswagen	E-Golf
Ford	Focus	Volvo	XC90
Ford	CMax	Zero	DS13

Customers could choose the charger they preferred from a list of qualified chargers that PSE maintained and regularly updated. The top five approved models selected by customers are shown in Figure 4 below. Tesla was the leading charger, although not the leading vehicle. This is because Tesla uses a proprietary connector, so only Tesla chargers were selected with Tesla vehicles. For other vehicles, consumers had a selection of many chargers due to interoperable connectors, so the charger selection was more varied.

Figure 4: Top five approved charger models



Customer satisfaction

PSE conducted a customer survey in March 2017 with the goal of understanding customer satisfaction with the rebate program along with EV behaviors. PSE distributed a customer survey to 528 approved rebate customers, and received 299 responses equating to a 57 percent response rate. PSE also sent the survey to 119 customers that were not approved for the program and received 49 responses, resulting in a 41 percent response rate. Given the larger sample size and participation in the PSE rebate program, the results presented in the figures throughout this section relate only to customers who were approved for the rebate program.

Customer feedback was generally positive regarding the EVCI program, with most negative feedback resulting from the processing time for rebates. PSE surveyed all customers that applied for a rebate, and feedback for those approved tended to be higher than those denied. As shown in Figure 5, 97 percent of approved applicants had positive to average experiences with the program. Applicants rated the ease of applying for the rebate the highest, and the speed of processing their application the lowest. The low rating for rebate processing speed could be due to rebates being processed by a third party vendor and taking up to 12 weeks to process.

Approximately 98 percent of approved customers indicated that they would participate in another PSE electric vehicle program.

Figure 5: Overall program experience for approved applicants

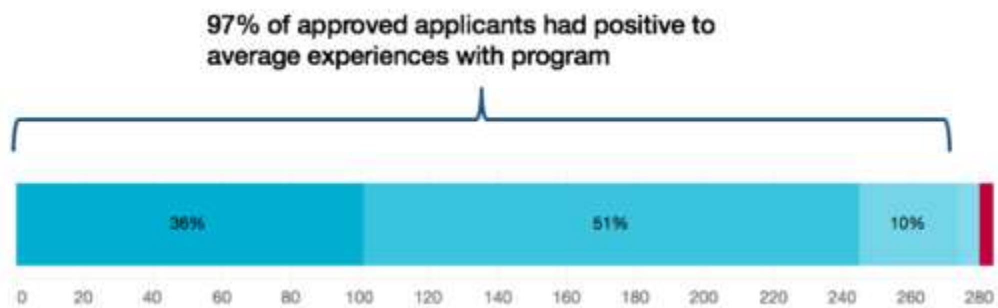


Figure 30: Approved applicant rating on program elements

DATA COLLECTION

One of the primary goals of PSE's pilot program was to better understand EV charging behavior and help plan for potential electric system impacts. In doing so, data collection and analysis was a critical component to program operations. The data discussed in this section relates to residential Level 2 charging, as this was the focus of the study. PSE also attempted to identify customers who were charging using Level 1 charging in their residences, but found these customers were difficult to develop connections with, as they had no reason to contact or work with PSE.

Throughout PSE's service territory, energy usage from residential customers' electric meters is typically stored once per day. PSE's metering records the electric use of the entire house. While this provides information on overall load, it doesn't illustrate the magnitude or time when EV charging takes place. To provide a more robust picture of vehicle charging behavior, PSE included a number of additional data collection methods in the program, as discussed in the following section.

Data was collected from customers through various channels. This section discusses data collection methods during the program, including the initial customer survey, daily meter data, 15-minute meter data and eGauge data.

Application survey

When applying for the rebate program, PSE collected initial survey data from customers to measure several aspects of customer behavior, including their use of EVs, driving patterns and charging patterns. PSE also collected the types of EVs customers drove and the distance driven each day.

Customers filled out a survey to report the daily anticipated driving distance of their EV and their current charging behavior. Table 2 shows the questions that were asked in the application survey.

Table 2: Summary of initial survey information

Information Collected in Initial Survey
What date did you start using your charger? (mm/dd/yyyy)
What time of day do you typically plan to start charging your EV? (AM/PM)
How far do you plan to drive your EV each day? (miles)
Which of the following charging locations do you plan to use? (Home, Work, Public Level 2, Public fast charger)
Are you interested in learning more about PSE's Green Power and Energy Efficiency programs? (Y/N)

Customers filled out the initial application survey and provided their email address as part of the application. See Appendix D for results from the application survey. PSE contacted groups of customers throughout the program in order to gather data around actual usage and satisfaction in the program.

Meter data: daily interval

PSE collected daily use data from customers' residential electric meters for all customers in the program. PSE used daily data obtained from meter reads for some customers to determine if daily data could be used to identify customers who had acquired an EV. Working with DataRaker, a meter data analysis company, a group of EV customers were compared to PSE's overall residential customers. The method analyzed how much the studied customers deviate from their past energy use to determine if there is a significant and sustained change in energy use.

Meter data: 15-minute interval

PSE collected 15-minute interval data from the customers' residential electric meter for customers in the program. In signing up for the rebate, customers acknowledged that PSE would collect additional information about their energy usage. In addition to collecting estimates from customers during program enrollment on when they would charge their EVs, capturing 15-minute interval data would allow PSE to better estimate when the EV charging load occurred at a home and potentially how large it was. Approximately 80 percent of rebate customers were placed on 15-minute interval data.

In order to identify and use only the EV charging load within the 15-minute data, PSE conducted an exercise to determine whether the EV load could be identified from the whole house load for an individual meter. This exercise is described in detail in the technology evaluation section (page 28).

eGauge data logger

PSE used eGauge data loggers to evaluate charging behavior with further precision, in addition to the 15-minute interval data collection described above. eGauge data loggers directly measured customers' EV charging along with total household load, and also if solar power was generated.

eGauge is an energy monitoring system that has the ability to measure home energy usage and solar generation. The eGauge is usually installed near the power distribution panel of a building, where there is easy access to the power circuits to be measured. The eGauge is permanently connected to charging equipment, unless the customer chooses to discontinue monitoring.

Figure 6: eGauge meter used during rebate program

Fifty customers were selected to participate in the eGauge data collection, with each customer representing a segment. These customers were segmented by daily driving distance and car type. Most customers had the eGauge meter installed in 2015, although some customers changed their residence causing alternate customers to be added to the sample in 2016 and 2017.

ANALYSIS AND PRESENTATION OF RESULTS

One of the primary goals of the program was to develop an understanding of when and how customers charge their EVs. This analysis resulted in load curves which are quantitative estimates of the amount of energy used to charge EVs during each hour of the day.

In following sections, the results of EV charging are compared to PSE's normal system loads for electricity, as well as to the output of renewable electricity generators.

The results of this analysis are considered both on the individual customer level as well as the entire residential customer base as a whole. The analyses include examining differences between customers, developing an aggregate load curve and energy usage for EV customers, and identifying how EV charging loads compare to PSE's system loads and renewable electricity generation. Results were also considered on different time scales and in different seasons to determine what differences exist within these variables.

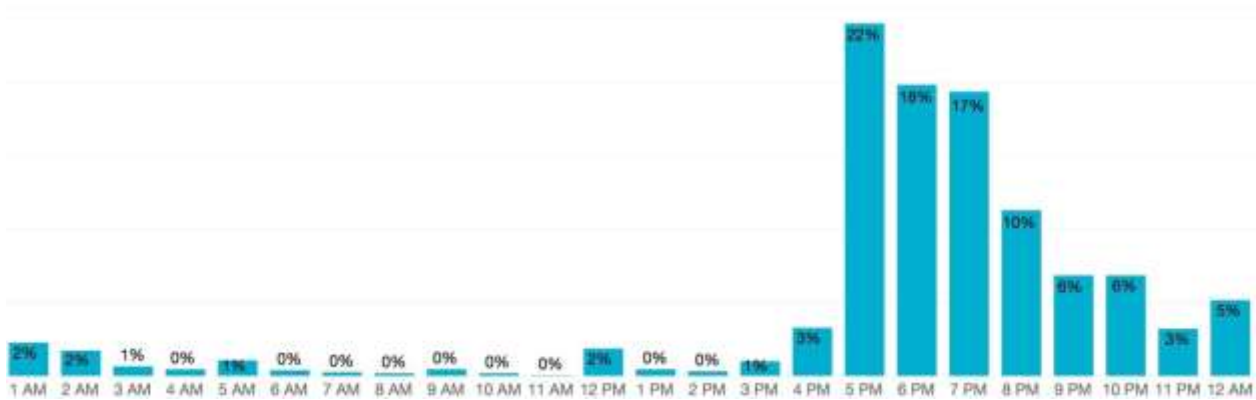
During the project, PSE tried new types of data analysis to attempt to determine what daily and hourly data might be able to tell us about charging. These analyses were intended to seek new findings about charging behavior based solely on whole-house monitoring, without use of end-use data logging, which was also performed for this project. These analyses and results are reported here for completeness, even where the initial results of the new methods indicated that they were unlikely to have enough accuracy to be used in future programs. These learnings are important in continuing to refine understanding of charging, and how to track charging over time as the number of vehicles grows.

The following sections describe these findings in more detail.

Application survey

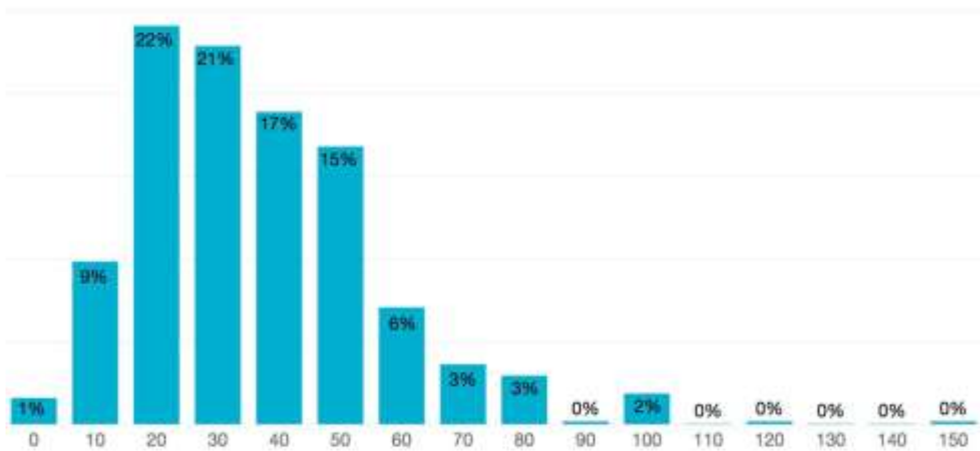
The rebate application survey asked customers to report when they planned to charge their EVs, the number of miles they planned to drive daily and their planned charging location. This information was typically collected when a customer just purchased their vehicle. This information provided data that could be used to better understand charging and driving patterns, including when charging is planned and how much energy will be used. As shown in Figure 7, 67 percent of customers reported they plan to charge their EVs from 5 p.m. through 8 p.m.

Figure 7: Planned time of day for charging EV



As shown in Figure 8, 75 percent of customers answering this question reported they plan to drive their EVs 20 to 50 miles per day, which is below the typical range of battery EV models. In addition to home charging, customers also indicated they planned to use public charging locations (Level 2 and Direct Current Fast Charging [DCFC]) and planned to use workplace charging.

Figure 8: Planned miles driven per day



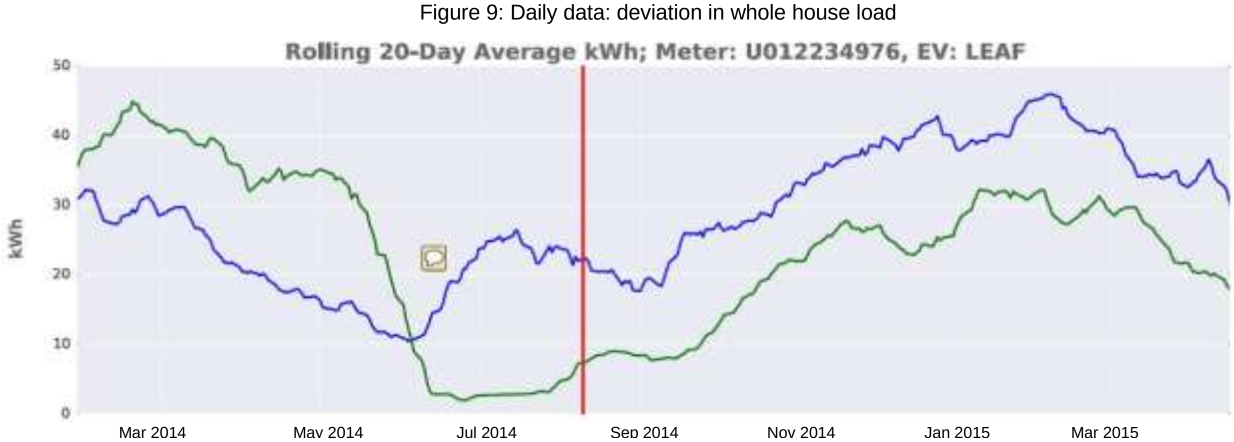
Meter data: daily interval

PSE engaged DataRaker, now part of Oracle, to determine if it was possible to differentiate how much daily energy customers with EVs used at their residences using daily meter readings. A set of 13 customers was initially selected in 2014 to provide a range of data in the variety and type of vehicle purchased.

For these customers, their daily electricity usage was compared during the same period in 2013 and 2014, selected to coincide with the date they bought their EV (according to their program application). This comparison was made around total household energy used and how the customer compared to the average of all residential customers (noted as usage factor in Figure 10).

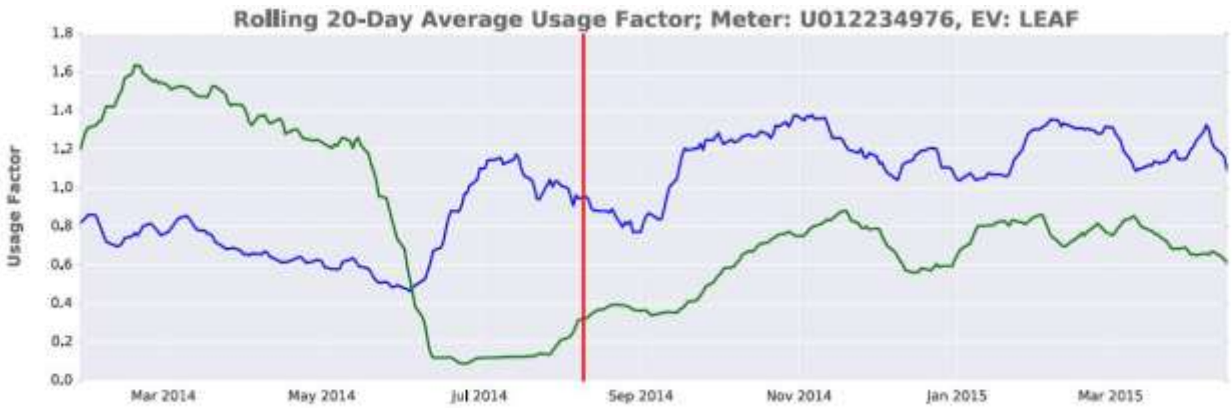
In Figure 9, the green line represents a customer's daily house load in 2013, and the blue line is the load in 2014. The vertical red line represents when the customer reported they started using their EV. The 2014 line reveals that the whole house load did increase annually, however this does not coincide exactly with the date that the customer reported acquiring an EV. This deviation in the date versus the load change could be due the customer reporting an inaccurate date for their vehicle acquisition.

Figure 9: Daily data: deviation in whole house load



This methodology was also normalized by comparing the customer to all residential customers, shown as the usage factor in Figure 10 below. Normalization was used to help minimize impacts of weather changes, as the entire group of customers was expected to increase or decrease usage in response to weather. This analysis shows a similar result, confirming that the change in load was most likely due to the addition of the EV.

Figure 10: Daily data: usage factor normalization



This method was repeated for another 12 customers. Of the 13 total customers analyzed, only 7 showed a clear change in energy use from one year to the next that was likely caused by the addition of an EV. These findings are based on a relatively small number of customers. The analysis was performed on this small number of customers to determine if the method produced reliable results that would warrant increasing the number of customers analyzed. These indicative results on a small number of customers indicate that daily use data could identify some EVs, but may not be accurate over time. This indicates that other means, such as customer self-identification or vehicle registration data, will be required to determine where EVs are located over time.

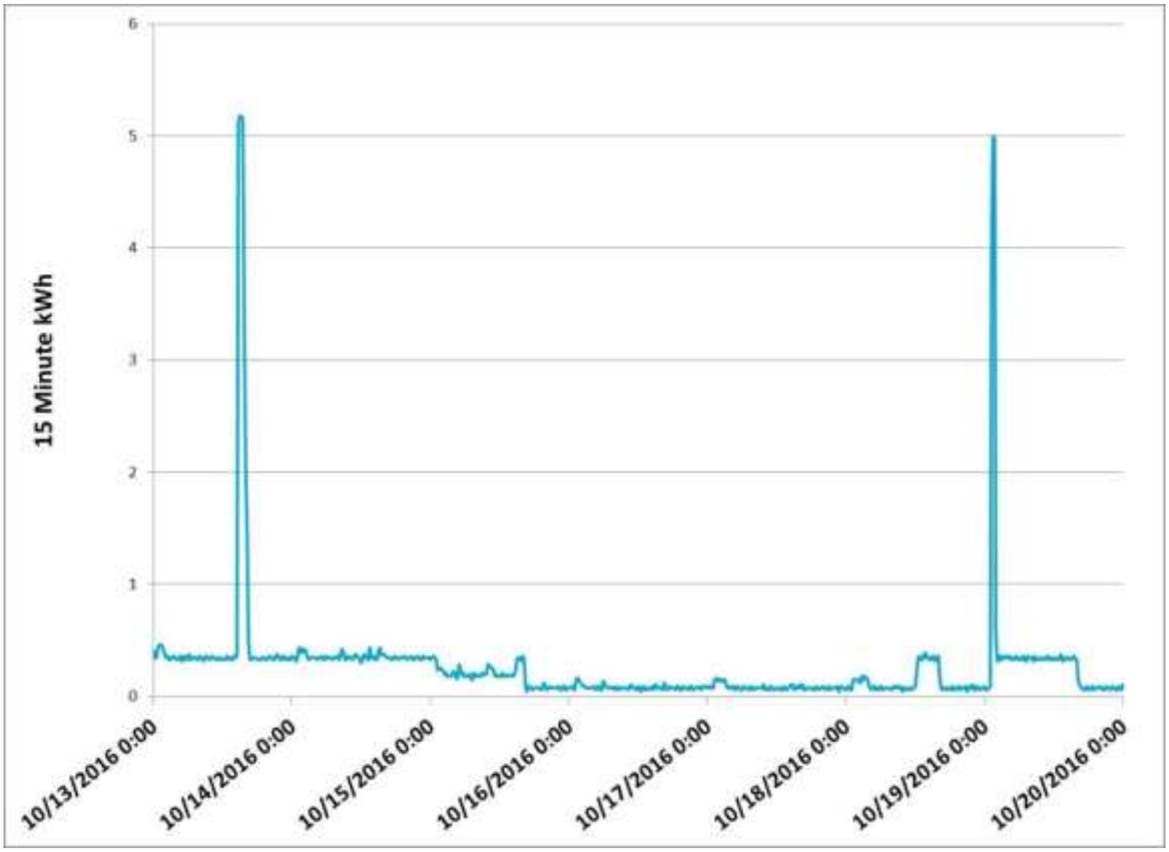
Meter data: 15-minute interval

As part of the rebate program, customers acknowledged that PSE would be collecting 15-minute interval data on their whole home energy usage. Through this Automatic Meter Reading (AMR) interval data, PSE wanted to explore whether charging events could be detected, the magnitude of charging and the timing of events. This 15-minute data was taken at the whole house, and therefore does not distinguish between vehicle charging and other activities occurring in the house such as routine use of appliances. Often whole house loads are shown with hourly data, but this is presented at the 15-minute interval, and therefore data may appear lower than anticipated. In addition, it should be noted that the graphics in this section are illustrative and for individual customers, which will be different than load shapes presented in later sections.

An example of interval metering data is shown in Figure 11 for a Tesla customer. In this case, there are distinct peaks in the interval data, which are likely charging events. Tesla batteries have a larger capacity and typically have a higher magnitude in charging events. For these reasons, these peak events shown in the data are likely to be charging events.

In addition, if the peaks are assumed to be charging events, this customer does not actually charge every day, taking an average of five days between charging events. This could also be accounted for by Tesla's larger battery pack that has more than 200 miles of range.

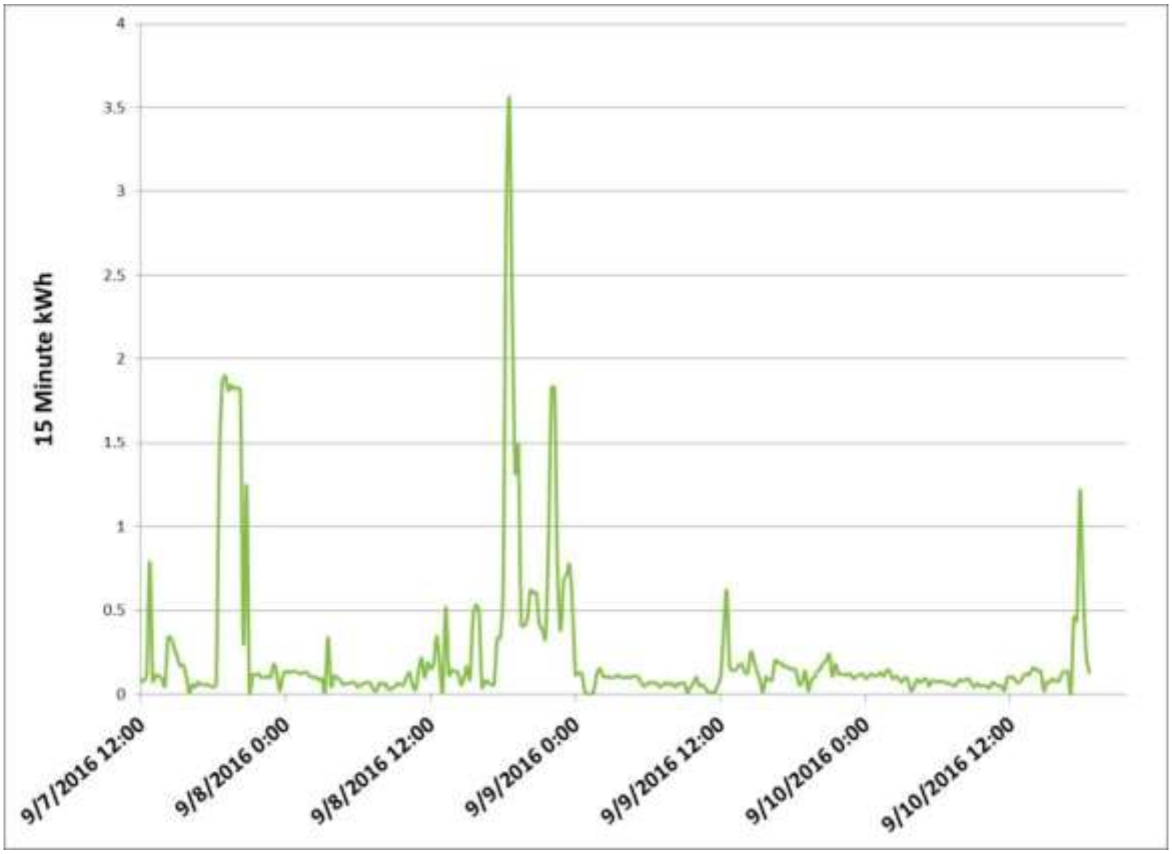
Figure 11: 2014 Tesla Model S 15-minute interval data



In Figure 12, data from a customer with a 2015 Kia Soul EV is shown. The Kia Soul EV has approximately 100 miles of range in the battery, and therefore may not have as distinctive of peaks when viewed in interval meter data. In this case, it appears that there is a charging event on Sept. 7, 2016, at approximately 2 kilowatts per hour (kWh) and another event on Sept. 8, 2016, at 3.5 kWh. For this customer, there is more noise with the whole house load, and because charging events are lower in magnitude (in comparison to Tesla), it's harder to detect significant events and have certainty that charging is occurring.

In addition, if Sept. 7 and Sept. 8 are assumed to be charging events, this customer appears to charge their vehicle more frequently than the Tesla customer.

Figure 12: 2015 Kia Soul EV 15 minute interval meter data



In both cases presented with Tesla and Kia, while the customer may indicate that they charge at a specific time, charging is largely based on need. There is also variability in charging events dependent on battery capacity and daily driving distance. These two variables will largely dictate how often a customer needs to charge. In the example of Tesla, this customer may have a shorter daily drive distance and therefore doesn't need to charge as often.

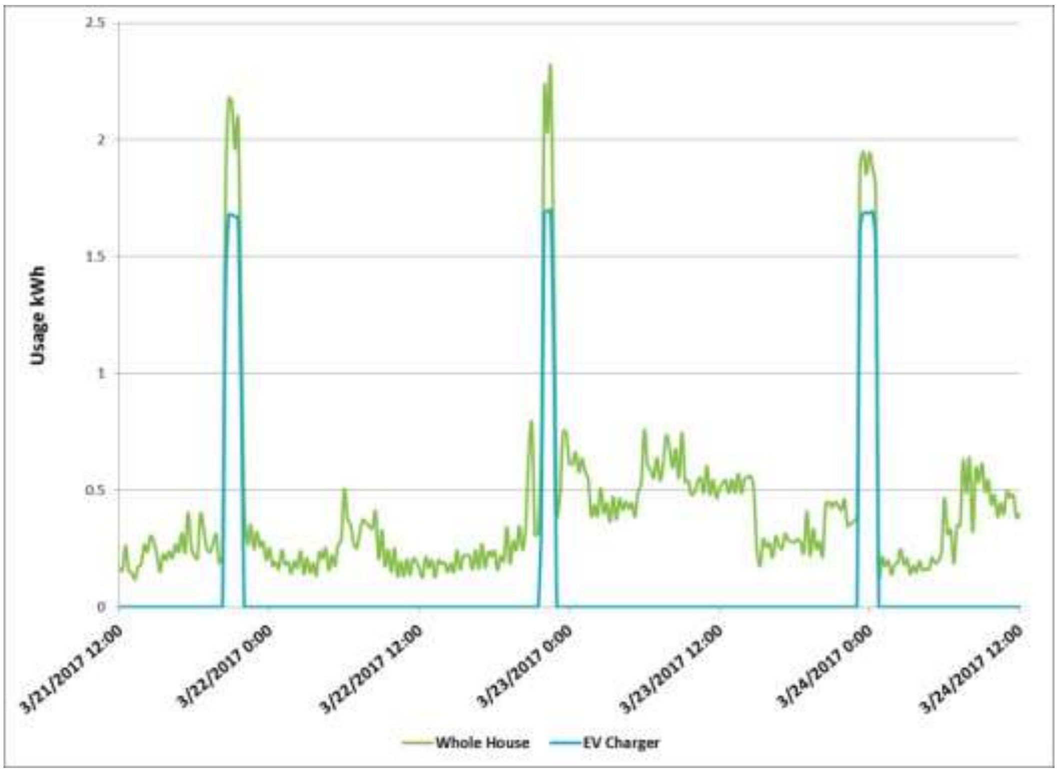
In addition, some customers may choose to charge their vehicle more frequently when they have a relatively high state of charge (SOC). For instance, some customers may prefer to plug in their vehicle every night even though their SOC may be sufficient for the next day's drive.

eGauge

In addition to placing 80 percent of rebate customers on interval metering data, PSE also analyzed a subset of 38 customers on an eGauge data-logger. This allowed PSE to directly see charging events and whole house load.

Results from the eGauge data-logger are shown in Figure 13, which shows data from a customer with a 2013 Nissan Leaf. This depicts the actual charging events and how the whole house load aligns. In the timeframe shown below, the customer charges every day, and it appears to occur around the midnight hour.

Figure 13: 2013 Nissan Leaf charging data

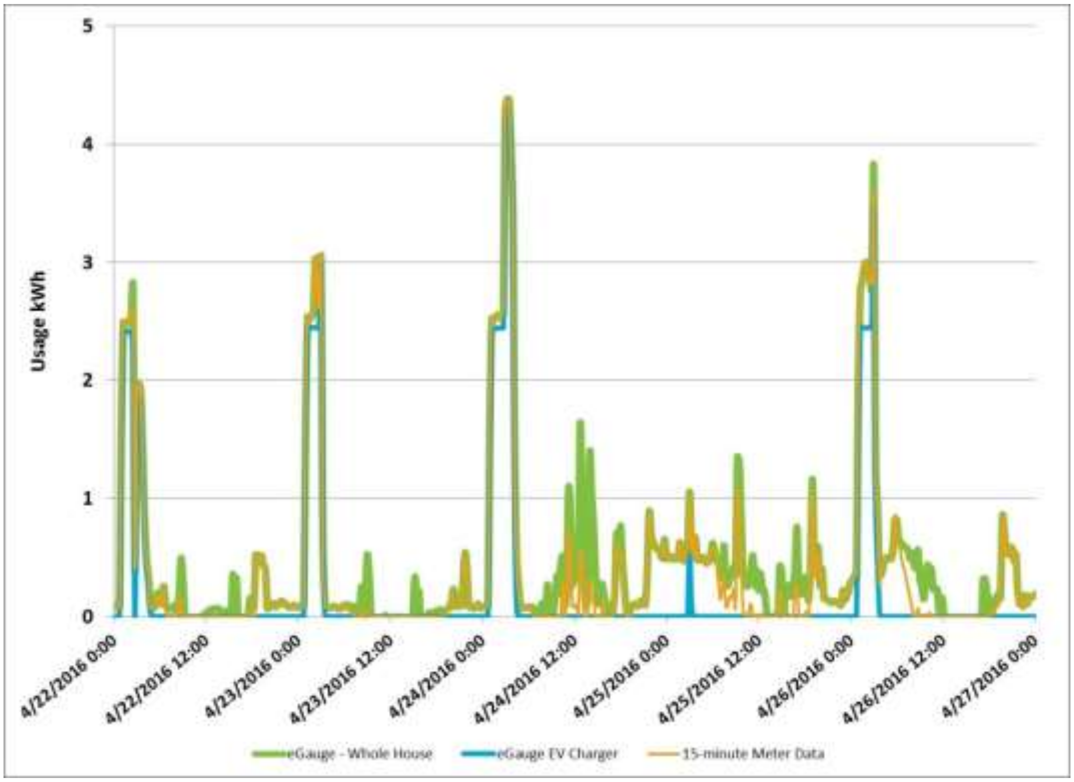


Alignment with 15-minute meter data

The 15-minute interval data and eGauge data were collected on separate systems, but in terms of data integrity, it was important to understand whether the data sources align. PSE was able to pull customer data from both interval metering and eGauge for comparison. Figure 14 reveals that the data for the charger and whole house essentially align between different sources when viewed as a visual representation.

This information was used in a later exercise (described in technology evaluation section, page 28) to determine whether the eGauge data, with known charge events, could be used as an analytical correlation measure to PSE's metering systems to detect charging. As shown in the technology evaluation section, DataRaker and PSE were not able to correlate the charging events with enough accuracy to use in future programs.

Figure 14: 2015 Tesla Model S charging data

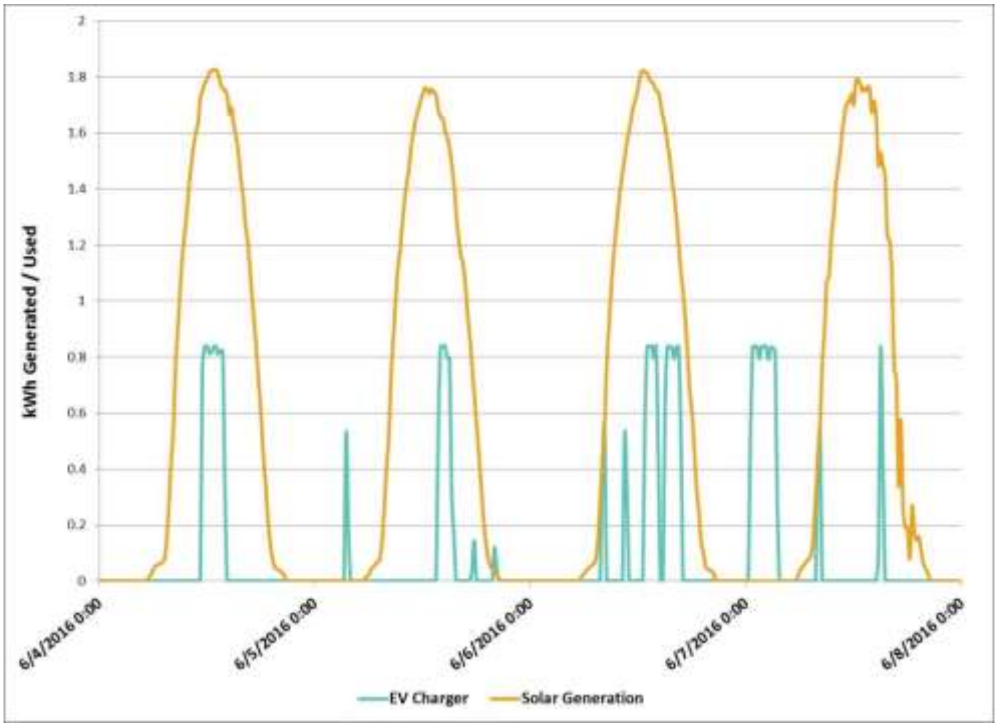


EVs and solar generation

This section considers how EV charging compares to renewable generation on an individual basis. To understand the alignment and impact of renewable generation on an individual level, a customer's eGauge data was viewed in times of peak solar output (June through July) and in times of peak demand (December through January). Time periods were selected from June because it contains the longest day of the year, and so can be a period of high solar production. Time periods were selected from December because it contains the shortest day of the year, and can contain PSE's peak loads of the year. This is a simple analysis to simply examine coincidence between solar generation and EV charging based on average curves. To analyze the potential ability of EVs to help integrate solar or other renewables, significant additional data and analysis would be required. Also important to remember is that analysis on EV use for renewable integration is largely hypothetical today. Real-world experience needs to be gained with scheduling charging to develop a complete understanding of the ability of EV charging to integrate renewable energy at scale.

