REPORT

Nexant

California Statewide PEV Submetering Pilot – Phase 1 Report

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Prepared for
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1 Executive Summary

1.1 Introduction

The California Plug-in Electric Vehicle (PEV) Submetering Pilot was designed to test the implementation and customer experience associated with submetering solutions for residential and commercial customers. Submetering allows customers to access TOU rates for PEVs without installing a separate Investor Owned Utility (IOU)[1] revenue grade meter. A key feature of the pilot was that the submetering hardware and service was provided by third party Submeter Meter Data Management Agents (MDMAs), while billing was handled by the utilities. Three third party MDMA suppliers actively participated in Phase 1 of the pilot—NRG eVgo (NRG), Ohmconnect, and eMotorWerks (eMW). These MDMAs were responsible for managing customer relationships during the pilot, which included recruitment, coordinating submeter installations, enrolling customers in the pilot, and providing customer service and support. MDMAs measured PEV electricity usage through the submeters and delivered data to the utilities on a daily basis for billing purposes.

The enrollment period for Phase 1 of the pilot began on September 1, 2014 and was conducted on a first-come, first-served basis[2] subject to an enrollment limit of 500 submeters for each IOU divided equally among the participating MDMAs. Due to delays associated with submeter certification, the enrollment period was extended six months to August 31, 2016. Total enrollment consisted of 241 customers—132 at PG&E, 92 at SCE, and 17 at SDG&E. The majority of participating customers enrolled through either eMW (192) or Ohmconnect (45). Approximately 25% of participants have solar PV systems with a net metering arrangement[3] in addition to their electric vehicle—43 in PG&E, 13 in SCE, and 3 in SDG&E. Phase 1 enrollment is summarized in Table 1-1, which also lists the submeter rates that are available to pilot participants in each territory.

[1] The three Investor Owned Utilities in California are Pacific Gas & Electric (PG&E), Southern California Edison (SCE) and San Diego Gas & Electric (SDG&E).

[2] The first three months of enrollment were an “Exclusivity Period” during which the MDMAs had “Exclusivity Rights” to their share of the total participants in each IOU’s territory. An “Open Period” of enrollment began in the fourth month during which MDMAs were allowed to enroll additional customers beyond their exclusivity rights and up to the 500 submeter limit on a first-come, first-serve basis.

[3] Net metered customers are allowed to make up a maximum of 20% of total pilot enrollments in each service territory.

Table 1-1: Phase 1 Enrollment

Utility	Total Enrollment	NEM Customers Enrolled	Enrollments by MDMA			Submeter Rate for Pilot Participants
			EMW	Ohmconnect	NRG	
PG&E	132	43	109	22	1	EV-B (Residential) $20 bill credit (Commercial)
SCE	92	13	71	19	2	TOU-EV-1 (Residential) TOU-EV-3 & 4 (Commercial)
SDG&E	17	3	12	4	1	EV-TOU (Residential) $20 bill credit (Commercial)
Total	**241**	**59**	**192**	**45**	**4**	**N/A**

In order to participate in the pilot, customers were required to enroll by submitting a Customer Enrollment Agreement signed by the customer and their MDMA to their IOU and install a submeter. The pilot was designed to allow both stand-alone submeters and submeters integrated with Level 2 charging stations, but almost all Phase 1 participants used eMW's stand-alone WattBox™. The WattBox™ is Wi-Fi enabled to transmit recorded usage data from the submeter to the MDMA—and ultimately to the IOU. MDMAs assisted customers with signing up for the TOU rate with their IOU and also helped them to schedule an appointment for the installation of the submeter by a licensed electrician.[4] For their participation, eMW customers received a full rebate for the WattBox™ in addition to incentive payments of $100 after installation and $50 after the first successful data transfer. The maximum duration for participation in Phase 1 was 12 months and customers were allowed to withdraw from the pilot at any time.[5]

After contacting an MDMA to express interest in the pilot, customers created an online account[6] and went through a pre-qualification check to make sure that they met the eligibility criteria for the pilot and could have a submeter successfully installed at their premise. After having their submeter installed, customers formally enrolled in the pilot by completing a customer enrollment application (CEA) with assistance from the MDMA, who submitted them to the appropriate IOU for approval. Upon approval of the CEAs, MDMAs began sending submeter data to the IOUs on a daily basis for billing.

4 eMW provided customers with a choice of having the installation performed by an eMW-contracted electrician for free or contributing up to $100 towards an installation performed by an electrician of the customer's choosing.

5 At the time of this report, 12 PG&E participants and 10 SCE participants had withdrawn from the pilot.

6 This step was not necessary for existing eMW customers.

1.2 Components of Evaluation

Phase 1 of the pilot focused on situations having a “single customer of record” in which the same customer was responsible for paying for all electricity consumption—including the submeter—at their service premise.[7] The evaluation objectives for Phase 1 were to:

- Identify the different submetering services provided by MDMAs;
- Evaluate the customer experience to determine customer benefits under submetering;
- Evaluate customer demand for submetering services; and
- Evaluate the potential impacts submetering can have on supporting the State’s ZEV goals of reducing the costs of PEV home charging, simplifying metering options, and establishing the submetering protocol to help homeowners access PEV time of use rates.

These research questions were addressed by organizing the Phase 1 evaluation into four principal components. First, a careful analysis of the business processes used by the MDMAs and IOUs was conducted based on interviews with the MDMAs and IOUs to understand how submetering was offered to consumers in the context of the pilot. Second, a sample of customers was selected from the pilot to install independent data loggers for the purposes of assessing the accuracy of the submeter measurements. Third, participants were surveyed to gather information about the pilot experience and their satisfaction with the submetering service provided. Finally, PEV customers who are not currently submetered were surveyed to assess customer preferences for submetering and the primary factors that will affect future submetering uptake using an Adaptive Choice-Based Conjoint (ACBC) methodology.[8]

1.3 Summary of Results

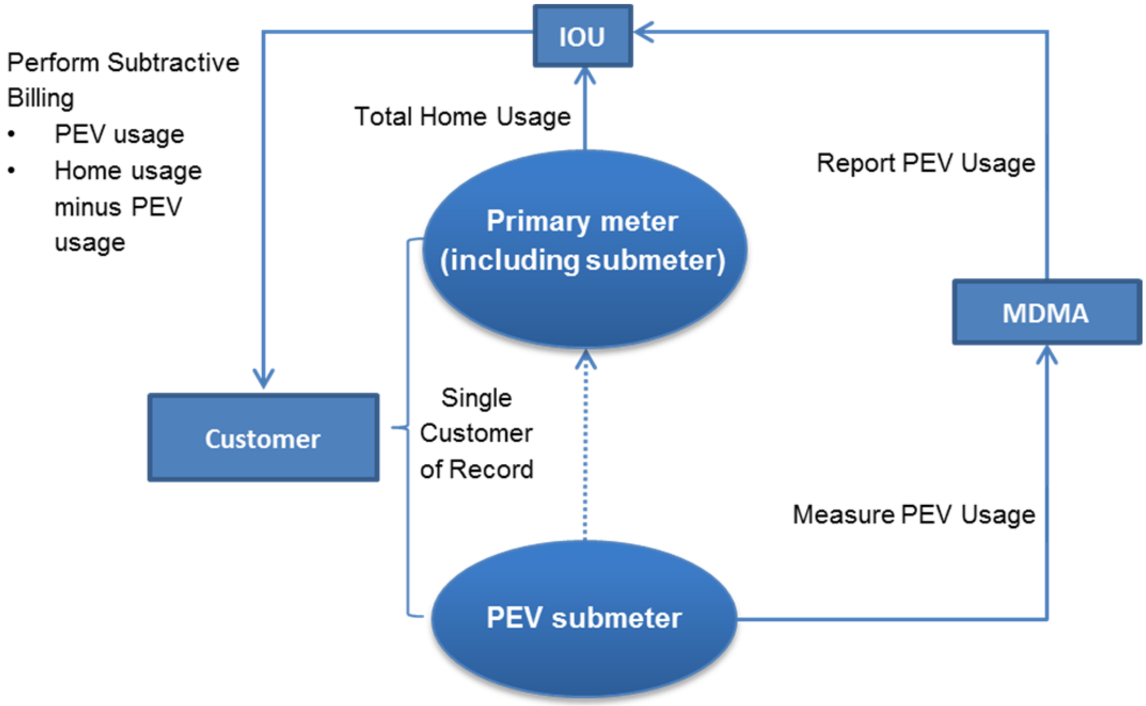
Providing submetering service to pilot participants during Phase 1 required a significant amount of coordination and information transfer between the MDMAs and IOUs. The data flows and communications between pilot stakeholders are shown in Figure 1-1. The primary role of the MDMA was to provide the IOU with accurate measurements of PEV electricity usage in a format that was compatible with the premise’s primary meter—15 minute intervals. The IOU then took the PEV usage in each interval and subtracted it from the primary meter to identify the amount of electricity used by the rest of the house and calculate a bill for each source using the appropriate rate—subtractive billing. Once the two bills were calculated, they were combined into a single document and sent to the customer at the end of their billing cycle.[9]

[7] Phase 2 of the pilot will focus on submetering in situations where there are “multiple customers of record,” i.e., circumstances where the customer of record for the consumption of the submeter is different from the customer of record for the rest of the premise.

[8] This methodology is described in Appendix C.

[9] Depending on the timing of enrollment, there was often a lag of 1 to 2 months between when a customer enrolled in the pilot and received their first bill.

Figure 1-1: Data Flows and Communication between Stakeholders in Phase 1



1.3.1 Submeter Accuracy

In order for submetering to be successful from both a business and customer satisfaction perspective, the submeters must be able to provide accurate measurements of PEV charging usage to the utilities for subtractive billing. Nexant assessed submeter accuracy by installing loggers for a sample of 34 submeters in the pilot—31 eMW submeters and 3 NRG submeters—for a period of two months. Due to technical issues[10] with some of the installed loggers and 3 submeters having spotty data coverage or being entirely offline during the study period,[11] only 14 logger-submeter pairs were available for analysis. In addition, a software issue with eMW's data server resulted in 24 hour time shifts for some submeters during the first month of the study period. Because these measurement errors would have overwhelmed the 5% accuracy threshold for any affected submeters, the analysis was limited to the second half of the study period—January 9 through February 12.

Submeter accuracy was formally assessed by conducting equivalence tests using a regression approach in which submeter measurements were regressed against logger readings. The tests consisted of the following steps:

1. Establish 5% region of equivalence for the slope (β1) equal to (0.95, 1.05).
2. Fit linear regression using the logger as the independent variable and the submeter observations as the dependent variable.

10 These included not properly synchronizing logger clocks with submeter clocks, being unable to record one time measurements needed to convert recorded amps to kW and loggers that stopped recording data midway through the study period.

11 Due to the missing data, these 3 submeters would not have met the 5% accuracy requirement.

3. Test the slope for equality to 1 by calculating two one-sided confidence intervals for the slope using the regression output and determine whether this interval is contained within the region of equivalence.

Results for the individual submeter tests are presented in Table 1-2 and show that most submeters for which data were available are able to meet the 5% accuracy requirement. The exception is submeter number 5, which stopped recording usage partway through the study period. Combined with the data issues experienced by some submeters in the sample, these results indicate that while most submeters were able to accurately measure PEV charging usage, some experienced measurement issues that affected customer bills and may account for some of the dissatisfaction customers expressed about billing accuracy.

Table 1-2: Equivalence Test Results Using Regression

Unique ID	Regression Coefficient	Standard Error	95% Lower	95% Upper	Reject Test of >5% Error	Count
1	1.00	0.00	1.00	1.01	Yes	479
2	1.02	0.00	1.01	1.02	Yes	349
3	1.03	0.00	1.02	1.04	Yes	100
4	1.03	0.00	1.02	1.03	Yes	385
5	0.24	0.05	0.16	0.33	No	445
6	0.99	0.00	0.99	1.00	Yes	364
7	1.00	0.00	0.99	1.00	Yes	247
8	1.01	0.00	1.01	1.02	Yes	274
9	1.00	0.00	1.00	1.01	Yes	447
10	0.96	0.00	0.95	0.97	Yes	723
11	1.02	0.00	1.01	1.02	Yes	411
12	1.04	0.00	1.03	1.04	Yes	375
13	1.00	0.00	1.00	1.00	Yes	132
14	1.00	0.01	0.99	1.01	Yes	114

1.3.2 Customer Experience

A survey of customers participating in Phase 1 found that more than 80% of participants reported that being able to pay a lower price for charging their PEV, getting an incentive for the submeter, and having the ability to measure the amount of electricity used by their PEV were either extremely important or somewhat important in their decision to participate in the pilot. Most customers (72%) said that they were “extremely satisfied” or “somewhat satisfied” with the submetering service provided during the pilot, while 15% of respondents rated their level of satisfaction as “somewhat dissatisfied” or “extremely dissatisfied.”

Customer satisfaction ratings for specific aspects of the pilot are shown in Table 1-3. Aspects that produced high levels of customer satisfaction included the reliability of the charging station, installation of the submeter, and remote access to information about whether and when a customer's PEV was charging. The aspects with the lowest satisfaction scores were customer service provided by the IOUs and the enrollment process.

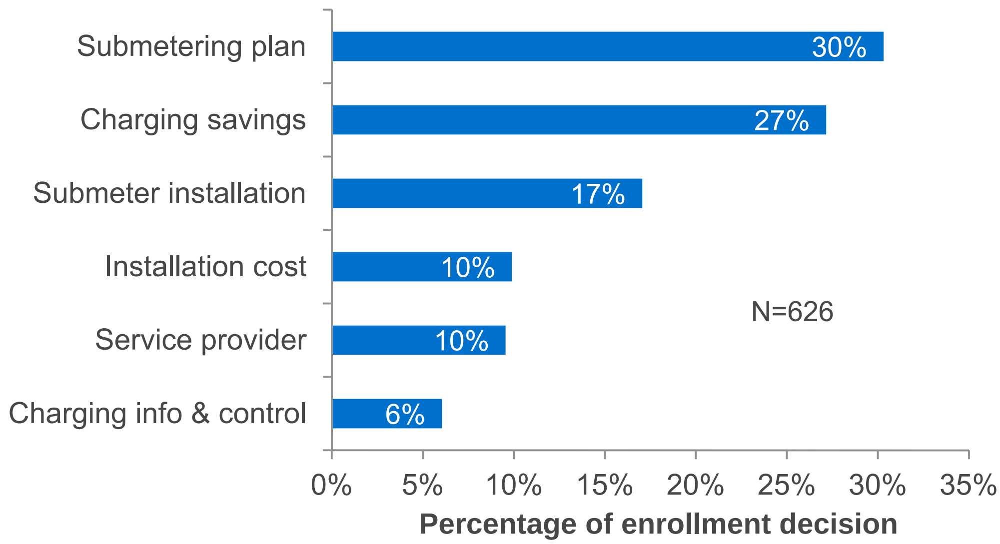
Table 1-3: Satisfaction Ratings for Specific Aspects of Phase 1 Pilot

Please rate the following aspects of your submetering service		No Experience	Poor	Fair	Good	Very Good	Excellent	Top 2 Box
Reliability of my charging station		10%	2%	5%	7%	18%	68%	86%
Safety of my charging station		17%	1%	2%	15%	20%	62%	82%
Accuracy of the measurement of electricity used by my PEV		24%	8%	8%	13%	24%	48%	72%
Installation		45%	6%	8%	17%	20%	49%	69%
Access to information about whether and when my vehicle is charging remotely		30%	7%	7%	18%	28%	39%	67%
Scheduling the installation of the meter or charging station		39%	4%	9%	24%	21%	42%	63%
Customer service provided by (insert MDMA name) after the meter or charging station was installed		14%	12%	6%	21%	20%	40%	60%
Accuracy of the PEV portion of my bill		27%	18%	7%	18%	22%	36%	58%
Ability to control my charging station remotely		58%	15%	7%	25%	19%	35%	54%
Signing up for the PEV rate	PG&E	5%	11%	19%	26%	19%	25%	44%
	SCE	1%	21%	10%	26%	23%	20%	43%
	SDG&E	0%	7%	13%	13%	20%	47%	67%
	All IOUs	**3%**	**15%**	**15%**	**25%**	**21%**	**25%**	**46%**
Customer service provided by IOU after PEV rate started	PG&E	33%	28%	18%	18%	17%	18%	36%
	SCE	32%	23%	18%	27%	18%	14%	32%
	SDG&E	27%	18%	18%	18%	9%	36%	45%
	All IOUs	**32%**	**25%**	**18%**	**22%**	**17%**	**18%**	**35%**

1.3.3 Factors Affecting Future Submetering Adoption

In addition to analyzing the experience of customers who enrolled in the pilot, the Phase 1 evaluation also explored the factors that will affect the future uptake of submetering by conducting a conjoint survey among PEV customers who did not have submeters. Results from the conjoint survey showed that the most important factors when considering submetering are the type of submetering plan—e.g., discounted rate or flat charging fee—the magnitude of charging cost savings, and type of submeter installation—e.g., plug-in, mobile, professionally installed submeter or submeter plus Level 2 charging station. These factors account for 74% of the enrollment decision and are summarized in Figure 1-2. Installation cost, service provider, and charging information comprise a second tier of attributes which drive the remaining 26% of the decision.

Figure 1-2: Relative Attribute Importance



One key area that is informed by the analysis of the conjoint survey is the demand for submetering in the population of existing PEV owners. Table 1-4 shows estimated enrollment likelihoods for all combinations of the attributes tested as part of the survey. For analysis purposes, a baseline offering (shaded) was defined to resemble the submetering offer available in Phase 1 as closely as possible within the constraints of the model. This baseline serves as an anchor point to interpret the remaining results. The enrollment likelihood in each cell corresponds to a submetering offer consisting of that specific attribute level and the baseline levels for all other attributes. This allows differences between cells to be interpreted as the marginal effect of each level on the likelihood of enrollment holding all other attributes constant.

Table 1-4: Demand for Submetering Services in Existing PEV Customer Population

Attribute	Level	Baseline level	Enrollment Likelihood	Pref. share as % change over baseline
Submetering Plan	Flat monthly fee (charge anywhere)		30%	-26%
	Flat monthly fee (charge at home)		34%	-18%
	Electricity discount	●	41%	0%
	Electricity discount + grid services		29%	-28%
Charging Info & Control	Bill only		36%	-12%
	Info	●	41%	0%
	Info + control		46%	12%
Service Provider	Utility logo		61%	48%
	Car brand name (or logo)		49%	18%
	Independent EV charging company	●	41%	0%
Submeter Installation	Simply plug-in		50%	23%
	Mobile (in-car)		54%	32%
	Meter (pro-install)	●	41%	0%
	Meter (pro-install) + Level 2 charger [Add $600 (or $12/mo) to submeter cost]		32%	-23%
Installation Cost	None	●	41%	0%
	$150 (or $3/mo for 60 months)		27%	-34%
	$300 (or $6/mo for 60 months)		21%	-49%
Charging savings	16% (min tested)		40%	-3%
	30%	●	41%	0%
	45%		63%	54%
	60%		74%	80%
	81% (max tested)		83%	103%

Within the context of the survey, 41% of current PEV customers said that they would enroll in the Phase 1 submetering offer if it was made available to them. Several caveats are necessary for this important result. The most important caveat is that the enrollment likelihood likely suffers from “hypothetical bias” that often exists with stated preference surveys since there is often a difference between what survey respondents say they will do and what they will actually do. Hypothetical bias is generally positive, meaning that survey respondents would be prone to overstate their true likelihood of enrolling in submetering. Another important caveat is that there is no guarantee that the current population of PEV owners will resemble the population of PEV owners that may exist in the future when some attributes may become available.

Despite the limitations of the absolute enrollment likelihood, changes in enrollment likelihoods can be analyzed to estimate the relative influence of different submetering attributes. Figure 1-3 summarizes the financial attributes included in the survey and shows that increasing the costs of submetering[12] to participants by $150 could reduce enrollment likelihood—compared to the likelihood of enrolling at zero installation cost—by about a third (34%), while increasing submetering installation costs to $300 could reduce the likelihood of enrolling in a submetering program by 50%.

Figure 1-3: Relative impact of Financial Attributes on Enrollment Likelihood

Installation cost	None [pilot]	
	$150 (or $3/mo for 60 months)	-34%
	$300 (or $6/mo for 60 months)	-49%
Charging savings (%)	16%	-2%
	30% [pilot]	
	45%	+54%
	60%	+80%
	81%	+103%

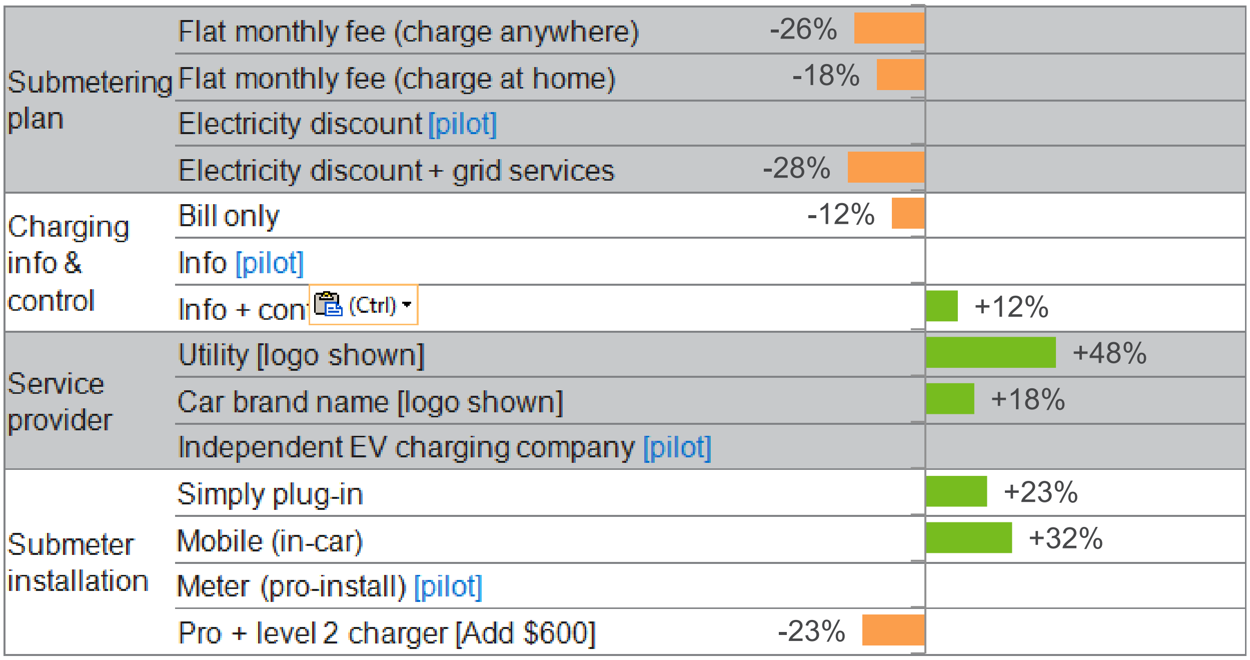
Charging savings[13] also have a significant impact on enrollment likelihood and the results of the conjoint suggest that there is a minimum amount of savings needed to attract interest in submetering. There is very little variation in uptake between 0 and 30% savings, but there is a substantial 54% enrollment increase for a similar increase in percent savings from 30% to 45%. This indicates that somewhere between 30% and 45% there is a threshold beyond which savings become meaningful. Increased savings beyond 45% by similar margins produces diminishing enrollment impacts.

In addition to the financial aspects of submetering, four attributes relating to business models and participant experience attributes—plan type, charging info & control, service provider, submetering installation—were also tested as part of the choice survey. Figure 1-4 shows the impacts of these attributes on the likelihood of enrollment relative to the attributes of Phase 1.

[12] It is important to clarify that this attribute was conceptually designed to test participant costs and so is not meant to distinguish between actual hardware and installation costs. The survey also controlled for underlying respondent preferences for upfront versus monthly payments, as recognition that reducing upfront costs may reduce the burden for some participants.

[13] In the context of the survey, charging savings were defined as a percentage reduction in the cost of charging a PEV each month. Each respondent's monthly charging cost was estimated based on self-reported monthly miles driven, percent of charging done at home, a marginal electricity price estimate based on each respondent's current electricity rate, and a conversion factor of miles to kWh for the respondent's PEV category collected earlier in the survey. To ensure the most numerically and cognitively valid estimates, respondents were given a choice of how to estimate miles driven—weekly average or age of vehicle and mileage—asked to confirm the estimate, and then finally given the opportunity to change the estimate to a manually entered value within a reasonable range. The average monthly cost was $53 with standard deviation of $49, which suggests that most monthly charging cost estimates fell between $0 and $100.

Figure 1-4: Relative Impact of Business Model and Participant Experience Attributes



Reduced charging costs were the most preferred business model, while charging information/analytics and the ability to control charging remotely increased the likelihood of enrollment by 14 to 28%. Respondents had a preference for IOUs and PEV manufacturers as submetering providers and mobile metering solutions increased the likelihood of enrollment by 38% relative to submeters that require installation by certified professional electricians.

1.4 Conclusions and Recommendations for Phase 2

Phase 1 of the PEV Submetering pilot successfully established third party submetering service for 241 customers throughout California. The three primary motivations for customers to participate in the pilot were the opportunity to pay a lower rate for electricity used by the PEV, the availability of an incentive for the PEV submeter, and the ability to monitor the amount of electricity used by PEVs. During the course of the pilot, several technical and customer service-oriented challenges were encountered by the participating MDMAs and IOUs that demonstrate areas where submetering operations and customer service can be improved in the future.

By all accounts, the enrollment process for Phase 1 was cumbersome and required a large number of manual processes and repeated customer interactions, which resulted in long processing times for CEAs and frustrations for customers, MDMAs, and IOUs alike. Only 46% of participants rated the process of signing up for the pilot as either very good or excellent. Customers needed assistance from the MDMAs to complete the required forms, which were submitted to IOUs via email as attached PDFs and regularly needed to be sent back for revisions due to missing or incomplete information. Numerous interactions between customers, MDMAs, and IOUs were required to successfully enroll a customer and all of these interactions were initiated manually by one of the stakeholders. Streamlining the enrollment process should be a priority for Phase 2 and include efforts to improve communication between the MDMAs and

IOUs regarding what is required from the customer as well as an investigation into whether infrastructure can be set up for CEAs to be completed more efficiently. This infrastructure could include the development of a website accessible by the MDMAs that creates a structured data environment for CEAs that is less prone to error than the manual process used in Phase 1.

Once customers were able to successfully enroll in the pilot, most (72%) said that they were satisfied with the overall service they received. However, 15% of participants reported being dissatisfied with their submetering service and highlighted areas where submetering operations could be improved. The primary causes of dissatisfaction were billing issues and poor customer service from the MDMA and/or IOU. Thirty percent of customers who responded to the participant survey reported experiencing a problem with their bills—delays were the most common description—and half of these customers said that their issues had not yet been resolved. When asked how to improve the pilot experience, the most common response from participants was for the IOUs/MDMAs to provide better support and communication.

The billing issues experienced by Phase 1 participants were likely a result of several different factors. First, the IOU subtractive billing processes created for the pilot existed outside the robust billing systems used for standard billing operations. Submeter data from the MDMAs was transferred manually to the IOUs via SFTP and required cleaning and processing before being combined with interval data from the IOUs' internal systems. Early in Phase 1, the IOUs spent significant effort educating the MDMAs about the intricacies of customer billing protocols and the data format necessary to ensure accurate billing. Despite these efforts, significant oversight from the IOUs was necessary throughout Phase 1 to ensure timely and correct data deliveries. Due to the manual nature of these steps and the amount of back and forth between IOUs and MDMAs, errors occurred at a higher rate than normal and the amount of time required for preparing customer bills increased. To the extent that these processes can be automated, the timeliness and accuracy of subtractive billing would improve.

Another factor that has an impact on the accuracy of customer bills is the accuracy of the submeters. Analysis comparing a sample of submeters to independently installed loggers revealed that most submeters were able to accurately record PEV usage data, but that 10 to 20% likely experienced some kind of accuracy problem during Phase 1. These problems resulted from spotty data coverage, submeters going offline for a period of time, and a server software malfunction that caused time shifts in the data for some submeters. All three of these events caused delays in billing and some resulted in erroneous bills being delivered to customers. For Phase 2, Nexant recommends that additional submeter accuracy testing be conducted using a threshold of +/- 1% in order to improve billing accuracy and reduce the number of billing disputes with participants. This testing would preferably be done in a laboratory setting prior to installation to avoid the difficulties and limitations associated with measuring accuracy in the field and should include tests to ensure that submeter clocks are capable of proper time synchronization with IOU AMI systems. New metering standards and testing protocols related to submeters currently being developed by the National Institute of Standards and Technology (NIST) and the California Division of Measurement Standards may be able to be leveraged as a guide for best practices.

In addition to analyzing the processes, customer experiences, and accuracy that were specific to Phase 1, Nexant also surveyed approximately 600 non-submetered PEV customers to analyze customer preferences for different submetering features and identify factors that are likely to drive future uptake of submetering. This analysis showed that the type of submetering plan—e.g., discounted rate or flat charging fee—magnitude of charging cost savings, and type of submeter installation—e.g., plug-in, mobile, professionally installed submeter, or submeter plus Level 2 charger—are the most important factors that influence submetering adoption decisions and that about 40% of current PEV customers would sign up for the submetering arrangement offered during Phase 1. For submetering to be attractive, a minimum amount of charging savings of 30-45% is needed and installation costs need to be kept low. Depending on the price differentials established for the opt-out TOU rates that will be rolled out to residential customers beginning in 2019, submetering plans with charging savings of 30-45% may be difficult to offer.

Installation cost, service provider, and charging information comprise a second tier of attributes that affect submetering adoption decisions. A mobile metering option was particularly popular among SDG&E respondents (+49% enrollment impact) and PG&E respondents (+41%), but had less of an impact on SCE respondents (+31%). While there was a preference for the utility or the PEV manufacturer to play the role of service provider, this was less pronounced for PG&E respondents than the other two IOUs. Nexant recommends offering additional submetering plans and pricing structures in Phase 2 along with exploring partnerships between MDMAs and IOUs as a way to provide more seamless service to the customer and achieve stronger brand equity.

2 PEV Submetering Pilot Background

As the adoption of PEVs continues to accelerate in California, PEV charging patterns will become an increasingly important end-use in the state's electricity system. In a future where PEVs make up a significant share of California's vehicle fleet, charging loads will need to be well-managed to avoid having PEVs exacerbate system peaks or negatively impact grid reliability in other ways. One effective tool for incentivizing charging during the most beneficial times is Time-Of-Use (TOU) electricity pricing. Customers can access PEV TOU rates in one of two ways—either by enrolling their entire house or facility into a TOU rate or by installing separate electrical service and meter dedicated to PEV charging. According to a recent survey of participants in the Clean Vehicle Rebate Program, a majority of drivers (65-80%) are aware of the special rates for PEV charging, and 62% use them.[14]

The California Plug-in Electric Vehicle (PEV) Submetering Pilot was designed to test the implementation and customer experience associated with submetering solutions for residential and commercial customers. A key feature of the pilot was that the submetering hardware and service was provided by third party Meter Data Management Agents (MDMAs),[15] while billing was handled by the utilities. This division of labor required coordination by the MDMAs and IOUs on pilot enrollment and data transfer in order to provide customers with accurate and timely bills for the electricity usage of their PEV and the rest of their home.

The remainder of this section provides a brief overview of the policy context and history related to the pilot, detailed descriptions of the services that were provided by the MDMAs and IOUs, and a summary of Phase 1 enrollment.

2.1 Policy Framework and Evaluation Goals

To proactively help manage PEV charging loads, California has established goals to provide customers with the proper incentives to charge their PEVs in a way that minimizes their negative impacts on the grid and maximizes their fuel and cost savings. Submetering is seen as an important contributor to both of these goals since it avoids the need to install a costly second meter, increases access to TOU rates that incentivize off-peak charging, and allows customers to potentially reduce their monthly bills by scheduling their charging for off-peak times. Furthermore, it was determined that allowing submetering solutions provided by third parties—i.e., non-utilities—may result in additional benefits to the PEV market by increasing customer choice and technological innovation.[16]

Discussions about a pilot program for PEV submetering date back to a 2011 workshop on the topic organized by CPUC Energy Division, which jumpstarted work on a roadmap report to outline potential submetering scenarios and assess the feasibility in the context of PEVs. The IOUs produced a draft report in early 2012 that was followed by a series of workshops and

[14] See http://public.tableau.com/profile/research.department#!/vizhome/shared/NJBH7MSDS.

[15] Customers were given the opportunity to own submeters as a result of CPUC Decision 11-07-029 (see p. 40-41).

[16] Besides increasing access to TOU rates, submetering also has potential applications as a distributed energy resource (DER) that can be aggregated and participate in CAISO demand response markets. See http://www.caiso.com/Documents/AgendaPresentation-DistributedEnergyResourceProvider-DraftFinalProposal.pdf

revised reports to develop rules for incorporating customer-owned submeters into IOU billing and metering systems—denoted the "PEV Submetering Protocol". A key outcome of this work was Resolution E-4651 in 2014, which approved a two phase pilot to better understand the costs and benefits of PEV submetering.[17]

The PEV submetering pilot was organized into two sequential phases to demonstrate and evaluate different potential submetering arrangements. Phase 1 focused on situations having a "single customer of record" in which the same customer was responsible for paying for all electricity consumption (including the submeter) at their service premise and is the focus of this interim report.[18] The evaluation objectives[19] for Phase 1 were to:

- Identify the different submetering services provided by MDMAs;
- Evaluate the customer experience to determine customer benefits under submetering;
- Evaluate customer demand for submetering services; and
- Evaluate the potential impacts submetering can have on supporting the State's ZEV goals of reducing the costs of PEV home charging, simplifying metering options, and establishing the submetering protocol to help homeowners access PEV time of use rates.

In addition to these stated goals, it is important to identify any findings from Phase 1 that could potentially inform or improve the execution of Phase 2. This report highlights these findings where appropriate and provides recommendations for how they can best be leveraged going forward.

2.2 Submetering Services Provided by MDMAs and IOUs

Three third party MDMA suppliers actively participated in Phase 1 of the pilot[20]—NRG, Ohmconnect, and eMotorWerks (eMW). These MDMAs were responsible for managing the customer relationship during the pilot—including recruitment, coordinating submeter installations, and providing customer service and support—accurately measuring PEV electricity usage and delivering data to the utilities on a daily basis for billing purposes. Throughout Phase 1, Ohmconnect and eMW worked as partners, with eMW supplying the submeter hardware and Ohmconnect providing software to provide customers with charging analytics and deliver data to the IOUs for billing.

The principal responsibilities of the three IOUs included processing enrollment applications and performing subtractive billing for pilot participants. Subtractive billing requires taking the submetered PEV usage data from the MDMAs, subtracting it from the whole-house usage, and

[17] Resolution E-4651 also approved a pro forma rate schedule for use in the pilot (PEVSP).See http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M097/K049/97049639.PDF for additional details.

[18] Phase 2 of the pilot will focus on submetering in situations where there are "multiple customers of record", i.e. circumstances where the customer of record for the consumption of the submeter is different from the customer of record for the rest of the premise.

[19] See CPUC Decision D.13-11-002

[20] Additional parties such as Tesla, FleetCarma and ChargePoint have expressed interest in becoming involved in Phase 2 of the pilot, but have not committed to participate.

providing the customer with a bill that reflected the appropriate rates for each of the two usage streams. Because all participants in Phase 1 were single customers of record, the bill was sent to customers as a single document that showed the breakdown between each of the two components—PEV and rest-of-house.

Staffing during Phase 1 was generally comprised of small teams at the MDMAs and IOUs. Ohmconnect estimated that 1.5 full-time employees (FTE) were actively involved in Phase 1 on average, with 4 to 6 FTE involved during peak periods of activity—e.g., enrollment and data transfer testing. For eMW, the average amount of labor required during Phase 1 was 0.5 FTE and 2 FTE were required for 2 to 3 months of peak activity. For each IOU, 3 to 5 FTE were required during project setup and enrollment, while 1 to 2 FTE were involved in performing the work associated with data transfer and billing.

In order to participate in the pilot, customers were required to enroll by submitting a Customer Enrollment Agreement signed by the customer and their MDMA to their IOU and install a submeter. Although the pilot was designed to allow both stand-alone submeters and submeters embedded in Level 2 chargers, almost all participants used eMW's stand-alone WattBox™ for Phase 1.[21] MDMAs assisted customers through the enrollment process, signed the customer up for the TOU rate with their IOU, and also helped to schedule an appointment for the installation of the submeter by a licensed electrician.[22] The WattBox™ is Wi-Fi enabled to transmit recorded usage data from the submeter to the MDMA—and ultimately to the IOU. For their participation, customers received a full rebate for the WattBox in addition to incentive payments of $100 after installation and $50 after the first successful data transfer.

2.3 Phase 1 Enrollment

The enrollment period for Phase 1 of the pilot began on September 1, 2014 and was conducted on a first-come, first-served basis[23] subject to an enrollment limit of 500 submeters for each IOU divided equally among the participating MDMAs. Due to delays associated with submeter certification, the enrollment period was extended six months to August 31, 2016.

In addition to recruiting participants from their existing customer bases, MDMAs also marketed the pilot through EV technology events and online forums for individual EV brands or models—LEAF, Tesla, etc. To enroll, customers were required to fill out a customer enrollment agreement (CEA)[24] with their utility, coordinate submeter installation with their MDMA, and

[21] eMW also offers an integrated submeter with its Level 2 electric vehicle service equipment (EVSE) known as JuiceBox™, but this product was still in the process of receiving UL certification during the enrollment period and therefore did not qualify for use in Phase 1.

[22] eMW provided customers with a choice of having the installation performed by an eMW-contracted electrician for free or contributing up to $100 towards an installation performed by an electrician of the customer's choosing.

[23] The first three months of enrollment were an "Exclusivity Period" during which the MDMAs had "Exclusivity Rights" to their share of the total participants in each IOU's territory. An "Open Period" of enrollment began in the fourth month during which MDMAs were allowed to enroll additional customers beyond their exclusivity rights and up to the 500 submeter limit on a first-come, first-serve basis.

[24] CEAs were similar for each IOU and contained the terms and conditions of the pilot, a list of eligibility criteria, a description of the duties and obligations of the participant and IOU and a form to provide information related to the submeter. CEAs could be rejected by the IOU if customers did not meet the eligibility criteria or if the CEA contained any missing, incorrect or crossed-out information.

create any online accounts needed for the MDMA to verify utility account information—eMW participants only.

Total participation at the end of the enrollment period consisted of 241 customers—132 at PG&E, 92 at SCE, and 17 at SDG&E—who nearly all enrolled during a six month extension to the enrollment period.[25] The majority of participating customers enrolled through either eMW (192) or Ohmconnect (45). Approximately 25% of participants had solar PV systems with a net metering arrangement[26] in addition to their electric vehicle—43 in PG&E, 13 in SCE, and 3 in SDG&E. Phase 1 enrollment is summarized in Table 2-1, which also includes the submeter rates that are available to pilot participants in each territory. The maximum duration for participation in Phase 1 was 12 months and customers were allowed to withdraw from the pilot at any time.[27]

Table 2-1: Phase 1 Enrollment

Utility	Total Enrollment	NEM Customers Enrolled	Enrollments by MDMA			Submeter Rate for Residential Pilot Participants
			EMW	Ohmconnect	NRG	
PG&E	132	43	109	22	1	EV-B (Residential) $20 bill credit (Commercial)
SCE	92	13	71	19	2	TOU-EV-1 (Residential) TOU-EV-3 & 4 (Commercial)
SDG&E	17	3	12	4	1	EV-TOU (Residential) $20 bill credit (Commercial)
Total	**241**	**59**	**192**	**45**	**4**	**N/A**

Enrollment in each IOU territory was significantly below the limit of 500 customers, despite the six month extension to the enrollment period. In response to the lower-than-anticipated enrollment, CPUC and the IOUs considered extending the enrollment deadline for a second time from August 31 to September 30, but ultimately decided to uphold the deadline of the first extension. As such, MDMAs were required to submit all completed CEAs to the IOUs and complete all submeter installations prior to 11:59 PM August 31 in order for customers to participate in Phase 1.

[25] No enrollment took place in the first six months of the enrollment period due to delays associated with submeter UL certification.

[26] Net metered customers are allowed to make up a maximum of 20% of total pilot enrollments in each service territory.

[27] At the time of this report, 12 PG&E participants and 10 SCE participants had withdrawn from the pilot.

3 Evaluation Methodology

There are four principal components of the Phase 1 evaluation. First, a careful analysis of the business processes used by the MDMAs and IOUs was done to understand how submetering was offered to consumers in the context of the pilot. Second, a sample of customers was selected from the pilot to install independent data loggers for the purposes of assessing the accuracy of the submeter measurements. Third, participants were surveyed to gather information about the pilot experience and their satisfaction with the submetering service provided. And finally, PEV customers who are not currently submetered were surveyed to assess customer preferences for submetering and the primary factors that will affect future submetering uptake. This section discusses the evaluation approach for each of these four components in greater detail.

3.1 Submetering Business Models and Operations

For an emerging industry such as electric vehicles, many of the details about the structure of business models and available opportunities involving third party submeters are either new or have yet to be determined. This portion of the analysis involved gathering information on the services offered by each MDMA, characterizing the interactions between the MDMA, utility, and customer and defining the business model employed by each stakeholder under submetering. Due to there being only three commercial participants, this component of the analysis was limited to residential customers.