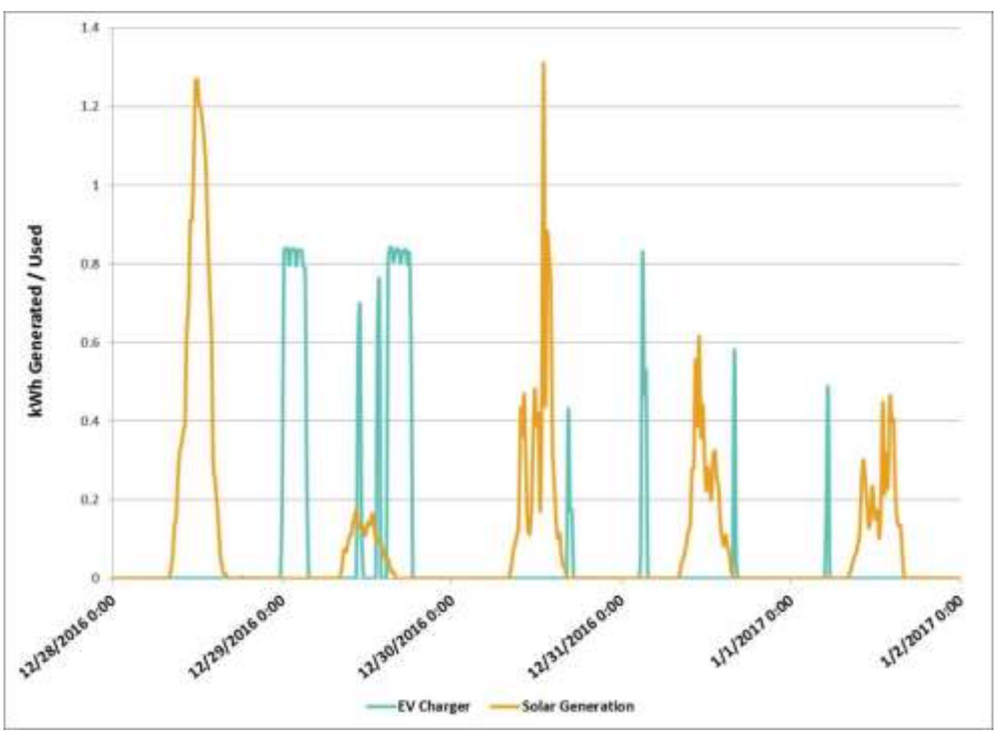
Figure 15 demonstrates an example of how a customer's charging behavior aligns with solar generation in June 2016. This period was chosen because it had reliable solar output each day, and so is illustrative of what can happen during extended periods of daily sun. In this example, this customer charges their EV during times of solar generation, therefore off-setting the charging load. However because EV charging often occurs when it is needed, rather than planned, not all charging takes place during daytime solar generation hours.

Figure 15: June solar generation with EV charging (Chevy Volt)



The same customer's charging and solar generation is also shown during the winter months in Figure 16. The days were selected to be indicative of inconsistent solar generation throughout a winter day. Solar generation during winter is significantly less than summer generation, and can often be less consistent in the days and duration. In this case, there is less ability to align EV charging with solar generation, perhaps because there is less predictability around generation timing.

Figure 16: December solar generation with EV charging (Chevy Volt)

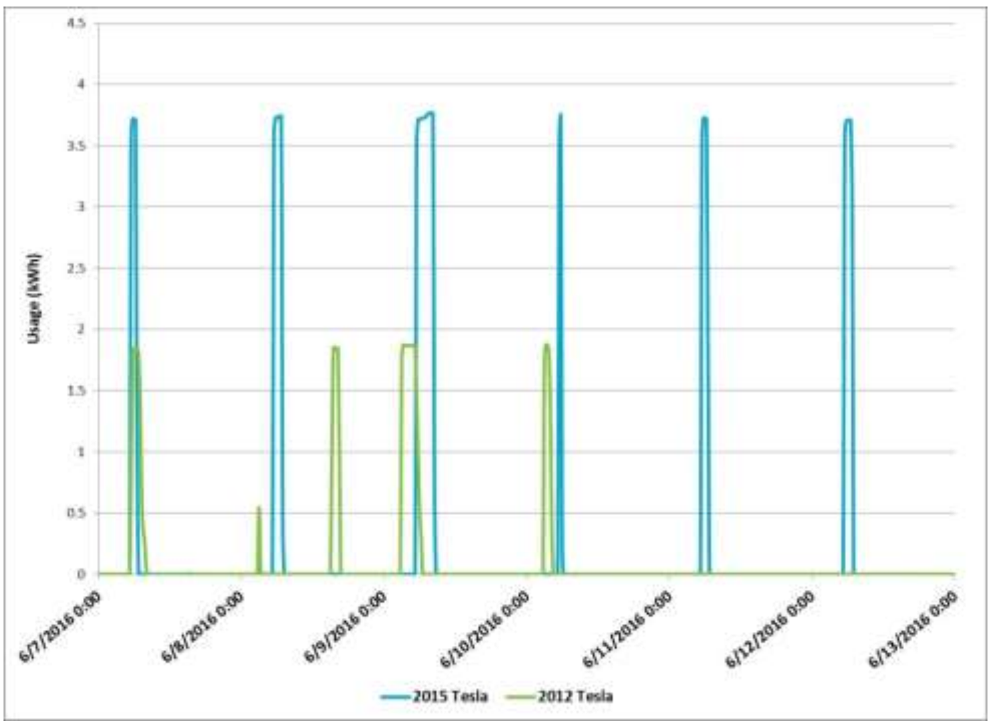


Multiple EVs in one home

Several customers with eGauge data-loggers installed owned multiple EVs. This provides a useful comparison to determine how charging might happen in an individual house when there are multiple EVs. While the sample size is small, this qualitative comparison can provide some indication of how much variability there can be in driving and charging patterns between different EV drivers. Where there were multiple EVs in the same home, a separate data-logger channel was used for each EV to allow charging patterns to be examined individually. While not monitored specifically to determine if each vehicle was using the same charger every time, it is believed that this is likely the case.

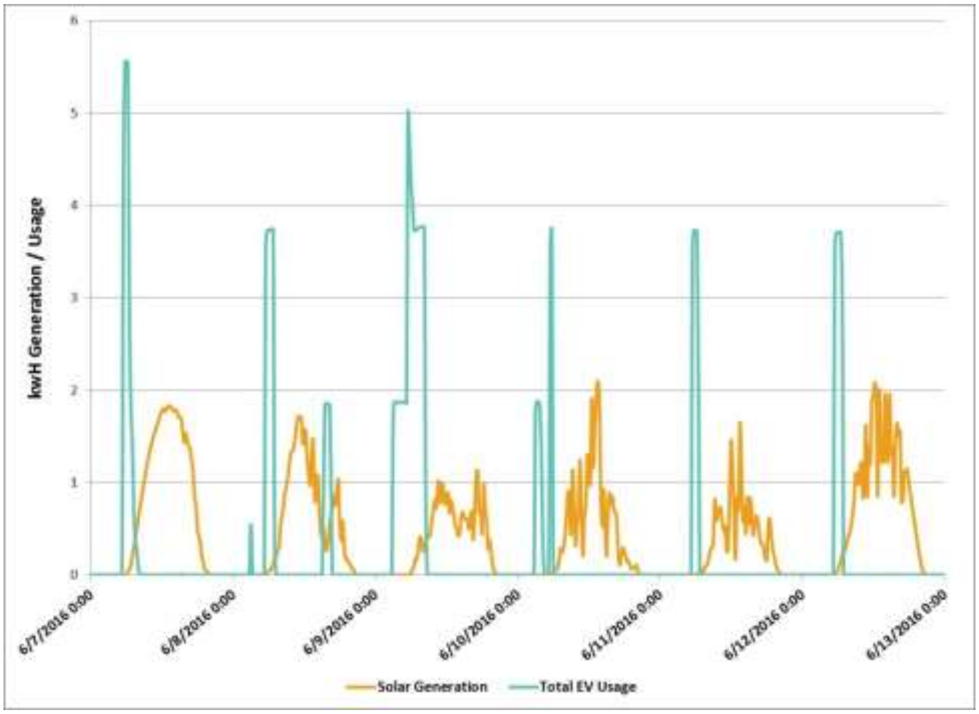
Analysis of the charging and whole house load data from a three day period during June 2016 clearly indicates significant peaks in electricity use caused by the EVs. This data is shown in Figure 17. However, the two EVs at this home only charged at the same time a few times during this period, and often charged at different times. This is due to driver behavior and indicates that different members of the same household have different use patterns for EVs.

Figure 17: Multiple EVs in one residence



In addition to owning multiple EVs, the customer shown in Figure 17 above also had a solar installation at their residence. If the solar system was generating at the same time that customers charged the EVs, it could offset some of their demand from EV charging. In Figure 18, the total load from EV charging is shown compared against the solar generation from this customer. For this time period, some of the EV charging is off-set by solar generation; however, it does not align on a consistent basis. In addition, the peaks from EV charging are far greater than the kWh from solar generation, which causes the spiked shape shown in the graphic.

Figure 18: Multiple EVs in one residence + solar generation



Of particular importance is the size of the additional load that multiple EVs can create. In this case, multiple EVs charging at once would create a peak higher than the normal peak load of this customer's home without the EVs being charged. Even given use pattern diversity, programs that caused multiple EVs to start charging at the same time could simply move the peak from the current time to another time. On a system-wide basis, this may not be a problem at this time given the relatively low number of EVs, the observed diversity of their charging and their energy use as compared to the overall system needs. However, on a localized basis, causing EVs to all charge during an off-peak period may not be sufficient, as high enough penetration could simply create another peak outside of the normal on-peak times.

System-wide basis

This section compares PSE's normal system loads and generation of renewable generation resources with the charging behavior of EVs. This comparison allows a determination of whether EVs will contribute to times of peak electrical demand on PSE's system and whether EV charging is coincident with periods of high renewable generation on PSE's system. This analysis is directional in nature, as opposed to definitive. It uses average load curves from the EV load profiling, as well as average model resource renewable generation shapes from PSE's 2017 Integrated Resources Plan (IRP). Actual performance and coincidence of EV charging with renewable resources is likely to be more variable than the analysis here, which is only based on averages. As PSE improves its data over time about both EV charging and distributed renewable generation, additional analyses will be possible.

A detailed discussion of the development of the average EV load profiles is included in Appendix F.

Coincidence with times of peak demand could require PSE to build additional generation or distribution system assets. Coincidence with times of high renewable generation could help manage renewable energy on the system by providing a new use for energy during the times of highest generation.

Charging coincidence with system loads

Hourly load forecasts for PSE's system were used to form a comparison to system loads. This load forecast is considered normal based on historical data and is used in the IRP to identify the shape of the energy that will need to be delivered. For this analysis, the 2018 system loads from the IRP were considered. This analysis is illustrative. A more rigorous analysis compared to PSE's measured loads over the 12 months ending in June 2017 is included in the load profiling report (Appendix F).

PSE's system load changes throughout the year based on customer demand. In general, PSE's system loads are highest in the morning and evening during the winter months. System loads are generally lower in the summer, but have the highest load each day in the evening.

The following graphs show the forecast 2018 system load and the average EV residential charging shapes in winter, represented by the December average, and summer, represented by the June average. These months were chosen to represent summer and winter because December is often the time of PSE's peak demand and June contains the longest day of the year, which will be important in the next section to discuss coincidence with renewable energy.

Figure 19: Forecast system loan compared to average EV residential charging shape – December

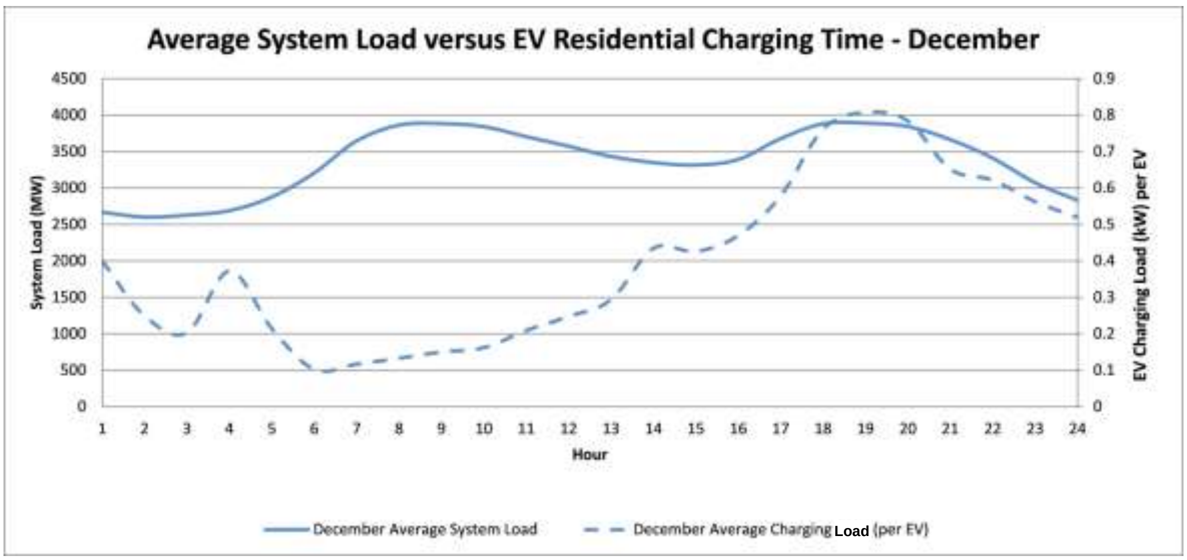
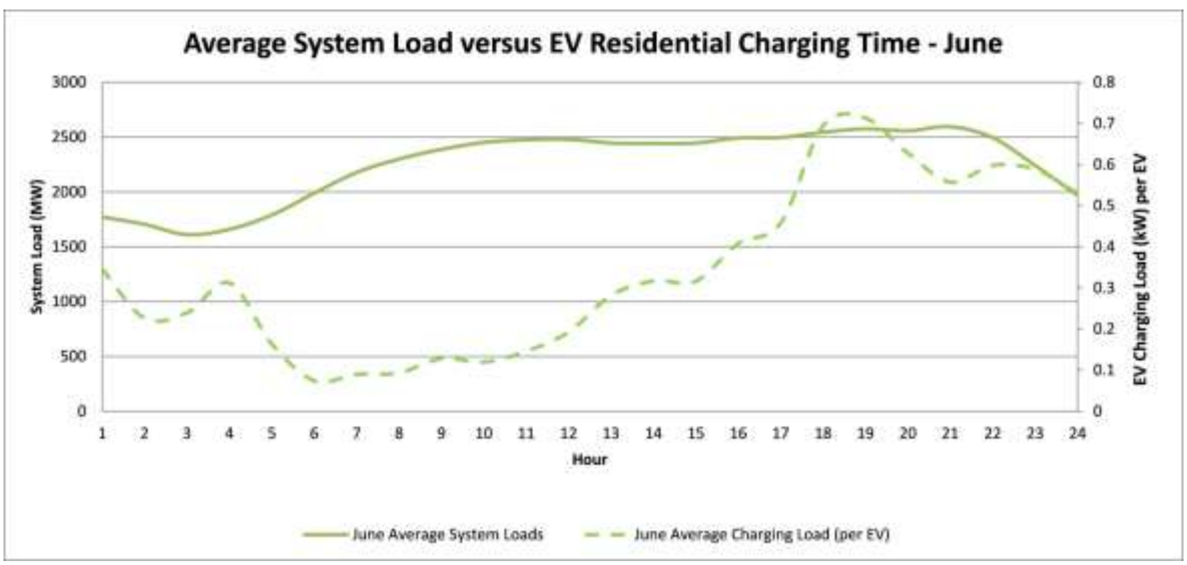


Figure 20: Forecast system load compared to average EV residential charging shape – June



Both analyses show that average residential EV charging will contribute to the average evening peak load hours. The exact amount each day is likely to vary from this analysis using a monthly average of loads and residential charging, but on the whole, there is likely to be a contribution. It is important to keep the amount of potential addition to peak in perspective. For the estimated 13,140 EVs in PSE's electric service territory, their average contribution to peak in December of approximately 0.8 kilowatt (kW) per EV is only 9.6 megawatt (MW). The maximum peak shown by EVs during the study period was 19.6 MW, but it did not coincide with PSE's system peak during the same period. In the 2017 IRP, PSE analyzed the potential impacts on PSE's generation portfolio of a significant penetration of EVs. A more detailed analysis of the customer charging data, as compared to PSE's actual loads, is included in Appendix F.

Solar generation coincidence with charging

PSE has identified the potential use of EVs to help integrate variable renewable energy sources as an area of great interest. While the total load available from EVs is small today, understanding how EV charging could be used to support variable renewable energy is important as the amount of variable renewable energy generation and the number of EVs grow in the future.

The first step in considering how EVs could support variable renewable generation sources is examining the natural coincidence of unmanaged charging with renewable energy generation. This section compares solar energy generation with Level 2 residential EV charging. The generic solar generation shape used in the 2017 IRP and the average residential EV charging shape are used for the comparison.

This comparison indicates that in the winter, the average peak for unmanaged residential EV charging takes place after solar production has fallen off for the day. In summer, more of the residential charging takes place during the hours of solar output; however, the peak of residential charging need occurs after the solar output has fallen off for the day.

While this considers charging and solar output on an average basis, the actual charging and solar output on a day to day basis can vary considerably. It is also important to keep in perspective the relatively small amount of energy required for EV charging versus the output of large solar facilities as modeled in the IRP. The addition of new solar resources would increase the annual renewable energy generation, which could supply sufficient renewable energy to cover the added load of electric vehicles.

Figure 21: Solar output compared to average EV residential charging shape – December

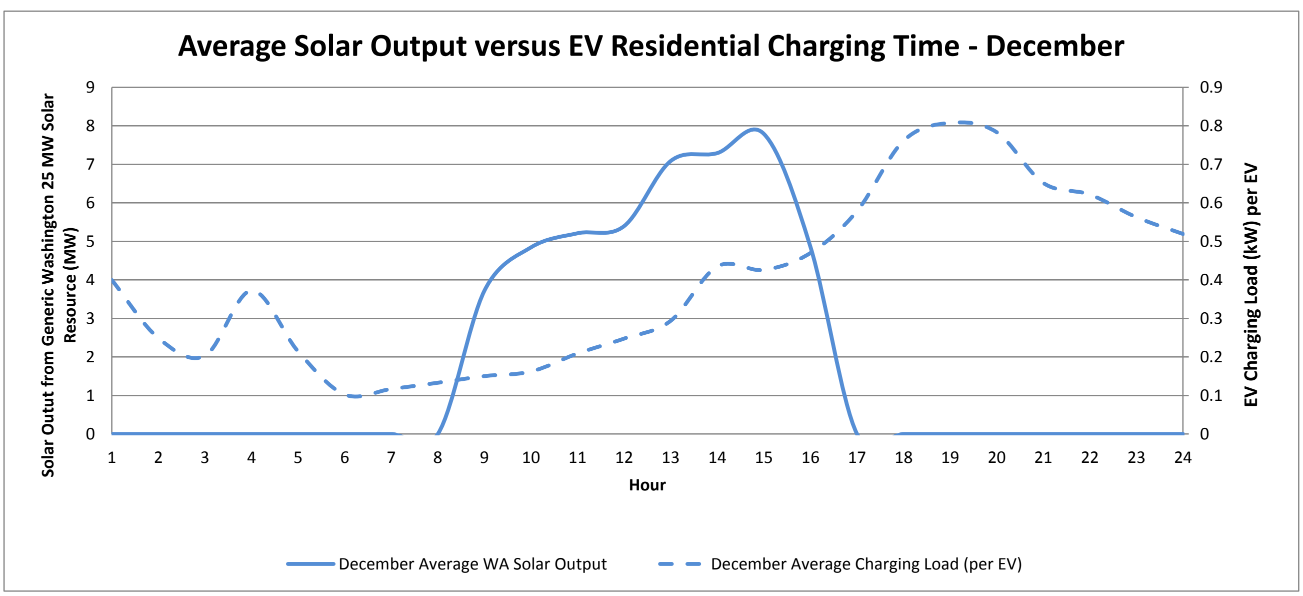
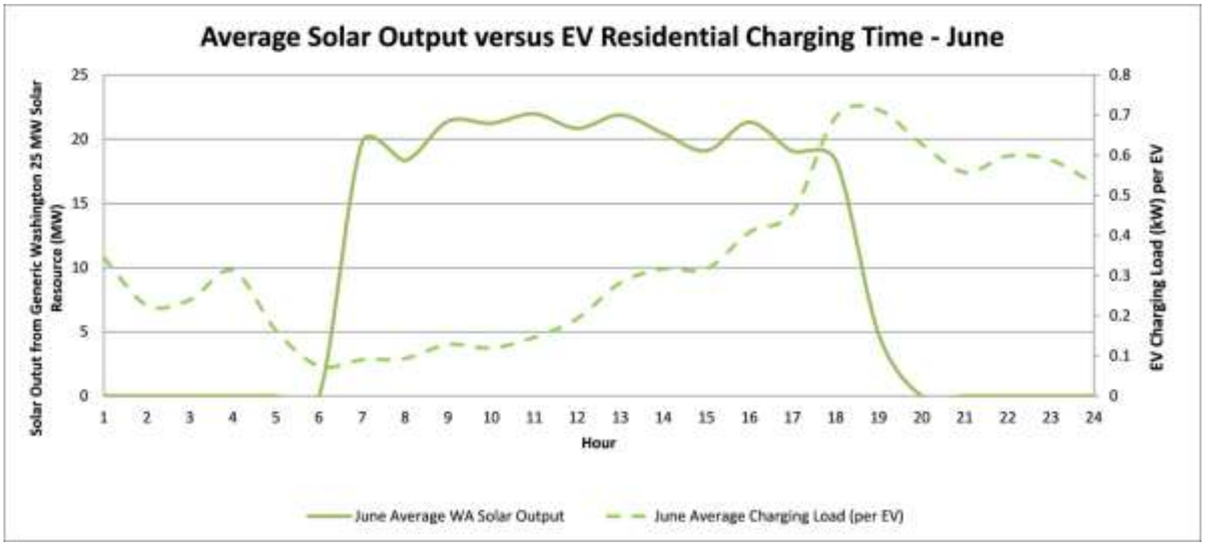


Figure 22: Solar output compared to average EV residential charging shape – June



EVs and wind generation

The average residential EV charging profile was compared to the average hourly output of generic wind resources in Washington and Montana, which was used in the 2017 IRP. The average outputs for these wind resources in December and June are shown below, as compared to the average residential EV charging profile in the same months. As can be observed in the charts, there is little correlation between the EV charging and the wind output.

As with solar, it is important to consider that these are monthly averages. Hourly changes can vary more significantly, as actual wind generation is variable from hour to hour and EV charging can vary each day and hour. As with solar, the annual output of new wind renewable resources is significantly larger than the added load of electric vehicles today.

Figure 23: Washington wind output compared to average EV residential charging shape – December

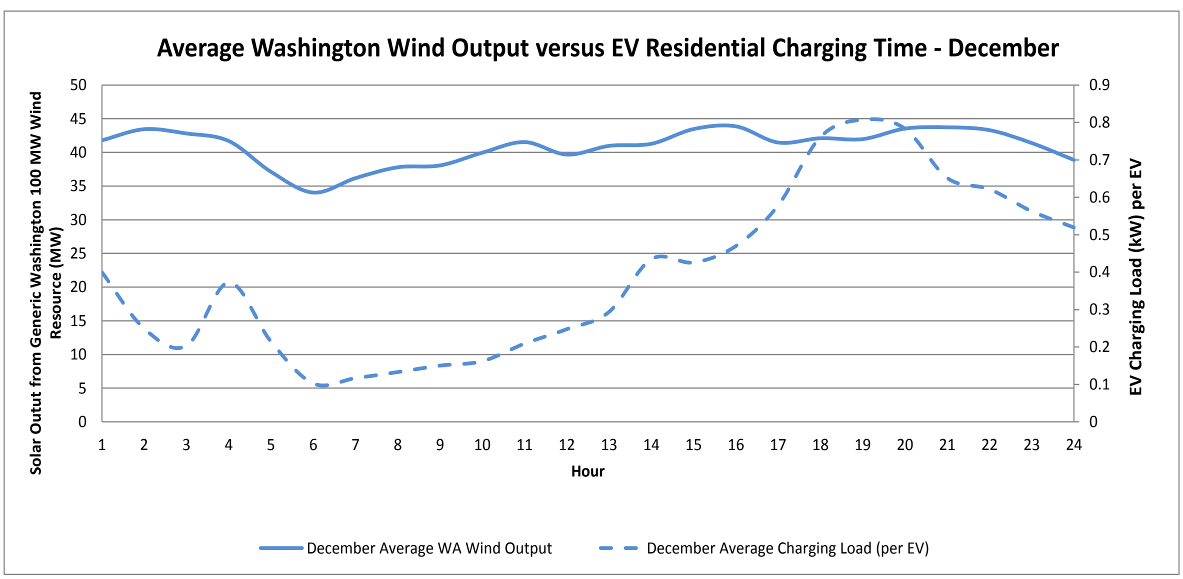


Figure 24: Washington wind output compared to average EV residential charging shape – June

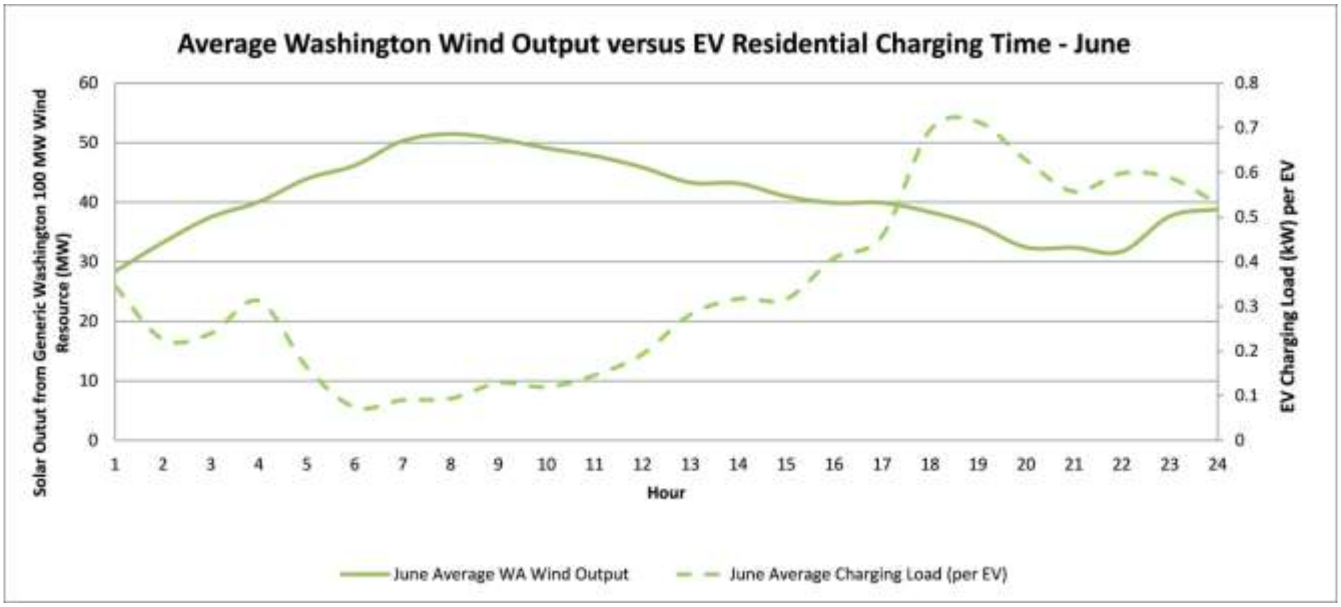


Figure 25: Montana wind output compared to average EV residential charging shape – December

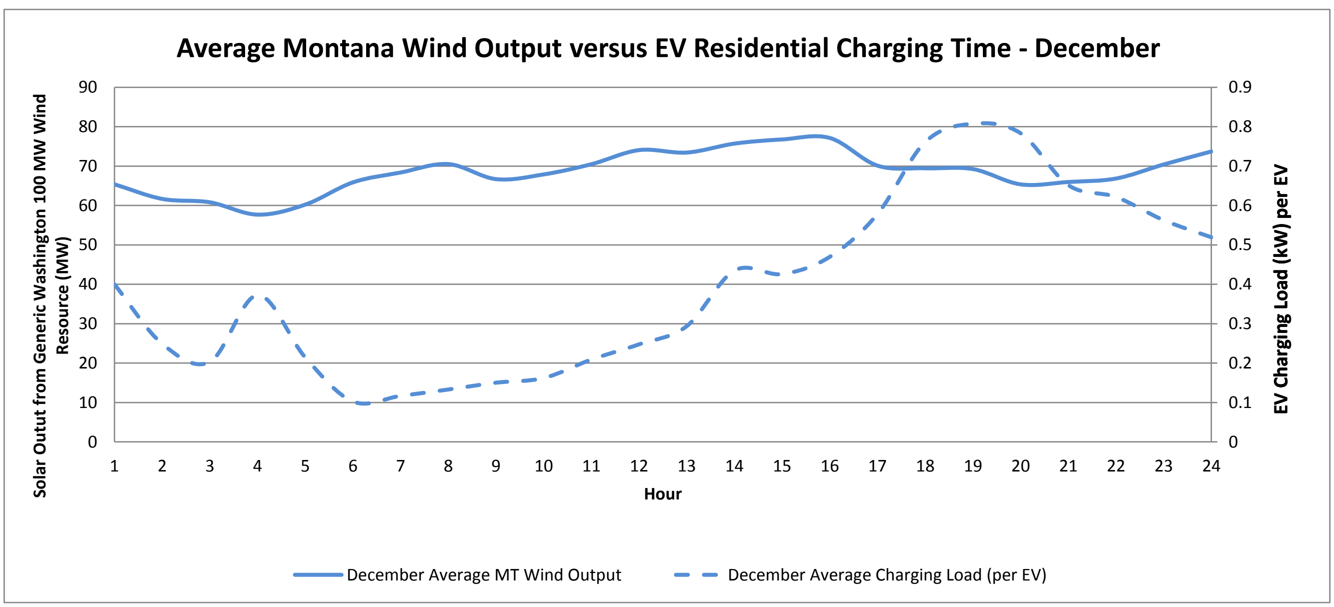
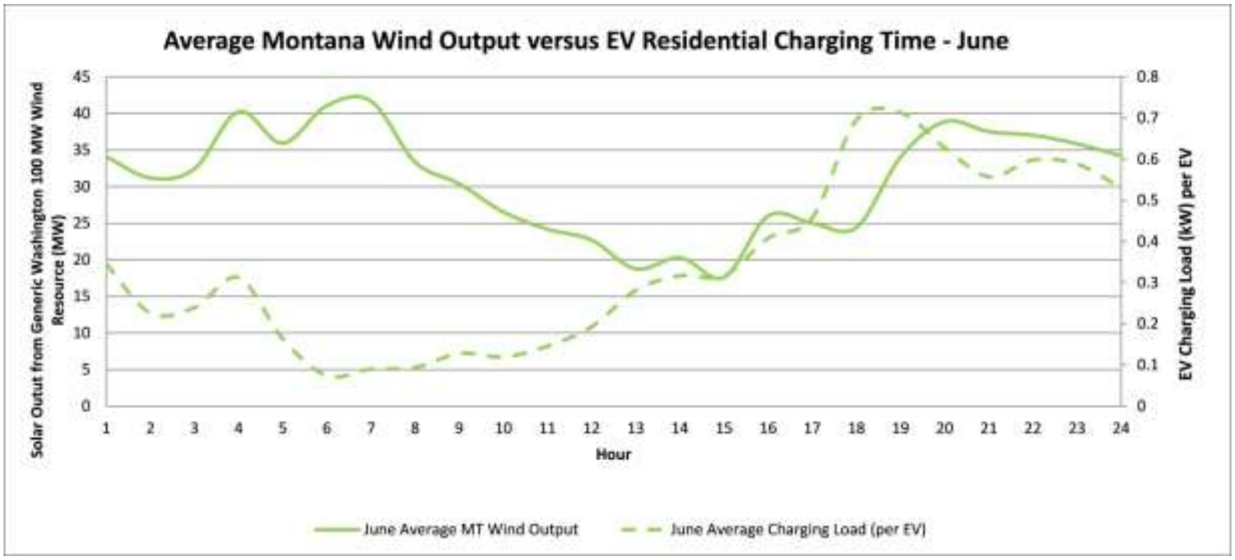


Figure 26: Montana wind output compared to average EV residential charging shape – June



IMPACTS

This section outlines some of the high level impacts to PSE as EV adoption continues. This is in consideration with system wide loads and also in specific areas throughout PSE's territory.