In order to analyze the business models that were employed by MDMAs—and could potentially be employed in the future—t was necessary to collect information about several aspects of their business operations, including:

- Charging devices and metering technologies offered during Phase 1—including relevant certifications for safety and meter accuracy;
- Business processes required to establish the submetered service—including explanations of:
    - How the submetering device was installed at customers' sites;
    - How MDMAs and utilities coordinated data transfer for customer billing;
    - The systems maintained by both IOUs and MDMAs;
    - The ongoing services provided to customers; and
    - How utilities and/or MDMAs communicated with customers to address questions and concerns.
- Marketing strategies and tactics employed by MDMAs in Phase 1;
- Billing protocols utilized by the IOUs; and
- Additional PEV services offered by MDMAs (if any).

The above information was collected through data requests and phone interviews conducted with representatives from each MDMA and IOU individually. The stakeholders who were interviewed for this part of the evaluation are shown in Table 3-1.

Table 3-1: Stakeholder Interviews Conducted for Phase 1 Evaluation

Organization	Person(s) Interviewed	Title/Role	Interview Date
Ohmconnect	Matt Duesterberg	Co-Founder/CEO	11/10/15
eMW	Val Miftakhov	Founder/CEO	11/6/15
	George Betak	VP, Business Development & Community	
	Alan White	EVP, Energy Markets	
NRG	Paul Glenney	Project Manager for Submetering Pilot	11/3/15
	Mehr Kouhkan	Marketing, EVgo	
PG&E	Morgan Davis	Project Manager for Submetering Pilot	11/10/15
	Terri Olson[28]	Consultant	
	Ryan Mullikin	Billing Operations	
SDG&E	J.C. Martin	Project Manager for Submetering Pilot	11/5/15
SCE	Al Shepetuk	Project Manager for Submetering Pilot	11/6/15

Interviews lasted for 30 to 60 minutes and focused primarily on the operations, marketing activities, and customer service of the IOU/MDMAs during Phase 1 of the pilot—including enrollment. Additional topics of interest included how each stakeholder interacted with customers, the effectiveness of MDMA/IOU cooperation, and any particular challenges that were encountered during the pilot. Separate banks of interview questions were prepared for the MDMAs and IOUs, which are provided in Appendix A.

After completing each interview, notes were compiled and cross-checked against other interviews for potential areas of consensus and/or disagreement. Further analysis summarized the most challenging aspects of the pilot for each stakeholder and the areas where operations could be improved for Phase 2. Finally, information on business models and future service offerings served as the basis for assessing conflicting incentives among stakeholders that were present and new applications for PEV submetering services that may become available to customers. The information gathered during the interviews was not only valuable for analyzing business models, but also informed the development of the surveys used to evaluate the customer's experience during the pilot.

[28] Ms. Olson was the PG&E project manager for the submetering pilot until December 2014. She currently works at the consulting firm Utilligent.

3.2 Submeter Accuracy

For Phase 1, a threshold of +/- 5% was set to be the maximum allowable error tolerance for participating submeters.[29] There were two distinct submeters involved in Phase 1—one offered by eMW/Ohmconnect (WattBox™) and a second offered by NRG. To evaluate the accuracy of these devices, data loggers were installed at a sample of 34 participant premises to determine whether each device met the +/- 5% accuracy threshold. In addition to assessing individual submeters, the entire sample was used to estimate the proportion of submeters in the pilot population that met the accuracy requirement. Because NRG had only three residential customers enrolled in the pilot, all NRG customers were included as part of the accuracy sample.

Early on, MDMAs were able to successfully deliver data for installed submeters, but not without some data quality issues. Two issues that were specifically mentioned by the IOUs were that submeters measured higher usage than their upstream whole-house meter and that submeters were not always appropriately synchronized with the utility whole-house meter. In light of these early integration issues, two months of submeter data from late in Phase 1 were used to achieve the best estimate of long run submeter accuracy. Analysis was performed at the individual customer level and results for individual submeters were pooled to provide an estimate of the fraction of all installed submeters that do not meet the 5% accuracy threshold.

3.2.1 Logger Installation and Recovery

A fleet of Onset Hobo HK-22 Microstation data loggers configured to measure current flowing on 50 amp circuits—i.e., 240 volt circuits that are normally used to supply residential and commercial AC loads—was used for accuracy assessment. These devices are capable of measuring the electric load on circuits to within plus or minus approximately 1% at intervals ranging from seconds to hours over a period of up to one year. Loggers were set to collect data at 15 minute intervals to match the interval of participating customers' whole-house meters and submeters.

Customer recruitment and installation scheduling were managed by Nexant's PRS laboratory, while logger installation and retrieval were performed by Nexant engineering staff. Recruitment began in November 2015 and installations occurred on a rolling basis during December 2015. Prior to installation, all loggers in the study were inspected, bench tested, and calibrated for accuracy. As part of this process, new batteries were installed in each logger to ensure that it was in good working order and would operate throughout the expected duration of the field test. Engineers returned to pick up the loggers in late February 2016 and sent them to Nexant's San Francisco office in March, where the recorded data was downloaded and combined with submeter usage information provided by MDMAs in preparation for analysis.

3.2.2 Accuracy Measurement

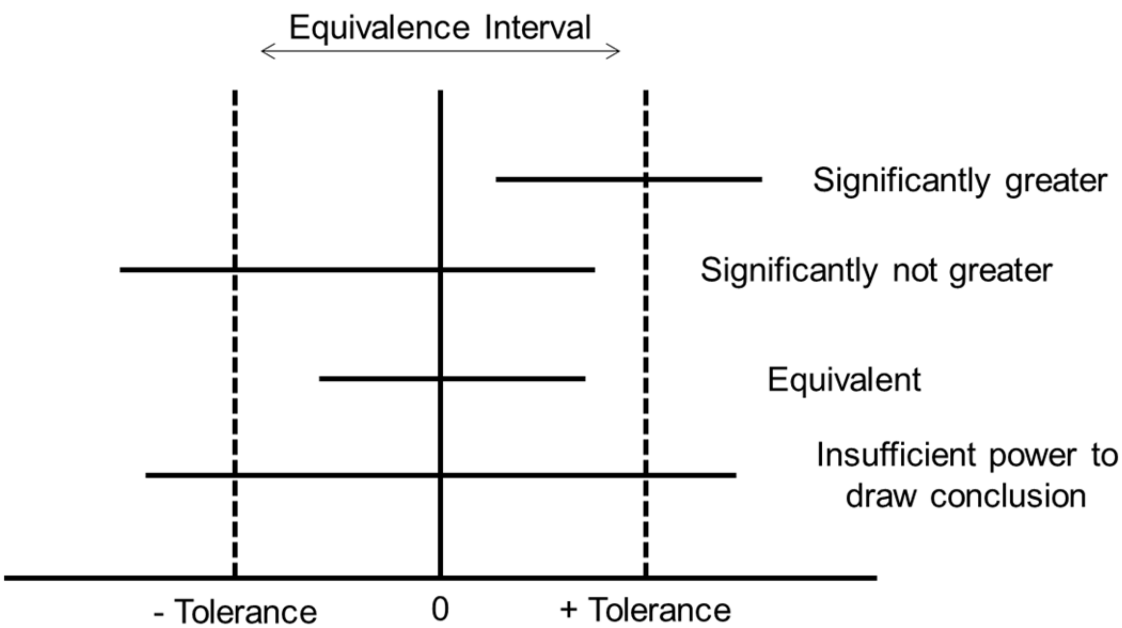
Meter accuracy was determined for each submeter by comparing the information obtained from the logger for the relevant measurement period with the usage measurements for the same

[29] This 5% accuracy tolerance is a significantly lower bar than the 0.5% tolerance that exists for residential utility meters.

period supplied by the MDMAs.[30] The analysis utilized an equivalence testing approach for kWh measurements in which the null hypothesis was that MDMA submeters were *not* accurate to within +/-5% and the alternative hypothesis was that they did meet the accuracy threshold.[31] Such an approach was better suited to accuracy assessment than more traditional hypothesis testing because it placed the burden of proof on the new meters and used the data to confirm the outcome of interest rather than fail to reject it.[32]

Equivalence tests were conducted using mean values and repeated measures to assess accuracy on a meter-by-meter basis. Using means, an equivalence band of +/- 5% was defined within which the submeter would be considered accurate. Based on the equivalence band, a confidence interval was calculated for the difference between the mean submeter and logger measurements. In situations where confidence interval lied entirely within the equivalence band, the null hypothesis (inaccuracy) was rejected and a submeter was classified as accurate. This approach is equivalent to conducting two one-tailed hypothesis tests simultaneously[33] and is shown graphically in Figure 3-1.

Figure 3-1: Conceptual Depiction of Equivalence Testing for Two Means



30 This is the same data that was transferred to the IOUs for billing purposes.

31 For a primer on equivalence testing, see Rogers et al. (1993) "Using Significance Tests to Evaluate Equivalence between Two Experimental Groups".

32 In a traditional hypothesis testing framework, the null hypothesis would have been that there was no difference between the logger and the submeter measurements. The p-value associated with such a test can be interpreted as the probability that any observed difference occurred by chance. A high p-value above the standard 0.05 or 0.10 thresholds does not confirm that the null hypothesis is true, but rather fails to provide evidence that it is false (statistically, these two things are not equivalent). Equivalence testing avoids this problem by setting up the problem up in such a way that a small p-value provides more direct evidence that that the submeter is accurate within the acceptable range.

33 The two tests are that the mean difference between submeter and logger readings is greater than the lower bound of the equivalence band and less than the upper bound.

To conduct the equivalence test using the full set of repeated measurements for the logger and the submeter, logger measurements were regressed on submeter measurements.[34] In this case, a confidence interval for the estimated slope coefficient from the regression was compared to an equivalence band of +/- 5% defined around the 45 degree line. Similar to the means case, a confidence interval that lied entirely within the equivalence band for both parameters resulted in rejecting the null hypothesis and concluding that a submeter was accurate to within +/-5%. Using the accuracy results at the individual submeter level, the fraction of submeters in the population that met the 5% accuracy threshold can be estimated as the total number of submeters in the sample classified as accurate divided by the sample size.

3.3 Customer Experience

To evaluate the customer experience, web-based surveys were used to collect information on various aspects of the pilot, including motivations for signing up for submetering, knowledge of submetering processes, customer service, problems encountered, and whether or not customers were satisfied with their submetering service. These topics are shown in Table 3-2.

Table 3-2: Topics for Customer Experience Survey

Topic	Evaluation Metrics
PEV Characteristics	Number of PEVs, make/model/year, miles driven per week and charging details
Motivations for Submetering	Identify the motivations the customer has to use submetering of PEV
Customer Knowledge	Measure the level of customer understanding of the submetering processes and TOU rates
Customer Satisfaction	Measure customer satisfaction with the submetering services provided by MDMAs and IOUs as well as their overall satisfaction with the Pilot
Issue Resolution	Identify the number, frequency and type of customer issues related to metering accuracy, data accessibility and billing
	Evaluate ability of Submeter MDMAs and IOUs to resolve customer issues

Due to the limited enrollment in Phase 1, it was necessary to recruit as many customers as possible for the participant survey to in order to obtain statistically valid results. To avoid overexposing participants to recruitment efforts for the different components of the evaluation and achieve the high response rates needed for the analysis, recruitment activities for the participant surveys and accuracy assessment were conducted jointly.

[34] For a primer on these methods, see Robinson, et al. (2005), "A regression-based equivalence test for model validation: shifting the burden of proof".

3.3.1 Survey Implementation

The participant survey was announced by a letter[35] delivered to all Phase 1 pilot participants by U.S. Mail. The letter was posted on November 18, 2015 and invited Phase 1 participants to complete two surveys online—one in 2015 and another in 2016—about their experience in the pilot. Customers were informed that they would receive a $25 check for completing each survey. Because email addresses were available for all pilot participants, invitations containing links directing the participant to the survey were sent via email as a follow-up on November 20. Reminder emails were sent to customers who had not yet completed the survey by December 1 and December 8. Additionally, customers who had not completed the survey by December 2 received a telephone call to remind them to complete the survey.

As of December 15, 2015—25 days after launch—a total of 210 surveys had been completed out of a total of 241 survey invitations sent for an 87% response rate. Response rate varied only slightly across the three IOUs with the highest response rate at SCE (89%) and the lowest at PG&E (86%). Table 3-3 presents a summary of participant survey response rates by IOU. The median completion time for the survey was approximately 12 minutes.

Table 3-3: Pilot Participant Survey Response Rates by IOU

IOU	Surveys Sent	Surveys Completed	Response Rate
PG&E	132	113	85.6%
SCE	92	82	89.1%
SDG&E	17	15	88.2%
Total	**241**	**210**	**87.1%**

Nearly all Phase 1 pilot participants (97%) had their submeters installed by the end of September 2015. The results presented in Section 4 therefore reflect Phase 1 pilot participants' experiences and opinions after at least two and a half months—and up to eight months for some participants—of enrollment in the pilot. The follow-up survey in 2016 will collect similar information in order to evaluate how, if at all, the customer experience in these areas changed during the course of the pilot. A copy of the full participant survey instrument is provided in Appendix B.

At the conclusion of the customer experience survey, respondents were provided information about the accuracy assessment portion of the evaluation and given an opportunity to declare their interest in participating by providing their name and phone number. Customers who provided their information were used as the recruiting pool for the accuracy assessment and were contacted by Nexant via phone at the number provided to schedule a data logger installation (see Section 3.2.1).

35 The invitation letter contained CPUC and Nexant co-branding and signatures.

3.4 Factors Affecting Future Submetering Adoption

In addition to evaluating the experience of participants, Phase 1 of the pilot provided a unique opportunity to study the features that will drive the future uptake of submetering arrangements in California. At present, experience marketing PEV submetering is very limited and there is almost no information about how PEV owners think about EV-TOU rates and submetering. To address this, surveys were designed to allow for a conjoint analysis capable of producing quantitative estimates of the relationships between different submetering characteristics and the probability of a customer enrolling in a submetering plan with a TOU rate for their PEV.[36] The survey was targeted at current PEV owners for each the three IOUs. In total, 8,001 qualified current residential customers in this group were invited to complete the PEV survey in February 2016. The survey was closed in early March 2016, at which time 626 qualified respondents had completed it.

In order to address all of the key research questions defined above, it was necessary to test many submetering plan options. To accommodate this complexity, an adaptive conjoint design was chosen. A detailed description of the adaptive conjoint design used for Phase 1 along with the methodology used for analysis is provided in Appendix C. The remainder of this section describes the overall design of the survey and its implementation.

3.4.1 Conjoint Survey Implementation

Sampling

The survey was targeted at a portion of the IOU residential population consisting of customers who were likely to own PEVs, not currently enrolled in a special EV rate, and did at least some amount of charging at home. These customers were identified with the help of datasets from the IOUs consisting of likely EV customers based on analyses of load shape patterns and customers who contacted the IOUs but were not participating in the Phase 1 Pilot. These datasets largely excluded multi-family residences but included net metered customers since a non-negligible portion of likely PEV owners are also net metered. Each utility classified these customers by PEV ownership likelihood and a group of 8,001 (2,667 from each IOU) randomly sampled customers was selected for use in the research study.

Survey Fielding and Response Rates

Table 3-4 summarizes the implementation timeline for the PEV survey. Development of the survey instrument itself included a thorough vetting process, which included Nexant research experts and PEV stakeholders. Nexant programmed the survey, including thorough testing of data recording and logic by survey fielding specialists. The language and appearance of recruiting materials and survey instrument were carefully reviewed by the core project team.

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[36] Often, the choices observed in a conjoint study are calibrated to observed choices in the real world before they are used to forecast future customer adoption decisions. Due to the limited amount of data available, however, calibration of the stated preference approach in each IOU territory was not possible so responses were calibrated to anchor questions in the survey about the likelihood of enrolling in submetering.

Table 3-4: Implementation Timeline for Survey

Implementation protocol	Date
Mailed letter invites including a $20 contingent incentive	Sent 2/17, arrived 2/19-2/20
Reminder email to incompletes and non-responders (PG&E and SDG&E only)	2/24
Reminder email to incompletes and non-responders (SDG&E only)	3/3
Survey closed	3/8

The research was designed to provide statistically reliable results with 200 responses in each segment (IOU). While response rates can be quite high with small non-contingent incentives of $2 to $5, research also shows that response rates are much higher when contingent incentives of much higher amounts—e.g., $20—are used. Because of the short fielding timeline and the possibility that a majority of customers solicited would not qualify for the survey,[37] invitees were offered a $20 contingent incentive check from Nexant in return for completing the survey.

The responses for SCE surpassed the target of 200 within the first day of the survey due to a high qualify rate. After this point, new entrants to the survey from SCE received an over quota message and were not able to begin the survey. To bring responses closer to the target 200 for the other IOUs, email reminders were sent to the subset of PG&E and SDG&E customers with email addresses on file. The survey remained open until March 8, 2016 at which point sufficient sample had been collected for all test cells.

Table 3-5 summarizes responses for the PEV survey overall and within each test cell. Table 3-6 summarizes the response rates, qualify rates, and completion rates for the survey. Nexant received 626 responses from participants including over 200 each from PG&E and SCE and 184 from SDG&E.[38]

Table 3-5: Response Summary for PEV Survey

Test Cell	PG&E	SCE	SDG&E	Total
Invitations sent	2,667	2,667	2,667	8,001
Responses received	452	691	584	1,727
Over-quota	1	419	0	420
Disqualified	193	11	328	532
Incomplete	49	28	72	149
Complete	209	233	184	626

37 To qualify respondents needed to be current PEV owners that do at least some of their charging at home

38 This was close enough to 200 to yield statistically significant results.

As shown in Table 3-6, the overall response rate was 22%. Response rate was highest for SCE customers despite the fact that this group did not receive any email reminders. Because email reminders were not sent to customers of all utilities, response rates cannot be compared between utilities. Furthermore, it is important to keep in mind that the survey only remained open for 18 days due to the constrained project schedule. Nexant typically keeps surveys open for longer periods of time—e.g., for four to six weeks—which usually results in much higher response rates. Despite the short fielding duration, response rates are still high enough to assuage concerns of response bias.

Table 3-6: Response Rate Summary for PEV Survey[39]

Test Cell	PG&E	SCE	SDG&E	Total
Response rate	17%	26%	22%	22%
Qualify rate	57%	96%	44%	59%
Complete rate (among qualified)	81%	89%	72%	81%

As noted above, the sample target for SCE was filled within two days of fielding. An assessment of qualify rates provides a possible explanation. At 96%, qualify rates for SCE invitees were nearly twice as high as they were for the invitees from the other two utilities. While it is not possible to know for sure, it is possible that response rates were higher for EV owners than for non-EV owners. If nearly all SCE invitees were EV owners compared with roughly half of customers from the other two IOUs, it is plausible that this explains the higher response and qualify rates for this group.

Survey Mode

As detailed above, an adaptive, computer-based design was chosen to support the complexity of the attribute levels being tested. The adaptive design means that the survey is uniquely tailored to each respondent so that the choices made in certain questions influence what is shown in following questions. The computer based design also incorporated interactive features such as establishing an estimated monthly charging cost for each respondent. This was based on each respondent's estimated marginal electricity rate—the middle tier of each respondent's rate—and a set of questions used to estimate monthly miles driven. Because of its adaptive, computer-based nature, the survey could only be administered via the internet—and not via a paper booklet or over the phone. Due to the complexity of some tasks that would have been too burdensome to read, customers were also not able to call in and complete the survey over the phone.

The advantages of the adaptive design were deemed to outweigh any potential selection bias that could result from single mode fielding because the population of interest—customers with PEVs—is likely to be familiar with digital technology and regularly use the internet. Moreover,

[39] See Table 3-5 for sample sizes pertaining to each row. For example, the relevant sample sizes for response rate are in the "Invitations sent" row.

the fielding protocol was designed to reduce survey coverage error as respondents were recruited through the mail and were still able to call-in to ask questions or receive assistance in accessing the survey. Any customers who did not have internet access were encouraged to call a designated hotline. Of the 8,001 customers invited to complete the survey only 1 called in to report a lack of internet access.

An additional feature of the survey was that it was mobile friendly. Because EV owners are typically more tech savvy than the general population, additional care was given to ensure that the survey experience was fully mobile compatible, including testing on medium sized smart phone screens. Table 3-7 summarizes the operating systems used by respondents. Operating systems are compared for respondents who completed the survey as compared to all other respondents to identify any significant differences. The percent of respondents accessing the survey from a mobile device was virtually the same for completing respondents (18%) as for all other respondents (19%), which validated the development effort put into this feature.

Table 3-7: Percent of Respondents Using Different Operating Systems

Type of Operating System	Operating System	Completes	All other responses[40]
Mobile Operating Systems	Android	3%	3%
	Chrome	1%	1%
	iPad	9%	7%
	iPhone	5%	9%
Desktop Operating Systems	Linux	1%	0%
	Mac OS	31%	26%
	Windows	50%	54%

3.4.2 Survey Instrument Design

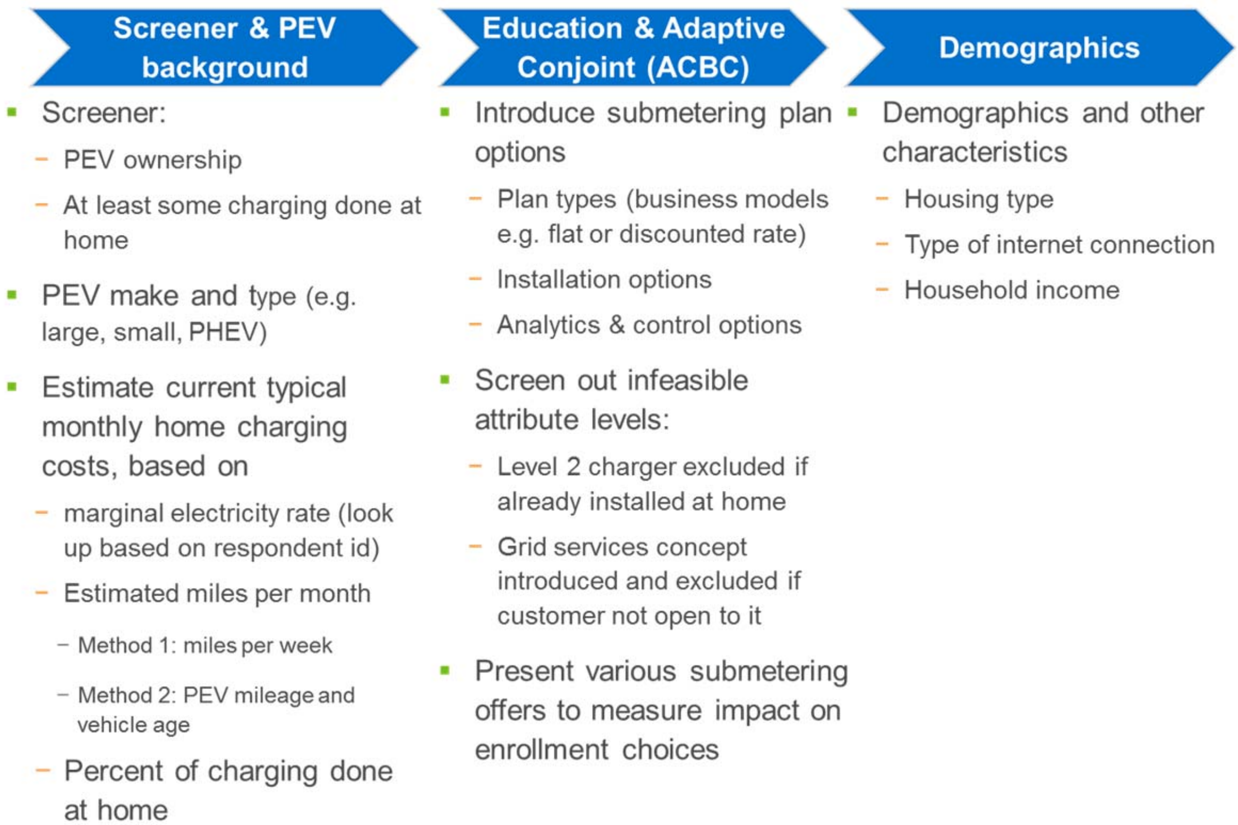
The PEV survey instrument used a computer-based, adaptive design to collect data on customer preferences for a variety of potential submetering plan design parameters. In order to collect valid data it was necessary to ensure all respondents had a basic level of understanding and familiarity with both the general concept of submetering and the specific parameters respondents were being asked to evaluate. As such, the survey instrument included the sections shown in Figure 3-2, with the following purposes:

- **Screener & PEV background**:
  - Screen out respondents who do not currently own a PEV or who do not do at least some charging at home
  - Background on type of PEV and typical miles driven to estimate typical monthly charging cost—respondents were asked to confirm validity of estimate and allowed to change it, including reducing to $1

[40] Includes incompletes, over-quota, and disqualified respondents

- **Education and Adaptive Conjoint**:
  - Introduce submetering options to ensure respondent familiarity with the parameters to be tested in the conjoint
  - Filter out unfeasible levels for each respondent
  - Use adaptive choice-based conjoint (ACBC) exercise to gauge enrollment choice impact of each option for each attribute
- **Demographic questions:**
  - Collect key demographic data and household background relevant to submetering

Figure 3-2: Overview of Survey Design



4 Results

The evaluation activities for Phase 1 produced a large amount of primary data to investigate the research questions described in Sections 2 and 3. This section presents and discusses the results for each of the four primary components of the evaluation.

4.1 Submetering Business Models and Operations

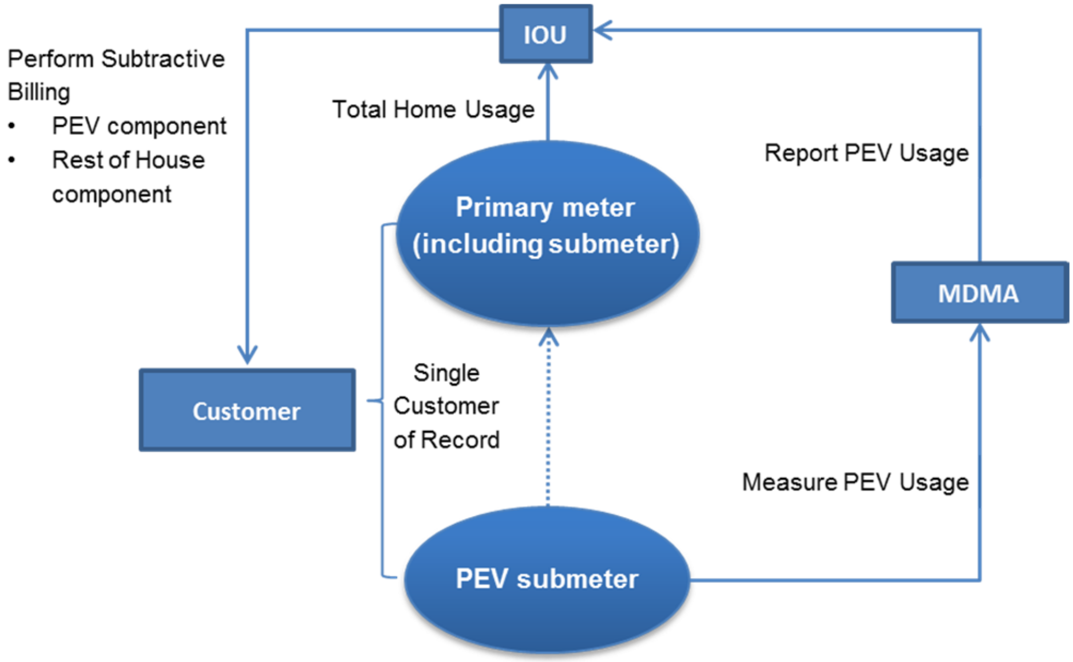
A crucial part of evaluating potential business models and opportunities was to understand the relationships between each stakeholder and identify relevant incentive structures. Figure 4-1 depicts these relationships for Phase 1 of the pilot in which a single customer of record was responsible for paying for all of the electricity consumption at a premise.[41] Participating customers in Phase 1 were almost entirely[42] residential customers living in a single/multi-family homes.

Electricity consumption data at a premise with submetering comes from two sources—the submeter and the primary meter for the premise, which includes the PEV usage. For the purposes of billing, the primary role of the MDMA was to provide the IOU with accurate measurements of PEV electricity usage in a format that was compatible with the premise's primary meter—15 minute intervals. The IOU then took the PEV usage in each interval and subtracted it from the primary meter to identify the amount of electricity used by the rest of the house and calculate a bill for each source using the appropriate rate. This process is known as subtractive billing, and once the two bills have been calculated, they were combined into a single document and sent to the customer for payment.

41 Master metered premises were not eligible for Phase 1 of the pilot.

42 One commercial customer enrolled in Phase 1 of the pilot, but was excluded from the analysis for obvious statistical reasons.

Figure 4-1: Activities and Responsibilities for Submetering Stakeholders in Phase 1



It is possible to have a PEV enrolled in a TOU rate and the rest of the home on a different rate without submetering; however, this requires customers to install a second utility-grade meter at their premise. Second meters cost thousands of dollars[43] and as a result, enrollment in separately metered rates has been low. Most PEV customers chose between one of two options for paying for their charging at home:

1. Remain on the same rate as before acquiring a PEV (typically a tiered rate); and
2. Enroll in a TOU rate that applies to the entire home (including the PEV).

These two options represent a tradeoff between gaining access to a low off-peak price beneficial for PEV charging and avoiding high prices during peak times that would increase the cost of afternoon and early evening usage that can't be shifted. Giving PEV customers a third option that eliminated this tradeoff at low cost was one of the primary motivations for conducting the pilot and including non-utility submeter providers.

Providing the submetering service, transferring the data, and performing the subtractive billing for the 241 participants in Phase 1 required substantial effort and coordination between the MDMAs and IOUs. The remainder of this section provides detailed descriptions of how each of the core tasks was carried out by the MDMAs and IOUs along with the challenges that were encountered.

43 This cost likely varies substantially for different customers, but includes the cost of the meter itself, all applicable permits, compliance with electrical codes and the labor costs associated with installation.

4.1.1 Technology Development

A prerequisite for providing submetering service is having a submetering product available for customers to install that is low-cost, safe, and reliable. All hardware for the pilot was required to be UL-certified to ensure the safety of pilot participants. UL-certified submeters for PEV charging were not on the market at the outset of the pilot and needed to be designed, built, and certified by the MDMAs. eMW and NRG took different approaches to technology development, which resulted in different experiences for each company. These experiences are presented as case studies below.

eMW

eMW is a privately held company based in San Carlos, CA that operates a network of distributed load control devices used to provide grid stabilization services to Independent System Operators (ISOs), utilities, and large commercial electricity consumers. The company's current offerings include EV charging stations with grid management and user-facing control features that are managed through a proprietary cloud-based platform. The grid management services provided by eMW include demand response, frequency regulation, peak shaving, and local load balancing to help utilities and ISOs better manage the grid volatility and increased EV adoption.

For the submetering pilot, eMW developed a standalone submetering product in-house called the WattBox-200, which featured Wi-Fi data telemetry and secure data storage. The built-in Wi-Fi transferred usage data from the submeter to eMW's servers and also provided access to several advanced energy management features such as access to real-time and historical energy use data via website or Smartphone and automatic notifications for when power exceeded/fell below a given threshold or energy use occurred outside of prescribed hours.[44] eMW estimated that the production of its WattBox™ submeter cost approximately $200/unit with additional overhead costs of $50/unit. These costs were approximately offset[45] by a one-time incentive payment of $212/unit and recurring incentive of $17.50 per month from the IOUs during Phase 1.

In addition to the WattBox, eMW also manufactures an integrated submeter with Level 2 EVSE called the JuiceBox™. Launched through a successful Kickstarter campaign in 2013, the JuiceBox provides high-power, Level 2 charging capable of up to 10kW and 40 Amp output with Wi-Fi remote telemetry, direct user controls, and advanced smart grid optimization features.[46] Although eMW hoped to offer the JuiceBox to customers in the pilot alongside the WattBox, it was still going through the UL-certification process during the enrollment window and was therefore not eligible for Phase 1.

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44 See https://emotorwerks.zendesk.com/hc/en-us/article_attachments/203870048/WattBox_Installation_Instructions_Draft_v26.pdf for a full list of WattBox-200 features.

45 The submetering pilot was revenue neutral to slightly negative for eMW.

46 See http://emotorwerks.com/index.php/juicebox for additional details.

eMW learned of the submetering pilot soon after beginning a partnership with Ohmconnect, an energy services company that monitors real-time power market conditions and participates in CAISO's ancillary services markets by aggregating load reductions from smart thermostats, smart plugs and electric vehicles in its customer network.

NRG

NRG currently operates the largest DC fast-charging network in the United States (eVgo) and has established business relationships with large auto original equipment manufacturer (OEM) dealerships including Nissan, Ford, and BMW. New Nissan LEAF owners are eligible to participate in the "no charge to charge" program where they receive 24 months of free access to the eVgo charging network. New Ford and BMW EV owners have similar programs available to them. Through these business relationships, NRG gained experience with a UL-certified Level 2 EVSE charging unit manufactured by Lite-On that contained integrated metering and 3G wireless communication capabilities.

After learning about the submetering pilot,[47] NRG contacted Lite-On about supplying EVSEs that could be offered to customers as part of Phase 1. NRG's strategy for recruitment was to initially offer these EVSEs internally to NRG and Gridscape[48] employees to test their functionality and assess the associated customer experience. After this small-scale initial deployment, the plan was to roll them out to the mass market through their existing OEM dealer relationships.

After receiving the EVSE charging units with integrated submeters from Lite-On for internal participants, NRG identified several performance issues with the devices. The delivered EVSEs were only capable of 2G communications instead of the 3G communications capability that was expected. A significant problem with the 2G technology is that it is being phased out by many communications providers and is scheduled to become entirely defunct on January 1, 2017. As a consequence, the charging stations supplied by Lite-On were already technically obsolete when they were delivered and will be completely unusable 18 months after delivery. In addition, NRG employees testing the Lite-On charger experienced irregular charging performance when the chargers stopped charging unpredictably, would not adhere to a set timer program, and created other "unsafe" charging experiences.

As a result of these issues, NRG replaced all of the existing Lite-On charging units in their eVgo network—approximately 500 EVSEs—and suspended their plans to offer submetering services to additional customers in Phase 1—internal participants remained in the pilot. This was done to avoid the risk of negative customer experiences with a new product that could negatively affect the company's brand. High customer satisfaction is central to the company's business model and the risk of damaging it outweighed any potential benefits of offering the integrated submeters to external customers. Despite the technical issues encountered in Phase 1, NRG remains very interested in participating in Phase 2 of the pilot, as are its OEM dealership partners.

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[47] NRG received a lot of interest in the pilot from customers who learned about it from CPUC/IOU websites.

[48] Gridscape is a 3rd party partner of NRG's that supplies the cloud services used to transfer data back and forth between the EVSE and the utility.

4.1.2 Pilot Enrollment and Establishing Submeter Service

Due to NRG's decision to limit Phase 1 participation to its own employees, analysis of the enrollment process is focused on the experience of eMW/Ohmconnect and the three IOUs. Recruitment of pilot participants was conducted by the MDMAs, who then also helped customers through a formal enrollment process with their IOU. Although eMW and Ohmconnect proactively reached out to their existing customers and advertised for the pilot through online PEV forums, the majority of Phase 1 participants found out about the pilot through dedicated pages on the CPUC/IOU websites and initiated contact with the MDMAs and IOUs.[49]

To be eligible to participate in the pilot, customers were required to complete a CEA and meet the following criteria:

- Have an active service account with their IOU;
- Have an eligible interval data recorder meter—i.e., smart meter;
- Charge a PEV at their account;
- Have an approved submeter installed for the exclusive use of tracking the energy used to charge the customer's PEV;
- Be a bundled service customer or community choice aggregation (CCA) customer; and
- Not participate in any automatic payment plan options[50] offered by the IOU.

The enrollment process consisted of several manual steps, which combined with the division of labor between the MDMAs and differing legal interpretations by the IOUs, led to frustrations between stakeholders and/or processing delays for customers. After contacting an MDMA to express interest in the pilot, customers first created an online account[51] and went through a pre-qualification check to make sure that they met the eligibility criteria and could have a submeter successfully installed at their premise. Once this sign-up was completed and a customer purchased a submeter, the MDMA arranged a submeter installation appointment and emailed the customer a blank CEA to complete.[52]

After having their submeter installed, customers formally enrolled in the pilot by completing a customer enrollment application (CEA) with assistance from the MDMA, who submitted them to the appropriate IOU for approval. Applications were submitted to the IOUs via email as scanned

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49 See http://www.pge.com/en/myhome/saveenergymoney/pev/submetering/index.page (PG&E), https://www.sce.com/wps/portal/home/residential/electric-cars/residential-rates/ev-submeter-pilot/!ut/p/b1/hdDLboMwEAXQr2GLLzYNTndGscAuDU2hKfGmIhUlVARHhIbfL42y6Xt2Mzp3pBliSEFMV56auhwa25XtR29mT1othBf5VIFrCZGxVIZJTEH9CWwmgF9K4L_8IzFn4vFIxCqDih5yARUuQi--VcDS_wp4HskJ3GC-vqPMD4JvG-4DCqXXMkIDj4LTC5hHkLFOJ5CvGBRbYZkJwYDZBfxxhSambu32_JGN6LaM18T01UvVV7371k_j3TAcjtcOHIzj6NbW1m3IPtu9g58iO3scSPFZksO-QKNer9pTIt4B8sQsyQ!!/dl4/d5/L2dBISEvZ0FBIS9nQSEh/ (SCE), http://www.sdge.com/clean-energy/ev-driver-pilot-program (SDG&E), and http://www.cpuc.ca.gov/general.aspx?id=5938 (CPUC).

50 These include the "Balance Payment Plan" or "Automatic Payment Plan" options offered by PG&E, the "Level Pay Plan" or "Direct Pay Plan" options offered by SCE and the "Level Pay Plan" or "Online Automatic Payment" options offered by SDG&E. Customers who were enrolled in any of these programs could de-enroll temporarily in order to participate in the pilot.

51 This step was not necessary for existing eMW customers.

52 Customers were also encouraged to sign up for Ohmconnect's standard service at this time.

PDF documents. The IOUs reviewed the completed CEAs and communicated any problems/issues back to the MDMA, who would then relay the message to their customers.

Due to differing interpretations of the CEA's legal importance for each IOU and the lack of an automated online system to process applications, submitted CEAs often needed to be sent back to customers for revisions[53] because they were incomplete or required corrections to minor issues such as improper address abbreviations, using shortened versions of a customer's name—e.g., "Bill" rather than "William"—or not submitting the pages of the CEA containing the terms and conditions, liability waiver, warranty disclaimer, etc. that did not require explicit responses from the customer. These errors occurred in spite of training that was provided to the MDMAs by the IOUs to help guide the completion of the CEAs. Resubmitting CEAs required additional back and forth between MDMAs, customers, and the IOUs. Given these complex logistics and the small number of MDMA/IOU employees participating in the pilot, the enrollment process took anywhere from several days to several weeks to complete.

4.1.3 Data Transfer and Subtractive Billing

To become an official MDMA in Phase 1 of the pilot, the MDMAs were required to go through testing with each of the three IOUs to demonstrate their ability to deliver data in a format that could be used for billing. Data transfer protocols during the testing phase mirrored the actual data transfer process in many respects. Individual data files were sent for each customer via secure file transfer protocol (SFTP) containing usage data for the submeter in 15 minute intervals along with a unique universal ID number attached to every interval.

Pre-pilot testing uncovered a variety of issues that needed to be addressed and as a result took six to eight months to complete. Obstacles included difficulties in setting up the SFTP, transferring data in a format that was compatible with IOU billing processes, clock synchronization issues with submeter intervals, and a rogue de-enrollment process[54] that was triggered when accessing certain customer accounts. Resolution of these issues required extended efforts by the IOUs to educate MDMAs that contributed to the long duration of the testing period, but by the end of the testing phase the MDMAs were able to successfully transfer data to each IOU.

Upon approval of the CEAs, the MDMAs began sending submeter data to the IOUs on a daily basis. The IOUs inspected the data to verify it was in the correct format and not missing any intervals. In the event that any issues were discovered, the IOUs would notify the MDMA of the problem and work with them to find a solution. Completed CEAs also established an official pilot "start date" for each customer based on their individual billing cycle. Because enrollments naturally occurred in the middle of billing cycles, customers received their first bill containing the submeter usage after their first full bill cycle in the pilot.[55] Launching a subtractive billing process

[53] 56 of the 92 customer agreements for SCE needed to be resubmitted by the MDMAs.

[54] This issue affected only 7 customers at SDG&E and was quickly resolved.

[55] For example, if a customer's CEA was accepted on July 21 and their current bill cycle ended on July 29, then the first bill that included submetering would not be sent until after the following bill cycle (e.g. July 29-August 31).

was an upfront investment for each IOU that was not built into existing billing processes for practical reasons.[56]

As a result, each IOU built systems to incorporate data from the MDMAs into a subtractive billing process that was conducted outside of their core billing systems. Given the uniqueness of each IOU's systems, different solutions were implemented with varying degrees of automation, but a common experience was the need to educate MDMAs about how the billing process works[57] and the associated data requirements. The following subsections detail the experience of each IOU in performing subtractive billing during Phase 1.

PG&E

PG&E leveraged a rarely used feature of their customer information system (CIS) as the basis for designing a new computer program to perform subtractive billing calculations.[58] The new routine involved several manual steps that were outside normal billing operations, including the subtraction itself, which was done for every 15 minute interval. Performing subtractive billing at the 15 minute interval level required the data for all intervals to be in the same format,[59] which required additional data validation steps for both the submeter data provided by the MDMA and interval data from PG&E's meter data management system.