System loads

As was shown in the previous section, EV charging peaks at a time coincident with the evening peak load on PSE's system.

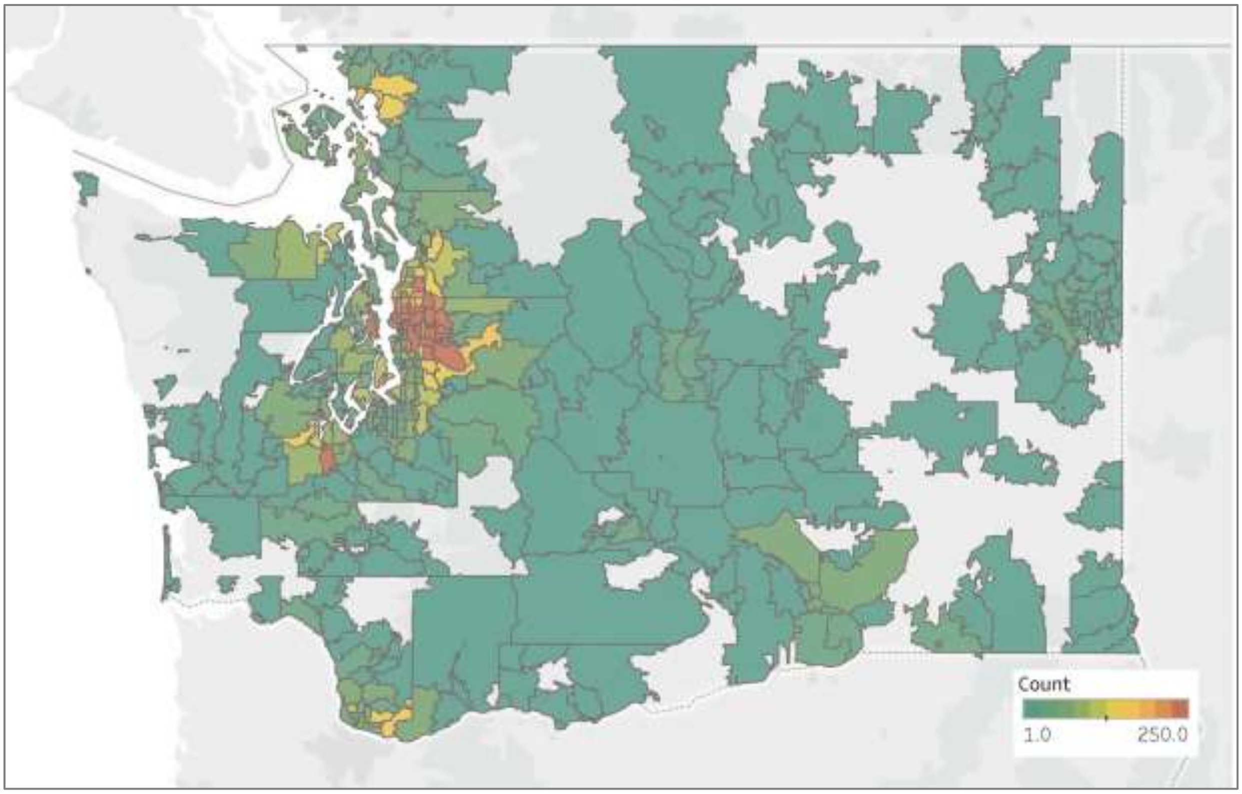
At the current time this impact is small, with a peak charging demand of 9.9 MW on the average weekday, which is only 0.3 percent of the residential customer class peak. Over time however, introduction of a significant number of EVs without managed charging could increase this peak load, which would result in the need for new resources. EV load was modeled as a sensitivity in PSE's 2017 IRP and the report found that over time, uncontrolled charging of EVs could result in both additional renewables and additional peaking resources.

EV distribution throughout service territory

In addition to the overall system load, it is also important to consider specific areas of higher concentration EVs throughout PSE's service territory. This becomes important because as more EVs are located in one area, the load could potentially overload circuits.

The overall distribution of electric vehicles throughout the state (as of June 2017) is shown in Figure 27. This is presented by zip code, where a lower number of registered EVs are in green and a higher number are in red. Figure 27 is based on Washington State Department of Licensing (DOL)/ Washington State Department of Transportation (WSDOT) vehicle registration data.

Figure 27: Heat map of registered vehicles in WA State as of June 2017



The heat map in Figure 28 measures distribution of the rebate applications throughout PSE's service territory by number of records. For example, zip code 98052 has 151 records. During the rebate program, there was a higher concentration of program participation in east King County and the surrounding area. This is depicted by the higher concentration in dark blue.

The heat map measures the penetration of PSE's rebate program by zip code.

Figure 28: Heat map of approved rebate applications

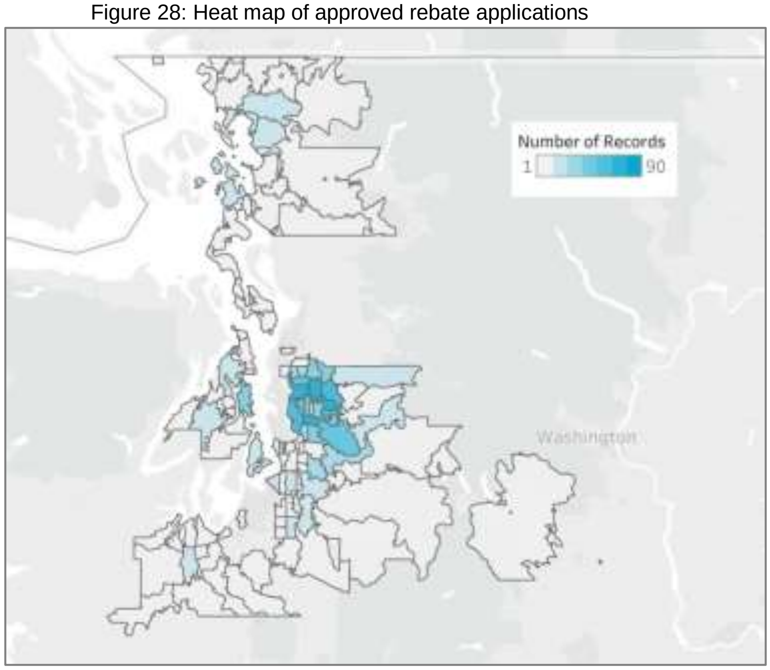


Figure 29 looks at the program enrollment as compared to electric vehicles in a particular area. This map uses PSE rebate program data and overlays it with DOL June 2017 EV registration data. Within a given zip code, if there are 10 total EV registrations in the DOL data and if the same zip code has 3 PSE rebate participants in the pilot program, then that zip code's penetration is 30 percent.

This illustrates the propensity of a customer to take part in PSE's program based on their location. It also illuminates whether PSE's records of EVs based on program participation are an actual reflection of vehicles on the roadway. In this case, while there are more vehicles registered in east King County, the propensity for participation in PSE's rebate program is lower. This could indicate that PSE is not capturing the total number of vehicles based on program data. The highest concentration of participation is around the Bellingham area and some outlying areas around Ellensburg.

Figure 29: Concentration of EVs in PSE program against DOL data

TECHNOLOGY EVALUATION

From the previous sections, PSE was able to better understand the types of vehicles, load shapes, timing of charging and concentrated location penetration. This exercise provided valuable information about EVs throughout PSE's service territory. In addition to gathering the data, PSE wanted to verify when customers charge their EVs as part of managing the increase in energy demand as EVs become more popular. The opportunities to verify and manage when vehicles are charging exist through several technologies and have been demonstrated by other utilities.

In 2016 and 2017, PSE assessed various technology platforms that could be used for verifying such an EV charging management program. PSE identified five approaches to measure and verify EV charging behavior. These include:

- Advanced metering infrastructure/automatic meter reading (AMI/AMR) load disaggregation
- Smart chargers
- The Open Vehicle Grid Integration Platform (OVGIP)
- Car telemetry
- Self-reporting

At this point in time, smart charging has emerged as the most reliable alternative because it provides PSE visibility into residential charging events, gives PSE control over the data and provides a service to the customer (ability to charge at home) in addition to monitoring charging events.

Table 3 summarizes PSE's overall qualitative assessment of the four direct-verification mechanisms. PSE assessed each verification pathway against technology effectiveness, cost, scalability and program risk.

Table 3: Charging detection technology pathway assessment

	Technology Effectiveness How accurate is the technology pathway at detecting charging events?	Cost What are the up-front and on-going costs associated with this pathway?	Scalability How easily can this pathway scale to a full program?	Program Risk What risks exists with this pathway and what is the likelihood of potential mitigation strategies?	Other Considerations
AMR/AMI Meter Data	Needs further refinement for detection analysis accuracy	$ Low	Good, doesn't measure use outside residential charging	Dependent on data analysis, which is currently not able to detect events at a satisfactory level	Improvements in algorithm detection may be made in next few years; continue to explore option
Car Telematics	Good	$$ Moderate to High; high upfront cost and subscription service charges.	Uncertain; Highly dependent on unit costs and vehicle compatibility.	Moderate risk, compatibility for different vehicles; data security.	Good for actively managed charging if PSE decides to implement this in the future. Cost is big consideration.
OVGIP	Good	$ Moderate, depends on incremental costs	Dependent on participation of auto manufacturers and utilities; may be a risk going forward.	Moderate risk	Ongoing improvements in participation and platform development
Smart Chargers	Good, doesn't include use outside residence	$$ Moderate to High; high upfront cost and subscription service charges.	Moderate; dependent on cost and customer willingness to install technology.	Moderate risk, back-end software must be compliant with PSE systems.	Data compatibility/format may be different for vendors.

Legend

- Not available
- Positive assessment
- Poor assessment
- Neutral assessment

The following section discusses the different verification methods in more detail. First, verification using AMI and AMR meter data is discussed, and then verification using smart charging and the availability of smart charging is discussed. These analyses are followed by an overview of additional verification methodology including OVGIP, vehicle telemetry, and self-reporting verification methods.

AMR/AMI data

PSE used meter data to collect customer load information throughout the rebate program. PSE's metering system was also explored as a potential method for detecting charging events. PSE analyzed whether the load associated with charging could be deciphered from the overall house load through the existing metering system. This section describes the analytics PSE investigated through the current metering data.

Daily meter reads

As discussed previously, the daily read method is an initial screen that can be used to look for significant variances in energy use over time. Analysis showed that for some customers, the addition of an EV made a clear impact on their energy use as measured on a daily basis. For other customers, the impact was not apparent. Across the sample of 13 customers, five customers had a clear and consistent increase in the amount of energy they used.

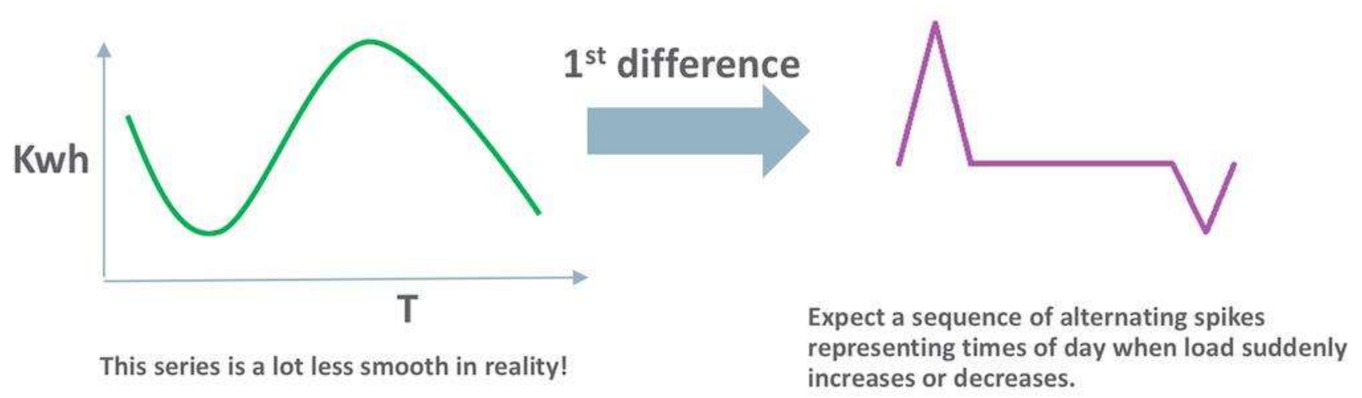
Based on this level of precision, it was found that using the daily electric use data did not provide an accurate enough test to measure both whether a customer had purchased an EV and the amount of energy it used. While the addition of an EV presents a potentially large load, other variables in energy use make it difficult to assign particular changes in load to EVs. For example, customers may have a change in the size of their household, install energy efficiency measures or have a job schedule change, all of which would affect their energy use. Furthermore, the data revealed that some customers did not drive their EV long distances each day and therefore did not need to fully charge their vehicle. This would lead to only a small increase in electric use, which would be difficult to differentiate from other uses.

15-minute meter reads

PSE and Oracle used 15-minute data to determine if a methodology could be developed that could determine which customers had EVs and when they were charging. The project initially started by using the 15-minute whole house data of customers enrolled in the program to determine if charging events could be reliably identified based on this data. These events were cross referenced with eGauge charging data directly logged from the customer's charger. These customers are known to have EVs and the time at which they charge is known based on the measurements of the eGauge data, so different methodologies could be tested for accuracy in identifying charging events. If a highly accurate methodology was developed using this smaller group of customers, the methodology could be tested across a larger set of customers to determine if the methodology could be broadly applied.

To develop a methodology to identify charging events, the team considered several potential identification factors of the load shape of EV charging. These are the increased load at the start of charging, the dropping load at the end of charging and the length of the charging event. To identify the start and stop of a charging event based solely on the 15-minute whole house meter data, the amount of change in load from one 15-minute period to the next 15-minute period was calculated. This method identifies the amount of load changes in a short period. Because of the size of the increase in load from EVs when charging, typically 3 kW to 7 kW, this will result in a large change in load in a short period. This method clearly identifies significant changes in load.

Figure 30: Charging general load shape from meter data



Because different EVs have different size batteries and chargers, a threshold was set for each type of vehicle based on its charger size to establish a screen that could differentiate EV charging from other household uses. For example, a vehicle that charges at 3.3 kW could be expected to show a change of up to 0.825 kWh use over a 15-minute period. These screening levels were established to identify changes in load that were large enough that they might be charging events based on the type of vehicle.

These screens were then applied to the dataset of the change in load over 15-minute periods for each of the customers who had eGauge data-loggers installed (known charging events). The results identified times of increased load for each customer. These times of increased load were compared to the actual charging events as recorded by the eGauge data-loggers.

In comparing the times of load changes in whole house meters to the actual charging times, it was found that the change in load identified the charging event less than half of the time. Table 4 shows the number of false detections that occurred in the research rounds. The correct detection was when the algorithm correctly identified a charging event, and false detection was when the algorithm did not detect a known charging event. The precision average is defined as the percentage overlap ("correct") between the known number of charging events and those detected, divided by the duration of the charging event.

It was determined that the accuracy of this methodology was insufficient to be considered a reliable method to identify charging events.

Table 4: AMI detection and false positives

Round	Total Detected	Correct Detection	Correct (percent)	False Detection	Precision Average (percent)
1	6337	2786	44 percent	3551	79 percent
2	8078	3023	37 percent	5055	76 percent
3	2025	949	47 percent	1076	88 percent
4	5387	2247	42 percent	3140	80 percent
5	4121	1400	34 percent	2721	80 percent
6	7363	2578	35 percent	4785	75 percent
7	15783	3442	22 percent	12341	62 percent

Smart chargers

For this report, PSE defines smart chargers as EV charging stations that provide several advanced features, including the ability to monitor and send EV charge event statistics to the utility. Smart chargers are generally compatible with all popular EV brands and have a robust data collection and transmission system. However, smart chargers are a fixed asset and limited to detecting charge events that occur at their location. External charge events or charging at public stations or chargers on other networks will be undetectable.

Request for information process

To better understand what smart chargers are available, their capabilities and current pricing, PSE issued a Request for Information (RFI) for EV chargers in August 2016. The RFI, a copy of which is included in Appendix E, was issued to 29 companies identified through discussion with the vendors and with other utilities who were likely to offer smart chargers or smart charging services. The RFI covered all aspects of available chargers, including hardware, software, customer experience, customer support and pricing in order to compare products from different vendors on a contemporaneous basis. For the RFI, PSE asked about Level 2 chargers and DCFC.

Twenty vendors responded to the RFI with varied responses. Some vendors who responded only offered charging hardware, some only offered charging software and some offered network services. There were, however, some responses from vendors who offered a broad suite of hardware, software and services. A summary of the responses by services provided is shown in Table 5.

Table 5: Summary of responses

	Number of Company Responses
Residential Level 2	3
Commercial/Public Level 2	15
DC Fast Chargers	9
Network/ Software Only	3

Respondents to the RFI were given the option to provide PSE with a mutual non-disclosure agreement and to mark some or all of their responses as confidential. Some respondents did sign the non-disclosure agreement. As such, analysis in this document is provided on an aggregated basis to provide information on the responses, but to prevent disclosing confidential information.

Charging hardware

As shown by the summary, there are a number of companies providing smart charging hardware for Level 2 or DCFC. For Level 2 chargers, they may be sold directly by the manufacturer, through a distributor or directly via a retailer. In general, both smart and non-smart Level 2 chargers are commonly available. Many manufacturers offer a variety of alternating current (AC) Level 2 chargers that might differ in their smart charging features, as well as exposure rating (indoor versus outdoor), and their intended use (residential settings, fleet settings and public settings). Some manufacturers may distribute chargers intended for different purposes through different channels.

DCFC are most commonly provided directly through the manufacturer or distributor. This equipment is also generally available, though it may require being built to order resulting in a longer lead time than that for a Level 2 charger.

Charging software

Several types of charging software were included in the RFI responses. The first type was the software included in the charging stations as part of networked smart chargers. This software provides basic functionality to the chargers and can communicate with the manufacturer to report on charger status, maintenance needs or other functional specifications. This software is typically supplied by and supported by the charger manufacturer.

The second type of software is that of networks. These networks provide functionality across a group of chargers using a common interface. Some of the networks were provided by the charger manufacturers, while others were provided by companies that provide only the network. Different networks had different functionality. Available functionality might include status monitoring for chargers, the ability to control charging levels and the ability to accept payment for charging.

Charging services

Some RFI respondents also included examples of services they could provide, such as installation or maintenance. Because these were not specifically requested in the RFI, responses varied. These responses were not evaluated for a like-for-like comparison because there was no industry standard to which they could be compared.

Equipment capability

Residential smart chargers are EV charging stations that provide several advanced features, including the ability to monitor and send EV charge event statistics to the utility, start and stop charging, and in some cases change the rate of charging. Smart chargers are generally compatible with all popular EV brands, and have a robust data collection and transmission system.

Pricing

Pricing was evaluated for AC Level 2 hardware, DCFC hardware and network software. Because there were different types of hardware included, in particular AC Level 2, a set of networked or smart chargers with the most similar functionality was used for benchmarking. Where a manufacturer only provided hardware with several charging ports, a per-port value was used for the Level 2 chargers. Other features that were priced separately, such as cord retraction mechanisms, were not included. For DCFC, most chargers included had 2 charging ports, so the unit price for the entire DCFC was included.

Table 6: Summary of prices in RFI as of August 2016

	Level 2 (per Port)	DC Fast Chargers (2 Ports)	Annual Network Fee (Per Port)
Maximum	$4,700	$64,000	$460
Minimum	$799	$20,000	$119
Average	$2,018	$37,950	$260
Number Responses	13	5	12

There is significant variation in pricing across all levels of chargers and network services. This analysis does not differentiate between features in specific smart chargers, so variation in pricing may be related to features or could be related to markets. However, all chargers considered were reported to have some basic load control functionality, so the range of prices can be used to consider what costs would be required to implement smart charging.

Open Vehicle-Grid Integration Platform

The Open Vehicle-Grid Integration Platform (OVGIP) is a software application that enables EV and charging infrastructure management. OVGIP is a joint utility industry and automotive industry initiative that has been led by the Electric Power Research Institute (EPRI) since its inception in late 2012. OVGIP has several benefits, including the robust ability to detect charge events both at the home and at public charging stations and a no-installation and hassle-free user experience. The integrated platform offered by OVGIP is still under development, and one of the primary limitations is the wide scale adoption by key auto manufacturers and utilities.

Car telemetry

Car telemetry involves the use of a physical device that plugs into a vehicle's monitoring system for monitoring a wide range of activities and statistics, including EV charge events. PSE has been in contact with manufacturers of car telemetry devices for EVs. Like OVGIP, telemetry devices would be able to monitor charging activity both within the home and outside the home. However, there are concerns about the overall cost if the technology was deployed at scale and the long term viability of the service offering.

Self-reporting

In addition to the direct measurement methods mentioned above, PSE is also considering self-reporting as another option to assess compliance with an EV load management program. Participants will be periodically asked about their charging behavior and their level of compliance.

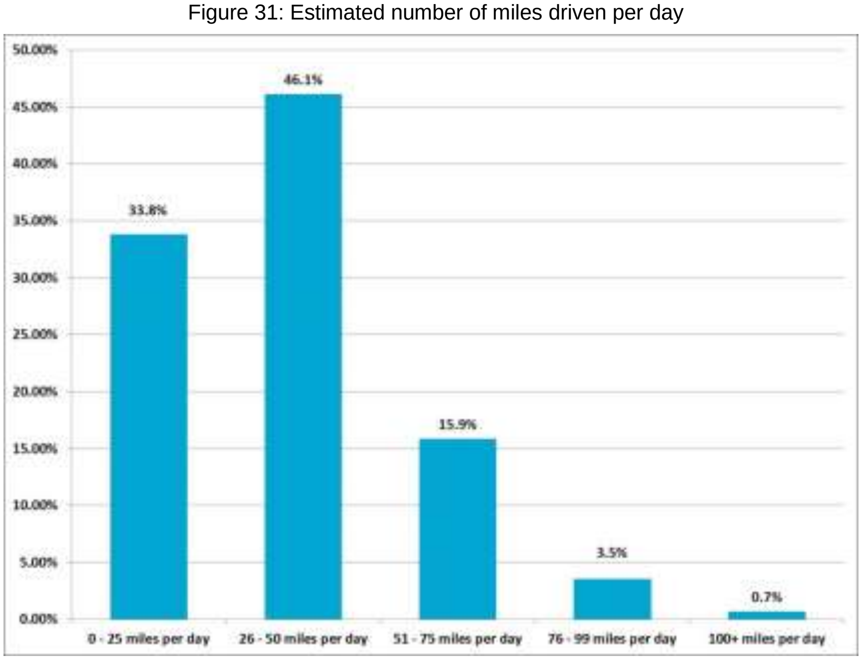
CUSTOMER FEEDBACK AND RESEARCH

PSE solicited customer feedback during the rebate program in order to understand customer satisfaction as well as learn more about customer behavior around EVs.

Driving behaviors

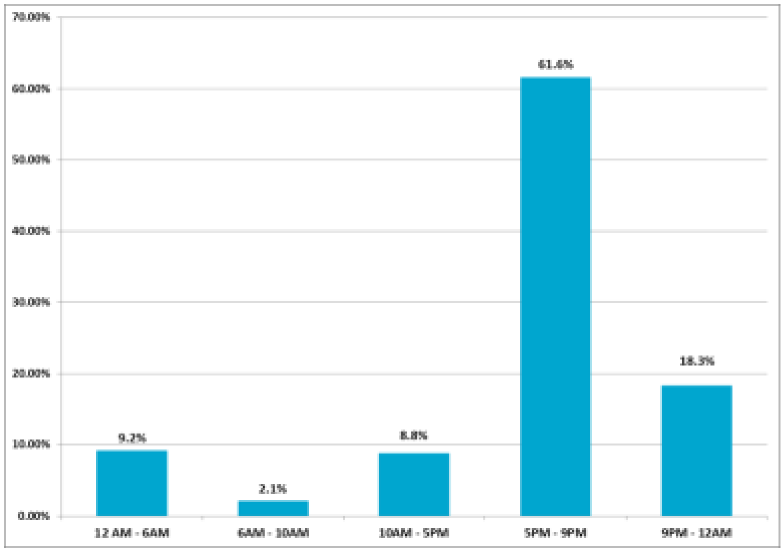
In addition to understanding more about customers' overall satisfaction, PSE also wanted to learn more about driving behaviors after customers had owned their vehicles for a period of time. PSE conducted customer surveys in early 2017 to learn more about these behaviors. As shown in Figure 31, the majority of customers indicated they drive less than 50 miles per day. In their rebate applications, customers estimated a similar pattern for their driving behavior, with the majority estimating they would drive less than 50 miles per day.

Figure 31: Estimated number of miles driven per day



As shown in Figure 32, 62 percent of customers reported that they charge their EVs between 5 p.m. to 9 p.m. These findings are similar to customers' responses on the rebate application, which indicated planned charging to occur was predominately from 5 p.m. through 8 p.m. In addition, 70 percent of customers reported they typically do not schedule a specific charging time.

Figure 32: Estimated charging start time



In addition to gathering feedback about driving and charging behavior, PSE also collected information about attitudes and perceived barriers to EVs. The key points from this customer survey discovered the following:

- A majority of customers do not think there is enough information about EVs.
- Internet research and word-of-mouth are the primary methods for finding information.
- Approximately half of rebate customers use public charging, with location and speed being the most sought after features.
- Top barriers to driving an EV include not enough public charging, taking too long to charge and not being able to drive far enough.

Figure 33: Ways customers find information about EVs

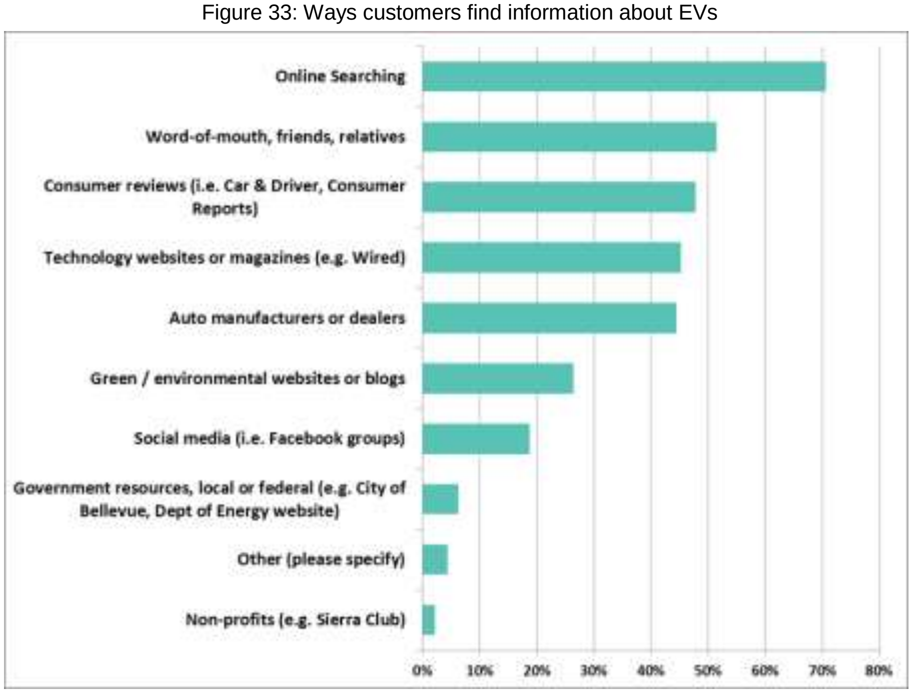
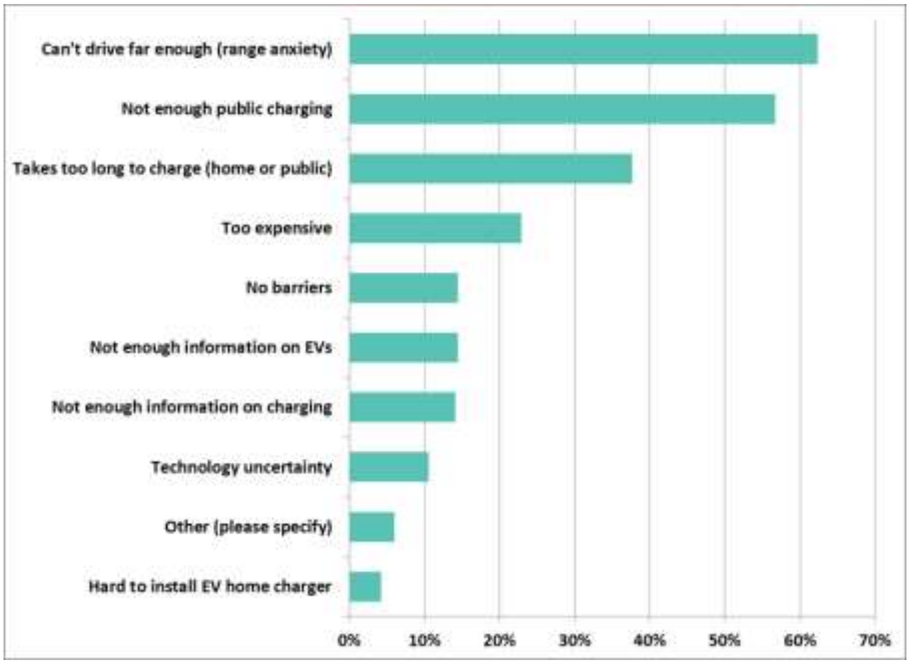


Figure 34: Barriers customers have experienced in driving an EV



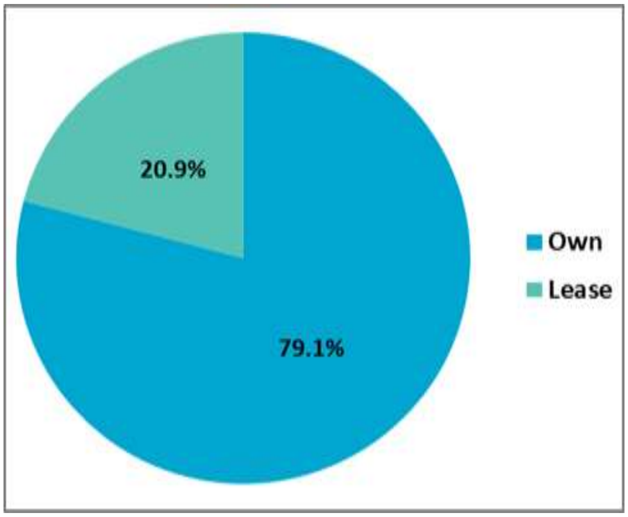
EVs in PSE's territory

In addition to the customer satisfaction survey with rebate participants, PSE also conducted a survey with a third-party vendor, PlugInsights, to understand EV drivers more broadly. Because the rebate program only included EV drivers that had a Level 2 home charger, PSE conducted a survey with PlugInsights focused on a wider audience throughout PSE's service territory. PlugInsights maintains its own panel of EV drivers, and can therefore conduct research through this channel.

The general goals of this survey were to better understand the incidence of Level 1 versus Level 2 home charging, as well as more information about customer attitudes towards EVs. Select graphics from the customer research are shown on the next page.

- 70 percent of the sample has Level 2 home charging. 26 percent are using a Level 1 charger, while four percent do not charge at home.
- 93 percent of respondents charge between 5 p.m. and 6 a.m.
- Most do not schedule a specific charging time.
- Customers charge in public 2-4 times per month on average.
- Drivers with hybrid or smaller battery capacity vehicles use public charging more often.
- Location and speed are the most important public charging features.

Figure 35 and 36: Percentage of EVs by own/lease and purchased new/used



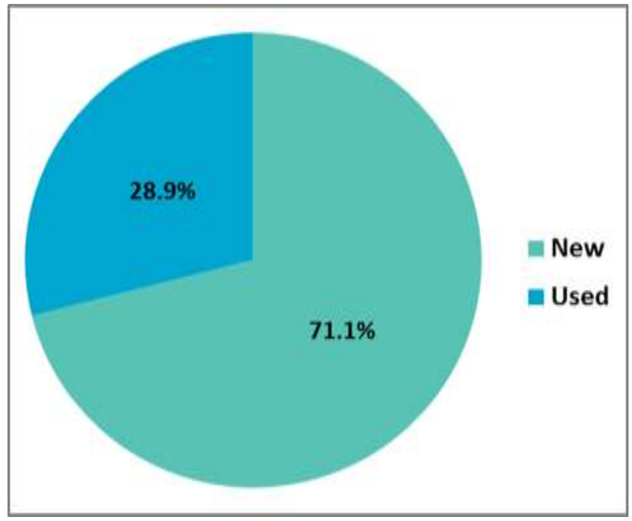


Figure 37: Primary type of home charging used

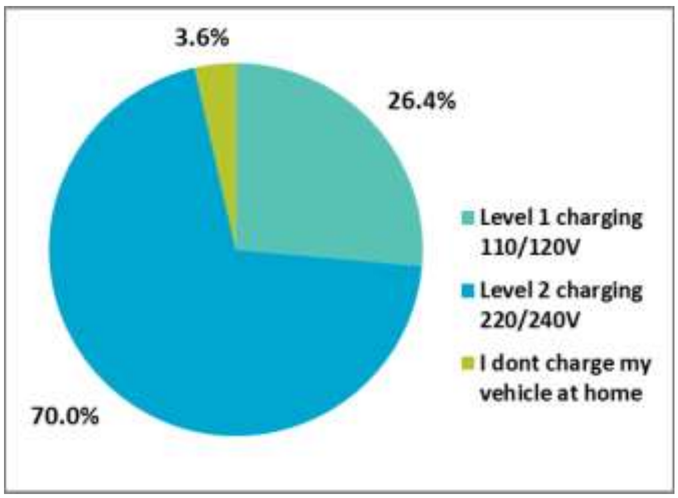


Figure 38: Types of public used, excluding workplace

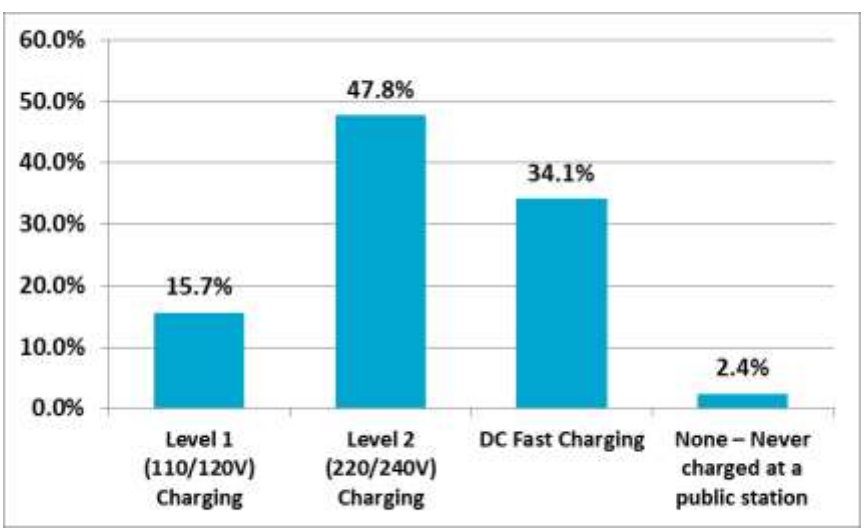
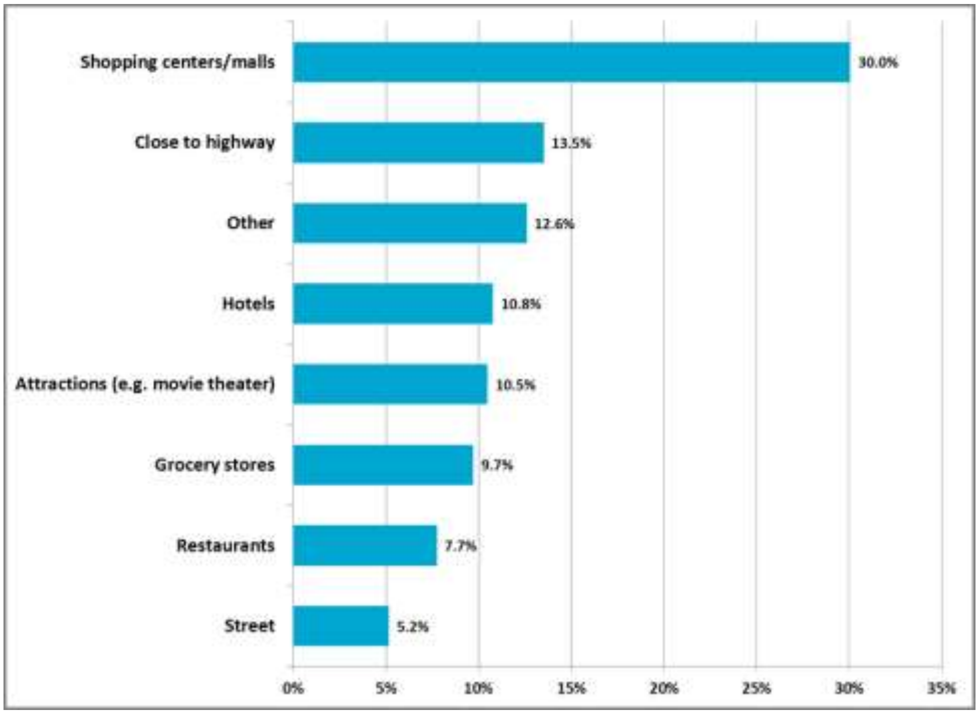


Figure 39: Where do you typically charge in public?



OPTIONS FOR THE FUTURE

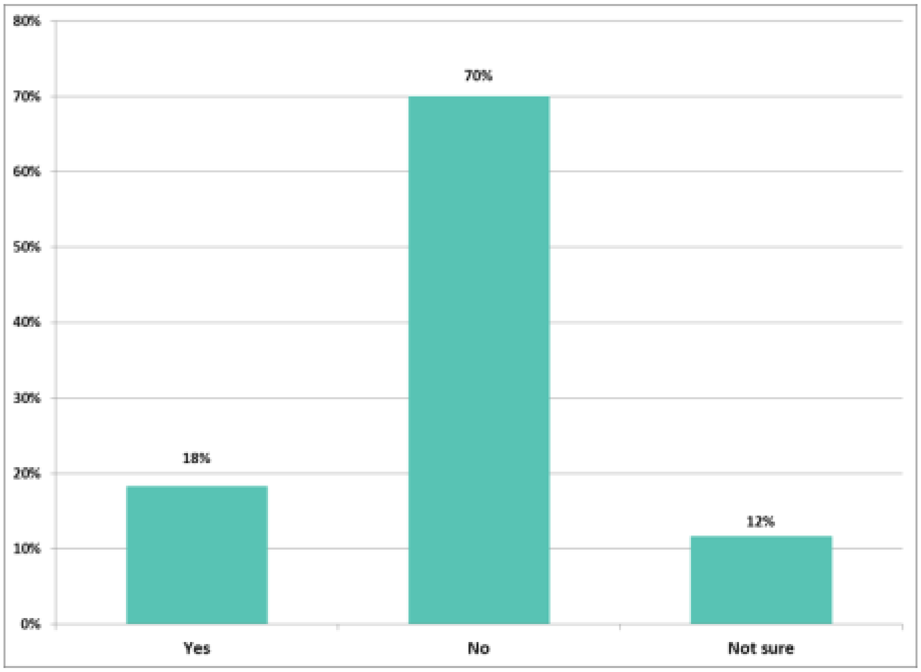
The EVCI program was a critical tool to gather information about EV customers in PSE's service territory. It not only helped support EV adoption throughout western Washington, but also provided PSE with important data around charging patterns and behaviors, impacts to load, technology evaluation and ways that PSE can support its customers in the future. This section describes what was learned from the program and how PSE could support market growth with programs in the future.

Background on consumer awareness

PSE conducted customer research to better understand customer needs and market barriers continuously throughout the program. This involved both quantitative (surveys) and qualitative (interviews, focus groups) research methods, which provided important data points and better servicing for customers.

One area to highlight is the ability to find information about EVs. In surveys, customers overwhelmingly felt that there is not enough information around EVs. In qualitative research, customers described the exhaustive process they went through to find information and that it was often difficult to find consistent information from different sources.

Figure 40: In your experience, has there been enough public information about electric vehicles?



PSE also conducted focus groups with current EV drivers, as well as those considering an EV purchase in the next 5 years. These focus groups were conducted with customers in PSE's service territory, and repeated themes around information were revealed.

1. Customers place value in family, friends, and trusted (un-biased) resources.

2. Ride and Drives and electric vehicle events promoted by dealerships were well received and desirable.

3. There were repeated questions about the total cost of ownership and what the trade-off is between a conventional and an EV. Customers liked the idea of tools or calculators.

Outside of customer research, PSE worked with automotive dealerships throughout our service territory. For customers, this is the primary method for purchasing a vehicle and the front line to receive information. Often the customer experience at dealerships can be a mixed experience and the information provided can be fragmented. PSE also found that dealerships have a high turnover of sales staff which can inhibit consistency.

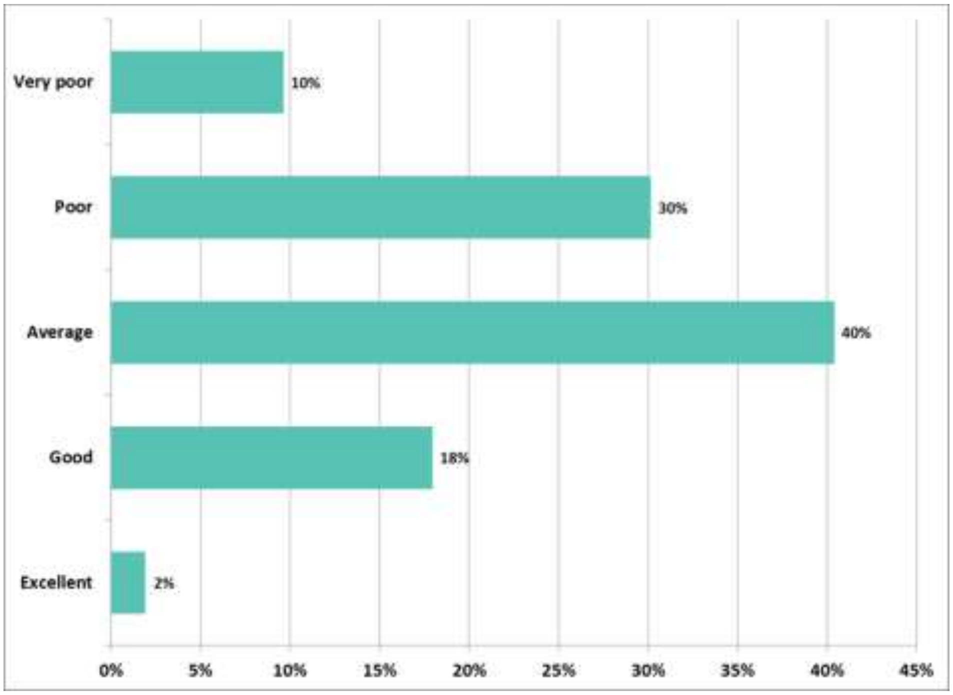
Charging services

Customers generally had a positive association with the EVCI rebate program, and commented on PSE's support of electric vehicles and charging. Among barriers that customers face in driving an electric vehicle, the top are not being able to drive far enough, not enough public charging and charging takes too long.

Customer research around charging found that location repeatedly becomes the most important attribute. This corresponds with customer desire for convenience in charging. Predominantly, vehicle charging occurs where the vehicle is parked overnight, which is the most convenient location. Customers have said they typically charge at public locations one to three times per month. When charging elsewhere, customers want to go to public places that are well sited and have access to amenities if the vehicle will be parked for longer than 30 minutes.

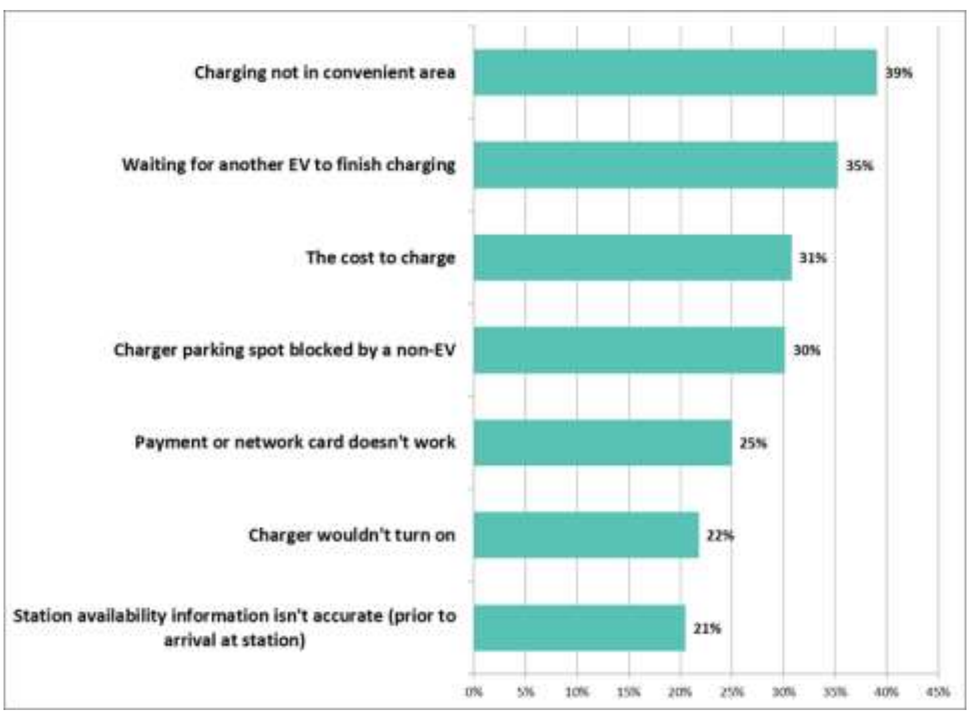
The available amount of charging away from home is also something customers believe is a barrier. Approximately 80 percent of customers stated that the quantity of public charging was average or below in meeting their needs.

Figure 41: In your experience, how would you rate the quantity of public chargers in meeting your needs?



Customers also sited that the main barrier to the reliability of the public charging network is around the convenience of charging locations. Other barriers include long wait times due to inadequate handle availability, not being able to access charging and the cost.

Figure 42: What have been the biggest issues with public charging reliability?



Lastly, many customers commented on the ability to pay for charging with network cards. In many cases, customers carry more than three different network cards and need to have different payment methods for each. Many customers commented they would prefer to utilize one unified payment method at all charging stations.

Managed charging

One of the goals of the pilot program was to identify means to shift the time at which customers charge their EVs, in order to avoid increasing the amount of charging that occurs at times of peak electricity demand. EVs could play a similar role to the charging of energy storage systems, providing a flexible resource that can be scheduled and ramped to provide balance on the system and charging during times of low system prices or demand. Eventually, vehicles may become energy storage resources through vehicle-to-grid technology, though for this discussion PSE focuses solely on controlling the time of charge. Technology has continued to evolve during the course of the pilot, with new technologies to control or time charging becoming available through both chargers and EVs. This is an area of continued development by many parties, including auto manufacturers, utilities and charging station manufacturers. Based on the progress during the time of this pilot, technology evolution will continue.

The evolution of this type of control will be based around different use cases and system needs. The simplest case is moving charging to off peak periods to reduce costs for additional generating resources and to avoid periods of typically high priced power. Some utilities are already trying to influence customer behavior in this way through rate structures including time of use rates and tiered rates. The more complicated case is to schedule the time of charging outside of peak periods, so that the flexible load of the EV charging could be used to absorb energy at times of high renewables demand or at times of low power prices or to meet ramping needs. This has been called "filling the belly of the duck", especially in reference to high amounts of solar generation during the day in California, which is referred to as the duck curve[4]. Finally, the most complicated case is for vehicles to interact in real time. This has been piloted by the Pacific Gas and Electric Company (PG&E), BMW, and the California Independent System Operator (ISO)[5].

In using managed charging to meet these use cases, there are also important factors including the number of vehicles plugged in at any given point in time, the location of those vehicles and the amount of uncharged battery available. If controlled charging of the vehicles is being used to minimize peak demand and power cost in wholesale power transactions, a large number of vehicles with significant storage space in their batteries may be required. If controlled charging is used to absorb additional energy during periods of high renewable generation on local circuits to help maintain voltage control, the number of vehicles and time at which they are needed to charge may be quite different.

To determine how best to optimize controlled charging, additional experience with controlling the charging and testing of use cases will be required. Similar work is already underway around stationary energy storage to develop and test use cases at the different levels of the grid system[6]. There are, however, some important differences in vehicles as they are not always connected to the grid, when they are connected it is likely to be at different locations, and their battery state of charge (i.e., how much power they can absorb) will not be predictable when they do plug in.

In being able to achieve the use case, it is also important to consider how the charging will be controlled, by whom and how. At the current time, controlled charging is in its early development and a single model has not yet emerged[7].

Who makes the decision to control the charging can also vary, which can lead to split incentives. A driver may choose to control charging to avoid demand charges, a network of charging stations may choose to control charging to

[4] Regulatory Assistance Project
[5] BMW Charge Forward Project
[6] Washington Clean Energy Fund
[7] SEPA, The Case for Managed Charging

minimize energy prices in a time of use energy rate and a utility may choose to control charging to minimize wholesale energy cost or to absorb excess renewables. In considering designs to control charging, it is important to ensure that the program will cause charging to occur at the optimal time based on the use case or cases it is designed around, including the scale (generation, transmission or distribution) that it is trying to address.

Control of charging and integration with utility systems is an area of ongoing research. In this pilot program, PSE has evaluated uncontrolled charging and the options to manage and measure controlled charging. This pilot program has shown that residential EV charging load is coincident with PSE's evening peak demand for electricity. While this impact is small today, it could be significant over time, as was evaluated in the 2017 IRP.

To mitigate future peak impacts and integrate EV charging with times of lowest power cost and renewables, additional work will be required to prove technology performance and customer receptiveness to managing times of charging. At the current time, industry experience in this area has been limited to a few pilots. Given the potential for long term peak impact, PSE should continue pursuing methods to shift charging to off-peak times.

NEXT STEPS

PSE's EVCI program was well received by customers and provided PSE with valuable information on how to plan for transportation electrification in our service territory. Adoption of EVs continues to increase in our region and will likely continue as more vehicle offerings come to the market.

The results from the rebate program will help to inform PSE and other stakeholders around how utilities can support transportation electrification in future offerings.

APPENDICES

APPENDIX A: Terminology and charging levels

AC Level 1

AC Level 1 charging, commonly known as Level 1 charging, is based on the same power as is commonly found in outlets in homes and businesses. This level charges at 120 volts (V) alternating current, and amperages up to 20 amps, but typically has a power level of 10 to 15 amps. Specific chargers exist in some cases, but commonly the charging equipment used is a portable cord that plugs into a standard wall outlet. Applications typically charge at about 1 kilowatt of power, which would put about 3 miles of electric range into an electric car for each hour of charging.

For AC Level 1 charging, the power supplied to the EV is alternating current. The rectifier to convert it to direct current that can be stored in vehicle batteries is contained on the vehicle.

While an AC Level 1 charger may be plugged directly into a wall socket, it typically includes a connector common with AC Level 2. This connector, the J1772 standard from the Society of Automotive Engineers, is common across nearly all EVs.

AC Level 2

AC Level 2 charging, commonly known as Level 2 charging, operates at a higher voltage and power than Level 1 charging. The current standard allows 208 to 240 volts at power levels up to 80 amps, though the most common is 15 or 30 amps. These chargers are typically installed as hardwired on dedicated circuits, though in some cases chargers will use 240V outlets to plug in and simply mount the charger to the wall. The most common configuration of these chargers allows 6.6 kilowatt of power, which puts about 20 miles of electric range into an electric car for each hour of charging.

Level 2 chargers are sold in both networked and non-networked configurations. Networked chargers typically have a communications device installed, such as a Wi-Fi connection or cellular modem. These devices allow the chargers to be connected to software over a network, which allows the status of the chargers to be monitored and in some cases, are used for payment authorization and connection to public facing software.

For AC Level 2 charging, as with AC Level 1 charging, the power supplied to the vehicle is alternating current. The rectifier to convert the alternating current to direct current that can be stored in batteries on the vehicle is performed by the vehicle.

Nearly all AC Level 2 charging uses the J1772 connector to connect the charger to the vehicle.

DC Fast Charging

DCFC, occasionally called Level 3 charging, provides high power direct current to the vehicle. This direct current can be used to charge the batteries, though a DC-DC power converter may be required to set it to the right voltage for use on the vehicle. The rectifier to convert alternating current provided by the utility to direct current is housed on or near the charger body.

There are currently three major types of connectors being used for DCFC in the United States. The CHAdeMO connector currently supports power of up to about 60 kW, though a higher powered version is currently in development. The Tesla Supercharger network supports power of up to 120 kW. The Society of Automotive Engineers (SAE) CCS connector is capable of supporting up to 150 kW, though most applications to-date have been at 50 kW. All of the major connectors are working on higher powered versions to support faster vehicle charging in the future. Vehicle manufacturers will typically choose one connector to include on their vehicle. Charger manufacturers may offer one or multiple different connectors on a single charger.

The high power of DCFC requires permanent installations that are wired in to an electrical panel. Typically, the power conversion equipment and charger are placed outdoors on concrete pads designed to support them.

Smart charging

Smart charging is a term used to denote when the charging of vehicles is controlled in time, power or both. This control can be supplied by the vehicle or the charger. Some chargers can support the communications and control necessary to enable smart charging, however not all chargers support this functionality. Those charges will simply charge when an EV is plugged in to them.

APPENDIX B: Copy of rebate application

PSE ELECTRIC VEHICLE CHARGER REBATE FORM

Receive your rebate faster by applying online: **www.smartenergy-zone.com/pse**

■ **$500** on qualified Level 2 Electric Vehicle Chargers

*PSE's electric vehicle charger rebate program could end before 04/01/2017 depending on available funds and customer participation.

MAIL-IN APPLICATION INSTRUCTIONS AND QUALIFICATIONS:

1) PSE residential rate schedule 7 customer and:
   - **Purchase and install a qualified electric vehicle charger within one year of the first registration of a new electric vehicle.**
     - *A list of qualified models can be found at **www.pse.com/electricvehicles** or you may call a PSE Energy Advisor at 1-800-562-1482.*
     - *Limit one rebate per electric vehicle.*

2) The electric vehicle charger must be installed such that the electricity is supplied by the existing residential electric service. It cannot be installed on a new electric service, unless the service is for a new residence. The charger must be installed at the location that is the principal charging location for the electric vehicle.

3) The charger must meet appropriate codes and standards. (UL, NEC, SAE-J1772).

4) The charger must be compatible with the electric vehicle purchased.

5) Customer agrees to be contacted by PSE for the purposes of load and program studies.

6) Submit application and the following documentation online or via mail by 04/01/2017.*
   - **This signed and dated rebate form with all information completed accurately and legibly.**
   - **A copy of your electric vehicle registration.**

Mail to:
PSE EV Charger Rebate
Offer # H345701
PO Box 540062
El Paso, TX 88554-0062

CUSTOMER INFORMATION — All fields are required to be completed.

PSE Account Number (12 digits):
(where electric vehicle charger was installed) |_|_|_|_|_|_|_|_|_|_|_|_|

☐ **Keep me up to date on PSE's energy efficiency programs**

First Name (to appear on check)	Last Name (to appear on check)		
Service Address *(where electric vehicle charger was installed)*	City	State	Zip Code
Mailing Address *(where rebate should be mailed)*	City	State	Zip Code
Email *(Used to send status updates regarding this application.)*	Phone		

CHARGER INFORMATION	PURCHASE DATE	BRAND	MODEL NUMBER
Electric Vehicle Charger = $500	MM/ DD/YYYY ____/____/______		

SURVEY QUESTIONS *(required)*

1. What date did you start using your charger? ____/____/______
2. What time of day do you typically plan to start charging your EV? ☐ AM ☐ PM
3. How far do you plan to drive your EV each day? ____________ Miles
4. Which of the following charging locations do you plan to use? ☐ Charge at home ☐ Charge at work ☐ Public level 2 charger ☐ Public fast charger
5. Are you interested in learning more about PSE's Green Power and Energy Efficiency programs? ☐ Yes ☐ No

TERMS & CONDITIONS

Customer agrees to PSE activation of interval data metering. (No additional charge to customer.) Prior to receiving the incentive, potentially eligible customers must be current electric schedule 7 customers of PSE and provide PSE with copies of the following documentation within one year of the date of becoming the registered owner of a new electric vehicle: vehicle registration, proof of purchase (receipt/invoice) of an electric vehicle charger; and signed rebate form stating that the customer is the current registered and/or legal owner of the electric vehicle, that the charger was installed according to all applicable codes, and that the charger is currently installed at the principal charging location for the customer's vehicle where PSE provides electric service to the customer. PSE, at its sole discretion, may inspect installations prior to the payment of the incentive. Customers must also consent to be contacted by PSE for the purposes of load and program studies. For complete details and eligibility visit pse.com/electricvehicles.

ACCEPTANCE OF TERMS & CONDITIONS

I acknowledge that the product described above has been purchased and installed at the location indicated which is my residence and principal charging location for the electric vehicle. I understand that PSE has made no express warranties or representations with regard to this production or its installation. I acknowledge that I am responsible for meeting applicable code requirements, determining the adequacy of installation, and paying all amounts owed to contractors/suppliers. The charger was installed in compliance with local building and/or electrical codes. Further, I understand that this is a tariffed service and is subject to change or termination without prior notice. PSE reserves the right to inspect any installation prior to rebate approval and/or after payment, and I agree to provide PSE reasonable access for such purposes. I authorize PSE to release my customer account information, including my billing and energy usage information, to an independent, third party evaluator solely for the purposes of evaluating the rebate program, confirming energy usage and for other quality assurance purposes. PSE may contact me for the purposes of load and program studies.

*Customer Signature: X________________________________ Date: ____/____/______
(Typed signature accepted.)

(!) IMPORTANT: Photocopy your entire submission and keep for your records. Checks will be mailed to qualifying customers within eight (8) weeks of the postmark date on your request. To apply online, view the status of your application, or if you have questions, visit **smartenergy-zone.com/pse** or call **1-855-839-5601.**

pse.com/electricvehicles

6570 12/01 H345701 (SG6)

PSE PUGET SOUND ENERGY

APPENDIX C: Order 01 in UE-140626

[Service date April 30, 2014]

BEFORE THE WASHINGTON
UTILITIES AND TRANSPORTATION COMMISSION

In the Matter of the Petition of PUGET SOUND ENERGY, Petitioner, For an Accounting Order Authorizing Accounting Treatment Related to Funding and Cost Recovery of the Electric Vehicle Charger Incentive Program and Waiver of WAC 480-100-223.	)	DOCKET UE-140626 ORDER 01 ORDER DENYING WAIVER AND APPROVING ACCOUNTING PETITION ON CONDITIONS

BACKGROUND

1 On August 28, 2013, Puget Sound Energy (PSE or Company) filed with the Washington Utilities and Transportation Commission (Commission) in Docket UE-131585 revisions to its currently effective Tariff WN U-260, Electric Tariff G, designating a new Schedule 195, *Electric Vehicle Charger Incentive* (EVCI). PSE proposed a program to provide a one-time $600 financial incentive to eligible PSE residential electric customers who install a "Level 2" electric vehicle (EV) charger at their residence, which enables the vehicles to be recharged faster than when using a standard charger. The Company proposed to fund the program through surcharges on Schedule 120, *Electricity Conservation Service Rider*. The original stated effective date of the tariff sheets was October 1, 2013, but the Company subsequently extended the effective date several times, most recently to May 1, 2014.

2 PSE estimates that there are now approximately 5,000 electric vehicles in its service territory, creating a large additional residential load with the potential to contribute to peak load, depending on customer charging behavior. Commission Staff (Staff) is concerned that on-peak electric vehicle charging may ultimately drive the need for new generation resources and distribution infrastructure. Identifying residential electric vehicle charging patterns will allow PSE to determine whether charging occurs on-peak, and if mechanisms to shift electric vehicle charging off-peak are appropriate. Staff believes that collection of this data is an essential first step to evaluate whether there is a need for load-shifting programs, and if so, inform the design of those programs.

3 On August 28, 2013, after working with Staff to refine the EVCI program, PSE filed with the Commission replacement pages, specifying that Schedule 195 would also fund data collection on customer charging patterns and analysis of EVs on PSE's system. The Company's filing included a Petition seeking an Accounting Order under WAC 480-07-370(b)(i) that authorizes PSE to fund the EVCI through surcharges on Schedule 120, as described above, and to defer the related costs of the EVCI program. The Company's filing also included a request for a waiver under WAC 480-100-223's rules on advertising.

4 On April 10, 2014, the Commission dedicated significant time at its regularly scheduled open meeting to discuss a variety of policy issues surrounding PSE's proposed EVCI program. Following that open meeting, the Commission assigned the Company's accounting petition and waiver request to Docket UE-140626.

5 On April 16, 2014, PSE filed replacement pages in Docket UE-131585 to lower the amount of the incentive to $500, cap the total number of participants to 5,000 over the duration of the program, and end the program at the end of 2016.

6 Staff reviewed the updated filing and supports the Company's efforts to design a study on EV load, including PSE's commitment to test multiple approaches to data collection and re-evaluate the study design after the first program year. Staff accepts that electric vehicle load will continue to increase in the near future. Staff believes that the $500 incentive for customers with an EV who purchase a Level 2 charger will mainly contribute to increased adoption of Level 2 chargers rather than increased EV sales in PSE's service territory, making the EVCI program unlikely to directly increase electricity consumption. As explained at the April 24, 2014, open meeting, there is an efficiency improvement in moving from Level 1 to Level 2 chargers. Staff has also expressed its concern that the impact on peak may be significant. Because there is an efficiency improvement, and because it is necessary to study end-use load impacts to support the development of appropriate conservation program design, Staff finds the program would be appropriate for cost-recovery under Schedule 120 subject to specific conditions.

7 Staff recommends granting the Company's petition for accounting treatment subject to the following conditions:

- The rebate will be limited to $500 per Level 2 vehicle charger;

- The company will study the end-use characteristics of electric vehicle load for a period of up to 32 months, to end no later than December 31, 2016;

- The number of participants in the study will be limited to 5,000, at least half of which will have interval metering data activated and collected at a minimum of one-hour intervals;

- During the study period, the company will regularly coordinate with its Conservation Resources Advisory Group and include the study's progress and findings in its regular reports of conservation accomplishments;

- At the end of the study, the company will consider, in consultation with the Conservation Resources Advisory Group, programs that will manage electric vehicle load in the most cost-effective manner, including but not limited to time-of-use rates, demand response, and direct load control.

The Company agrees that Staff's recommended conditions are acceptable.

8 Staff also reviewed the waiver request under WAC 480-100-223, the Commission's rule prohibiting recovery in rates of expenses for promotional advertising. Promotional advertising is defined as "advertising to encourage any person or business to select or use the service or additional services of an electric utility, to select or install any appliance or equipment designed to use the electric utility's service, or to influence consumers' opinions of the electric utility." WAC 480-100-223(2)(f) specifically excludes utility announcements or explanations of proposed tariffs and rate schedules from the definition of promotional advertising.

9 Staff agrees with the Company's characterization of the EVCI as a conservation program. Although some EV users participating in the incentive program may use additional electricity by charging their vehicles on PSE's system, the ultimate aim of the program is to conserve energy by obtaining data about customer charging habits and avoid the need to procure additional simple-cycle gas-fired peaking units. According to studies by the Idaho National Laboratory (INL) and others, the installation of a higher-voltage Level 2 charger is expected to generate 2 to 3 percent efficiency savings compared to Level 1 charging. Similar to other demand-side resources, Staff views such savings as significant if the deployment of EV's accelerates over the next several years. To obtain data on customer charging habits, the Company must publicize the proposed tariff and explain the EVCI program, as allowed by the rule. Therefore, Staff recommends that the waiver request be denied as unnecessary.

DISCUSSION

10 PSE must demonstrate that its EV charger incentive program is in the public interest and if so, that the Company's proposed method and rates for recovering the costs of that program are fair, just, reasonable, and sufficient. In Docket UE-131585, we determined to take no action on the filing and allow the Company's proposed tariff Schedule 195 to go into effect on April 25, 2014. Here, a majority of the Commission determines that although the Company's program is not perfect, it is fair, just, and reasonable starting point for collecting load data associated with the increasing trend of EV usage in PSE's service territory.