The construction of the subtractive billing process was an iterative effort that required fixes early on in the pilot to address data issues that were uncovered. As the pilot continued, PG&E was able to automate several steps of the process to improve speed and reliability, but some steps remained mostly manual—e.g., dealing with estimated meter reads in whole-house data. In PG&E's assessment, additional automation will be needed to further improve the reliability of the subtractive billing process.

SCE

Similar to PG&E, subtractive billing was an entirely new process for SCE. Unlike PG&E, however, SCE managed the new stream of submetering data in a more automated fashion rather than performing the majority of tasks manually. This involved software changes within SCE's data system and setting up a new account for each pilot participant to manage PEV submeter usage and whole-house usage separately. While much of the data management was able to be automated, the subtractive billing process itself was still performed manually by a member of the project team. SCE estimates that fully automating the subtractive billing process would cost tens of millions of dollars and take several years to complete.

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[56] As stated in R.09-08-009, "Prior to making significant capital upgrades to the utility billing process, the Commission wants to understand the demand for submetering, evaluate the costs of a billing system, and determine how that cost will be assigned."

[57] This included the timing of when customers would receive their first submetered bill, helping customers understand what rate they were on and whether changes were being made to their account, specific data formatting necessary to integrate with IOU billing systems, electronic vs. paper bills, etc.

[58] The referenced CIS feature had previously been used only with monthly data, not 15 minute interval data.

[59] This was an issue for the small percentage of intervals from PG&E smart meters that contain estimated meter reads for the whole-house as well as any missing submeter reads.

During the course of Phase 1, SCE encountered a synchronization issue with the submeter clocks when compared to the whole house meter clocks.[60] This led to some 15 minute intervals showing submeter measurements that were larger than the whole house measurements. As a rule, SCE rejected any submeter measurements where this occurred and billed all usage for those intervals on the whole house rate. Per the PEVSP tariff, any incorrect bills due to data errors of this kind were not updated retroactively in the event that the submeter data was corrected at a later time.[61]

SDG&E

Unlike PG&E and SCE, SDG&E had some previous experience with submetered PEVs prior to the pilot from another pilot that was conducted for estimating the impacts of TOU pricing on EV charging behavior.[62] Because of this, much of the subtractive billing process for Phase 1 fit into SDG&E's existing systems. The key new development work needed consisted of adapting the existing system to incorporate a new data stream from the MDMAs. Data received from the MDMAs was not integrated into SDG&E's other data systems—per the rules of the pilot—and was therefore stored on a separate server from the whole-house data recorded by SDG&E's smart meters.

The subtractive billing calculation itself was automated and triggered manually by a member of the SDG&E pilot team based on the end dates of customers' billing cycles. Like SCE, SG&E rejected any submeter measurements where the measured PEV charging usage during the 15 minute interval is greater than the whole house usage during the same interval. SDG&E estimated that such synchronization issues affected less than 5% of the total kWh recorded by the submeters of participants in Phase 1. After completing the subtractive billing, SDG&E sends each customer a bill containing two sections[63]—one for their normal SDG&E electric account, excluding the PEV and a separate service point for the PEV that is billed according to the EV TOU rate.

By SDG&E's own assessment, the internal system created for Phase 1 was somewhat brittle due to a large number of manual interventions that were required and a low level of expected enrollment. For Phase 2, SDG&E's goal is to fully automate the process to improve reliability and timeliness and support subtractive billing for a larger number of customers.

4.2 Submeter Accuracy

In order for submetering to be successful from both a business and customer satisfaction perspective, submetering devices must be able to provide accurate measurements of PEV charging usage to the utilities for subtractive billing. As part of the Phase 1 evaluation, Nexant

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60 Ohmconnect estimated that this issue potentially affected 5% of customers in Phase 1.

61 SCE is investigating changing this practice for Phase 2.

62 See "Final Evaluation for San Diego Gas & Electric's Plug-in Electric Vehicle TOU Pricing and Technology Study" (2014) - https://www.sdge.com/sites/default/files/documents/1681437983/SDGE%20EV%20%20Pricing%20%26%20Tech%20Study.pdf

63 Net metered customers received their PEV bill as a component of their monthly gas bill because many produce enough electricity from PV systems so that they owe nothing to SDG&E.

installed data loggers for a sample of 34 submeters at participating customers' premises for the period December 14 through February 12 to independently measure PEV charging loads. The accuracy sample included 31 eMW submeters and three NRG submeters.

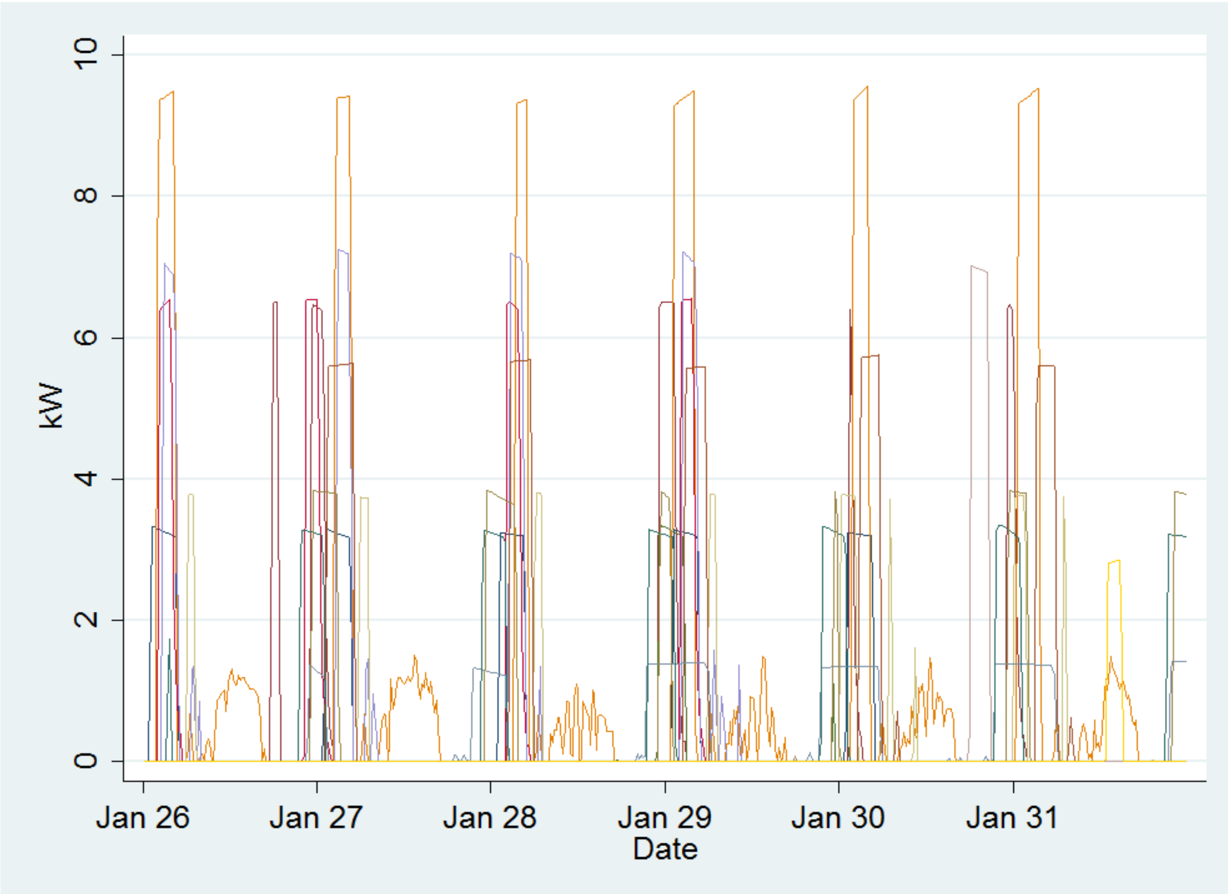
Data collected from the loggers was compared to submetering data over the same period to assess the accuracy of the submeters. During the data collection period, however, eMW experienced server-side data processing software issues that caused erroneous measurements for 16 to 24% of PEV charging loads for some pilot participants. The most serious issue occurred as an unintended side effect of eMW's server migration that took place on October 26, causing a 24 hour shift for some 15 minute data intervals. eMW was notified of the problem in December through customer complaints of overbilling[64] and resolved the issue on January 8 and 9 via fixes to the server. Because of this known issue and the fact that any measurement errors resulting from affected loggers would have overwhelmed the 5% accuracy threshold, the analysis dataset was split into two periods—December 14 through January 8 and January 9 through February 12. Unless otherwise stated, the results and figures presented in this section utilize the second half of the study period when the eMW software issue was not a concern.

In addition to the server malfunction, eMW also reported two submeters in the accuracy sample that had sporadic data coverage and one that was completely offline during the study period. Due to the missing data, these submeters would not have met the 5% accuracy requirement and were dropped from the analysis. Nexant also experienced some attrition in its logger sample due to technical and fielding issues. Out of the initial sample of 34 loggers, 3 were not usable because the amps recorded by the logger could not be converted to kW, 2 stopped recording data in the middle of the study period, 2 did not pass data validation checks, and 11 were installed without properly synchronizing the logger clock with the smart meter or submeter clock. Combining the remaining 16 loggers with the eMW/NRG submeters with reliable data resulted in 14 logger-submeter pairs that were available for analysis.

A time plot of these 14 submeters for one week in January is shown in Figure 4-2, where each colored line represents an individual submeter. As seen in the graph, the nature of PEV charging loads is essentially on/off—the PEV is either plugged in and consuming electricity at a steady rate or it is not plugged in and usage is zero. Because PEVs are charging for only a few hours each day—if at all—most of the 15 minute intervals have 0 kWh of consumption.

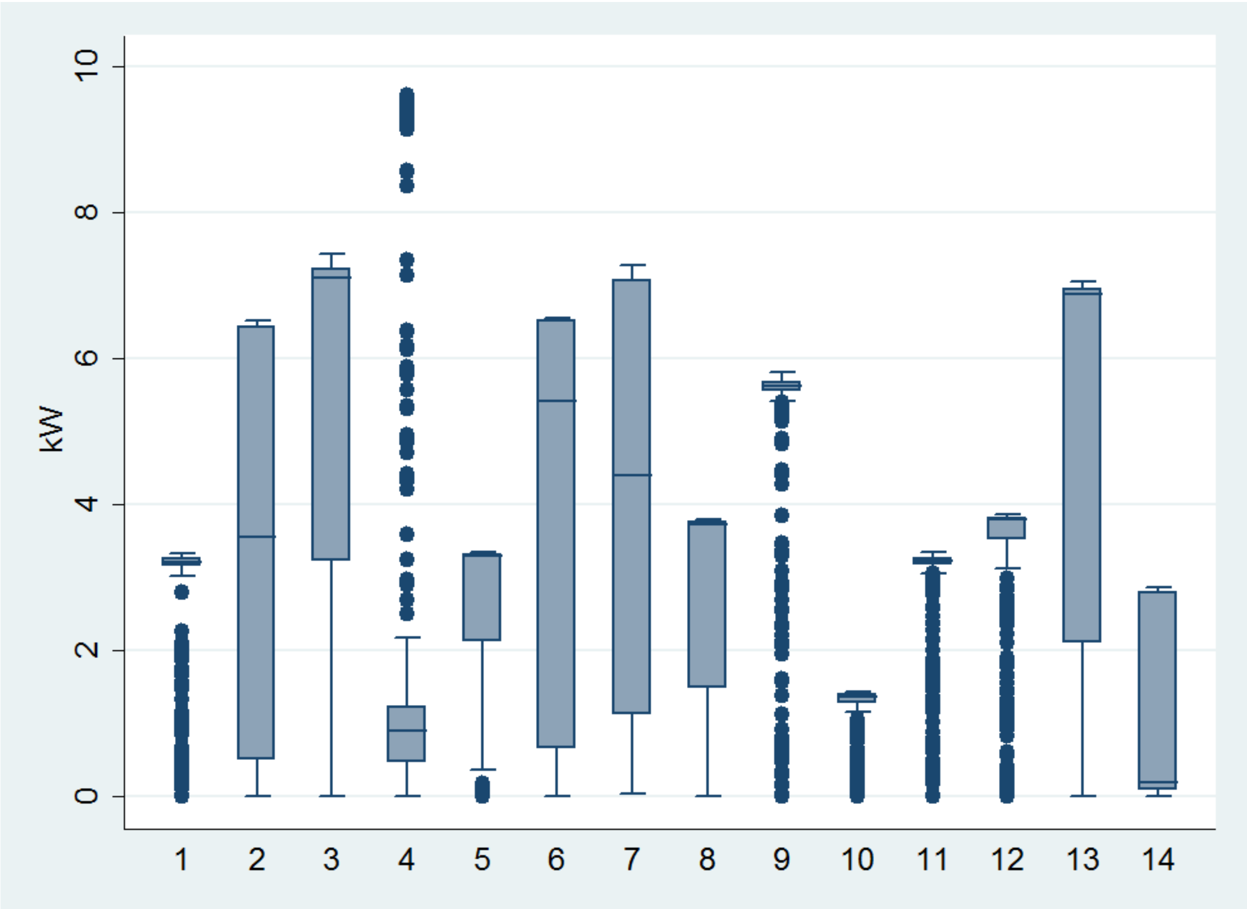
[64] Across the 3 to 5 initial complaints in December, customers generally reported apparent overbilling by $20 to $30/month.

Figure 4-2: Time Plots for Submeters in Accuracy Sample



Box plots showing the distributions of non-zero measurements are shown in Figure 4-3. For most submeters, the distribution is very skewed with a long tail either extending toward zero or the top end of the distribution. Tails toward zero are an artifact of discretizing continuous time since it is unlikely that charging will begin or end exactly at the end of a 15 minute interval. Outliers in each distribution are denoted as individual points.

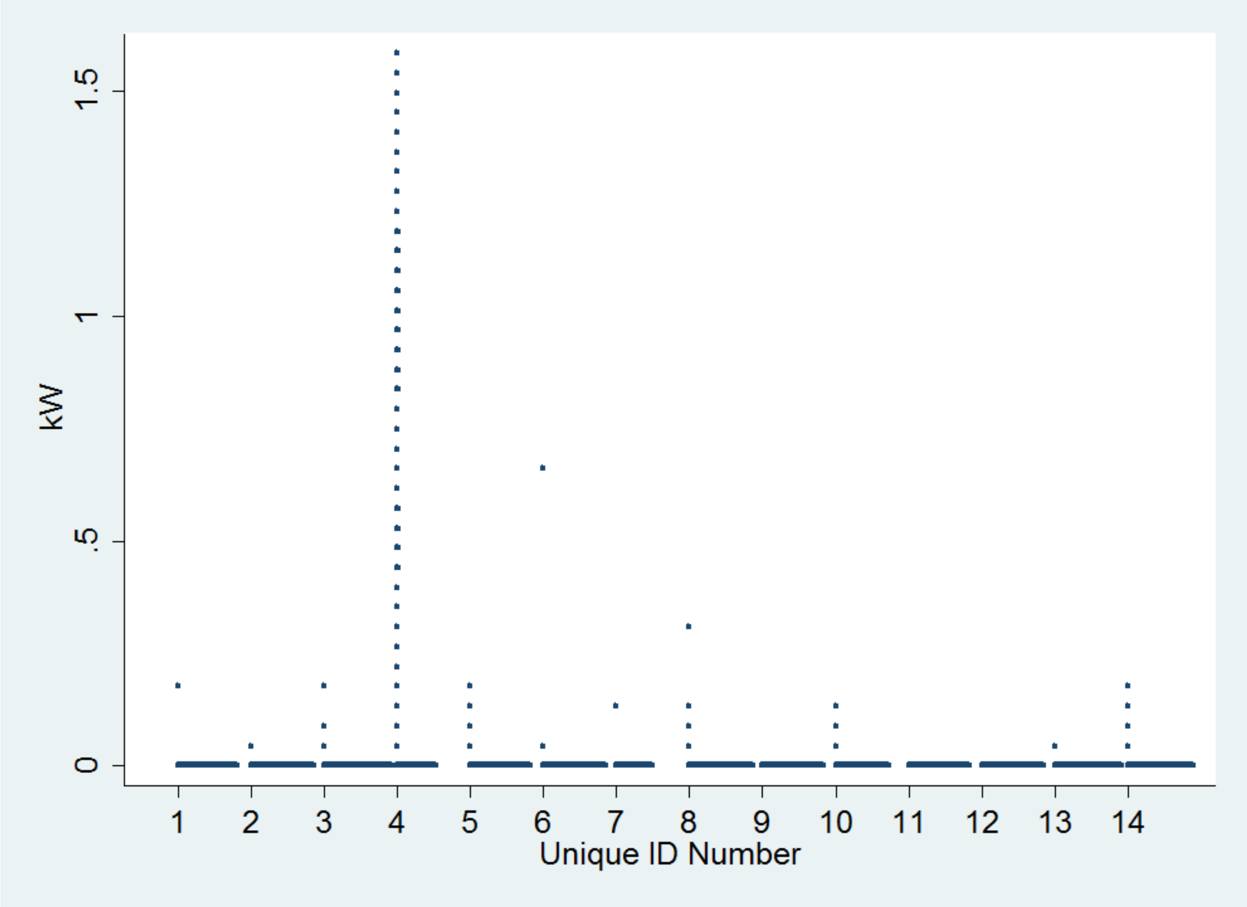
Figure 4-3: Box Plots of Non-zero Submeter Measurements



The on/off nature of charging loads suggests a two-pronged approach for assessing accuracy. First, it is informative to examine whether submeters are recording values of zero when there is no charging occurring. Figure 4-4 shows dot plots for each submeter in the sample for all intervals where a logger has a reading of zero. Each dot represents a single 15 minute interval and the plots show that the number of incorrect submeter measurements when PEV usage is zero is very small.[65]

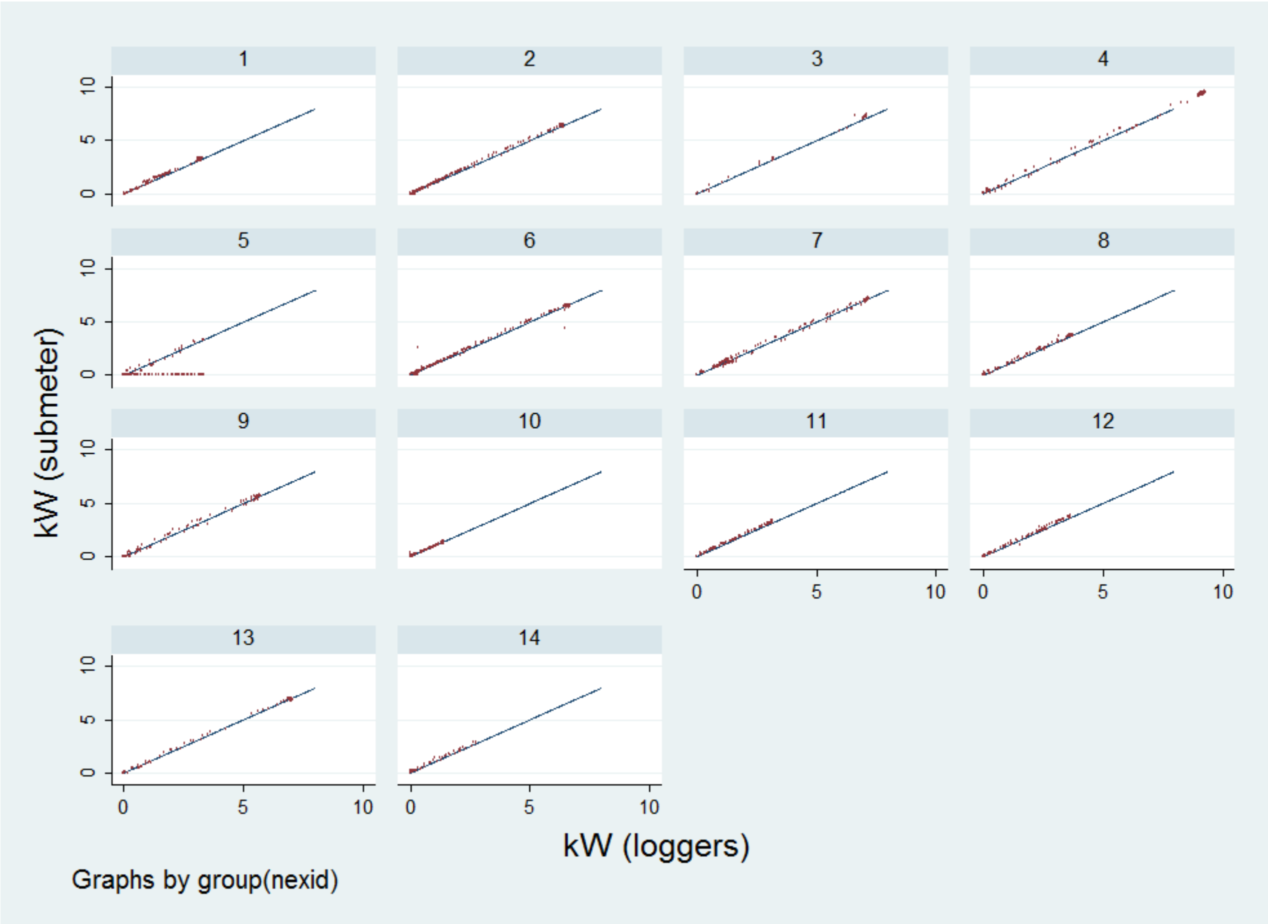
65 The total number of observations for each submeter ranges from 1,000 to 2,000. Submeter measurements of zero stack up in the figure so that they resemble a line.