11 We view the Company's proposal as a pilot program to evaluate projections of future load growth due to PSE's customers buying and driving EVs. The Company may be able to avoid increased future peak demand if it can learn more about how and when customers charge their EVs and educate them on the overall system benefits of non-peak charging. We wish to minimize the need for additional peaking resources in the future, if possible, and believe that this pilot program will contribute both to our knowledge of peak reduction techniques and assist in educating consumers of the need to plan carefully when recharging their EV batteries. Like our colleague Commissioner Goltz, we recognize that the financial incentive provided to qualifying customers who purchase a Level 2 charger will result in a small cost imposed on all customers across PSE's electric system. However, we see the study data and the incremental conservation savings, as well as the potential avoidance of acquiring new generation resources, as benefits justifying such costs.

12 We approve the Company's EVCI as a pilot program to study EV charging across PSE's service territory for Level 1 and Level 2 charging and expect the Company to continue working with Staff to refine the incentives created by Schedule 195. PSE's petition for an accounting order should be granted, subject to the following conditions:

- This is clearly a pilot for the purpose of studying charging usage in the Company's service territory among both Level 1 and Level 2 charging;
- The rebate is capped at up to $500 per Level 2 vehicle charger;
- The Company studies the end-use characteristics of EV load for a period of up to 32 months, ending no later than December 31, 2016;

- The Company limits the number of participants in the study to 5,000, at least half of which will have interval metering data activated and collected at a minimum of one-hour intervals;
- During the study period, the Company regularly coordinates with its Conservation Resources Advisory Group and includes the study's progress and findings in its regular reports of conservation accomplishments; and
- At or before the end of the study, the Company will consider, in consultation with the Conservation Resources Advisory Group, programs that will manage EV load in the most cost-effective manner, including but not limited to time-of-use rates, demand response, and direct load control.

We encourage the Company to reach out to and request participation in the study from as many EV owners as possible during the course of this pilot program, including those customers with existing Level 1 chargers.

13 We agree with Staff that PSE's petition for a waiver of WAC 480-100-123 is unnecessary. In the context of this pilot program, publicizing Schedule 195 and the EVCI does not amount to promotional advertising. Accordingly, the waiver should be denied.

FINDINGS AND CONCLUSIONS

14 (1) The Washington Utilities and Transportation Commission is an agency of the State of Washington vested by statute with the authority to regulate rates, regulations, and practices of public service companies, including electric companies.

15 (2) PSE is an electric company and a public service company subject to Commission jurisdiction.

16 (3) The proposed accounting petition requested by PSE is reasonable and in the public interest and should be approved subject to the conditions set out in this Order.

17 (4) No rule waiver is necessary in this matter.

18 (5) This matter came before the Commission at its regularly scheduled meeting on April 24, 2014.

19 (6) The petition for an accounting order should be approved, subject to the conditions set out in this Order, and the petition for a waiver of WAC 480-100-223 should be denied.

O R D E R

THE COMMISSION ORDERS:

20 (1) Puget Sound Energy's requested accounting treatment for the costs associated with the Electric Vehicle Charger Incentive is approved. Puget Sound Energy is authorized to recover the costs of the Electric Vehicle Charger Incentive program through Schedule 120 and defer costs associated with this program consistent with all other programs falling under Schedule 120, subject to the conditions set out in this Order.

21 (2) This Order shall not affect the Commission's authority over rates, services, accounts evaluations, estimates, or determination of costs in any matters that may come before it, nor be construed as acquiescence in any estimate or determination of costs claimed or asserted.

(3) The Commission retains jurisdiction over the subject matter and Puget Sound Energy to enforce the provisions of this Order.

DATED at Olympia, Washington, and effective April 30, 2014.

WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

DAVID W. DANNER, Chairman

PHILIP B. JONES, Commissioner

Separate statement of Commissioner Goltz:

22 I concur with this order on PSE's Petition for an Accounting (Docket No. UE-140626), but I write separately to restate my reasons, given orally at the April 24, 2014, Open Meeting, for opposing allowing the underlying tariff implementing PSE's Electric Vehicle Charger Incentive (EVCI) from going into effect (Docket No. UE-131585). If the Commission had accepted my proposal to suspend the EVCI tariff, this petition for an accounting order would not have been necessary.

23 Various parties supported the EVCI for differing reasons. Electric vehicle advocates supported it because it would increase incentives for PSE's customers to purchase electric vehicles (EVs), thereby resulting in a benefit to PSE's customers.[1] Commission Staff supported it as a means of gathering data on charging patterns of owners of EVs. The Company and the Energy Office within the Department of Commerce urged acceptance of the tariff on both grounds. As articulated below, I find neither the argument to be persuasive. The EVCI, as currently crafted, will not result in a net benefit to PSE's ratepayers. While it may result in data that is valuable to PSE and to the Commission to develop appropriate rate designs as more EVs come on line, the overall price of this research project – up to $3.8 million – is too large a price to pay for data that in all probability could be obtained for a fraction of that cost.

The EVCI Will Not Result in a Net Benefit to PSE's Ratepayers

24 PSE and Commission Staff estimate that the total cost of the two-plus year program will be $3.8 million. There will be a maximum of 5000 incentives of $500 each paid to new or existing EV owners. That totals a maximum of $2.5 million. The remaining amount, perhaps up to $1.3 million,[2] would be available to PSE to do research on EV charging patterns.[3]

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[1] *See* Letter from John McCoy, Seattle Electric Vehicle Ass'n (April 22, 1014).

[2] A good portion of this amount, perhaps several hundred thousand dollars, would be for the gathering of data. However, even given that fact, the total cost of the research seems exorbitant.

[3] Of course, not all of this money may be spent, and the prudency of expenditures for the research would come before the Commission at a later date.

25 The Commission has approved ratepayer-funded incentives in other contexts, most notably energy conservation. However, the ratepayer charges that fund utility conservation programs are justified through a variety of economic tests designed to measure whether there are benefits to the system as a whole (system benefits) that outweigh the costs imposed on the ratepayers.

26 Here, the Company and the Energy Office argue that the increased load attributable to greater deployment of EVs will result in greater sales of electricity by PSE and therefore greater revenues. Those revenues, or at least a portion of them, would be redistributed to PSEs customers through PSE's revenue decoupling mechanism. According to PSE, each electric vehicle will contribute approximately $770 to the utility's margin.

27 Even accepting that $770 figure, the only incremental revenue to the Company would be that associated with EVs that would not have been purchased but for the incentive. So the benefit would be limited to incremental EVs, while the cost would be attributable to all EVs. (Indeed, the incentive is even available to those who purchased EVs back to 2012 and do not have a level 2 charger in their home.) As Commission Staff indicated at the April 24 Open Meeting, we do not know how many vehicles that would be. One can surmise with some confidence, however, that it will be but a fraction of the total EV sales. Adoption of EVs is growing, and would continue to grow, even without the $500 EVCI. Indeed, there is in place a state sales and use tax exemption for the purchase of EVs that dwarfs the $500 at issue here,[4] so any incremental EV acquisition likely would be a function of the larger tax exemption.[5]

28 A number of parties also argue that, in addition, there will be environmental benefits associated with the EVCI. These could result from the displacement of gasoline-powered vehicles by EVs, with resulting benefits. However, those are societal benefits and, while worthy of consideration, the Commission should not go down the road of imposing on one utility's ratepayers burdens that benefit all of society.

[4] RCW 82.08.809 (sales tax); RCW 82.12.809 (use tax).

[5] Of course, to the extent that more fast chargers are deployed than otherwise would be, there likely would be some incremental increase in usage of electricity by EV owners with fast chargers as their vehicles would be available to them during more hours of the day. However, there is no information on the impact of additional fast charger deployment.

Indeed, historically, the Commission has resisted that the imposition of such financial burdens by not allowing a transfer of funds from ratepayers as a whole to a subset of ratepayers, even where there exists a "public purpose" rationale. The Commission so stated in a case involving PSE's predecessor, Washington Natural Gas (WNG). WNG had proposed a tariff rider to fund the construction of a series of compressed natural gas (CNG) fueling stations. While there was a public purpose behind the proposal to increase the use of CNG vehicles, the Commission rejected the proposal, stating:

> The company proposes a transfer of funds from ratepayers to benefit a small group of users, although to support a public purpose. It may be more appropriate to spread the burden of supporting that public purpose among all the body politic, who all receive the social benefit, than to impose it on those who happen to be company ratepayers, who are a small group of that larger body politic. That is a task for the legislature, not for the Commission.[6]

29 Even if we were able to quantify the societal benefits attributable to incremental EVs displacing gasoline-powered vehicles, it would be a major stretch to conclude that this tariff proposal would be cost-effective on that basis. The Seattle Electric Vehicle Association estimated that the "ratepayer and global benefit" would be worth $900 to $4600 per vehicle. But, again, the subsidies would go to all owners of vehicles, while this incremental environmental benefit would only be associated with the incremental EV sales.[7]

30 This is not merely a policy issue; it is a legal one as well. While the Commission has broad authority to "regulate in the public interest," that authority is qualified by the phrase "as provided by the public service laws."[8] Where the Commission has used ratepayer dollars for broader public purposes, it has done so with specific authorization "by the public service laws." Implementing renewable portfolio

[6] *Washington Utilities & Transportation Comm'n v. Washington Natural Gas Co.*, Docket UG-920840, 3d Supp. Order (Mar. 12, 1993).

[7] Further, if we were going to include "global benefit" in the cost-benefit analysis, one would also have to include all costs. Among the cost to the State would be the foregone sales tax revenues. *See* note 3, *supra*.

[8] RCW 80.01.040(3); *see Cole v. Utilities & Transportation Comm'n*, 79 Wn.2d 302, 306, 485 P.2d 71 (1971).

standards and providing for assistance to low income customers are two examples.[9] But I do not find in the public service laws authority to use ratepayer funds to subsidize owners of EVs where there is no corresponding system benefit.

The Proposed Study of EV Charging Behavior Does Not Justify the EVCI Tariff

31 Commission Staff agrees that the EVCI cannot be justified based on financial or environmental benefits to ratepayers. Rather, Staff seeks to justify the incentive based on its interest in a study that has become part of the overall proposal. The $500 subsidy for a fast charger would be contingent on PSE having access to the customer's load information for the purpose of data collection.

32 I have two issues with this argument. First, evaluating future loads seems like a function that the utility should have been performing all along. These research costs should be part of the general expenses of the utility, recoverable as any other expense. Every new topic for utility research need not be accompanied by a tariff surcharge. Second, the overall $3.8 million cost of this study, including the $500 payments to each of 5000 customers as an incentive to have access to their data, seems extremely high for a research project, even when one considers that the company has to spend a fair amount to collect the data from meters. I suspect that a request for proposals to research organizations and to research universities would have yielded proposals at far lower costs.[10]

Conclusion

33 For these reasons, I urged my colleagues to follow the sound recommendation of Public Counsel and suspend this tariff so that we could collaboratively seek to make the EVCI a better program. I share the view that more electric vehicles on the road

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[9] RCW 19.285; RCW 80.28.068.

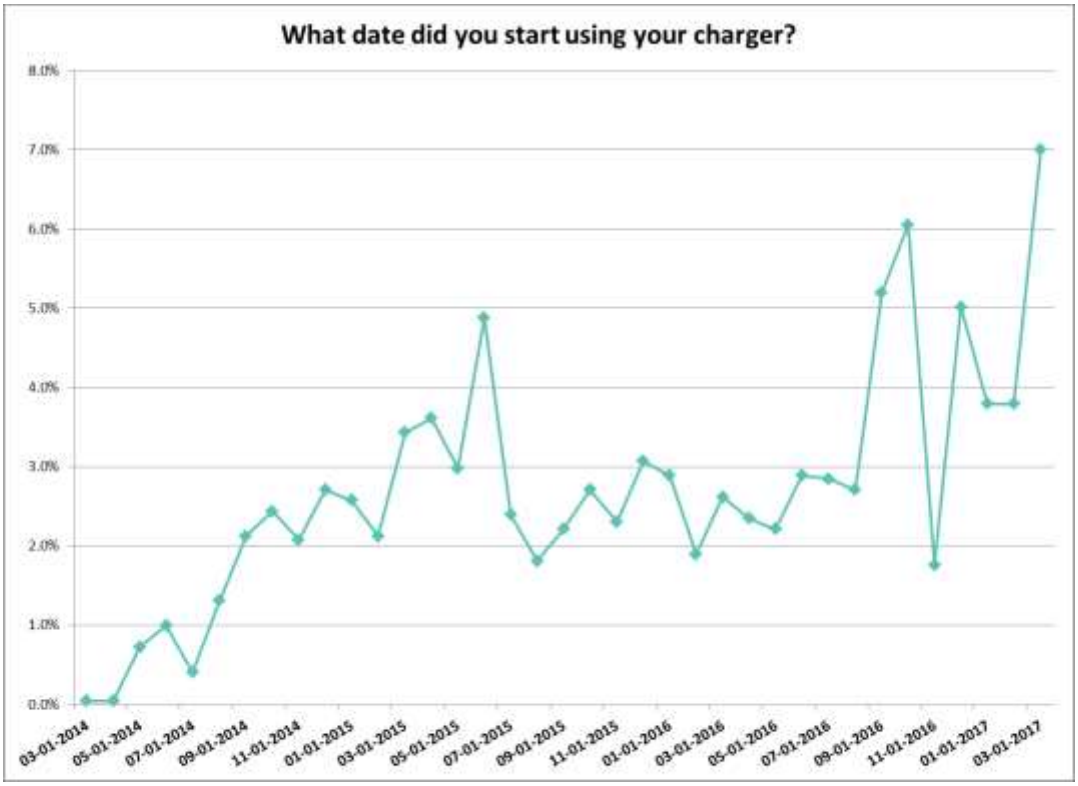
[10] There are some ways to improve on the research effort to be funded by this tariff. First, PSE should collect end-use load data for customers who use Level 1 chargers at their homes. Second, PSE should use its meters to collect 15 minute interval data from as many participants as possible. Third, PSE should provide a written report on the results of this program, including an analysis of the load profile of Level 1 and Level 2 EV charging to its Conservation Resource Advisory Group (CRAG). Given the discussions at the Open Meeting, it appears that the Company and Commission Staff will strive for these and perhaps other improvements in the research design and implementation.

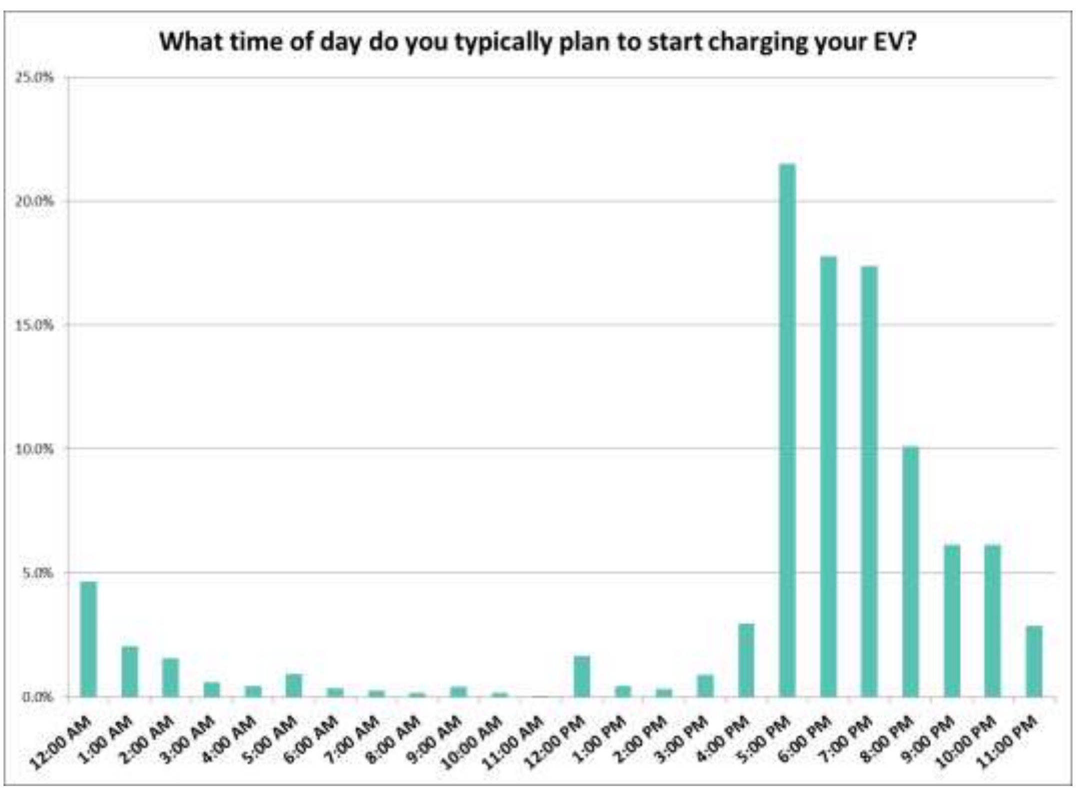
will serve the public interest. Indeed, that is state legislative policy given the substantial sales and use tax exemption in place. Yet our job as economic regulators is to ensure that each program brought before us promotes the public interest at the least cost. Suspension of this tariff would have allowed us the opportunity to reduce the cost of this program and improve the load study's design.

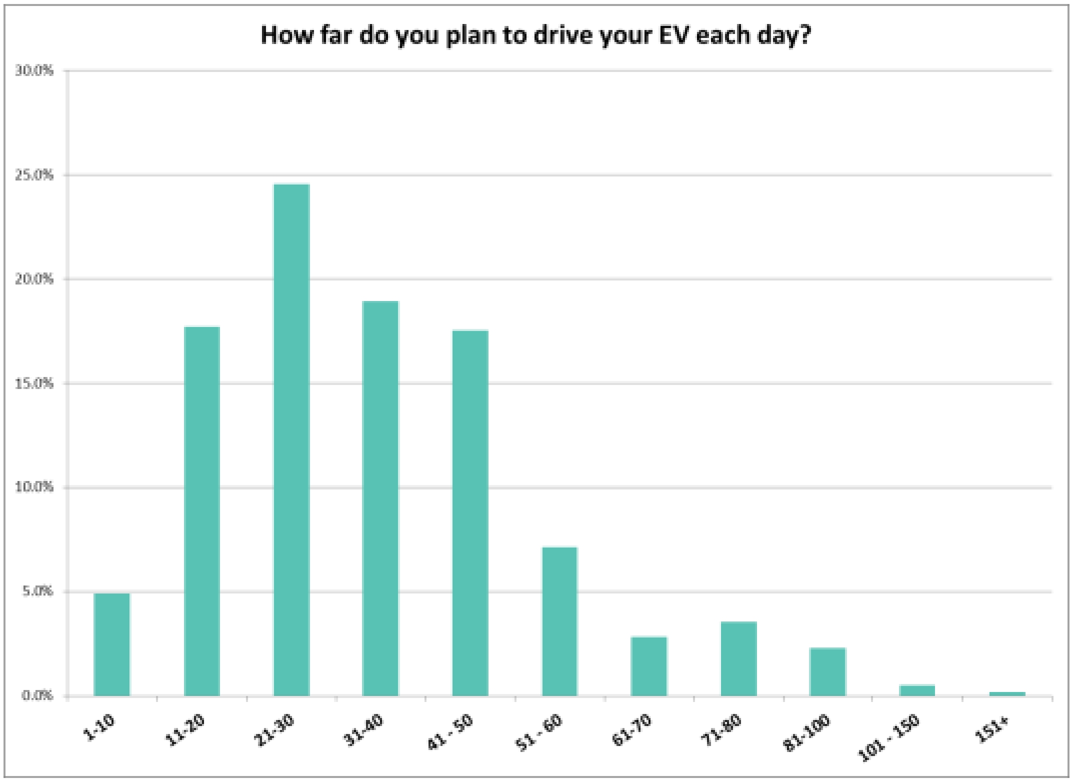
34 However, because this matter was not suspended, and it has taken effect, I now support the related accounting order.

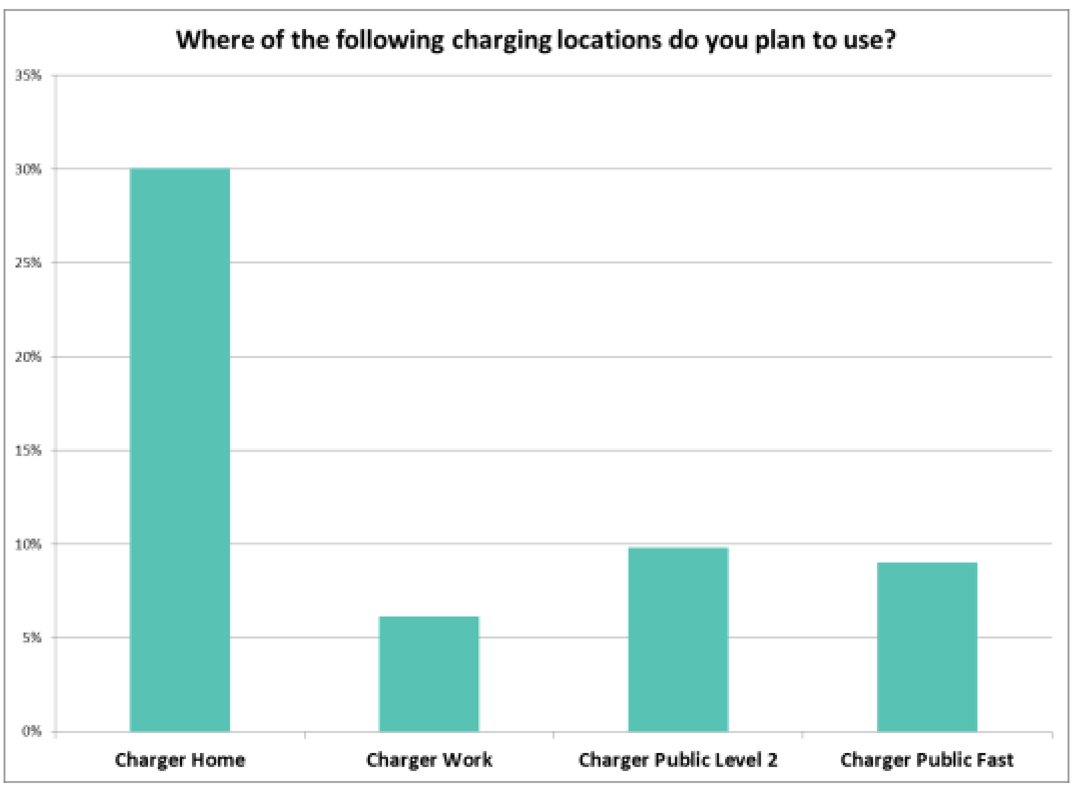
JEFFREY D. GOLTZ, Commissioner

APPENDIX D: Results of survey at time of enrollment






How far do you plan to drive your EV each day?
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
1-10
11-20
21-30
31-40
41 - 50
51 - 60
61-70
71-80
81-100
101 - 150
151+


Where of the following charging locations do you plan to use?
35%
30%
25%
20%
15%
10%
5%
0%
Charger Home
Charger Work
Charger Public Level 2
Charger Public Fast

APPENDIX E: Request for information

PUGET SOUND ENERGY

REQUEST FOR INFORMATION

FOR

ELECTRIC VEHICLE SUPPLY EQUIPMENT AND RELATED SERVICES

AUGUST 25, 2016

TABLE OF CONTENTS

1 INTRODUCTION

Puget Sound Energy (PSE) is interested in identifying potential sources of supply, with whom PSE may consider establishing one or more sourcing relationships in the future to support electric vehicle (EV) charging equipment and services. Towards that end, PSE invites your company to participate in and complete the following survey.

The survey is intended to explore some of PSE's views regarding the EV marketplace and technology offerings; solicit current EV Supply Equipment and Services industry best practices and company information; assess the level of potential compatibility between PSE and your company, and assess the level of interest on the part of your company.

PLEASE NOTE THAT THIS NOTICE AND THE RELATED REQUESTS FOR INFORMATION SHOULD NOT BE CONSIDERED A SOLICITATION FOR QUOTATION OR A REQUEST FOR PROPOSAL, AND NOTHING IN THIS NOTICE, THE SURVEY OR THE SPECIFICATIONS OBLIGATES PSE TO ISSUE ANY SUCH SOLICITATIONS NOW OR IN THE FUTURE OR TO CONSIDER ANY UNSOLICITED RESPONSES. FURTHER, PSE MAINTAINS NO OBLIGATION TO REIMBURSE RESPONDENT FOR ANY COSTS INCURRED IN ASSOCIATION WITH THIS RFI.

1.1 About Puget Sound Energy

Washington State's oldest local energy company, Puget Sound Energy serves approximately 1.1 million electric customers and more than 760,000 natural gas customers in 10 counties.

A subsidiary of Puget Energy, PSE meets the energy needs of its customers, in part, through incremental, cost-effective energy efficiency, procurement of sustainable energy resources, and far-sighted investment in the energy-delivery infrastructure.

PSE employees are dedicated to providing great customer service and delivering energy that is safe, dependable and efficient.

Puget Sound Energy's service area:

Electric Service: all of Kitsap, Skagit, Thurston, and Whatcom counties; parts of Island, King (not Seattle), Kittitas, and Pierce (not Tacoma) counties.

Natural Gas Service: parts of King (not Enumclaw), Kittitas (not Ellensburg), Lewis, Pierce (not Buckley), Snohomish, and Thurston counties.

For more information, visit www.PSE.com.

We look forward to your survey response and thank you for your company's participation.

Cordially,

Dan Flores, Senior Buyer
Puget Sound Energy
(425) 462-3691 - phone
dan.flores@pse.com

2 INDICATION OF INTEREST

If your company is interested in being considered to participate in PSE's **EV Supply Equipment and Services**, for any or a combination of providing goods, integration and associated services please complete this survey to your company's best efforts and return via e-mail by the indicated deadline. Include any attachments or other documentation as needed. If other documentation can not be sent by e-mail, it must also be received at the following address by the due date and time shown below.

If your company is not interested, please notify PSE by filling out this page only and return it via e-mail by the indicated deadline.

Please provide the point of contact information and mailing address for the appropriate participant in any future activities regarding this initiative.

Company Name ____

Address ____

City, State, Zip____

Contact Name ______________________ e-Mail Address ____________________

Telephone Number ___________________ Facsimile Number__________________

Interested _________

Not Interested _________

Information submitted through this survey could be used to assist PSE in preparing a request for proposal (RFP) and to identify candidate suppliers.

3 CONFIDENTIALITY, OWNERSHIP AND USE OF INFORMATION

By completing and returning this survey, your company agrees that it will take all appropriate action to ensure the confidentiality and security of, and not disclose or release to any third party, any of PSE's information contained in or referenced in this survey or provided through other means during the course of the survey process. Your company further agrees to return promptly or destroy all copies of this survey and any other related information or materials upon PSE's request.

Your response to the survey shall become the property of PSE upon its receipt by PSE, and you agree that PSE may use or disclose such information for any purpose, as determined by PSE in its sole judgment, and PSE shall not be liable in any respect for any use or disclosure of such information. Thus, it is recommended that you do not include any information in your response that your company claims to be proprietary or confidential, without the prior written agreement of

PSE. Thereafter, if PSE accepts the inclusion of such proprietary or confidential information, your company must clearly mark such information to be confidential or proprietary.

Unless your company has PSE's prior written permission, it will not (1) associate your company's products or services with PSE or PSE's operations or (2) represent to anyone that PSE has employed or endorsed your company's products or services.
Furthermore, in conjunction with your response to this RFI, please complete and sign a non-disclosure agreement attached hereto.

Agrmnt
Confidentiality & Non

4 INSTRUCTIONS

4.1 Time Table

Activity	Target Completion Dates
Release of RFI	August 25, 2016
Information Responses Due	September 9, 2016 at 3:00pm Pacific Time

4.2 Response Format

Suppliers are being asked to adhere to the specific format set forth in the table below to aid the project team in their efforts to evaluate efficiently all information. Reponses that deviate from the requested format will increase the time required to review and evaluate its contents.

Responses should be tailored specifically to answer this RFI. High-level "sales" material should not be used within the body of the response. If desired, Suppliers may attach such material in a separate appendix. It is essential that the response be thorough, yet concise. Avoid broad, unenforceable, or unmeasurable responses.

Electronic (e-mail) responses are preferred and should be sent to dan.flores@pse.com as an attached Microsoft Word or Adobe PDF document. Please note that our e-mail server will not accept e-mails over 10MB or containing .zip files.

Responses must be emailed to and submitted so as to be received by PSE **no later than 3 PM Pacific Time September 9, 2016,** at the following email address:

dan.flores@pse.com
with cc to:
meghan.weinman@pse.com & benjamin.farrow@pse.com

In order to facilitate Puget Sound Energy's review of the submitted proposals, Suppliers are required to provide the requested information in the following format.

Section	Section Title	Contents/Deliverables
1	Indication of Interest	Under signature of authorized representative, identify interest or non-interest in this initiative.
2	Company Overview	(Self explanatory)
3	References	Three References w/ Contact Information and brief project description
4	Executive Summary	Top-level summary of the most important aspects of the response.
5	Question Responses	Provide detailed responses to PSE requests in accordance with Section 7 of this document. Clearly identify and detail the proposed applications, services and resources required by the requirements defined.
6	Appendices (Optional)	Additional Supplier Information

5 INTRODUCTION TO PROJECT

PSE's ongoing electric vehicle charging rebate program has been well received by our customers and has helped PSE better understand the EV landscape in our region. In order to better meet the needs of our customers in the future, we are looking ways to support the EV ecosystem while also minimizing impact on our peak demand.

5.1 Project Objective

PSE would like to explore offerings in the electric vehicle supply equipment (EVSE) marketplace in order to help inform our strategy for supporting electric vehicle deployment while minimizing impact on peak demand. Through this RFI, PSE would like to evaluate various technology offerings and how these may be integrated into PSE's larger EV program.

5.2 Current State

PSE has some understanding of the EVSE marketplace, but would like to have better technical knowledge.

5.3 Desired State

PSE would like to have a better understanding about currently available and planned equipment offerings and integrated solutions for EVSEs.

6 QUESTIONS

Request/Question	Answer/Statement
6.1 General	
Please provide a general overview of your firm. That is, size, location(s), operations overview, etc.	
How long have you been in business?	
How many EVSE units have you sold?	
Does your company have demonstrated experience providing EVSEs to electric utilities?	
Does your firm have a local presence to the Puget Sound area (Western Washington) or in the northwest? If not, where is your closest location that houses project implementation staff?	
What are your local (or "closest location") staffing levels? How many of those employees are engaged in: • Project implementations? • Post "go-live" technical support?	
6.2 Hardware	
1. What type of electric vehicle supply equipment (EVSE) does your company offer? (i.e. Level 1, Level 2, Fast-Charging)	
a. What is/are the maximum power level of your EVSE(s)? (e.g. 50 kW)	
2. What is included in the standard EVSE you offer?	
a. Are there any additional parts required for equipment functionality? (e.g. cords, screws)	

Request/Question	Answer/Statement
b. How is the pedestal mounted?	
c. Does the unit have dual ports?	
3. Is there any optional equipment that can be included with the EVSE?	
6.3 Software *(where different hardware models may use different software, please specify by hardware)*	
1. What software is provided with the EVSE?	
2. What user interface is included with your company's EVSE?	
3. What software support/updates does your company provide?	
a. How often is software updated?	
4. Is there [also] a web and/or smartphone interface provided to customers via cloud or other platform?	
6.4 Control, Metering, Measurement *(where different hardware models may use different equipment, please specify by hardware)*	
1. How do EVSEs measure power?	
a. To what accuracy?	
b. What parameters are measured? e.g. consumption (accumulated, per session), demand (peak, average, per session)	
2. Does your EVSE only have on/off functionality or can it throttle at different levels during controlled charging events?	
a. How are charging events scheduled?	
b. Can your system inform owners, operators, and users of controlled charging events?	

Request/Question	Answer/Statement
c. Are owners, operators, and users able to set their participation or non-participation in controlled charging events?	
i. If yes, how do customers set their participation or non-participation?	
ii. How are the benefits and risks of controlled charging communicated to the customer?	
d. Can your system change fees based on users' decision to comply with controlled charging events?	
e. What ability does the utility have to direct or request level of charge?	
3. How are multiple EVSE chargers controlled?	
6.5 Communications & Reporting	
1. How are EVSE charging events and performance reported to the customer?	
a. What information is provided?	
2. How are EVSE charging events and performance reported to the utility?	
a. What information is provided?	
3. Can your system support delivery of messages to the customer in near real-time?	
4. How are systems issues (i.e. EVSE is non-operational) communicated to customers?	
5. What communication protocols (with the EVSE equipment) are in place?	

Request/Question	Answer/Statement
a. What type of platform does the EVSE use for communication (cell, wifi, meter)?	
b. What is the latency of the EVSE communication?	
6.6 Customer Experience	
1. What is your customer sign-up process?	
a. Do customers need to register with your platform before using the EVSE?	
2. Does your company provide customer support?	
a. If yes, by what method – phone, email, web-interface, other?	
3. How quickly is your company able to respond to customer complaints?	
a. What is the average response time?	
4. If your company has call centers, what are the metrics for the following support services?	
a. Operating hours?	
b. Number of calls handled in a month?	
c. Hold time for customers?	
5. How is customer feedback incorporated into EVSE design (hardware/software)?	
6.7 Authentication & Payment	
1. For public charging, does the EVSE have swipe-capability to accept and process user payments with debit/credit cards?	
a. If yes, how are cards processed?	
b. If not, how does a customer pay for use?	

Request/Question	Answer/Statement
2. Does a public EVSE require membership to a payment platform in order to process transactions?	
3. What is the frequency of customer invoicing/processing?	
a. Is it monthly, transactional, other?	
4. What billing capabilities exist?	
a. How do customers receive billing?	
5. Does your system authenticate users in public charging?	
a. If yes, how?	
6. Is your system compliant with Payment Card Industry (PCI) security standards?	
6.8 Servicing / Operations & Maintenance	
1. Is your company able to provide installation services such as:	
a. Required local inspections/approvals?	
b. Obtaining required permits?	
c. Coordinating construction work?	
d. Overseeing subcontractor work?	
2. Can your company test the EVSE and all safety mechanism for satisfactory operation, prior to the EVSE becoming operational?	
3. What is the warranty on your equipment?	
4. Does your company provide maintenance services?	
5. What system maintenance requirements are there for:	

Request/Question	Answer/Statement
a. Hardware	
b. Firmware	
c. Software	
6. How do you communicate issues with the EVSE to customers?	
6.9 Other	
1. Describe any unique features, technology, strategy, etc that sets your company apart from other firms.	
2. What are some key opportunities with EV and EVSEs in PSE's service area? Key challenges? What are some recommended approaches for overcoming these challenges?	
3. Please describe any new products or services your company may be providing in the next 1-2 years.	
6.4 Cost and Schedule Estimates	
To assist PSE with its project budget planning, please provide a ballpark MSRP price estimate based on the information provided for your company's standard unit (on a per unit basis). Break this cost estimate into: hardware, software, and services. Please include equipment specifications that correspond to the estimated costs.	

APPENDIX F: Load profiling report

Electric Vehicle Household and Charger Load Profiling

Puget Sound Energy

February 2018

Table of Contents

I. Executive Summary

The Electric Vehicle Charger Incentive (EVCI) Pilot Program, which went into effect on May 1, 2014, allowed PSE to offer a $500 rebate to customers who purchase and install a Level 2 electric vehicle charger.[1] As a condition for approving the EVCI program cost recovery, the Commission required PSE to study the end-use characteristics of EV load for a period of up to 32 months, ending no later than December 31, 2016.[2] In November 2016, the EVCI program was extended through April 30, 2017.[3] The "Electric Vehicle Household and Charger Load Profiling" study presented in this report was performed to satisfy the stipulation attached to the Commission's approval of the EVCI pilot program. With the EVCI offered through the end of April 2017, the study period was set for the twelve-month period ending June 2017 to take advantage of the most current data available.

As of June 2017, it is estimated that there were 13,140 electric vehicles registered in PSE service area, of which 9,480 were 100% battery-operated (BEV) and the remaining 3,660 were plug-in hybrid vehicles (PHEV).[4] By the end of April 2017 when the EVCI program expired, 1,993 electric vehicle (EV) owners had participated in the program and received a $500 rebate for the Level-2 chargers installed in their home. PSE's EVCI program enabled PSE to collect the metering and end-use survey data used to estimate the whole-house and EV charger hourly load shapes for its EV Customers who charge their EV's primarily at home using level 2 chargers. The EV charger and household load data were collected for 40 customers sampled from the EVCI Program participant list. Their whole-house and EV charger loads were metered with real-time load readings for the twelve-month period ending June 30, 2017. An end-use survey of 349 EV owners in PSE's service area was performed by PlugInsights and the survey results became available in June 2017.[5]

Key findings of this study are as follows:

1) On a typical weekday, hourly load per Level 2 EV charger varies between 0.1 kW and 0.9 kW while hourly load per Level 1 charger ranges between 0.06 kW and 0.6 kW.[6]
2) On a typical weekend day, hourly load per Level 2 charger changes between 0.08 kW and 0.6 kW while the range of hourly load per Level 1 charger is 0.04 kW to 0.5 kW.
3) Daily peak of the residential EV charger population load occurs mostly in the early evening hours of 6:00 PM to 8:00 PM, as monthly system peak demand does.
4) Monthly load factor and system coincidence factor of the residential EV charger population load are fairly low for most of the months. During the study period, all of the monthly load factors were below 0.29 while eight of twelve monthly system coincidence factors were lower than 0.40. However, the system

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[1] *Docket UE-131585*

[2] *Docket UE-140626, Order 01 ¶ 7*

[3] *Docket UE-161156*

[4] *A list of EV's registered through the end of June 2017 was provided by Washington State Department of Licensing.*

[5] *PlugInsights, Puget Sound Energy Charging Study: A Research Study for Puget Sound Energy, June 2017.*

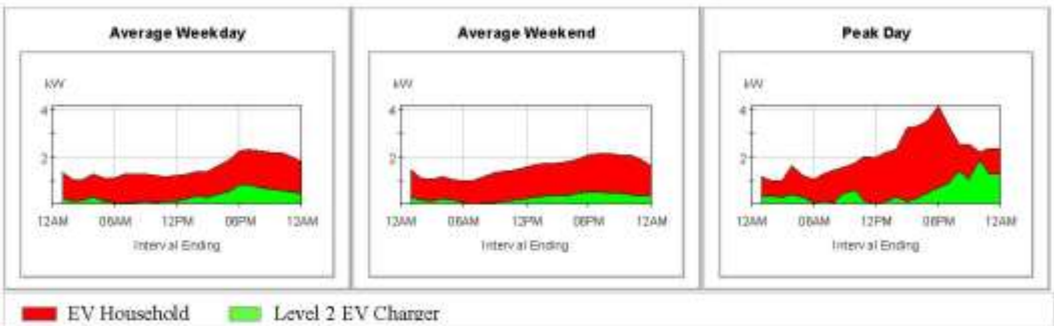
[6] *The average hourly load per EV charger should not be interpreted as the hourly energy use by a typical EV charger. For example, a typical Level 2 charger uses between 1.1 kW and 2.6 kW while in use and close to zero while not in use. An individual Level 2 charger load shape would be characterized by a flat load at nearly zero kW for most of the day, interrupted by one or more charging events which last up to several hours per event. On the other hand, the average hourly load per Level 2 EV charger was calculated dividing the Level 2 EV charger class load by population count of the Level 2 chargers installed at home. The Level 2 charger class hourly load shape was developed by expanding the sample estimate of charger load differentiated by EV battery type and daily driving distance to its segment population and summing up the segment population estimates for all of the EV segments. The population expansion and the class load shape development procedures are explained in detail in the following sections.*

coincidence factor will become very high if monthly system peak and EV charger peak loads occur on the same day, as happened in March 2017 when the system coincidence factor was 0.91.

5) Although the total load of residential EV chargers represents less than 0.7 percent of the residential class load now, it will grow rapidly to take up a significant portion of the residential class load during the next ten to fifteen years. With 250,000 EV's driven by PSE residential customers, annual peak load of their EV chargers is estimated to be 371 MW or over 10 percent of the residential class peak.

Figure 1.1 illustrates the average hourly load shape of a Level 2 EV charger installed at home, along with the average hourly load shape of EV household electricity use including its Level 2 charger load. **Figure 1.1** presents three graphs for three different types of day; *Average Weekday, Average Weekend Day, and Annual Peak Day.* The EV charger and household hourly load shapes are shown together in each graph.

Figure 1.1 – Level-2 EV Charger and EV Household Load Shapes: Weekday, Weekend Day and Annual Peak Day



According to the *Average Weekday* graph in **Figure 1.1**, the EV household hourly load fluctuates between 1.1 kW and 2.4 kW. It stays low in the morning hours, except for a brief surge occurring early in the morning between 4:00 AM and 5:00 AM before ramping up to a daily peak occurring sometime between 6:00 PM and 7:00 PM. The early morning uptick also seen in the Level 2 EV charger load shape indicates that the uptick may be caused by a time-programmed operation of some EV chargers. Hourly load shapes appear similar between the whole-house load and the Level 2 EV charger load, while the EV charger hourly load varies in the range of 0.1 kW and 0.9 kW. Non-EV use of electricity by an EV household can be estimated by subtracting the EV charger load from the whole-house load.

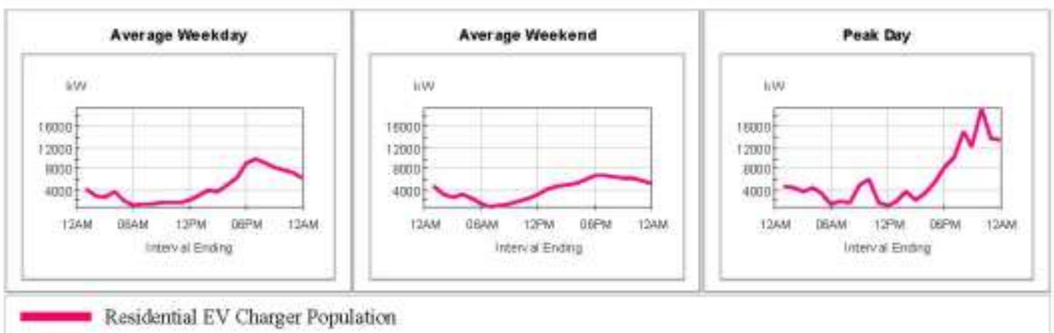
The *Average Weekend Day* graph displays flattened hourly load shapes for EV household and charger, compared with their *Average Weekday* load shapes. The early morning surge is also observed in the *Average Weekend Day* hourly load shapes. Both EV household and charger hourly loads increase continuously from the lowest point occurring at around 7:00 AM to a daily peak reaching at about 7:00 PM. The whole-house hourly load on an *Average Weekend Day* ranges between 1.0 kW and 2.2 kW, while the EV charger hourly load varies between 0.08 kW and 0.6 kW.

The *Annual Peak Day* hourly loads of Level 2 EV charger and household presented in **Figure 1.1** are non-coincident. The EV charger and household peak day load shapes represent the hourly loads on December 13, 2016 and January 8, 2017, respectively. Monthly system-coincident peaks, coincidence factors and load factors of the EV charger and household loads are discussed in the later sections of this report. The *Annual Peak day* graph presents the EV household and charger hourly load shapes much different from *Average Weekday's* and *Average Weekend*

Day's. The EV charger load on the peak day hits its daily peak at 10:00 PM whereas the EV charger daily peaks on *Average Weekday* and *Average Weekend Day* occur between 6:00 PM and 7:00 PM. The reason why daily peak of EV charger load occurs later in the evening on its annual peak day is unknown and is to be investigated as more historical observations become available. The difference between EV Household hourly load shape on its *Annual Peak Day* and the shapes on *Average Weekday* and *Weekend Day* is mainly due to the impact of severe winter weather conditions experienced on the peak day. The range of fluctuations for whole-house hourly loads on the *Annual Peak Day* is 1.0 kW to 4.2 kW while the range for Level 2 EV charger hourly loads is 0.07 kW to 1.9 kW.

Figure 1.2 presents *Average Weekday*, *Average Weekend Day*, and *Annual Peak Day* load shapes for the whole population of Level 1 and Level 2 EV chargers installed at home. With only 13,140 registered electric vehicles in PSE's service area in June 2017, the total loads of at-home EV chargers represent only a minimal portion of the residential class load. For example, the residential EV charger population load reached its annual peak of 19.5 MW occurred at 10:00 PM on Tuesday, December 13th, 2016. It is only 0.7**%** of the residential class annual peak of 2,876.9 MW for the twelve months ending September 2016.[7] The daily peaks on *Average Weekday* and *Average Weekend Day* were 9.9 MW and 6.9 MW, respectively.

Figure 1.2 – Residential EV Charger Population Load: Weekday, Weekend Day and Annual Peak Day



This situation will change as the number of EVs in PSE's service area increases rapidly in the forthcoming years. **Figure 1.3** presents *Average Weekday*, *Average Weekend Day*, and *Annual Peak Day* load shapes of the EV charger population for two hypothetical cases in which number of EV's registered in PSE's service area reaches 250,000 and 500,000, respectively. The estimates were made by assuming that EV population compositions of daily driving distances, daily schedules of EV charging and charger types will stay the same.

According to the high adoption scenario provided in the recent study of EV load impacts performed by Energy and Environmental Economics (E^3), the number of EV's in PSE service area will reach about 250,000 by 2027.[8] The base case scenario of the same study foresees that it will take nine more years to reach that level of EV population. The high adoption scenario also predicts that the number of EV's in the PSE service area will increase to 500,000 by 2033. Based on the PlugInsights' survey study results, about 70 percent of those EV's will be charged with At-Home Level 2 chargers, 26 percent with Level 1 chargers, and 4 percent not charged at home.[9] In these two

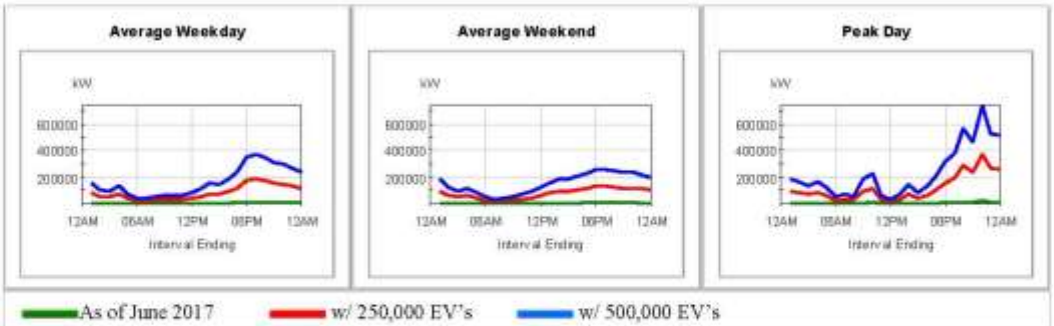
[7] *The annual peak of EV charger load is for the twelve months ending June 2017.*

[8] *Energy and Environmental Economics, Economic and Grid Impacts of Plug-In Electric Vehicle Adoption in Washington & Oregon, March 2017, p. 303.*

[9] *PlugInsights, Puget Sound Energy Charging Study, p. 11.*

hypothetical cases, the at-home EV charger load will take a significant portion of the Residential Class load, and will become a main contributor to future increase in the residential class load. For example, EV charger population load on its annual peak day will reach 371 MW with 250,000 EV's and 742 MW with 500,000 EV's.[10]

Figure 1.3 – Residential EV Charger Population Loads w/ 250,000 & 500,000 EV's: Weekday, Weekend Day and Annual Peak Day



The following sections discuss the input data, the methodologies and the results of this EV load profiling study in detail. The segmentation of EV customer samples and population done for EV household and charger load profiling is explained in **Attachment F-1**. The Level 2 EV charger load profiles for average weekday, weekend day and peak day by battery type are presented in **Attachment F-2**.

[10] *The annual peak loads of EV chargers were projected for the hypothetical cases of 250,000 and 500,000 EV's through a linear expansion of the current estimate of 19.5 MW with 13,140 EV's for the assumed numbers of EV's.*

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II. Data, Methodologies and Study Results

1) Electric Vehicle Household Load Profiling

Data

1,993 EV households participated in PSE's EVCI Program by the end of April 2017. From the list of EVCI program participants, 40 customers were sampled for two separate real-time load readings: 1) their total electricity use at home including the EV charger load; and 2) the electricity used by the Level 2 chargers installed at their homes. The sampling methodology was designed to yield a fair representation of the EV population diversity in car models, daily driving distances and access to public chargers. PSE collected real-time load data with "eGauge" metering system.[11] The real-time load data were integrated to produce hourly load shapes of EV household total energy use and its EV charger energy use. A list of the registered electric vehicles by zip code as of June 2017 was provided by Washington Department of Licensing (WDOL). PlugInsights performed an end-use survey of the PSE's EV customers sampled to study their EV charging behaviors in April 2017. The EV customer survey results were also utilized in this study.

Methodologies

The "EV household" load represents average electric energy use of PSE residential customers who own both an electric vehicle and a level 2 charger installed at home. Based on PlugInsights' survey study results, 95 percent of Long-Range Battery Electric Vehicle (LBEV) owners have a Level 2 charger installed at home, while 60 percent of Mid-Range Battery Electric Vehicle (MBEV) owners and 56 percent of Plug-In Hybrid Electric Vehicle (PHEV) owners have a Level 2 charger at home.[12] In total, about 70 percent of the EV customers in PSE service area use Level 2 chargers to charge their EV's at home. As explained in Attachment F-1, the EV sample customers and population were segmented into six groups, characterized by EV battery types and average daily driving distances. Since the information provided by WDOL contains only EV make and model years (therefore, EV battery types) but not the information regarding daily driving distances, the population segmentation was completed by using the same percentage distribution of EV drivers' daily driving distances for each of the three EV battery types estimated with PlugInsights' survey study results.[13]

Average hourly load shapes on weekday, weekend day and class peak day for an EV household in each segment were developed by using the eGauge-monitored load data collected from the 40 EV households sampled and segmented for this study. Hourly load shapes for EV population by segment were developed by multiplying the average EV household hourly loads by the population count for each of the six segments. EV household class load shapes were then produced by aggregating the segment load shapes

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[11] *"eGauge" metering system is developed by eGauge Systems LLC in Boulder, Colorado. The metering system consists of the real-time load monitoring system and the web-configured user interface to display energy use every second and recent historical data. The metering system can monitor energy use simultaneously at up to twelve different circuits. The monitored load data can be stored in a solid state memory space built in the on-site eGauge system for up to seven or thirty years depending on a user's choice. The historical load data can be transmitted for analysis through either Powerline Communication (Model EG 3100) or Ethernet Direct (Model EG 3000) where Powerline Communication is not available. The load data can be exported in a spreadsheet form.*

[12] *PlugInsights, p. 11. LBEV is a battery-powered vehicle with a real world driving range of 200 miles or more. MBEV is a battery-powered vehicle with a real world driving range of 100 miles or less. PHEV is a plug-in vehicle which is fueled by a combination of a battery and some form of internal combustion engine/generator. A list of EV's by battery type is provided in Table A.1.1 of Attachment F-1.*

[13] *Ibid., p. 7.*

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for all of the six segments. Average hourly load shape for an EV household was determined by dividing the EV household class hourly load values by the population count of EV owners with Level 2 chargers. Based on **Table A.1.4** in **Attachment F-1**, the population count of EV households with a Level 2 EV charger was 9,202 in June 2017, assuming that no more than one Level 2 charger was owned by the EV households in PSE service area.

Study Results

Table 2.1 presents summary statistics for the EV Household class load, in which their household energy use includes the Level 2 EV charger load. The table displays monthly energy use, timing of the class peak demand, magnitude of the class peak demand, average demand, load factor based on the class peak demand, timing of the system peak and class load at the time of system peak, and the coincidence factor calculated as the class system coincident load divided by the class peak. As shown in the table, annual peak demand of the EV Household class was 38.2 MW for the study period, while the annual average demand was 14.5 MW. Monthly load factors of the EV Household class range between 35.3 percent and 50.8 percent. They are significantly lower than monthly load factors of the whole residential class, which were between 55.1 percent and 66.2 percent for the twelve months ending September 2016.[14] Monthly system coincidence factors of 38.3 percent to 84.5 percent are also much lower than those of the residential class. Monthly system coincidence factors of the entire residential class were between 73.6 percent and 100.0 percent.[15] The lower load factor and system coincident factor are mainly due to the poor monthly load factor and system coincidence factor of the Level 2 EV charger loads, which will be discussed later.

Table 2.1 – EV Household Class Load: Summary Statistics (kW)

EV Household Class Total		Household Peak Demand					Household Demand at System Peak Hour			
Month	Monthly Energy Use (kWh)	Date	Time	Peak Demand (kW)	Average Demand (kW)	Load Factor (%)	Date	Time	Coincident Demand (kW)	Coincidence Factor (%)
Jul-16	9,672,856	Monday, July 25, 2016	10:00 PM	36,823	13,001	35.3%	Thursday, July 28, 2016	6:00 PM	17,487	47.5%
Aug-16	10,108,784	Friday, August 12, 2016	11:00 PM	31,893	13,587	42.6%	Friday, August 19, 2016	5:00 PM	19,488	61.1%
Sep-16	9,016,662	Friday, September 16, 2016	9:00 PM	27,989	12,523	44.7%	Monday, September 26, 2016	8:00 PM	16,054	57.4%
Oct-16	10,323,488	Tuesday, October 11, 2016	5:00 PM	31,120	13,878	44.6%	Wednesday, October 12, 2016	8:00 AM	15,141	48.7%
Nov-16	10,897,158	Sunday, November 27, 2016	6:00 PM	32,998	15,135	45.9%	Wednesday, November 30, 2016	6:00 PM	23,598	71.5%
Dec-16	13,428,782	Thursday, December 29, 2016	6:00 PM	35,508	18,047	50.8%	Thursday, December 08, 2016	6:00 PM	24,778	69.8%
Jan-17	13,050,473	Sunday, January 08, 2017	6:00 PM	38,208	17,541	45.9%	Thursday, January 05, 2017	8:00 AM	18,069	47.3%
Feb-17	10,735,823	Saturday, February 11, 2017	7:00 PM	33,403	15,976	47.8%	Thursday, February 02, 2017	8:00 AM	20,421	61.1%
Mar-17	11,279,988	Thursday, March 09, 2017	8:00 PM	36,588	15,161	41.5%	Monday, March 06, 2017	8:00 PM	30,891	84.5%
Apr-17	9,777,362	Tuesday, April 18, 2017	7:00 PM	32,501	13,588	41.8%	Tuesday, April 11, 2017	8:00 AM	12,453	38.3%
May-17	9,500,580	Thursday, May 04, 2017	6:00 PM	26,720	12,769	47.8%	Monday, May 01, 2017	9:00 AM	11,148	41.7%
Jun-17	9,266,642	Monday, June 26, 2017	7:00 PM	30,962	12,870	41.6%	Sunday, June 25, 2017	6:00 PM	22,198	71.7%
Total	127,056,411	Annual Peak/Average Demand		38,208	14,504	38.0%	Annual Coincident Demand		18,069	47.3%

Figure 2.1 provides the average weekday, average weekend day, and class peak day load shapes of the EV Household class. According to the *Average Weekday* graph, the EV Household class has the lowest usage for a few early morning hours before facing a brief surge at around 5:00 AM. Its electric energy use then rises slightly and stabilizes until the mid-afternoon and escalates rapidly afterward until the early evening when it reaches a daily peak just after 6:00 PM. After the peak, its electricity usage keeps decreasing until the early morning hours. The *Average Weekend Day* graph displays a similar early morning usage pattern to the one seen in the *Average Weekday* graph. But, the usage increases continuously after 6:00 AM,

[14] *Rates and Regulatory Affairs Department, Puget Sound Energy Load Research Report: Class Load Profiling for October 2015 – September 2016, March 2017, page 3-5, Table 8.*

[15] *Ibid.*

with a brief stoppage in the mid-afternoon, before hitting a daily peak around the same time as the average weekday peak time. This difference in the weekday and the weekend day load shapes implies that a majority of EV household members are away from home during the weekday daytime hours, possibly at work. The *Peak day* graph clearly demonstrates a winter weather impact on hourly loads. Since the class annual peak occurred on Sunday (January 8, 2017), the peak day load shape also reveals the weekend energy use pattern in which hourly energy use increases continuously through the daytime hours. An early morning surge shown at around 5:00 AM in all of the three day types may be caused by a time-programmed coincidence among some of the Level 2 charger loads.

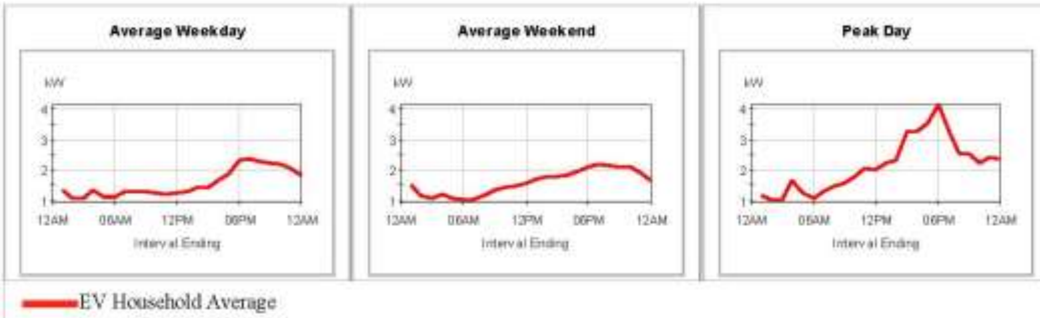
Figure 2.1 – EV Household Class Load: Weekday, Weekend Day and Class Peak Day

The Average EV Household load profile represents a weighted average of EV household electric energy use. The weighted average of use per EV customer for all of the six segments was calculated by dividing the EV household class load by the population count of EV owners with level 2 chargers at home. **Table 2.2** presents summary statistics for the Average EV Household load. Annual peak demand of Average EV Household was 4.2 kW during the twelve-month period ending June 2017 and its annual average demand was 1.6 kW. Its annual system coincident demand was 2.0 kW. The Average EV Household's hourly load shapes shown in **Figure 2.2** look the same as its class load shapes presented in **Figure 2.1**, except the kW scales reduced to about1/10,000.

Table 2.2 – Average EV Household Load: Summary Statistics (kW)

EV Household Average		Household Peak Demand					Household Demand at System Peak Hour			
Month	Monthly Energy Use (kWh)	Date	Time	Peak Demand (kW)	Average Demand (kW)	Load Factor (%)	Date	Time	Coincident Demand (kW)	Coincidence Factor (%)
Jul-16	1,051.17	Monday, July 25, 2016	10:00 PM	4.08	1.41	35.3%	Thursday, July 28, 2016	6:00 PM	1.98	47.5%
Aug-16	1,098.53	Friday, August 12, 2016	11:00 PM	3.47	1.48	42.6%	Friday, August 19, 2016	5:00 PM	2.12	61.1%
Sep-16	979.18	Friday, September 16, 2016	9:00 PM	3.04	1.36	44.7%	Monday, September 26, 2016	8:00 PM	1.74	57.4%
Oct-16	1,121.87	Tuesday, October 11, 2016	5:00 PM	3.38	1.51	44.6%	Wednesday, October 12, 2016	8:00 AM	1.65	48.7%
Nov-16	1,184.22	Sunday, November 27, 2016	6:00 PM	3.59	1.64	45.9%	Wednesday, November 30, 2016	6:00 PM	2.58	71.5%
Dec-16	1,459.12	Thursday, December 29, 2016	6:00 PM	3.88	1.96	50.8%	Thursday, December 08, 2016	6:00 PM	2.69	69.5%
Jan-17	1,418.22	Sunday, January 08, 2017	6:00 PM	4.15	1.91	45.9%	Thursday, January 05, 2017	8:00 AM	1.98	47.3%
Feb-17	1,166.63	Saturday, February 11, 2017	7:00 PM	3.63	1.74	47.9%	Thursday, February 02, 2017	8:00 AM	2.22	61.1%
Mar-17	1,225.82	Thursday, March 09, 2017	9:00 PM	3.97	1.65	41.5%	Monday, March 06, 2017	8:00 PM	3.36	84.5%
Apr-17	1,062.53	Tuesday, April 18, 2017	7:00 PM	3.53	1.48	41.8%	Tuesday, April 11, 2017	8:00 AM	1.35	38.3%
May-17	1,033.44	Thursday, May 04, 2017	6:00 PM	2.98	1.39	47.8%	Monday, May 01, 2017	9:00 AM	1.21	41.7%
Jun-17	1,067.81	Monday, June 26, 2017	7:00 PM	3.36	1.48	41.6%	Sunday, June 25, 2017	6:00 PM	2.41	71.7%
Total	13,807.48	Annual Peak/Average Demand	-	4.15	1.58	38.0%	Annual Coincident Demand	-	1.96	47.3%

Figure 2.2 – Average EV Household Load: Weekday, Weekend Day and Class Peak Day



2) Level 2 Electric Vehicle Charger Load Profiling

Data

As explained in the previous section, Level 2 EV charger load data were collected with eGauge's real-time load readings of electric energy use by level 2 chargers owned by 40 EV customers sampled and segmented for this study. The real-time load data were collected for the 12 months ending June 30, 2017. As done for EV Household load profiling, WDOL list of electric vehicles registered in PSE service area and PlugInsights' survey study results were also utilized for segmentation of EV chargers and population expansion of EV charger load profiles.

Methodologies

The Level 2 EV Charger load profile by type of day shows the hourly changes in electricity use by EV owners when charging their EV's with Level 2 chargers installed at their homes. The Level 2 EV charger and its class load profiles were developed by following the same methodologies used for the EV Household load profiling. With the end-use metering data collected from the Level 2 chargers owned by 40 EV customers sampled for this study, Level 2 EV charger load profiles were developed for each of the six segments. The Level 2 EV Charger load profile by segment was expanded to the population level using the segment population count. The segment population count was estimated by applying the percentage distribution by segment calculated with PlugInsights' 2017 survey study results to the total number of EV's charged at home with Level 2 chargers. PlugInsights' survey results indicate that 70 percent of the EV owners in PSE service area charge their EV's with the Level 2 chargers installed at their homes. The EV population count by segment and charger type is listed in **Table A.1.4** of **Attachment F-1**. The Level 2 EV Charger class load profile was then produced by aggregating the segment population load profiles for all of the six segments.

Study Results

Table 2.3 presents summary statistics for the Level 2 EV Charger class Load. The table shows that annual peak demand of the Level 2 Charger class was 17.4 MW for the twelve-month period of July 2016 through June 2017 and the class annual average demand was 3.3 MW. It is notable that monthly load factors and system coincident factors of the Level 2 EV charger class load are fairly low. Especially, the coincidence factor at the annual system peak hour was only 9.1 percent. Monthly load factors were below 25 percent

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in 11 months of the study year. Since the EV charging load is not weather-sensitive, the monthly peak demand dates for EV charging hardly overlap the monthly system peak dates, which are determined mainly by severe summer and winter weather conditions. This is why monthly system coincidence factors tend to be low. Meanwhile, most of the Level 2 EV Charger class peaks occur during the early evening hours between 6:00 PM and 8:00 PM. Most of the monthly peaks for the system load also occur during the similar evening hours. This implies that there is a potential for the system coincidence factor to increase sharply, as revealed on March 6, 2017. In fact, the monthly system coincidence factors of Level 2 EV Charger load tend to fluctuate in a wide range.

Table 2.3 – Level 2 EV Charger Class Load: Summary Statistics (kW)

Level 2 Charger Class Total		Charger Peak Demand					Charger Demand at System Peak Hour			
Month	Monthly Energy Use (kWh)	Date	Time	Peak Demand (kW)	Average Demand (kW)	Load Factor (%)	Date	Time	Coincident Demand (kW)	Coincidence Factor (%)
Jul-16	2,083,869	Thursday, July 14, 2016	7:00 PM	14,368	2,801	19.5%	Thursday, July 28, 2016	6:00 PM	4,609	32.1%
Aug-16	2,200,279	Thursday, August 18, 2016	6:00 PM	13,131	2,957	22.5%	Friday, August 19, 2016	5:00 PM	4,848	36.3%
Sep-16	2,303,225	Thursday, September 01, 2016	6:00 PM	13,538	3,199	23.6%	Monday, September 26, 2016	8:00 PM	5,778	42.6%
Oct-16	2,496,976	Monday, October 24, 2016	7:00 PM	17,204	3,338	19.5%	Wednesday, October 12, 2016	8:00 AM	2,178	12.6%
Nov-16	2,563,528	Tuesday, November 01, 2016	6:00 PM	14,759	3,560	24.1%	Wednesday, November 30, 2016	6:00 PM	5,558	38.3%
Dec-16	2,701,433	Tuesday, December 13, 2016	10:00 PM	17,359	3,631	20.9%	Thursday, December 08, 2016	6:00 PM	8,283	47.7%
Jan-17	2,898,887	Monday, January 30, 2017	8:00 PM	13,833	3,895	25.9%	Thursday, January 05, 2017	8:00 AM	1,883	10.5%
Feb-17	2,334,119	Monday, February 13, 2017	8:00 PM	17,197	3,473	20.2%	Thursday, February 02, 2017	8:00 AM	3,132	19.2%
Mar-17	2,794,183	Monday, March 06, 2017	6:00 PM	15,628	3,758	24.0%	Monday, March 06, 2017	6:00 PM	13,308	85.1%
Apr-17	2,366,255	Tuesday, April 18, 2017	7:00 PM	15,458	3,288	21.2%	Tuesday, April 11, 2017	8:00 AM	968	6.2%
May-17	2,268,934	Thursday, May 04, 2017	6:00 PM	13,973	3,058	21.8%	Monday, May 01, 2017	9:00 AM	1,915	13.7%
Jun-17	2,270,470	Monday, June 26, 2017	7:00 PM	13,920	3,153	19.9%	Sunday, June 25, 2017	6:00 PM	1,108	7.3%
Total	29,281,279	Annual Peak/Average Demand		17,359	3,343	19.3%	Annual Coincident Demand		1,583	9.1%

Figures 2.3 presents the average weekday, average weekend day, and class peak day load shapes for the Level 2 EV Charger class. According to the *Average Weekday* graph, the Level 2 EV Charger class load is low for an hour or so before experiencing a brief surge between 4:00 AM and 5:00 AM. The Level 2 EV Charger class load starts decreasing after the uptick and stays low for the remainder of morning hours. The hourly load rises again at around noon and keeps increasing to its daily peak reached between 6:00 PM and 7:00 PM. After the daily peak, the load declines gradually through the night hours. The *Average Weekend Day* graph displays a similar hourly usage pattern to the one observed in the *Average Weekday* graph but the level of daily peak is substantially lower than the average weekday's. The *Peak day* graph shows several spikes in the Level 2 EV Charger class hourly load shape. The load spikes can happen at any time of day, except the late night and early morning hours between 11:00 PM through 4:00 AM. The levels of mid-morning spike and evening spikes are clearly identifiable. The daily peak reached on peak day is more than doubled than the daily peak on average weekday.