Figure 4-4: Submeter Measurements when PEV is Not Charging



For intervals where charging usage was greater than zero according to the logger, submeter measurements were directly compared to logger readings. Figure 4-5 shows these comparisons for each submeter in the form of scatter plots. Each interval is represented in the figure by a red dot. Perfect agreement between the submeters and loggers is represented by the blue 45 degree line. According to this preliminary examination, most of the plots show strong agreement between submeter measurements and their corresponding logger readings. The exception to this is submeter number 5, which did not record any usage for most of the study period, but then accurately recorded usage at the end of the period.

Figure 4-5: Submeter Measurements vs. Logger Readings for Non-zero Usage Intervals



To formally test the similarities between the submeter measurements and logger readings, an equivalence testing approach with a threshold of 5% (see Section 3.2) was used in two distinct ways. The first was to use a paired t-test approach consisting of two separate tests, one of the null hypothesis that the submeter mean is at least 5% less than the logger mean and the second of the null hypothesis that the submeter mean is at least 5% greater than the logger mean. The results of the equivalence tests for each submeter are shown in Table 4-1 and show that all submeters in the data except for number 5 easily reject the null hypotheses of greater than 5% error.

Table 4-1: Equivalence Test Results for Mean Submeter and Logger Measurements

Unique ID	Mean		P-Value		Number of Observations
	Submeter Data	Logger Data	Lower	Upper	
1	2.79	2.78	0.00	0.00	479
2	3.32	3.29	0.00	0.00	349
3	5.40	5.28	0.00	0.00	100
4	6.75	6.59	0.00	0.00	385
5	0.65	2.70	0.00	1.00	445
6	3.77	3.81	0.00	0.00	364
7	4.03	4.04	0.00	0.00	247
8	2.79	2.78	0.00	0.00	274
9	4.94	4.93	0.00	0.00	447
10	1.23	1.24	0.00	0.00	723
11	2.93	2.84	0.00	0.00	411
12	3.26	3.15	0.00	0.00	375
13	4.88	4.91	0.00	0.00	132
14	2.18	2.12	0.00	0.00	114

The second method for conducting the equivalence test is to use a regression approach consisting of the following three steps:

1. Establish 5% region of equivalence for the slope ($\beta 1$) equal to (0.95, 1.05).
2. Fit linear regression using the logger as the independent variable and the submeter observations as the dependent variable.
3. Test the slope for equality to 1 by calculating two one-sided confidence intervals for the slope using the regression output and determine whether this interval is contained within the region of equivalence.

Equivalence test results using the regression approach are presented in Table 4-2.

Table 4-2: Equivalence Test Results Using Regression

Unique ID	Regression Coefficient	Standard Error	95% Lower	95% Upper	Reject Test of >5% Error	Count
1	1.00	0.00	1.00	1.01	Yes	479
2	1.02	0.00	1.01	1.02	Yes	349
3	1.03	0.00	1.02	1.04	Yes	100
4	1.03	0.00	1.02	1.03	Yes	385
5	0.24	0.05	0.16	0.33	No	445
6	0.99	0.00	0.99	1.00	Yes	364
7	1.00	0.00	0.99	1.00	Yes	247
8	1.01	0.00	1.01	1.02	Yes	274
9	1.00	0.00	1.00	1.01	Yes	447
10	0.96	0.00	0.95	0.97	Yes	723
11	1.02	0.00	1.01	1.02	Yes	411
12	1.04	0.00	1.03	1.04	Yes	375
13	1.00	0.00	1.00	1.00	Yes	132
14	1.00	0.01	0.99	1.01	Yes	114

The regression results demonstrate equivalence between the submeter and logger data, which corroborates the results of the tests using mean values as well as the visual diagnostics in Figure 4-5. As a final test of submeter accuracy, usage from the submeter was summed in each TOU period over the course of the study period—Jan 9 through Feb 12—and compared to aggregated logger data to simulate a billing cycle. These comparisons are shown in Table 4-3.

Table 4-3: Comparing Submeter and Logger Data for Simulated Billing Month

Utility	Unique ID	Off Peak (kWh)		Partial Peak (kWh)		Peak (kWh)		Achieves 5% Accuracy for All Periods
		Submeter	Logger	Submeter	Logger	Submeter	Logger	
SDG&E	1	290	288	2	2	7	7	Yes
PG&E	2	185	183	0	0	83	82	Yes
PG&E	3	135	132	0	0	0	0	Yes
PG&E	4	627	575	97	2	52	0	No
PG&E	5	53	229	3	7	17	45	No
PG&E	6	314	317	0	0	0	0	Yes
PG&E	8	173	172	2	2	6	6	Yes
PG&E	9	473	472	0	0	0	0	Yes
SCE	10	205	208	0	0	1	0	Yes
SCE	11	277	268	0	0	0	0	Yes
SCE	12	214	207	0	0	39	38	Yes
SCE	13	80	80	0	0	34	34	Yes
SCE	14	20	18	0	0	35	33	No*

* This is a result of low total usage for this submeter over the course of the month

Based on the results of the various equivalence tests, most submeters for which data was available meet the 5% accuracy threshold specified by Phase 1 of the pilot. However, one submeter in the sample was offline for a portion of the study period and a second incorrectly allocated some usage to the peak and partial peak periods during the simulated billing cycle. In addition, the results should be caveated by the fact that 4 out of 31 eMW submeters in the analysis sample were not included in the analysis due to data issues and half of the analysis period was affected by a software malfunction that caused data errors for some eMW customers. These measurement errors would certainly have affected customer bills and may account for some of the dissatisfaction customers expressed about billing accuracy.

4.3 Customer Experience during Pilot

A key objective for Phase 1 was to evaluate the customer experience in order to determine customer benefits under submetering.[66] To that end, all Phase 1 pilot participants were contacted with a request to complete a participant survey in November 2015.[67] This survey was designed to collect information on a number of topics related to the pilot:

- PEV ownership and usage;
- Customer knowledge of the submetering process and electric rate structure;

66 See page 18 of the CPUC Decision 13-11.002 for a list of the goals of the California PEV Submetering Pilot.

67 Phase 1 pilot participants will be contacted again in 2016 with a request to complete a follow-up survey.

- Customer satisfaction; and
- Issue resolution.

Information collected from the participant survey—in addition to the data collected by the other components of this evaluation—was analyzed to identify ways to improve submetering service and identify opportunities to expand submetering tariffs or programs to additional PEV customers. In addition, the participant survey provides an opportunity to identify ways to improve the experience of customers who participate in Phase 2 of the pilot.

The remainder of this section presents the survey results associated with each of the research topics described above.

4.3.1 PEV Ownership and Usage

The survey showed that Phase 1 participants predominantly own a single PEV that was purchased or leased in 2014 or 2015. Specifically, 80% of respondents reported owning one PEV, while 18% own two PEVs and 2% own three or more PEVs. A total of 80% of respondents acquired their PEV(s) in either 2014 or 2015, while 16% of respondents' PEVs were purchased in 2012 or 2013, and 3% were purchased in 2010 or 2011. A majority (61%) of survey respondents report having PEVs manufactured by Chevrolet, Nissan, Tesla, or Toyota. Despite this concentration, responses to this survey indicate that the California PEV market is beginning to diversify. Table 4-4 presents frequencies of vehicle make and model as reported by survey respondents and includes 12 manufacturers in addition to the 4 listed above[68].

Table 4-4: Frequencies of PEV Make and Model Owned by Pilot Participants

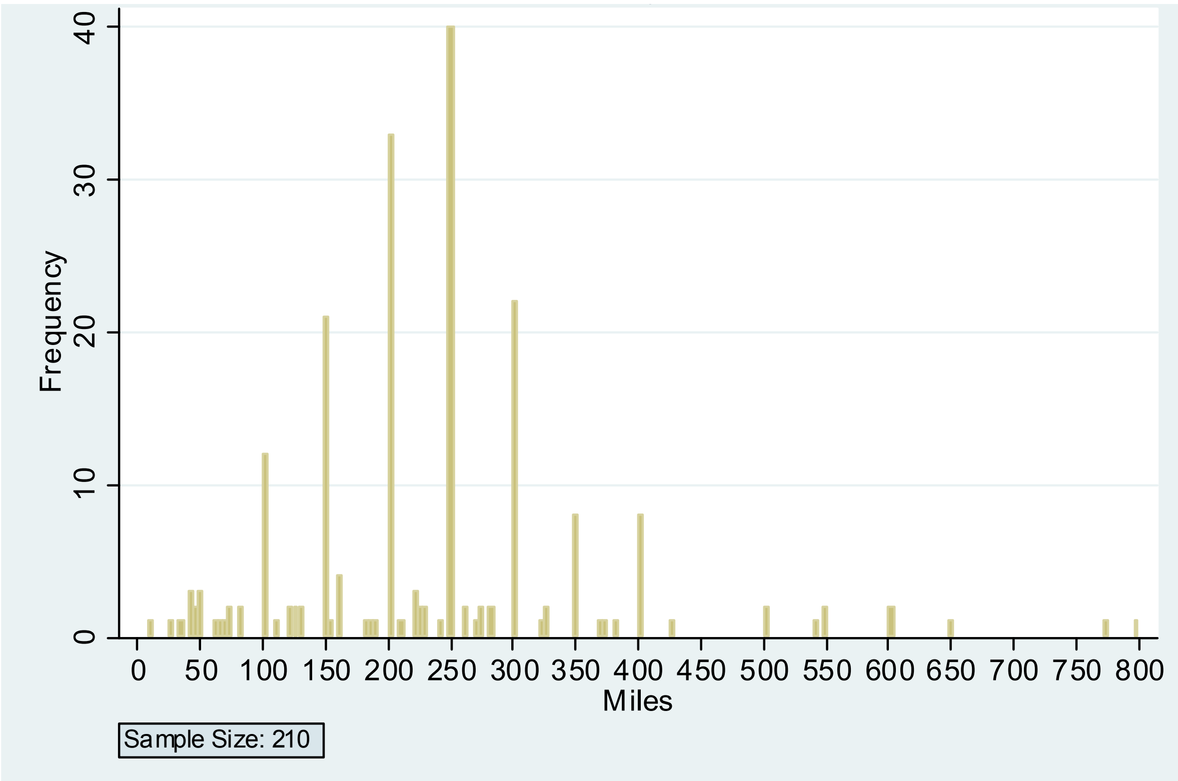
Make and Model	Frequency	Make and Model	Frequency
Nissan LEAF	47	Honda Fit EV	5
Chevrolet Volt	41	Toyota Prius Plug-in	5
Toyota RAV4 EV	26	Kia Soul EV	4
Tesla Model S	24	Ford C-Max Energi	3
Fiat 500e	23	Smart fortwo electric drive	2
BMW i3	17	Volkswagen EV Conversion	2
Chevrolet Spark EV	14	Corbin Sparrow	1
Ford Focus Electric	14	Honda Accord	1
Volkswagen e-Golf	8	MG BGT EV	1
Mercedes-Benz B-Class Electric Drive	6	Mitsubishi i-MiEV	1
Coda Sedan	5	Zero S[69] 11.4	1
Ford Fusion Energi	5	**Total**	**256**

68 The total number of PEVs shown in Table 4-4does not total 210 due to the fact that customers report owning more than one PEV in some cases.

69 The Zero S is an electric motorcycle.

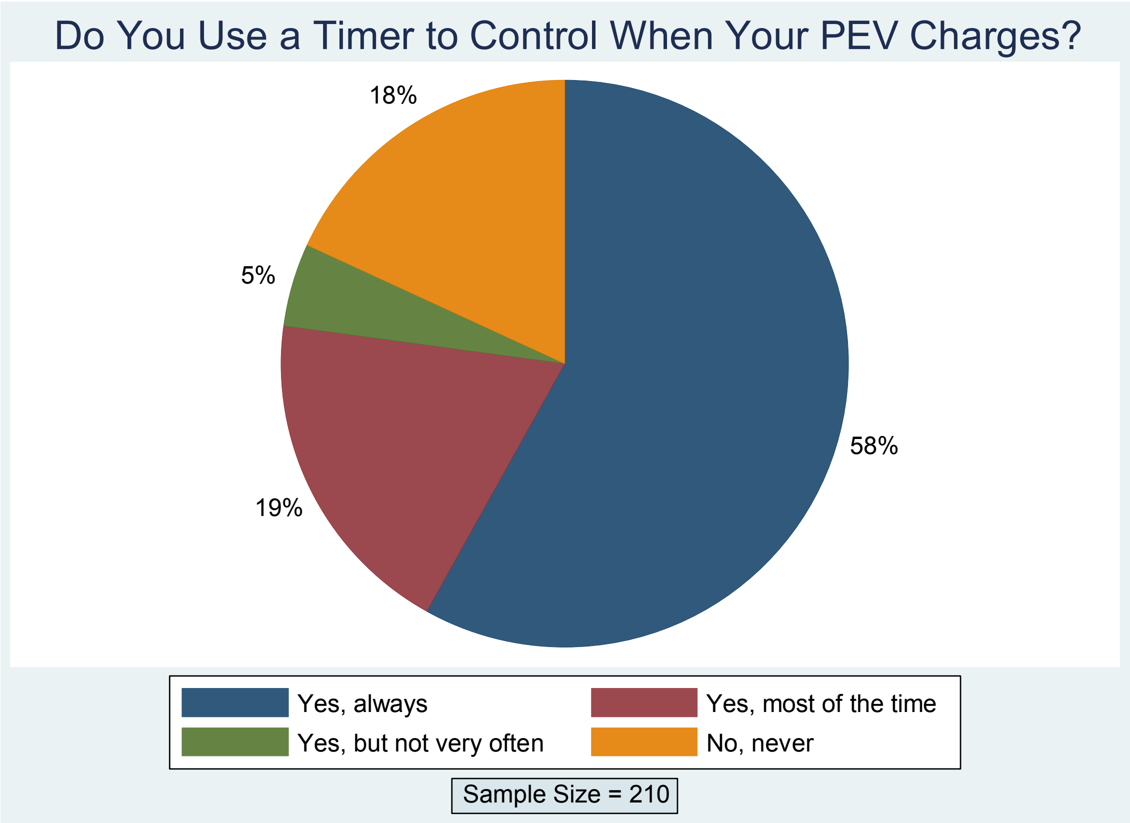
Survey respondents were also asked about how much they use their PEV in a typical week. Most respondents reported driving between 100 and 400 miles in their PEV during the work week—Monday through Friday. Figure 4-6 presents response frequencies; the modal, or most common, response was 250 miles driven per workweek.

Figure 4-6: PEV Weekly (Monday through Friday) Mileage



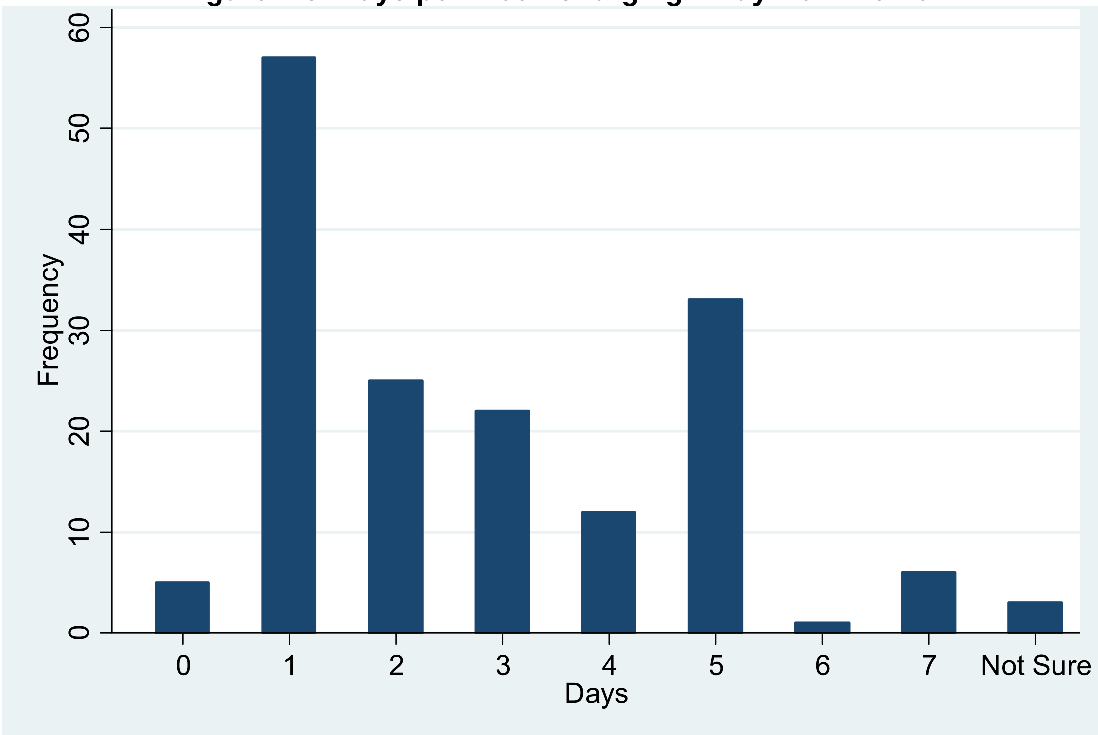
A majority of survey respondents (58%) also reported that they always use a timer when they charge their PEV, while only 18% reported that they never use a timer to control their PEV charging. Figure 4-7 shows the distribution of responses to the question of how often Phase 1 pilot participants use timers to control when their PEV charges.

Figure 4-7: Timer Use to Control Charging



The survey also included questions about pilot participants' charging behavior away from home, since away-from-home charging is not observed by the IOUs, but can affect how much charging is done at home. Thirty-seven percent of respondents reported that they do not ever charge their PEV away from home, while half of customers who do charge away from home do so two days a week or fewer. Figure 4-8 shows the response frequencies for reported number of days of PEV charging away from the home.

Figure 4-8: Days per Week Charging Away from Home



When charging away from home, a majority of respondents (76%) reported using Level 2 charging stations, 19% reported using DC fast charging stations, and the remaining 5% of respondents stated that they are not sure about what type of charging station they use away from home. Table 4-5 tabulates the frequency of responses for each response category for average duration of away-from-home charging sessions. Charging sessions away from home were nearly equally divided between the choices of less than one hour, between one and two hours, between two and three hours, and between three and four hours. This result shows that there is no “typical” duration of charging sessions away from the home for the PEV owners who participated in Phase 1.

Table 4-5: Average Duration of Charging Away from Home

Average Duration	Frequency
Less than 1 hour	35
Between 1 and 2 hours	38
Between 2 and 3 hours	35
Between 3 and 4 hours	34
More than 4 hours	21
Not sure	1

4.3.2 Customer Knowledge of Submetering Process and Electric Rates

A critical component of future submetering programs will be success in creating awareness of the program among potential participants and providing useful information about how the program works vis a vis other electric rate options on offer. Phase 1 appears to have succeeded in educating participants on the electric rate options available to them for both the whole house and also the PEV charger. A total of 93% of survey respondents correctly stated that the price structure of electricity used by their PEV is more expensive when charged during the peak period and less expensive during the off-peak period. Similarly, 93% of respondents said that they were aware at the time of enrollment in the pilot that whole-house TOU electricity rates were also available to them.

Participants were also asked about their knowledge of their whole-house rate. While 68% of the customers who completed the survey actually have a whole-house electric rate that is not time-differentiated, only 57% reported that their whole-house electric rate is not time-differentiated. This means that 22 customers or about 10% of survey respondents incorrectly identified the type of whole-house electric rate, which is only somewhat higher than the percent of respondents (7%) that incorrectly identified their type of PEV submeter rate.

4.3.3 Customer Satisfaction

One of the most important metrics for the Phase 1 evaluation is the extent to which pilot participants were satisfied with the submetering service they received. To be properly interpreted, reported levels of satisfaction should be grounded by information on what motivated a customer to participate in the pilot in the first place. The survey results show that the three most important motivations for enrolling in the Phase 1 pilot were the following:

- Ability to pay a lower rate for electricity used by the PEV;
- The availability of an incentive for the PEV meter; and
- Ability to measure the amount of electricity my vehicle is using.