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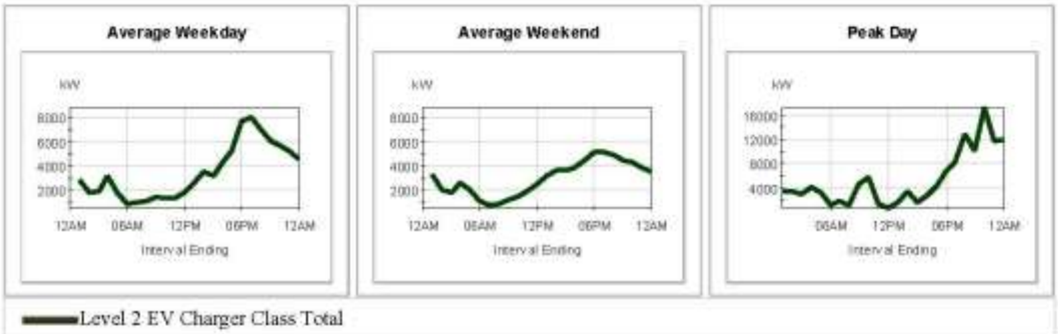
Figure 2.3 – Level 2 EV Charger Class Load: Weekday, Weekend Day and Class Peak Day

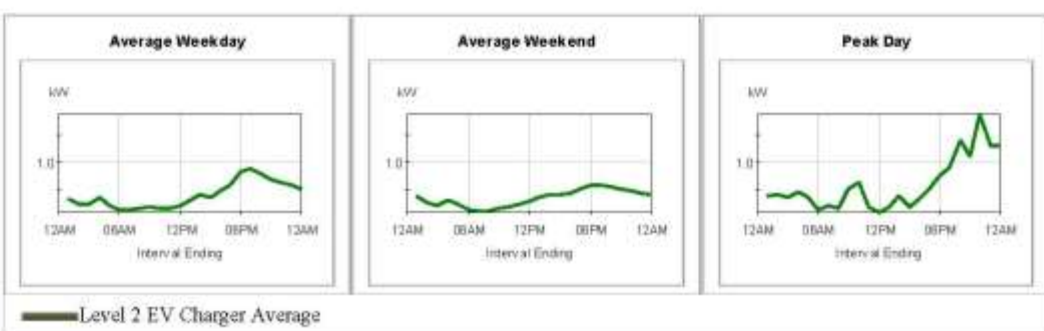


The weighted average of electricity use per Level 2 charger for all of the six EV segments was calculated dividing the Level 2 EV charger class load by population count of the Level 2 chargers installed at home. **Table 2.4** presents summary statistics for the average load per Level 2 charger. As shown in the table, average annual peak demand of the Level 2 charger was 1.9 kW for the study period and the annual average demand was 0.4 kW. Average hourly load shapes of a Level 2 charger for average weekday, average weekend day, and the class peak day are shown in **Figure 2.4.** They look the same as the class load shapes shown in **Figure 2.3**, except the kW scales set to about 1/10,000.

Table 2.4 – Average Level 2 EV Charger Load: Summary Statistics (kW)

Level 2 Charger Average		Charger Peak Demand					Charger Demand at System Peak Hour			
Month	Monthly Energy Use (kWh)	Date	Time	Peak Demand (kW)	Average Demand (kW)	Load Factor (%)	Date	Time	Coincident Demand (kW)	Coincidence Factor (%)
Jul-16	226.46	Thursday, July 14, 2016	7:00 PM	1.58	0.38	19.5%	Thursday, July 28, 2016	6:00 PM	0.58	33.1%
Aug-16	239.11	Thursday, August 18, 2016	6:00 PM	1.43	0.32	22.5%	Friday, August 19, 2016	5:00 PM	0.53	36.8%
Sep-16	250.39	Thursday, September 01, 2016	6:00 PM	1.47	0.35	23.6%	Monday, September 26, 2016	8:00 PM	0.63	42.6%
Oct-16	271.35	Monday, October 24, 2016	7:00 PM	1.87	0.36	19.5%	Wednesday, October 12, 2016	8:00 AM	0.24	12.6%
Nov-16	278.58	Tuesday, November 01, 2016	6:00 PM	1.60	0.39	24.1%	Wednesday, November 30, 2016	6:00 PM	0.58	36.3%
Dec-16	295.57	Tuesday, December 13, 2016	10:00 PM	1.89	0.39	20.9%	Thursday, December 08, 2016	6:00 PM	0.90	47.7%
Jan-17	314.53	Monday, January 30, 2017	8:00 PM	1.63	0.42	25.9%	Thursday, January 05, 2017	8:00 AM	0.17	10.5%
Feb-17	253.65	Monday, February 13, 2017	8:00 PM	1.87	0.38	20.2%	Thursday, February 02, 2017	8:00 AM	0.34	18.2%
Mar-17	302.65	Monday, March 06, 2017	6:00 PM	1.70	0.41	24.0%	Monday, March 06, 2017	8:00 PM	1.45	85.1%
Apr-17	257.15	Tuesday, April 18, 2017	7:00 PM	1.68	0.36	21.2%	Tuesday, April 11, 2017	8:00 AM	0.10	6.2%
May-17	246.57	Thursday, May 04, 2017	6:00 PM	1.52	0.33	21.8%	Monday, May 01, 2017	9:00 AM	0.21	13.7%
Jun-17	246.74	Monday, June 26, 2017	7:00 PM	1.73	0.34	19.8%	Sunday, June 25, 2017	6:00 PM	0.13	7.3%
Total	3,182.86	Annual Peak/Average Demand	-	1.89	0.36	19.3%	Annual Coincident Demand	-	0.17	9.1%

Figure 2.4 – Average Level 2 EV Charger Load: Weekday, Weekend Day and Class Peak Day



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3) Level 1 Electric Vehicle Charger Load Profiling

Data

Level 1 EV charger load data were provided by Energy and Environmental Economics (E^3). E^3 developed Level 1 charger average load shapes based on the data collected by Idaho National Laboratory for its light-duty plug-in electric vehicle (PEV) and charging infrastructure demonstration project, titled "The EV Project."[16] The Level 1 charger hourly load shapes obtained from E^3 are differentiated by type of day and EV technology: 1) average weekday load shape for plug-in hybrid electric vehicle (PHEV), 2) average weekday load shape for battery electric vehicle (BEV), 3) average weekend day load shape for PHEV, and 4) average weekend day load shape for BEV. PSE has tried to recruit volunteers to collect their Level 1 EV charger load data by the eGauge metering system, but could not secure a sufficient number of samples to produce a reliable database.

Methodologies

The Level 1 EV Charger class hourly load profile for the twelve months ending June 2017 was developed by using the Level 1 charger loads shapes provided by E^3. The Level 1 charger hourly load profiles for PHEV and BEV were constructed by assuming their average weekday load shapes for every non-weekend days in the study year period and their average weekend day load shapes for all of the weekend days. The PHEV and BEV Level 1 charger load profiles were expanded to their population levels by multiplying the hourly loads by PHEV and BEV Level 1 charger population counts. BEV population count is equal to the sum of LBEV and MBEV population counts. According to PlugInsights' 2017 survey study results, 26 percent of the EV owners in PSE service area charge their EV's with a Level 1 charger at home.[17] Among the Level 1 charger users, 28 percent of them own PHEV and 72 percent own BEV. As explained in **Attachment F-1**, PHEV and BEV Level 1 charger population counts were estimated by applying those percentage breakdowns to the PSE total EV population count of 13,140. The Level 1 EV Charger class hourly load profile was then developed by summing the hourly load values estimated for PHEV and BEV Level I charger populations.

Study Results

Table 2.5 presents summary statistics for the Level 1 EV Charger class Load. The table shows that annual peak demand of the Level 1 Charger class was 2.1 MW for the study period of July 2016 through June 2017 and the class annual average demand was 955 kW. The annual system coincident demand was 290 kW. Since the average hourly load shape of weekdays is assumed for every weekday in the study period and the average weekend hourly load shape tends to be flatter than the average weekday's, monthly peak demand is expected to occur on a weekday. Therefore, the class peak day load shape becomes identical to the average weekday load shape. This why monthly peak demand listed in **Table 2.5** stays constant at 2.1 MW. Monthly load factors and system coincident factors of the Level 1 EV Charger class load tend to be higher than those of the Level 2 Charger class load, because EV charging with a Level 1 charger is slower and requires a larger number of hours than a Level 2 charger. The coincidence factor at

[16] *U.S. Department of Energy, INL News Release, "Electric Vehicle Charging Habits Revealed," September 30, 2015.*

[17] PlugInsights, p. 11.

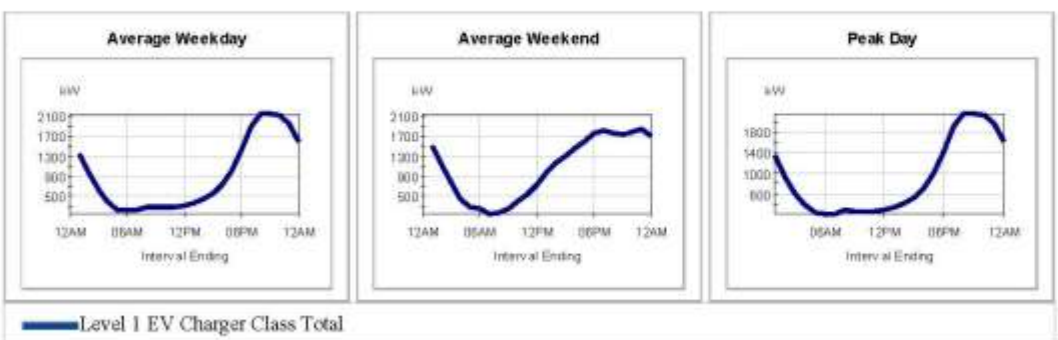
the annual system peak hour was 13.5 percent, compared with 9.1 percent for the Level 2 Charger class load. Annual load factor was 44.4 percent, much higher than the Level 2 Charger class annual load factor of 19.3 percent.

Table 2.5 – Level 1 EV Charger Class Load: Summary Statistics (kW)

Level 1 Charger Class Total		Charger Peak Demand					Charger Demand at System Peak Hour			
Month	Monthly Energy Use (kWh)	Date	Time	Peak Demand (kW)	Average Demand (kW)	Load Factor (%)	Date	Time	Coincident Demand (kW)	Coincidence Factor (%)
Jul-16	714,507	Weekday, July, 2016	8:00 PM	2,148	968	44.7%	Thursday, July 28, 2016	6:00 PM	1,428	66.5%
Aug-16	707,114	Weekday, August, 2016	8:00 PM	2,148	958	44.3%	Friday, August 19, 2016	5:00 PM	1,016	47.3%
Sep-16	685,258	Weekday, September, 2016	8:00 PM	2,148	952	44.3%	Monday, September 26, 2016	8:00 PM	2,148	100.0%
Oct-16	714,507	Weekday, October, 2016	8:00 PM	2,148	968	44.7%	Wednesday, October 12, 2016	8:00 AM	288	13.3%
Nov-16	685,258	Weekday, November 2016	8:00 PM	2,148	952	44.3%	Wednesday, November 30, 2016	6:00 PM	1,428	66.5%
Dec-16	718,811	Weekday, December 2016	8:00 PM	2,148	955	44.5%	Thursday, December 08, 2016	6:00 PM	1,428	66.5%
Jan-17	718,811	Weekday, January 2017	8:00 PM	2,148	955	44.5%	Thursday, January 05, 2017	8:00 AM	290	13.5%
Feb-17	641,345	Weekday, February 2017	8:00 PM	2,148	955	44.5%	Thursday, February 02, 2017	8:00 AM	290	13.5%
Mar-17	707,114	Weekday, March 2017	8:00 PM	2,148	958	44.3%	Monday, March 06, 2017	8:00 PM	2,148	100.0%
Apr-17	692,651	Weekday, April, 2017	8:00 PM	2,148	962	44.8%	Tuesday, April 11, 2017	8:00 AM	288	13.5%
May-17	707,114	Weekday, May, 2017	8:00 PM	2,148	958	44.3%	Monday, May 01, 2017	9:00 AM	279	13.0%
Jun-17	685,258	Weekday, June, 2017	8:00 PM	2,148	952	44.3%	Sunday, June 25, 2017	6:00 PM	1,755	81.7%
Total	8,361,946	Annual Peak/Average Demand		2,148	955	44.4%	Annual Coincident Demand		290	13.5%

Figures 2.5 presents the average weekday, average weekend day, and class peak day load shapes for the Level 1 EV Charger class. According to the *Average Weekday* graph, the EV charger class load declines rapidly after reaching the daily peak between 7 PM and 10 PM to the daily minimum demand at around 5 AM and stays low for the remainder of morning hours. There is no early morning surge observed in the Level 2 charger load shape. The Level 1 EV Charger class load starts increasing at around noon and keeps increasing to its daily peak reached in the evening hours. The *Average Weekend Day* graph displays a lower and flatter hourly usage pattern for the peak period of evening hours than the *Average Weekday's*. It is also notable that the Level 1 Charger class load on a weekend day hits the daily minimum at 7 AM and keeps increasing afterward until the evening peak hours. As explained earlier, the *Peak day* graph is identical to the *Average Weekday* graph.

Figure 2.5 – Level 1 EV Charger Class Load: Weekday, Weekend Day and Class Peak Day



The weighted average of electricity use per Level 1 charger was calculated dividing the Level 1 EV charger class load by the population count of Level 1 chargers. As shown in **Table A.1.4**, the total number of Level 1 chargers being used by PSE residential EV owners was 3,470. **Table 2.6** presents summary statistics for the Average Level 1 EV Charger load. As shown in the table, average annual peak demand of the Level 1 EV charger was 0.6 kW for the study period and the annual average demand was 0.3 kW. The annual system coincident demand is fairly low at 0.1 kW. The hourly load shapes of average load per Level 1 EV

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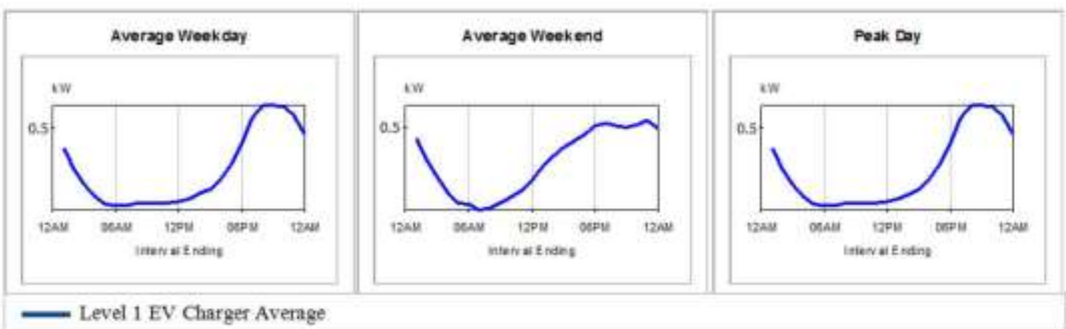
charger are shown for average weekday, average weekend day, and class peak day in **Figure 2.6.** Those load shapes look the same as their counter parts of the Level 1 charger class load shapes shown in **Figure 2.5**, with the kW scales reduced to about 3/10,000.

Table 2.6 – Average Level 1 EV Charger Load: Summary Statistics (kW)

Level 1 Charger Average		Charger Peak Demand					Charger Demand at System Peak Hour			
Month	Monthly Energy Use (kWh)	Date	Time	Peak Demand (kW)	Average Demand (kW)	Load Factor (%)	Date	Time	Coincident Demand (kW)	Coincidence Factor (%)
Jul-16	203.98	Weekday, July, 2016	8:00 PM	0.62	0.28	44.7%	Thursday, July 28, 2016	8:00 PM	0.41	66.5%
Aug-16	203.77	Weekday, August, 2016	8:00 PM	0.62	0.27	44.3%	Friday, August 19, 2016	5:00 PM	0.29	47.3%
Sep-16	197.47	Weekday, September, 2016	8:00 PM	0.62	0.27	44.3%	Monday, September 26, 2016	8:00 PM	0.62	100.0%
Oct-16	203.98	Weekday, October, 2016	8:00 PM	0.62	0.28	44.7%	Wednesday, October 12, 2016	8:00 AM	0.08	13.5%
Nov-16	197.47	Weekday, November 2016	8:00 PM	0.62	0.27	44.3%	Wednesday, November 30, 2016	6:00 PM	0.41	66.5%
Dec-16	204.83	Weekday, December 2016	8:00 PM	0.62	0.28	44.5%	Thursday, December 08, 2016	6:00 PM	0.41	66.5%
Jan-17	204.83	Weekday, January 2017	8:00 PM	0.62	0.28	44.5%	Thursday, January 05, 2017	8:00 AM	0.08	13.5%
Feb-17	184.37	Weekday, February 2017	8:00 PM	0.62	0.28	44.5%	Thursday, February 02, 2017	8:00 AM	0.08	13.5%
Mar-17	203.77	Weekday, March 2017	8:00 PM	0.62	0.27	44.3%	Monday, March 06, 2017	8:00 PM	0.62	100.0%
Apr-17	199.68	Weekday, April, 2017	8:00 PM	0.62	0.28	44.0%	Tuesday, April 11, 2017	8:00 AM	0.08	13.5%
May-17	203.77	Weekday, May, 2017	8:00 PM	0.62	0.27	44.3%	Monday, May 01, 2017	9:00 AM	0.08	13.0%
Jun-17	197.47	Weekday, June, 2017	8:00 PM	0.62	0.27	44.3%	Sunday, June 25, 2017	6:00 PM	0.51	81.7%
Total	2,403.64	Annual Peak/Average Demand		0.62	0.28	44.4%	Annual Coincident Demand		0.08	13.5%

Figure 2.6 – Average Level 1 EV Charger Load: Weekday, Weekend Day and Class Peak Day



4) Residential Electric Vehicle Charger Load Profiling

Electric Vehicle charger load profile for all of the Level 1 and the Level 2 chargers being used at home by PSE residential customers was produced by combining the hourly load shapes estimated for the Level 1 and the Level 2 Charger classes. **Table 2.7** provides summary statistics for the Residential EV Charger class load. As shown in the table, annual peak demand of the Residential EV Charger class was 19.5 MW for the study period and the class annual average demand was 4.2 MW. Annual coincidence demand at the time of system peak was low at 1.9 MW. Monthly system coincidence demand fluctuated between 1.3 MW to 15.4 MW. Monthly system coincidence factor varies in the range of 7.2 percent and 90.6 percent. Monthly load factors are slightly higher than the case of Level 2 charger only, but are still lower than 30 percent in all of the twelve months. The *Average Weekday, Average Weekend Day*, and *Class Peak Day* load shapes for the Residential EV Charger class are presented in **Figure 2.7** and were also provided in **Figure 1.2** with some discussion in the "Executive Summary" section.

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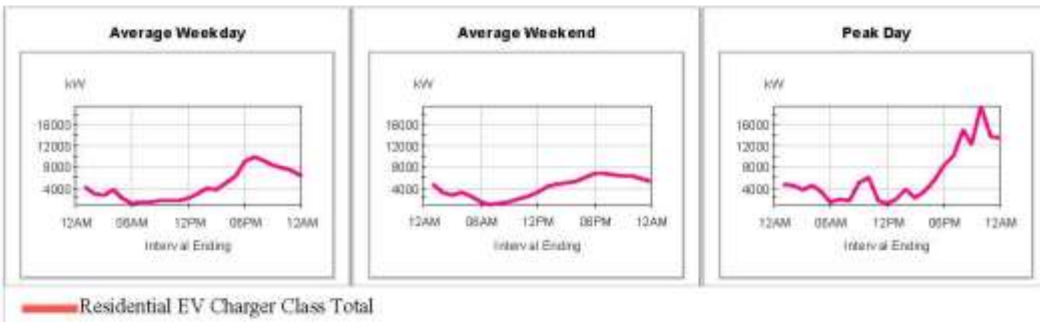
Table 2.7 – Residential EV Charger Class Load: Summary Statistics (kW)

Residential EV Charger Class Total		Charger Peak Demand					Charger Demand in System Peak Hour			
Month	Monthly Energy Use (kWh)	Date	Time	Peak Demand (kW)	Average Demand (kW)	Load Factor (%)	Date	Time	Coincident Demand (kW)	Coincidence Factor (%)
Jul-16	2,798,377	Thursday, July 14, 2016	7:00 PM	16,264	3,761	23.1%	Thursday, July 28, 2016	6:08 PM	6,837	37.1%
Aug-16	2,907,395	Tuesday, August 16, 2016	8:00 PM	14,723	3,888	26.5%	Friday, August 19, 2016	5:08 PM	5,562	38.8%
Sep-16	2,988,403	Thursday, September 01, 2016	6:00 PM	14,964	4,151	27.7%	Monday, September 26, 2016	8:08 PM	7,818	52.9%
Oct-16	3,211,404	Monday, October 24, 2016	7:00 PM	19,103	4,327	22.6%	Wednesday, October 12, 2016	8:08 AM	2,466	12.9%
Nov-16	3,249,786	Tuesday, November 01, 2016	6:00 PM	16,167	4,512	27.9%	Wednesday, November 30, 2016	6:08 PM	6,786	41.9%
Dec-16	3,412,343	Tuesday, December 13, 2016	10:00 PM	19,490	4,588	23.5%	Thursday, December 08, 2016	6:08 PM	9,711	49.8%
Jan-17	3,608,816	Monday, January 30, 2017	8:00 PM	17,180	4,851	28.2%	Thursday, January 05, 2017	8:08 AM	1,877	18.9%
Feb-17	2,975,664	Monday, February 13, 2017	8:00 PM	19,345	4,428	22.8%	Thursday, February 02, 2017	8:08 AM	5,422	37.7%
Mar-17	3,501,297	Monday, March 06, 2017	6:00 PM	17,184	4,708	27.4%	Monday, March 06, 2017	8:08 PM	15,448	98.6%
Apr-17	3,058,907	Tuesday, April 18, 2017	7:00 PM	17,503	4,248	24.4%	Tuesday, April 11, 2017	8:08 AM	1,258	7.2%
May-17	2,976,047	Thursday, May 04, 2017	6:00 PM	15,401	4,088	26.8%	Monday, May 01, 2017	9:08 AM	2,193	14.2%
Jun-17	2,955,720	Monday, June 26, 2017	7:00 PM	17,819	4,105	23.0%	Sunday, June 25, 2017	6:08 PM	2,922	16.4%
Total	37,643,225	Annual Peak/Average Demand		19,490	4,217	21.6%	Annual Coincident Demand		1,873	8.0%

Figure 2.7 – Residential EV Charger Class Load: Weekday, Weekend Day and Class Peak Day

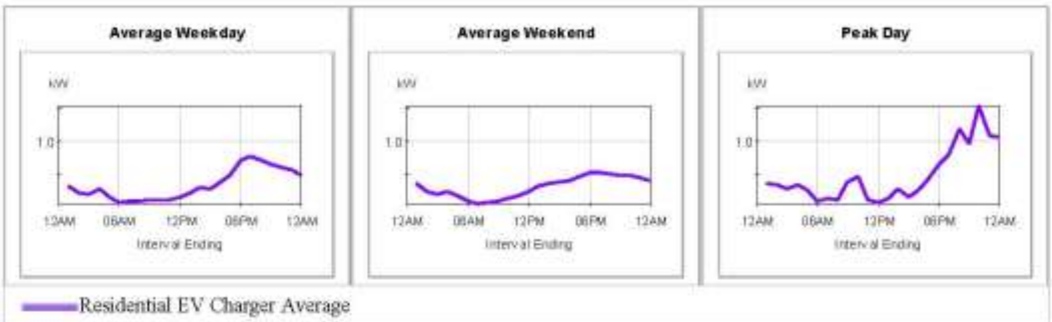


A weighted average of hourly load per EV charger was calculated by dividing the Residential EV Charger class load by sum of the population counts for Level 1 and Level 2 chargers. Based on **Table A.1.4**, the total number of Level 1 and Level 2 chargers being used at home by PSE residential customers was 12,672. 468 EV customers do not charge their EV's at home. **Table 2.8** presents summary statistics for the average load per EV charger. Annual peak demand and average demand per at-home EV charger was 1.5 kW and 0.3 kW, respectively. Annual system coincident demand was 0.2 kW while the maximum monthly system coincidence demand was 1.2 kW. The *Average Weekday*, *Average Weekend Day*, and *Class Peak Day* load shapes for the average load per residential EV charger are provided in **Figure 2.8.**

Table 2.8 – Average Residential EV Charger Load: Summary Statistics (kW)

Residential EV Charger Class Average		Charger Peak Demand					Charger Demand at System Peak Hour			
Month	Monthly Energy Use (kWh)	Date	Time	Peak Demand (kW)	Average Demand (kW)	Load Factor (%)	Date	Time	Coincident Demand (kW)	Coincidence Factor (%)
Jul-16	220.83	Thursday, July 14, 2016	7:00 PM	1.28	0.30	23.1%	Thursday, July 28, 2016	6:08 PM	0.48	37.1%
Aug-16	229.43	Tuesday, August 16, 2016	8:00 PM	1.16	0.31	26.5%	Friday, August 19, 2016	5:08 PM	0.44	38.8%
Sep-16	235.83	Thursday, September 01, 2016	6:00 PM	1.18	0.33	27.7%	Monday, September 26, 2016	8:08 PM	0.62	52.9%
Oct-16	253.43	Monday, October 24, 2016	7:00 PM	1.51	0.34	22.6%	Wednesday, October 12, 2016	8:08 AM	0.19	12.9%
Nov-16	256.37	Tuesday, November 01, 2016	6:00 PM	1.28	0.36	27.9%	Wednesday, November 30, 2016	6:08 PM	0.54	41.9%
Dec-16	269.27	Tuesday, December 13, 2016	10:00 PM	1.54	0.36	23.5%	Thursday, December 08, 2016	6:08 PM	0.77	49.8%
Jan-17	284.78	Monday, January 30, 2017	8:00 PM	1.36	0.38	28.2%	Thursday, January 05, 2017	8:08 AM	0.15	18.9%
Feb-17	234.83	Monday, February 13, 2017	8:00 PM	1.53	0.35	22.8%	Thursday, February 02, 2017	8:08 AM	0.27	17.7%
Mar-17	276.30	Monday, March 06, 2017	6:00 PM	1.35	0.37	27.4%	Monday, March 06, 2017	8:08 PM	1.22	98.6%
Apr-17	241.39	Tuesday, April 18, 2017	7:00 PM	1.37	0.34	24.4%	Tuesday, April 11, 2017	8:08 AM	0.10	7.2%
May-17	234.83	Thursday, May 04, 2017	6:00 PM	1.22	0.32	26.8%	Monday, May 01, 2017	9:08 AM	0.17	14.2%
Jun-17	233.24	Monday, June 26, 2017	7:00 PM	1.41	0.32	23.0%	Sunday, June 25, 2017	6:08 PM	0.23	16.4%
Total	2,970.53	Annual Peak/Average Demand	--	1.54	0.33	21.6%	Annual Coincident Demand	--	0.15	8.0%

Figure 2.8 – Average Residential EV Charger Load: Weekday, Weekend Day and Class Peak Day



Attachment F-1: Segmentation of EV Customer Samples and Population

The EV customer samples and population in PSE service area were segmented into six distinct groups defined by a combination of battery type and average daily driving distance. The first segmentation was done by their EV battery type: (1) Plug-in Hybrid Electric Vehicle (PHEV), (2) Medium Range Battery-Only Electric Vehicle (MBEV), and (3) Long Range Battery-Only Electric Vehicle (LBEV). Car models were categorized into these three battery types as defined by PlugInsights in its survey study report.[18] **Table A.1.1** provides a list of car models that are classified by battery type.

Table A.1.1 – Cars by Battery Type

Battery Type	Car Examples
Plug-in Hybrid Electric Vehicle (PHEV)	Audi A3 E-tron, BMW 330E, BMW i8, BMW X5,Cadilac ELR, Chevy Volt, Ford C-Max, Ford Fusion, Hyundai Sonata, Porsche Cayenne, Toyota Prius HB, Toyota Prius Prime, Volvo XC90
Medium-Range Battery Electric Vehicle (MBEV)	BMW i3, Chevy Spark, Fiat 500E, Ford Focus, Kia Soul EV, Mercedes B-Class Electric, Mitsubishi i-MiEV, Nissan Leaf, Smart Fortwo, Toyota Rav4 EV, Volkswagen E-Golf, Zero DS13
Long-Range Battery Electric Vehicle (LBEV)	Chevy Bolt, Tesla Model S, Tesla Model X

The second segmentation criterion was EV owner's average daily drive distance: (1) less than 50 miles per day and (2) 50 or more miles per day. Those two criteria were combined with the three battery types to create six segments for the EV customer samples and population. A list of descriptions for those six segments is provided in **Table A.1.2**.

Table A.1.2 – EV Customer Segment Descriptions

Segment	Description
PHEV 0 – 49	Plug-In hybrid Electric Vehicles with a Drive Distance of less than 50 miles per day.
PHEV 50+	Plug-In hybrid Electric Vehicles with a Drive Distance of 50 or more miles per day.
MBEV 0-49	Medium Range Battery-Only Electric Vehicles with a Drive Distance of less than 50 miles per day.
MBEV 50+	Medium Range Battery-Only Electric Vehicles with a Drive Distance of 50 or more per day.
LBEV 0-49	Long Range Battery-Only Electric Vehicles with a Drive Distance of less than 50 miles per day.
LBEV 50+	Long Range Battery-Only Electric Vehicles with a Drive Distance of 50 or more miles per day.

PSE EVCI Program Participants reported their average daily drive distance on their applications for a $500 rebate. In PlugInsights' survey conducted in May 2017, the survey respondents provided the information regarding their EV model names, average drive distances per weekday and weekend day, their motivations and perceived barriers to drive an EV, their EV charger technologies and daily charging schedules, use of public chargers, demographics, etc. With the survey data, average daily drive distance was calculated by giving 5/7 weight to the drive distance

[18] *Ibid., p. 3.*

per week day and 2/7 weight to the drive distance per weekend day. The State Department of Licensing's (WDOL's) list of the EV's registered in PSE service area includes only the information regarding car make, model and year, registration date and zip code. Since no daily drive distance information is available from the WDOL's list, the same percentage share of daily drive distance by EV battery type estimated with PlugInsight's EV survey results was used to segment the EV customer population, after identifying their EV battery types with the car model information provided in the WDOL's list.

Table A.1.3 shows the percentage distribution by EV battery type and daily drive distance estimated from PlugInsights' PSE EV customer survey study results. The percentage distribution is further broken down by EV charger type being used at home: 1) Not charged at home, 2) Level 1 charger, and 3) Level 2 charger.

Table A.1.3– Percentage Distribution of PSE EV Customers by Segment

	Drive Distance by Charger Type					
Battery Type	No Home		Level 1		Level 2	
	0-49	50+	0-49	50+	0-49	50+
LBEV	2.53%	1.03%	18.79%	7.62%	49.81%	20.21%
MBEV	2.87%	0.69%	21.27%	5.14%	56.41%	13.62%
PHEV	3.10%	0.46%	23.00%	3.41%	60.99%	9.04%

The share percentage figures shown in **Table A.1.3** were used to estimate the number of EV customers by charger type and daily drive distance from the EV customer population count of 13,140. **Table A.1.4** presents the resulting population count of EV customers by segment.