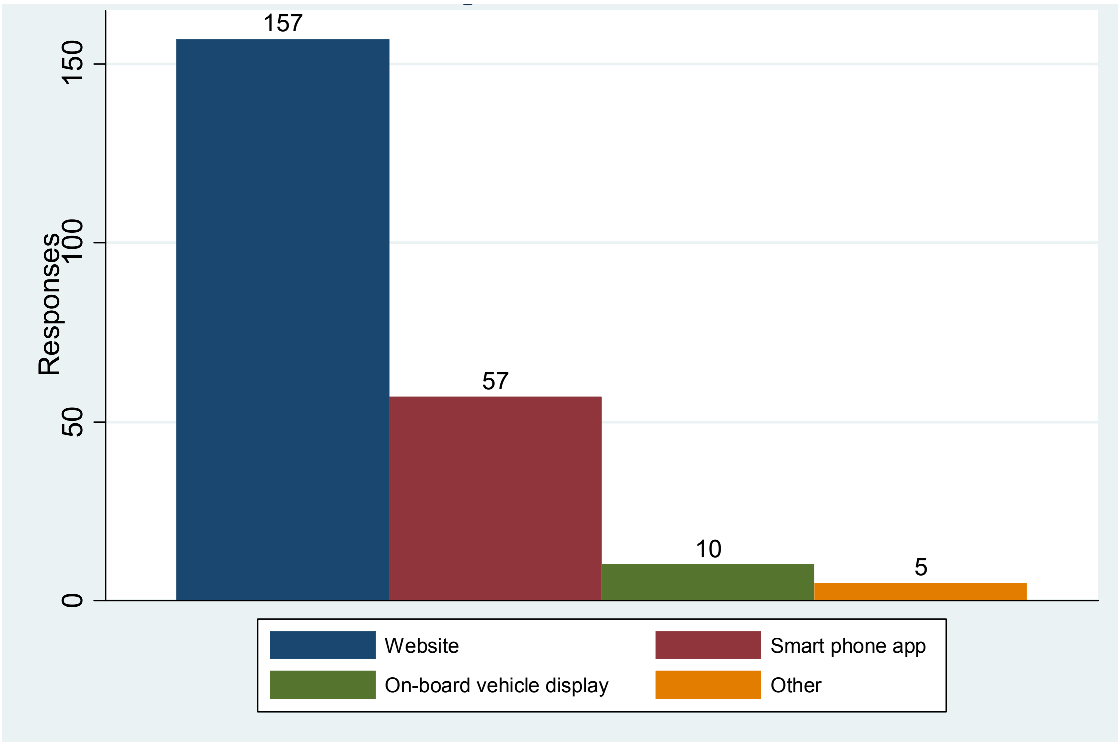
These three aspects of the pilot received top 2 box scores over 80%, meaning that more than 80% of customers thought that these considerations were either extremely important or somewhat important in their decision to participate in the pilot. The ability to pay a lower rate for electricity used by the PEV received a very high top 2 box score of 98%.Table 4-6 summarizes the motivations for Phase 1 participation.

Table 4-6: Importance of Factors in Deciding to Enroll in the Pilot

How important was each of the following aspects of submetering in deciding to sign up for the pilot?	Not Important at All	Somewhat Unimportant	Somewhat Important	Extremely Important	Top 2 Box
Ability to pay a lower rate for electricity used by my PEV	1%	1%	8%	90%	98%
The availability of an incentive for the PEV meter	4%	9%	31%	56%	87%
Ability to measure the amount of electricity my vehicle is using	6%	11%	45%	38%	83%
The cost of the vehicle charger	17%	11%	35%	38%	73%
The safety and reliability of the charging station	17%	16%	32%	35%	67%
The monthly service charge	19%	17%	32%	32%	64%
Ability to charge my vehicle more quickly	28%	13%	29%	31%	60%
The ability to control the charging station from my smart phone	30%	27%	25%	19%	44%

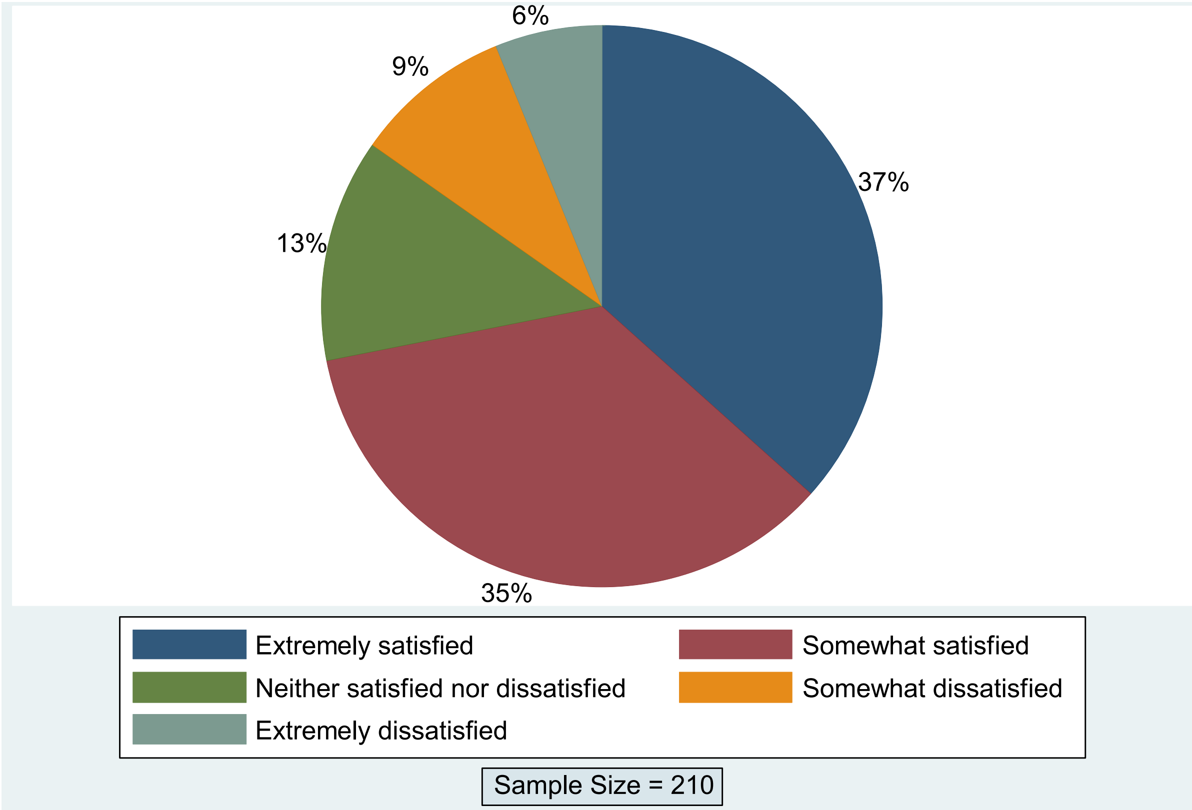
The ability to measure the amount of electricity that the PEV is using was rated third highest in terms of importance as a factor in deciding to enroll in the pilot. One feature of PEV submetering is that it affords the customer an opportunity to access this data directly, including other information derived from the interval consumption data recorded by the PEV submeter such as the cost of the electricity used by the PEV charger and the carbon emissions associated with that electricity usage. Eighty percent of respondents stated that they accessed the data collected by their submeter. All of those customers reported viewing their PEV usage data, but only 40% reported looking at the data pertaining to the cost of charging. Just 4% of respondents reported viewing the emissions data pertaining to their PEV electricity usage. Most survey respondents (93%) reported using their MDMA’s website to access their submeter data, while 34% reported using a smartphone app and 6% reported using their PEV’s onboard display to view the data. Figure 4-9 shows the distribution of responses to the question of how Phase 1 pilot participants access their charging data.

Figure 4-9: Modes for Accessing PEV Charging Data



Several questions towards the end of the survey dealt with the topic of customer satisfaction in Phase 1. Participants were first asked to rate their overall satisfaction with their submetering service using a 5 point scale, which covered the following ratings: “extremely satisfied,” “somewhat satisfied,” “neither satisfied nor dissatisfied,” “somewhat dissatisfied,” and “extremely dissatisfied.” Figure 4-10 illustrates the distribution of responses to the overall satisfaction survey question. A majority of customers (72%) said that they were “extremely satisfied” or “somewhat satisfied,” while 15% of respondents rated their level of satisfaction as “somewhat dissatisfied” or “extremely dissatisfied.” The remaining 13% responded as “neither satisfied nor dissatisfied. “

Figure 4-10: Overall Customer Satisfaction with Submetering Service



Of the 32 respondents who were dissatisfied, nearly three quarters (23) reported that their dissatisfaction was a result of billing issues or poor customer service/support from their IOU or MDMA. When asked to expand upon their satisfaction, 50% of respondents reiterated their overall satisfaction with the pilot, stated that they liked paying a lower electricity rate for their PEV charging or said that they like reducing their monthly bill. Table 4-7 and 4-8 summarizes the open-ended responses about the specific reasons for dissatisfaction or satisfaction.[70]

Table 4-7: Reasons for Dissatisfaction with the Phase 1 Pilot

Dissatisfaction Responses	Frequency
I've had billing issues	12
I've experienced poor customer service or support from IOU or MDMA	11
Other	5
I've experienced technical problems	4
Total	**32**

[70] Customers who gave a satisfaction rating of "neither satisfied nor dissatisfied" did not see the open-ended follow up question for rationale and are therefore not included in the tables.

Table 4-8: Reasons for Satisfaction with the Phase 1 Pilot

Satisfaction Responses	Frequency
I'm satisfied with the program overall	38
I like paying a lower rate, reducing my electricity bill	37
Other	26
I've experienced billing issues	17
I can track how much I pay for my EV usage separate from my household usage	13
It's easy to set up and configure	12
I avoid the cost of installing a second meter	8
Total	**151**

In addition to overall satisfaction with the pilot, the survey also asked about satisfaction with more specific aspects of the participant experience. Table 4-9 presents customer ratings of various aspects of the submetering service. The percentage shares for each rating and the top two box score in the table only reflect those customers who did not select “no experience.” The aspects of the pilot that respondents reported the least experience with were the installation appointment and controlling their PEV charger remotely. Nearly half (45%) of respondents indicated that they had no experience with the PEV submeter installation, while 39% indicated that they were not involved in the scheduling of the installation appointment. Additionally, 58% of respondents stated that they had no experience remotely controlling their charging station. Notably, 17 customers who identified themselves as satisfied used the prompt as an opportunity to describe billing problems that they had experienced. As a result, the total number of customers who report billing issues is more than double than the count in Table 4-7 indicates.

Among respondents who did have experience with the aspects of the pilot shown in Table 4-9, the highest rated aspects in terms of customer satisfaction were the safety and reliability of the charging station, which both had top two box satisfaction scores over 80%. In this case, the top two box scores represent the percentage of customers that express high satisfaction ratings for each aspect of the service. The perceived accuracy of the measurement of electricity used by the PEV was third highest with a top-two box satisfaction score of 72%. The next tier of satisfaction includes installation, access to charger data and customer service from the MDMA, which all had top two box scores between 60% and 69%. The aspects of the pilot with the lowest satisfaction ratings—as measured by the top two box score—were related to enrollment, IOU customer service, and billing. Customers had mixed feelings about the accuracy of the PEV portion of their bills—top two score of 58%—while the experience of signing up for the PEV rate with the IOU and customer service after the rate began received top two box scores of 35% and 46%, respectively.

Table 4-9: Satisfaction Ratings for Specific Aspects of Phase 1 Pilot

Please rate the following aspects of your submetering service		No Experience	Poor	Fair	Good	Very Good	Excellent	Top 2 Box
Reliability of my charging station		10%	2%	5%	7%	18%	68%	86%
Safety of my charging station		17%	1%	2%	15%	20%	62%	82%
Accuracy of the measurement of electricity used by my PEV		24%	8%	8%	13%	24%	48%	72%
Installation		45%	6%	8%	17%	20%	49%	69%
Access to information about whether and when my vehicle is charging remotely		30%	7%	7%	18%	28%	39%	67%
Scheduling the installation of the meter or charging station		39%	4%	9%	24%	21%	42%	63%
Customer service provided by (insert MDMA name) after the meter or charging station was installed		14%	12%	6%	21%	20%	40%	60%
Accuracy of the PEV portion of my bill		27%	18%	7%	18%	22%	36%	58%
Ability to control my charging station remotely		58%	15%	7%	25%	19%	35%	54%
Signing up for the PEV rate	PG&E	5%	11%	19%	26%	19%	25%	44%
	SCE	1%	21%	10%	26%	23%	20%	43%
	SDG&E	0%	7%	13%	13%	20%	47%	67%
	All IOUs	**3%**	**15%**	**15%**	**25%**	**21%**	**25%**	**46%**
Customer service provided by IOU after PEV rate started	PG&E	33%	28%	18%	18%	17%	18%	36%
	SCE	32%	23%	18%	27%	18%	14%	32%
	SDG&E	27%	18%	18%	18%	9%	36%	45%
	All IOUs	**32%**	**25%**	**18%**	**22%**	**17%**	**18%**	**35%**

4.3.4 Issue Resolution

To further understand the underlying causes of satisfaction and dissatisfaction, the survey asked participants about whether or not they experienced different types of issues, including technical problems related to the submeter and problems related to billing. In addition to asking whether participants experienced these issues, follow-up questions were asked about how well the problems were resolved.

Most pilot participants (83%) reported that they have not experienced any technical problems with their charging station. Of the 12% (26 respondents) that did report technical problems, most reported issues were related to Wi-Fi connectivity, general failure of charging equipment, inaccurate measurement data, or unsuccessful transmittal of measurement data to the IOU. Table 4-10 presents satisfaction ratings for the resolution of these technical problems.[71] About a quarter (23%) of respondents who experienced technical problems stated that the problem was still unresolved. Among those whose problems had been solved, the top two box satisfaction score is 75%.

Table 4-10: Satisfaction Ratings for Resolution of Technical Problems

	The Problem(s) is/are Still Unresolved	Extremely Dissatisfied	Somewhat Dissatisfied	Neither Satisfied nor Dissatisfied	Somewhat Satisfied	Extremely Satisfied	Top 2 Box
How satisfied were you with the resolution of the technical problem(s)?	23%	0%	15%	10%	25%	50%	75%

Pilot participants were also asked whether they experienced any billing problems associated with their submetering service. Thirty percent of participants indicated that they had experienced billing problems, while another 23% responded that they were not sure if they have experienced billing problems. A total of 62 participants experienced problems with their bills—34 PG&E customers, 18 SCE customers and 10 SDG&E customers. Most of these customers described the problem as receiving a delayed bill, which caused them to pay for multiple months of service at once. Others responded that their bill inaccurately reflected their PEV's usage. Table 4-11 presents satisfaction ratings for the resolution of billing problems. Notably, 48% of respondents say that their billing problem is still unresolved. Among the other respondents with resolved billing problems, the top two box satisfaction score is only 47%.

Table 4-11: Satisfaction Ratings for Resolution of Billing Problems

Question	The Problem(s) is/are Still Unresolved	Extremely Dissatisfied	Somewhat Dissatisfied	Neither Satisfied nor Dissatisfied	Somewhat Satisfied	Extremely Satisfied	Top 2 Box
How satisfied were you with the resolution of the billing problem(s)?	48%	9%	16%	28%	34%	13%	47%

71 , This question was only answer by participants who reported having technical problems.

In the final part of the survey, Phase 1 pilot participants were given an opportunity to describe what improvements they would like to see in their submetering service. The most common response (21%) was "None;" however, the next two most common responses were better support and communication from the IOU or MDMA and improvements in the accuracy and timeliness of billing. Together, those two response categories accounted for 32% of the total responses. Table 4-12 organizes the open ended responses into nine broad categories and shows the number of participants who mentioned each one.

Table 4-12: Suggested Improvements in Submetering Service

Responses	Frequency
None	44
Better support and communication from the IOU or MDMA	36
Improve inaccurate and delayed billing	32
Better reporting and real time usage viewing	29
Technical improvements	29
Better remote access via an app	12
Other	12
Clearer instructions regarding the program and timeline of the process	9
Ability to have continued use after pilot program is complete	7
Total	**210**

4.4 Factors Affecting Future Submetering Adoption

The conjoint survey described in Section 3.4 evaluated customer preferences for different options within six submetering plan attributes and the impact on enrollment likelihood of the various options. This section presents results based on the information collected from the survey. Customers were sampled equally from the IOUs with a goal of obtaining 200 completed surveys from each one. This approach was taken to ensure sufficient sample from each IOU to produce statistically significant results. In order to enable interpretation of average survey results as indicative of preferences for the average California PEV owner—or future PEV owners—it was necessary to weight respondents to reflect the residential customer population within each IOU. Table 4-13 summarizes the population percentages used to create the weights used throughout the analysis.

Table 4-13: Population distribution used for weights

Utility	Residential Customer Population Count[72]	Population %	Sample Size for Survey	Sample %
PG&E	4,792,227	46.1%	209	33.4%
SCE	4,333,875	41.7%	233	37.2%
SDG&E	1,251,312	12.0%	184	29.4%

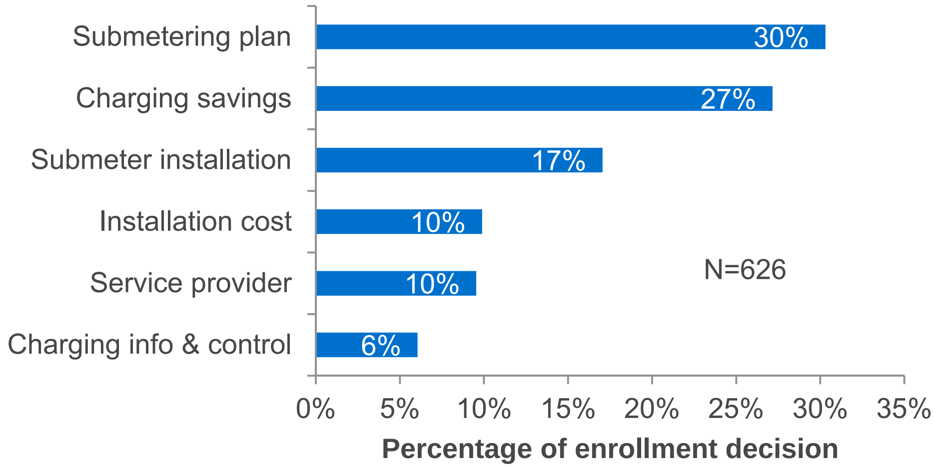
4.4.1 Relative attribute importance

The conjoint survey measured attribute importance by asking respondents to make choices between the options available for the different product attributes under study. For example, a PEV owner was asked to choose between a submetering service with a $150 installation charge offered by a utility and another submetering service offered by a third party that involved no installation cost; and vice versa. From the choices customers made, it is possible to infer how important the different attributes are in the customers' decision making process. One of the strengths of the conjoint design is that such tradeoffs elicit more differentiation in the importance of different attributes than asking respondents to directly assess importance.

Evaluating the importance of each attribute was done for individual respondents using the adaptive conjoint methodology described in Appendix C. Attribute preferences provide a measure of how much each attribute influenced respondent choices, given the levels tested in the survey. Relative importance values for each attribute sum to 100% since they represent portions of a single decision. Figure 4-11 summarizes the relative importance of each attribute in the study. Because there are six attributes, the average importance is 17%; attributes with greater importance have above average importance and vice versa. These relative importance values appear to reflect two tiers of attributes. Submetering plan—e.g., discounted rate or flat charging fee—Charging savings, and Submeter installation—e.g., plug-in, mobile, professionally installed submeter, or submeter plus Level 2 charger—form a top tier which influences 74% of the enrollment decision. Installation cost, service provider, and charging information comprise a second tier of attributes, which drive the remaining 26% of the decision. These second tier attributes do influence enrollment choices but none on its own is likely to be a key or important driver of the decision—unlike the attributes in the higher tier.

72 Source: Form EIA-861 available at https://www.eia.gov/electricity/data/eia861/

Figure 4-11: Relative Attribute Importance



When interpreting this result it is important to remember that values reflect the specific levels tested for each attribute. For example, the levels tested for Submetering Plan and Submeter Installation each included a level that was excluded from the conjoint for respondents for whom the level was determined to be infeasible based on pre-conjoint questions.[73] These levels were:

- Discounted rate plus grid services[74] submetering plan: infeasible for 36% of respondents; and
- Professionally installed submeter plus Level 2 charger at a cost of $600—incremental to a submeter installation cost of $150 to $300[75]: infeasible for 55% of respondents—43% due to already having a Level 2 charger at home and the remaining 12% after evaluating the option in the ACBC. It is possible the cost of the Level 2 charger contributed to its infeasibility for respondents.

Despite these caveats, it is still a noteworthy research finding that charging savings was not the most important attribute; it was about as important as the type of submetering plan. Also noteworthy is that submeter installation was a very important attribute responsible for 17% of the decision, but submeter cost was a less important factor that was responsible for only 10% of enrollment choice. What this shows is that monetary benefits explain only about half[76] of customer choices for submetering plans.