Table A.1.4– Number of PSE EV Customers by Segment

Load Profile Title	Population by Charger Type		
	No home Charger	Level 1	Level 2
LBEV 0-49	78	575	1,525
LBEV 50+	31	233	619
MBEV 0-49	184	1,365	3,621
MBEV 50+	44	330	874
PHEV 0-49	114	842	2,232
PHEV 50+	17	125	331
Total	468	3,470	9,202

Attachment F-2: Level 2 EV Charger Load Profiles by Battery Type

A residential electric vehicle charger load profile presents hourly electricity demand of a charger being used at home. In this study, Level 2 charger load profiles were developed from the real-time load data collected for 40 EV customers sampled and recruited from the PSE EVCI program participants. An hourly load profile was developed for each of the six EV customer segments: (1) PHEV 0-49, (2) PHEV 50+, (3) MBEV 0-49, (4) MBEV 50+, (5) LBEV 0-49, and (6) LBEV 50+. Each segment load profile represents the hourly loads averaged for the sampled customers in the segment. These six charger load profiles were then expanded to the segment population levels multiplying the hourly load values by the Level 2 Charger segment population counts shown in **Table A.1.4**.

Figure B.2.1, **Figure B.2.2**, and **Figure B.2.3** display the average Weekday, average weekend day, and peak day load shapes by EV battery type: 1) PHEV, (2) MBEV and (3) LBEV. The graphs in each figure present load shapes for an EV customer with average daily drive distance of less than 50 miles (in Blue) and an EV customer with average daily drive distance of 50 or more miles (in Red).

Figure B.2.1 – PHEV Level 2 Charger Load: Weekday, Weekend Day and Peak Day

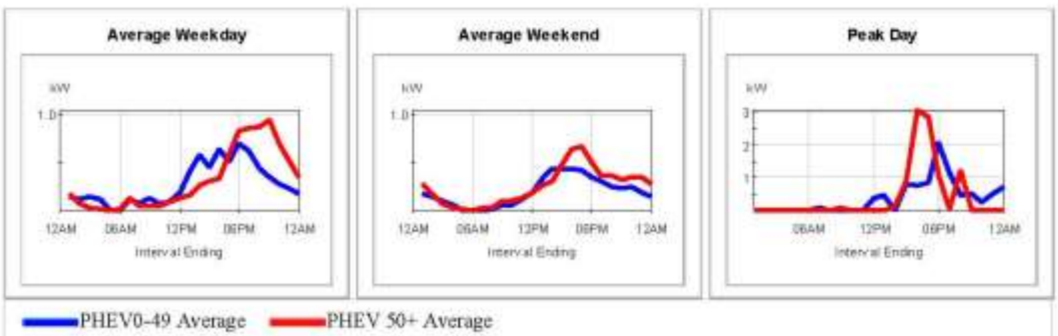


Figure B.2.2 – MBEV Charger Load: Weekday, Weekend Day and Peak Day

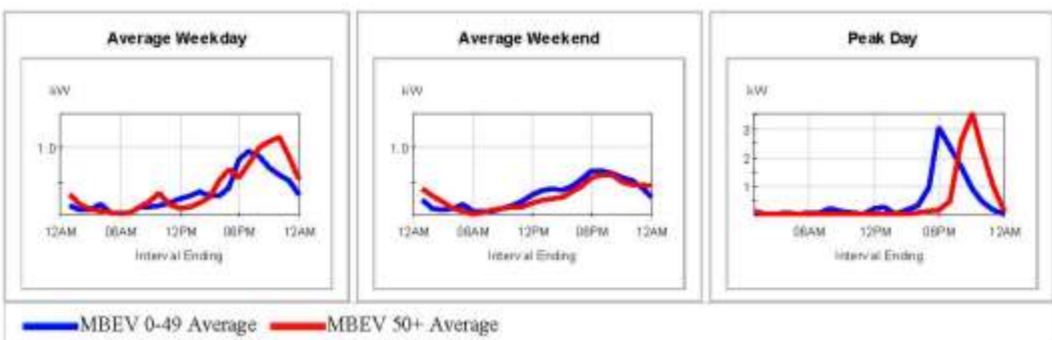


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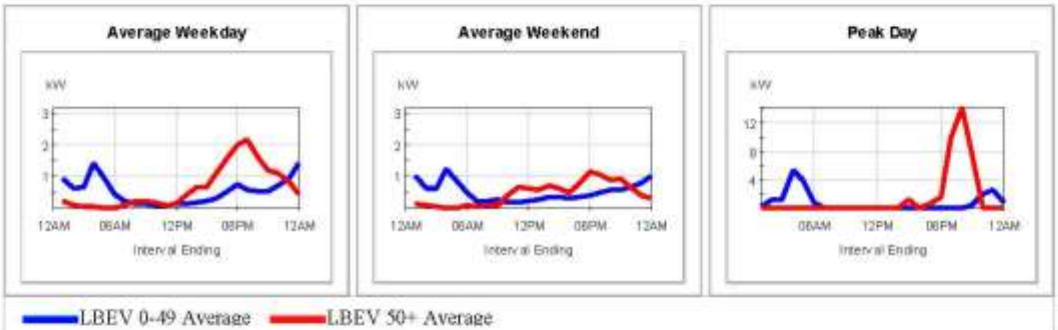
Figure B.2.3 – LBEV Charger Load: Weekday, Weekend Day and Peak Day



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APPENDIX G: Updates to the CRAG

Conservation Resource Advisory Group

PUGET SOUND ENERGY

Energy Efficiency

Third Meeting of 2014

Electric Vehicle Charger Program Status

- PSE has been working to set up the mechanics of the program. Activities include:
  - Activating interval meter data monitoring using several known EV customers
  - Identifying monitoring means and potential vendors for "smart charger" pilots.
  - Developing methods to identify EV customers prior to EV purchase.
  - Setting up systems to capture customer sign-ups and process incentives.
  - Updating customer-facing website to reflect program.
  - Training internal customer service staff on program.
- PSE anticipates making the sign-up system available to customers in early August, subject to testing of vendor website functionality.
- After the program is functional, PSE will be meeting with and providing training for key customer contacts, including auto dealers and charging station manufacturers to help inform customers about the program.

PSE PUGET SOUND ENERGY

Please contact Ben Farrow for further details.
Benjamin.Farrow@pse.com

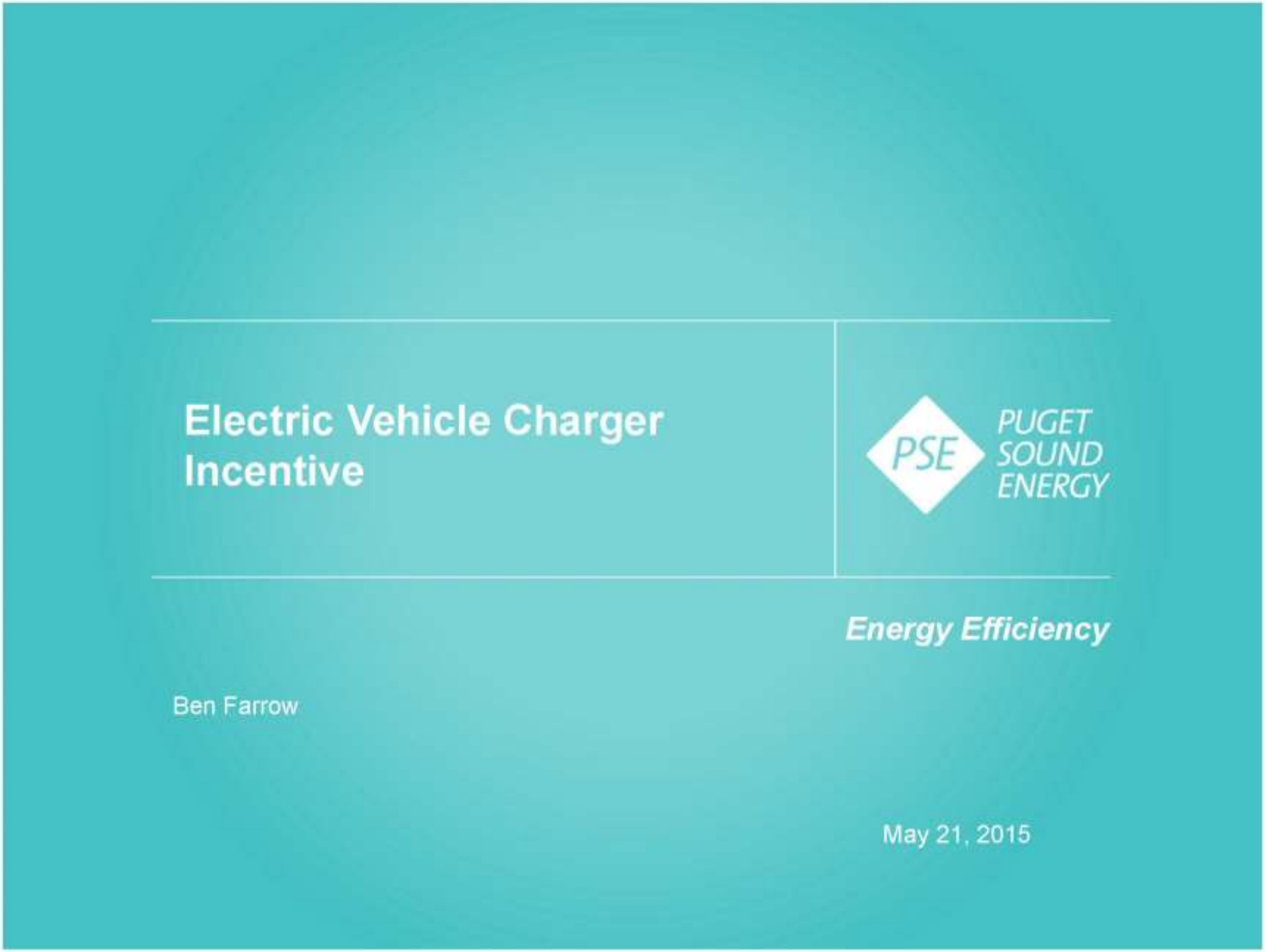
August 7, 2014 CRAG Meeting | 12

Conservation Resource Advisory Group

Energy Efficiency

First Meeting of 2015

May 21, 2015


Electric Vehicle Charger
Incentive
PSE
PUGET
SOUND
ENERGY
Energy Efficiency
Ben Farrow
May 21, 2015

Overall Program Outline

Goals

- Collect data on EV charging load.
- Determine impact on PSE energy/demand profile.
- Look at ways to mitigate impact – shift time of charging.
- Encourage energy efficient charging.

Methods

- Provide rebate to customer for Level 2 residential chargers.
- Monitoring whole home usage and EV usage.
- Develop experience with technology types ("smart" versus "non-networked").

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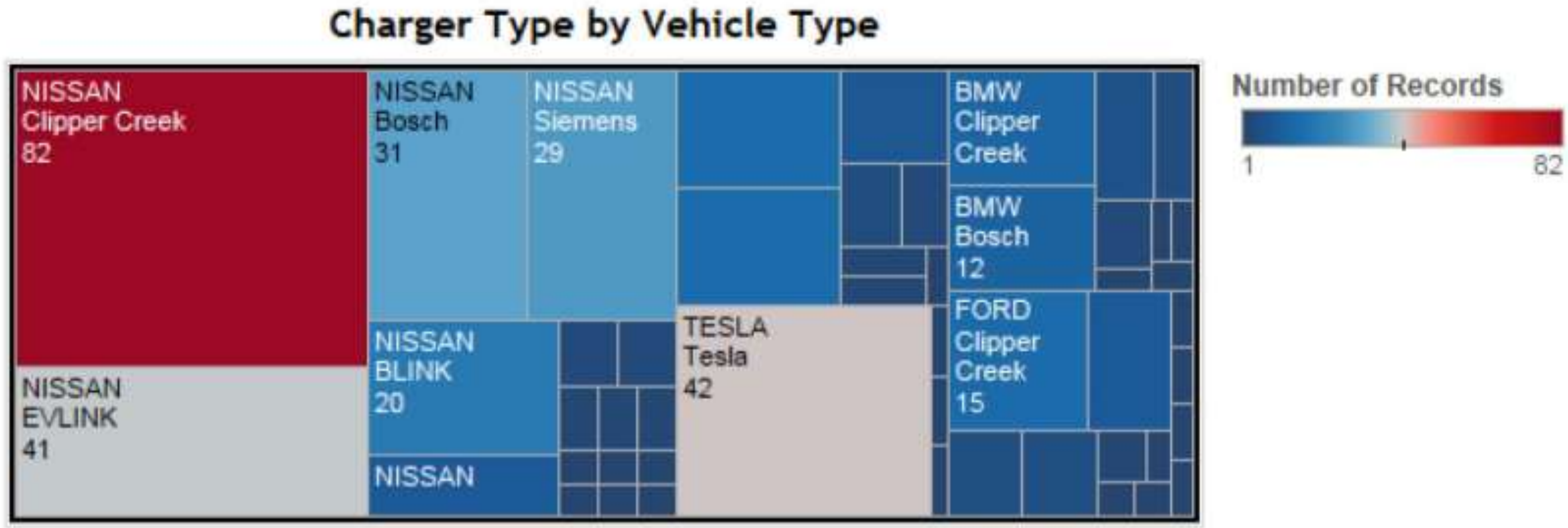
May 21, 2015 CRAG Meeting 115

Program To Date



Vehicle Make (group), Manufacturer (group) and sum of Number of Records. Color shows sum of Number of Records. Size shows sum of Number of Records. The marks are labeled by Vehicle Make (group), Manufacturer (group) and sum of Number of Records.

- 625 applications to date/511 approved.
- 441 meters on interval data.
- Starting to analyze early usage data
  - Participants generally follow pattern of overall EV sales.
  - Usage can vary significantly from one customer to the next.

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Next Steps

- Start end-use monitoring of direct EV use.
- Continue to build data set to improve load shape.
- Look for new ways to get data from customers prior to EV purchase, Level 1 charging, Public charging.

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Conservation Resource Advisory Group
PSE
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Energy Efficiency
Second Meeting of 2016
May 18, 2016 CRAG Meeting

Electric Vehicle Charger Incentives Pilot Update

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Energy Efficiency

Ben Farrow

May 18, 2016 CRAG Meeting

Load Analysis Progress

Ben Farrow

- Approximately 1090 customers enrolled in program, 873 customers on whole house interval metering, 41 end use metering points installed.
- Good mix of vehicle types and travel distances.
- Aligning data collection periods with other load research efforts and baseline sample.
- Working to locate and recruit additional Level 1 participants.

Current Program Participants by Vehicle Type and Charger Type.

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UE-140626 Order Requirements

Ben Farrow

Requirement (Order 01 in UE-140626, pages 4 and 5)	Status
"This is clearly a pilot for the purpose of studying charging usage in the Company's service territory among both Level 1 and Level 2 charging;"	All outreach has identified the program as a time and customer limited pilot program designed to study charging and prepare for more EVs.
"The rebate is capped at up to $500 per Level 2 vehicle charger;"	Ongoing.
"The Company studies the end-use characteristics of EV load for a period of up to 32 months, ending no later than December 31, 2016;"	Ongoing.
"The Company limits the number of participants in the study to 5,000, at least half of which will have interval metering data activated and collected at a minimum of one-hour intervals;"	Ongoing.
"During the study period, the Company regularly coordinates with its Conservation Resources Advisory Group and includes the study's progress and findings in its regular reports of conservation accomplishments; and"	Program has been included in Biennial Conservation Plan and Annual Conservation Plan filings, included in CRAG meetings, and information provided to CRAG members upon request.
"At or before the end of the study, the Company will consider, in consultation with the Conservation Resources Advisory Group, programs that will manage EV load in the most cost-effective manner, including but not limited to time of-use rates, demand response, and direct load control."	To be completed.

Conservation Resource Advisory Group

PUGET SOUND ENERGY

Smart Buildings Center, Large Conference Room
1200 12th Avenue South, Suite 110
Seattle, WA 98144

Energy Efficiency

Third Meeting of 2017

July 26, 2017 CRAG Meeting

EV Charger Incentive Pilot Review

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Energy Efficiency

Ben Farrow
Meghan Weinman

July 26, 2017 CRAG Meeting

Outline

- Current Program – Draft Results
  - Customer Behavior
  - Load Shapes of Individuals
  - Comparison to System Load and Renewables
- Policy Statement

UE-140626 Order Requirements

Requirement (Order 01 in UE-140626, pages 4 and 5)	Status
"This is clearly a pilot for the purpose of studying charging usage in the Company's service territory among both Level 1 and Level 2 charging;"	Complete. All outreach has identified the program as a time and customer limited pilot program designed to study charging and prepare for more EVs.
"The rebate is capped at up to $500 per Level 2 vehicle charger;"	Complete.
"The Company studies the end-use characteristics of EV load for a period of up to 32 months, ending no later than December 31, 2016;" ***Note: Program enrollments were extended to 4/1/2017 under Docket UE-161156***	Complete.
"The Company limits the number of participants in the study to 5,000, at least half of which will have interval metering data activated and collected at a minimum of one-hour intervals;"	Complete. A total of 2,005 customers were enrolled in the program. Of these, 1,300 customers were placed on 15-minute interval metering. Data loggers were installed in 50 customers' homes.
"During the study period, the Company regularly coordinates with its Conservation Resources Advisory Group [sic] and includes the study's progress and findings in its regular reports of conservation accomplishments; and"	Program has been included in Biennial Conservation Plan and Annual Conservation Plan filings, included in CRAG meetings, and information provided to CRAG members upon request.
"At or before the end of the study, the Company will consider, in consultation with the Conservation Resources Advisory Group [sic], programs that will manage EV load in the most cost-effective manner, including but not limited to time of-use rates, demand response, and direct load control."	See balance of presentation.

Findings

- Home charging is dominant, with 96% of EV drivers charging at home. The majority of these use Level 2 charging.
- The aggregate customer impact from home charging is coincident with evening peak hours, but there is significant load diversity:
  - Customer charge at different times
  - Customers don't charge every day
  - Some customers simply don't need Level 2 home charging
- Despite relatively low utilization, customers continue to cite access to public charging as a key market barrier to EV adoption:
  - 95% of EV drivers have used public charging, but they only average 2-4 uses/month
  - EV drivers cite lack of public charging and vehicle battery range as a key market barrier
  - Location is the most important factor in public charging, speed the second most important in public charging
- "Smart Charging" ability is available, but no single standard or system has evolved yet and prices can range considerably.

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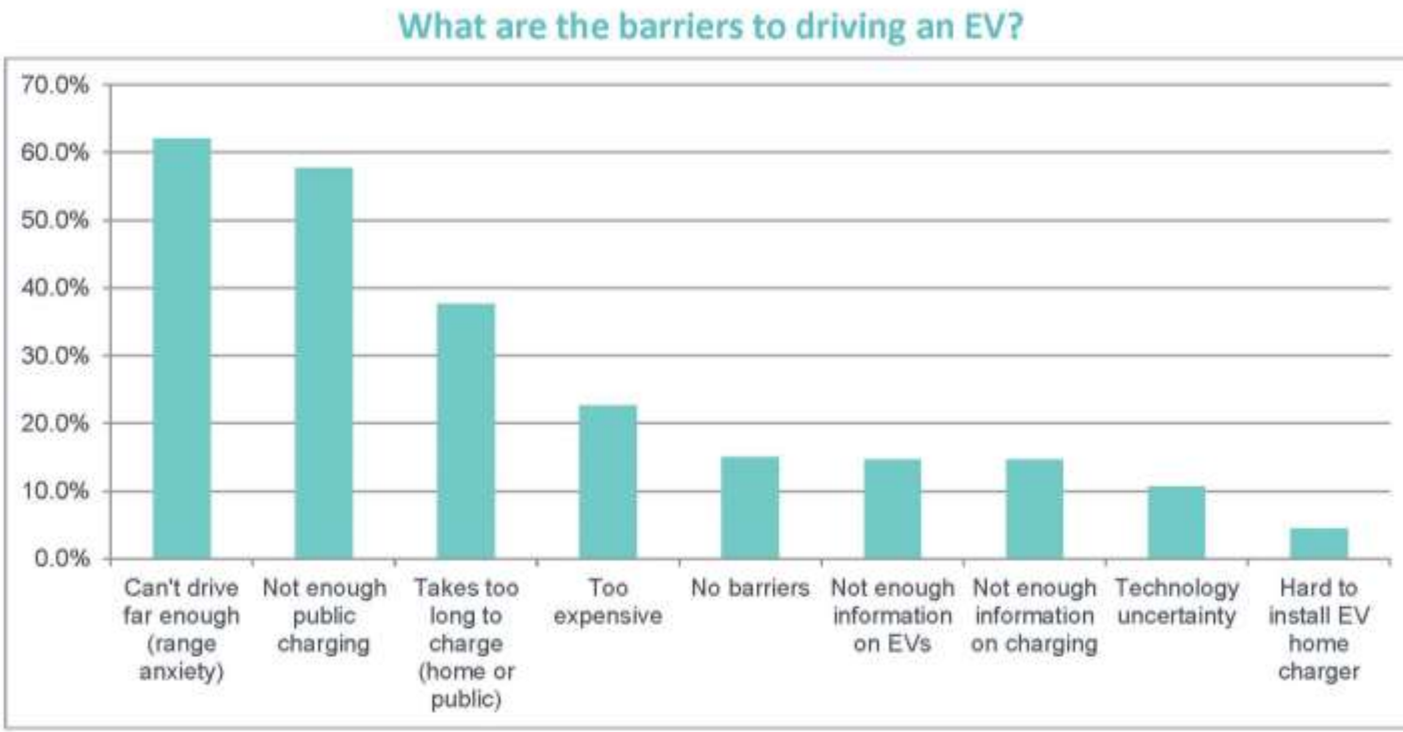
EV Customer Research



* Sample from 340 PSE rebate participants (approved & denied)

50% of respondents use public charging

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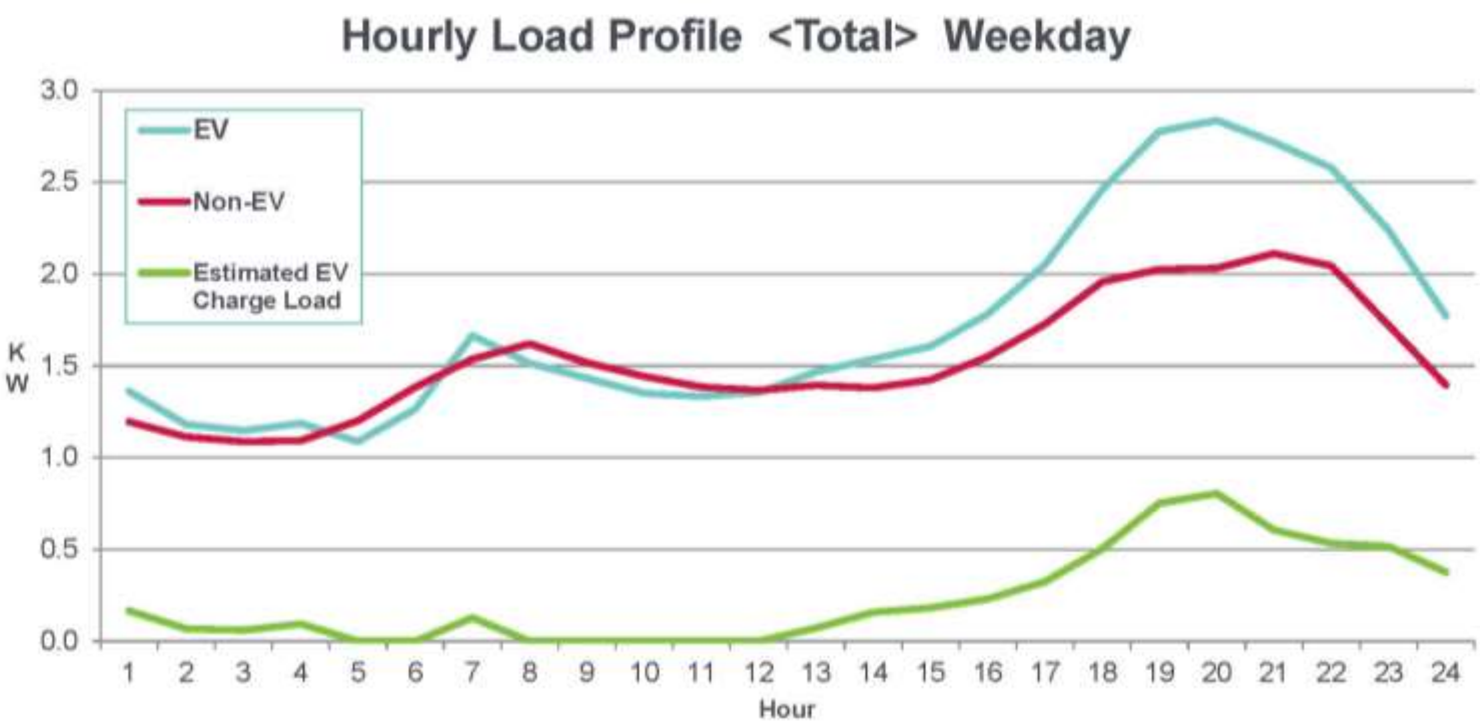
Average Load Shape – Directional, Not Final



Based on comparison of 31 EV customers enrolled in the program as of mid-2015 compared to comparable sample of non-EV customers. Analysis of specific end use measurement of charging shape is ongoing.

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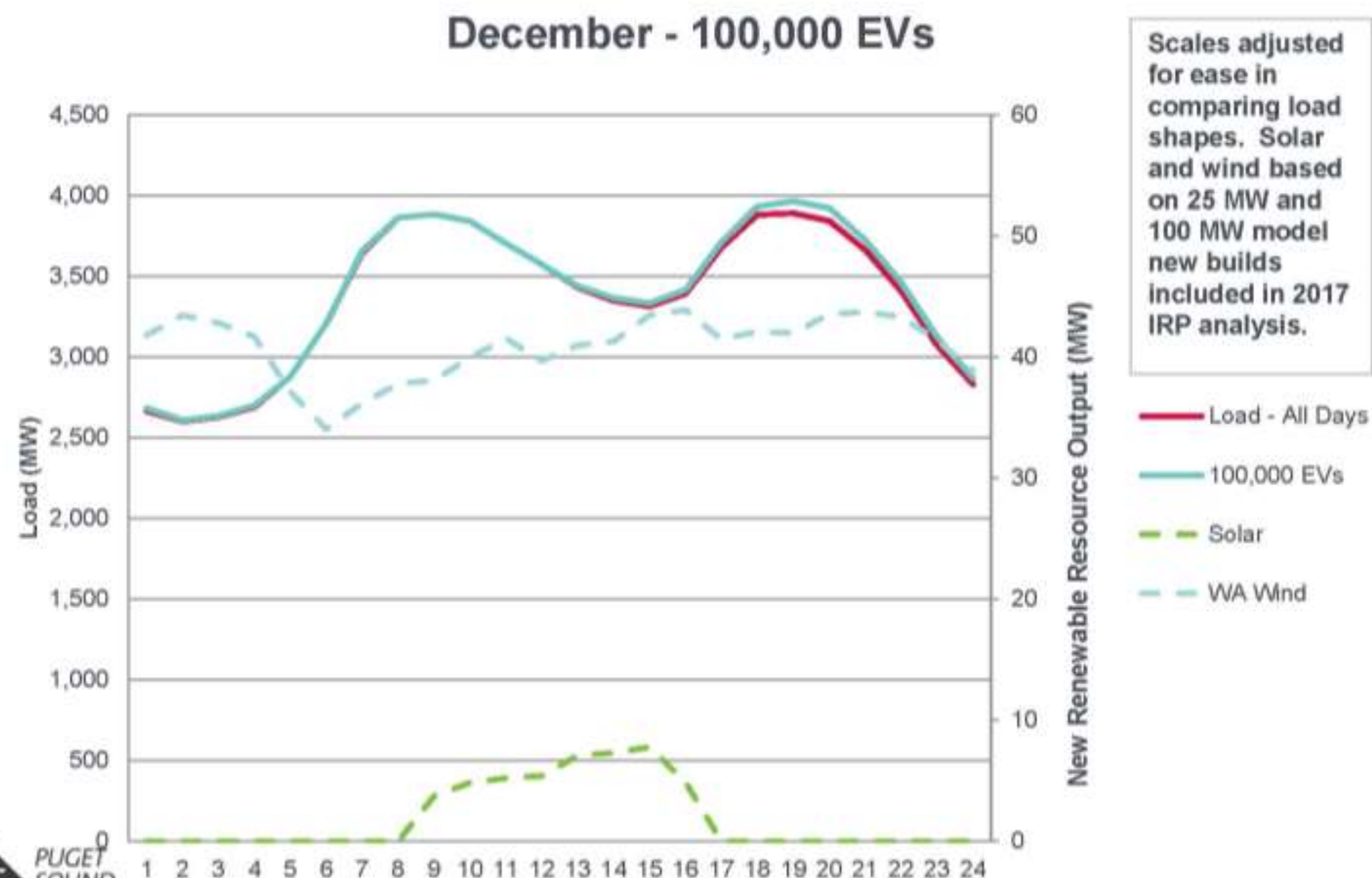
Load Shape Comparison - December



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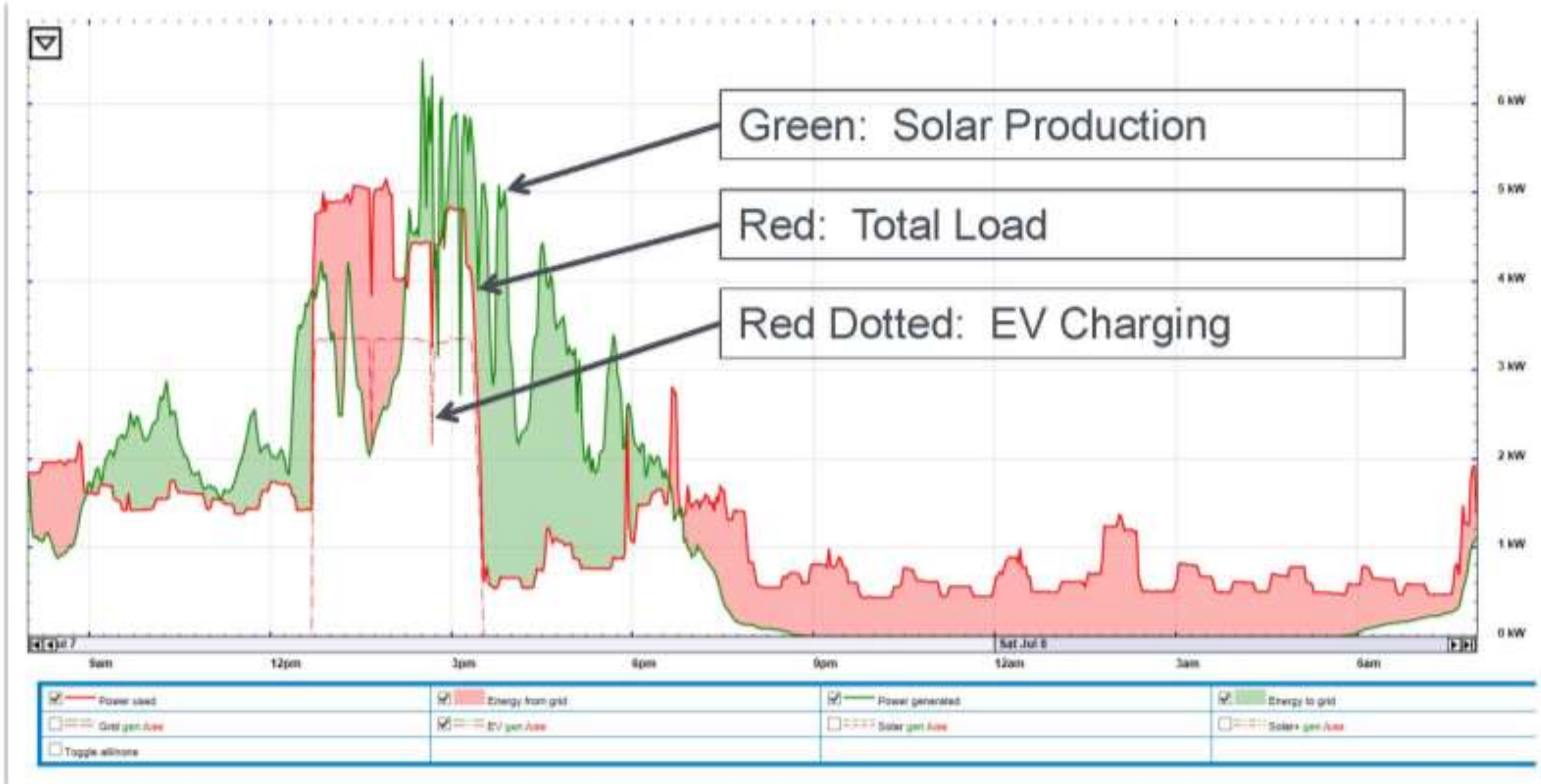
Load Shape Comparison - Distributed Solar Customer – July Day



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EV Policy Statement

- Role of Utilities in Education and Outreach
- Importance of Controlling Charging Load
- Importance of Consumer Protection and Service Quality
- Portfolio of Programs, including Low Income Customers
- Business Case Analysis
- Cost-Benefit Tests
- Stakeholder Input

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