4.4.2 Level preferences

The attributes and levels included in the survey were carefully selected to construct an enrollment choice model that would allow for key research questions to be addressed and

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73 Utilities for these excluded levels were assumed to be below those for the remaining levels, thereby driving broader variation in level utilities and a contributing to higher relative importance

74 Excluded for respondents who stated they would not "at least consider" grid services after the concept was thoroughly described

75 Excluded for respondents who already had a level 2 charger at home

76 27% for Charging savings plus 10% for Submeter cost plus perhaps some portion of the importance of Submetering installation, though only 20% of respondents determined the level 2 charger option to be an infeasible option after being exposed to its incremental cost

the Phase 1 submetering offer to be modeled. The enrollment choice model consists of predicting the impact of different attribute levels on program enrollment for each respondent, given a program design consisting of any one level for each attribute.

The choice model was estimated using the survey data collected and allows for comparing predicted respondent preferences for different program designs. This section discusses the predicted impact on enrollment for each level as compared to a baseline level. The baseline level for each attribute is defined as the level that best describes the submetering offer in Phase 1. Table 4-14 summarizes the level definitions for the prototypical pilot design. It also summarizes two other submetering plan designs and their predicted relative impact on program enrollment as compared to the Phase 1 pilot. The design on the left denotes the least attractive offer, which shows the combined effects of switching out levels in the pilot design for levels of any attribute where a less preferred level was tested. The most attractive offer in the right column is defined in a corresponding manner and shows the combination of attributes that had the highest enrollment likelihood.

The combined impact of adjusting attributes from their levels in the pilot to the levels in the least attractive offer would be a decrease in enrollment of about 64% compared to the actual pilot enrollment rates. Similarly, the combined impact of adjusting attributes from their levels in the pilot to the levels in the most attractive offer would be an increase in enrollment of about 126%—i.e., a 2.26 fold increase compared to enrollment rates for the pilot. It is notable that there appears to be far more potential upside in enrollment than downside—an increase of 126% is greater in magnitude than a decrease of 64%, though both are substantial.

Table 4-14: Combined Enrollment Impact of Levels Tested as Compared to Phase 1 Pilot

	Least Attractive	Pilot	Most Attractive
Submetering Plan	Discounted rate + grid services	Discounted rate	Discounted rate
Charging Info & Control	Bill only	Info	Info + Control
Service Provider	Independent charging company	Independent charging company	Utility
Submeter Installation	Pro-install + Level 2 charger (+$600 submeter cost)	Pro-install	Mobile (in-car)
Installation Cost	$300	None	None
Charging savings	16%	30%	81%
Change in enrollment over Pilot	**-64%**	**0%**	**+126%**
Change in enrollment if savings stay at 30%	**-62%**	**0%**	**+81%**

The range of enrollment impacts from least attractive to most attractive represents lower and upper bounds for enrollment likelihood impacts tested in the adaptive choice model. The following sections will describe in more detail the incremental enrollment impact of each level compared to the pilot. This means that results should be interpreted as “all else equal” program designs where the only change to the pilot is a single level of interest. Some levels have relative enrollment impacts that are quite high; others have almost zero impact. However, because the choice model is a logistic model, these individual level impacts are non-additive. For example, if the impact of adjusting the pilot design by switching to another level for attribute A is an enrollment decrease of 30% and the impact of switching to another level for attribute B is an enrollment decrease of 15%, the impact of switching to those levels for attributes A and B will not be an enrollment decrease of 45%.[77]

Second, these two extremes are meant to represent extreme enrollment outcomes in a range of possible submetering design scenarios. As such the least attractive and most attractive offers are not necessarily meant to represent realistic designs, nor should they be misinterpreted as “best” or “worst.” Indeed, considerations beyond enrollment, such as cost-effectiveness may make a scenario infeasible and unattractive.

The third point to keep in mind when interpreting the results in Table 4-14, and in the following sections, is that the range of enrollment impacts is directly driven by the choice of attributes and levels tested. Many of the options tested do not yet exist and may takes month or years to develop, especially for the case of the Charging information/control and mobile submeter options in the most attractive offer. The remainder of this section discusses estimates of baseline demand for submetering among current PEV customers as well as the impacts of the monetary and experience related submetering attributes tested in the choice set on enrollment likelihood.

Baseline Demand for Submetering

One key area that is informed by the analysis of the conjoint survey is the demand for submetering in the population of existing PEV owners. Table 4-15 shows enrollment likelihoods for all combinations of the attributes tested as part of the survey. For analysis purposes, a baseline offering (shaded) was defined to resemble the submetering offer available in Phase 1 as closely as possible within the constraints of the model. This baseline is important because it serves as an anchor point to interpret the remaining results. The enrollment likelihood in each cell corresponds to a submetering offer consisting of that specific attribute level and the baseline levels for all other attributes. This allows differences between cells to be interpreted as the marginal effect of each level on the likelihood of enrollment, while holding all other attributes constant.

77 The combined effect will be less.

Table 4-15: Demand for Submetering Services in Existing PEV Customer Population

Attribute	Level	Baseline level	Enrollment Likelihood	Pref. share as % change over baseline
Submetering Plan	Flat monthly fee (charge anywhere)		30%	-26%
	Flat monthly fee (charge at home)		34%	-18%
	Electricity discount	●	41%	0%
	Electricity discount + grid services		29%	-28%
Charging Info & Control	Bill only		36%	-12%
	Info	●	41%	0%
	Info + control		46%	12%
Service Provider	Utility logo		61%	48%
	Car brand name (or logo)		49%	18%
	Independent EV charging company	●	41%	0%
Submeter Installation	Simply plug-in		50%	23%
	Mobile (in-car)		54%	32%
	Meter (pro-install)	●	41%	0%
	Meter (pro-install) + Level 2 charger [Add $600 (or $12/mo) to submeter cost]		32%	-23%
Installation Cost	None	●	41%	0%
	$150 (or $3/mo for 60 months)		27%	-34%
	$300 (or $6/mo for 60 months)		21%	-49%
Charging savings	16% (min tested)		40%	-3%
	30%	●	41%	0%
	45%		63%	54%
	60%		74%	80%
	81% (max tested)		83%	103%

Within the context of the survey, the average PEV customer would enroll in the Phase 1 submetering offer with a probability of 0.41. Put another way, 41% of current PEV customers said that they would enroll in the Phase 1 submetering offer if it was made available to them. Several caveats are necessary for this important result. The most important caveat is that the enrollment likelihood likely suffers from “hypothetical bias” that often exists with stated preference surveys. Simply put, there is often a difference between what survey respondents say they will do and what they will actually do.[78] Hypothetical bias is generally positive, meaning that survey respondents would be prone to overstate their true likelihood of enrolling in submetering. Another important caveat is that there is no guarantee that the current population of PEV owners will resemble the population of PEV owners that may exist in the future when some attributes may become available. Despite these limitations, the results in Table 4-15 illustrate that there is significant demand for submetering among current PEV owners and that there are several ways in which new offers could be made that would increase the likelihood of adoption. The effects of each attribute are discussed in the following two subsections.

Monetary Attributes

One goal of the PEV submetering pilot was to gain a better understanding of the extent to which enrollment would be changed by altering the economics of submetering plans, be it by varying achievable charging savings (up or down) or by asking participants to contribute to the cost of submeter installation (installation was largely subsidized during the Phase 1 pilot). To this aim, the choice survey included charging savings and submeter installation cost as attributes to be tested. Figure 4-12 summarizes these attributes and levels along with the modeled relative enrollment impact each level would have as compared to the levels comprising a prototypical program design similar to those offered in the Phase 1 pilot.

Figure 4-12: Relative Impact on Enrollment Compared to Pilot: Financial Attributes

Installation cost	None [pilot]		
	$150 (or $3/mo for 60 months)	-34%	
	$300 (or $6/mo for 60 months)	-49%	
Charging savings (%)	16%	-2%	
	30% [pilot]		
	45%		+54%
	60%		+80%
	81%		+103%

Intuitively, increasing submeter installation costs for participants would decrease enrollment. It is important to clarify that this attribute was conceptually designed to test participant costs and so is not meant to distinguish between hardware, installation, and any other costs. This allows for flexibility in modeling potential future submetering plans for which these costs may be partially subsidized or for which these costs may vary. All else equal, passing $150 of these installation costs to participants could reduce enrollment by over a third (36%) and passing on $300 of these costs could cut enrollment in half. Such enrollment decreases would have to be balanced against the potential benefit of reducing costs to service providers—or entities considering subsidization.

[78] See https://www.unisa.edu.au/Global/business/centres/i4c/docs/publications/hypothetical%20bias%20in%20stated%20choice%20experiments.pdf

It is important to note that the survey also controlled for underlying respondent preferences for upfront versus monthly payments, as recognition that reducing upfront costs may reduce the burden for some participants. Before the conjoint exercise, respondents were told of the possibility of installation costs and asked if they would prefer to spread the cost of the submeter over five years for a small fee. While a plurality of respondents (43%) preferred the upfront charge, about 23% preferred the monthly payment option and the remaining 34% had no preference. These preferences were significantly correlated with income level: preference for the upfront payment increased steadily and significantly across increasing income groups. Preference for the upfront payment ranged from 18% for respondents with annual incomes below $50,000 to 55% for respondents with incomes above $250,000. Throughout the conjoint, all installation costs were displayed using the respondent's preferred payment structure.[79]

The other attribute with a monetary impact on participants was the charging savings, which was tested in the conjoint as a percent savings. On every screen in the conjoint this percent savings was displayed adjacent to a respondent's specific monthly charging cost that was estimated using customer responses to survey questions prior to the conjoint exercise.[80,81] Because savings can vary widely, it is important to reemphasize that the 30% pilot baseline figure is meant to be a rough, yet reasonable approximation for average savings across participants. Ultimately, some of the most meaningful parts of the interpretation of the resulting percent enrollment impact figures are their relative values. For example, there is a nearly insignificant 2% change in enrollment between 30% savings and 16% savings but that there is a substantial 54% enrollment increase for a similar increase in percent savings from 30% to 45%. This indicates that somewhere between 30% and 45% there is a psychological threshold beyond which savings become meaningful. Increased savings beyond 45% by similar margins produces diminishing enrollment impacts.

Interestingly, percent savings is the attribute that exhibited the widest potential enrollment impacts—the only one with the capacity to more than double enrollment—though that would require substantial savings levels of over 60%. For certain segments, enrollment impacts are even more pronounced. In particular, respondents on NEM rates and SDG&E customers—which have a large degree of overlap[82]—would enroll in submetering plans at even higher rates. Respondents whose estimated monthly charging costs were above $50 were also more responsive to higher percent savings. For these customers, increasing percent savings from

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79 Payment structure was randomly assigned to respondents with no preference to avoiding biasing one way or another.

80 This estimate was based on self-reported monthly miles driven, percent of charging done at home, a marginal electricity price estimate based on each respondent's current electricity rate, and a conversion factor of miles to kWh based on the respondent's PEV category also stated earlier in the survey. To ensure the most numerically and cognitively valid estimates, respondents were given a choice of how to estimate miles driven—weekly average or age of vehicle and mileage—asked to confirm the estimate, and then finally given the opportunity to change the estimate to a manually entered value within a reasonable range. Average monthly cost was $53—a standard deviation of $49 reflects that most monthly charging cost estimates fell between $0 and $100.

81 Because the perceived and actual dollar value of a percent change in cost will vary with the basis to which the percent change is applied—e.g., monthly charging cost—this charging cost was used as a covariate when calculating utilities to ensure this variation was captured in the utilities for a different savings level.

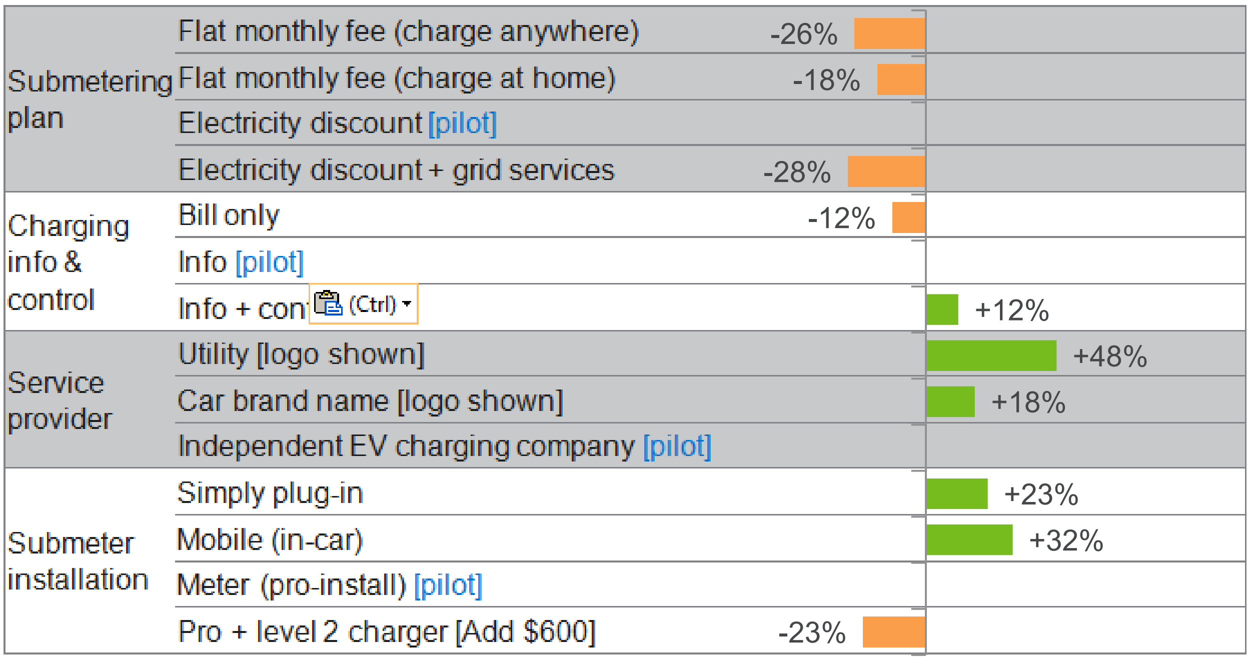
82 There is a large degree of overlap between these segments: 77% of SDG&E respondents were net metered compared to just 28% of PG&E respondents and 0% of SCE respondents.

30% to 60% could increase enrollment by 101% compared to only a 65% increase for respondents with charging cost below the $50 threshold.

Business Model and Participant Experience Attributes

Another goal of the research was to gain a better understanding of which potential future business models and features for submetering plans could increase appeal to PEV owners. To address this research question, four attributes relating to participant experience were tested—plan type, charging info & control, service provider, submetering installation. Figure 4-13 summarizes these attributes and levels along with the modeled relative enrollment impact each level would have compared to the corresponding levels of a prototypical submetering similar to Phase 1.

Figure 4-13: Relative Impact on Enrollment Compared to Phase 1: Business Model and Participant Experience Attributes



The submetering plan attribute was intended to test the openness of PEV owners to different possible submetering business models. In particular, it tested a flat monthly charging fee—which may or may not include charging on a network of public chargers for no extra cost—and a discounted rate that may or may not include a higher discount in return grid services through demand response. As described in Section 3.4.2, respondents were carefully educated on the concept of grid services before the conjoint and an option was only included for respondents who indicated they might consider it. The current submetering plan, which simply includes access to a discounted rate, was largely preferred. However, the preference against the other submetering models was small enough that it could be addressed by designing a plan with other more desirable options to counterbalance the enrollment impacts.

Such plans may also be more effective if targeted at segments more open to these new business models. One reasonable indicator of this is current rate. Customers who are not currently net metered and who are on a time-of-use (TOU) rate are far more open to a flat charging fee.[83] Similarly, PG&E respondents indicated at much higher rates than the other IOUs that they would consider a discounted rate, which required them to provide gird services—just 27% of PG&E would not consider grid services compared with 42% and 45% for SCE and SDG&E respectively. Among respondents who were open to grid services, modeled enrollment actually increased by 6% by moving to that design and holding all other attributes equal to those in the pilot.

Submeter installation was the other attribute from which a level was removed for certain respondents.[84] Once again, significant differentiation between respondents from different IOUs was evident. While only 44% of PG&E respondents and 39% of SCE respondents reported having a Level 2 charger, 75% of SDG&E respondents reported having a Level 2 charger.[85] An additional 10% each of PG&E and SCE respondents evaluated the submeter plus Level 2 charger option in the conjoint but still determined the option to be unacceptable—likely due to the $600 incremental cost.

The two other submeter installation options tested were simply plug-in and mobile submetering, which are not currently widely available. Both of these features were positively perceived by respondents and could increase enrollment by 23% and 32%, respectively. The mobile metering option was particularly popular among SDG&E respondents (+39% enrollment impact) and PG&E respondents (+35%), but was less appealing to SCE respondents (+27%). SCE respondents had no preference between the mobile metering and the simply plug-in option, as either would increase enrollment by about 27%.

Charging Information & Control and Service Provider are the two remaining participant experience related attributes. For Charging Info & Control, SDG&E respondents once again exhibited more pronounced preferences. Relative degrees of enrollment impacts appear to reflect the same ordering between IOUs as with mobile submetering—the other new, as yet undeveloped feature. That is to say, SDG&E and PG&E customers would be most swayed to enroll at higher rates (+14% each) due to additional info and control features, followed by SCE (+9%).

The three levels tested for the Service provider attribute were the respondent's IOU, the respondent's PEV manufacturer—both of which were displayed using logos—and an independent EV charging company—e.g., the vendors in the Phase 1 pilot. IOU and PEV manufacturers were preferred to independent charging companies as service providers and most respondents largely preferred a utility service provider to a PEV manufacturer. While there was a preference for the IOU or the PEV manufacturer to play the role of service provider, this was less pronounced for PG&E respondents, who had an average enrollment impact that was 10 to 15 percentage points below the impact for SCE and SDG&E respondents. The exceptions to this result were owners of high mileage EVs, nearly all of whom were Tesla

[83] 30% of NEM respondents and 28% of TOU respondents found at least one of the flat monthly fee plans to be unacceptable, compared with 18% of non-NEM and 15% of non-TOU respondents.

[84] Those who reported already having a Level 2 charger at home were not shown this option.

[85] This is likely due to past PEV pilot programs that have been conducted by SDG&E.

owners. For this group a PEV manufacturer would elicit a 42% enrollment increase compared to a 50% increase for a utility provider—both as compared to the independent charging company.

5 Conclusions and Recommendations for Phase 2

Phase 1 of the PEV Submetering pilot successfully established third party submetering service for 241 customers throughout California. The primary motivations for customers to participate in the pilot were the opportunity to pay a lower rate for electricity used by the PEV, the availability of an incentive for the PEV submeter, and the ability to monitor the amount of electricity used by PEVs. During the course of the pilot, several technical and customer service-oriented challenges were encountered by the participating MDMAs and IOUs that demonstrate areas where submetering operations and customer service can be improved in the future.

By all accounts, the enrollment process for Phase 1 was cumbersome and required a large number of manual processes and repeated customer interactions, which resulted in long processing times for CEAs and frustrations for customers, MDMAs, and IOUs alike. Only 46% of participants rated the process of signing up for the pilot as either very good or excellent. Customers often needed assistance from the MDMAs to complete the required forms, which were submitted to IOUs via email as attached PDFs and regularly needed to be sent back for revisions due to missing or incomplete information. Numerous interactions between customers, MDMAs, and IOUs were required to successfully enroll a customer and all of these interactions were initiated manually by one of the stakeholders. Streamlining the enrollment process should be a priority for Phase 2 and include efforts to improve communication between the MDMAs and IOUs regarding what is required from the customer as well as an investigation into whether infrastructure can be set up for CEAs to be completed more efficiently. This infrastructure could include the development of a website accessible by the MDMAs that creates a structured data environment for CEAs that is less prone to error than the manual process used in Phase 1.

Once customers were able to successfully enroll in the pilot, most (72%) said that they were satisfied with the overall service they received. However, 15% of participants reported being dissatisfied with their submetering service and highlighted areas where submetering operations could be improved. The primary causes of dissatisfaction were billing issues and poor customer service from the MDMA and/or IOU. Thirty percent of customers who responded to the participant survey reported experiencing a problem with their bills—delays were the most common description—and half of these customers said that their issues had not yet been resolved. When asked how to improve the pilot experience, the most common response from participants was for the IOUs/MDMAs to provide better support and communication.

The billing issues experienced by Phase 1 participants were likely a result of several different factors. First, the IOU subtractive billing processes created for the pilot existed outside the robust billing systems used for standard billing operations. Early in Phase 1, the IOUs spent significant effort educating the MDMAs about the intricacies of customer billing protocols and the data format necessary to ensure accurate billing. Submeter data from the MDMAs was transferred manually via SFTP and required cleaning and processing before being combined with interval data from the IOUs' internal systems. Due to the manual nature of these steps, errors occurred at a higher rate than normal and the amount of time required for preparing customer bills increased. To the extent that these processes can be automated, the timeliness and accuracy of subtractive billing would improve.

Another factor that has an impact on the accuracy of customer bills is the accuracy of the submeters. Analysis comparing a sample of submeters to independently installed loggers revealed that most submeters were able to accurately record PEV usage data, but that 10 to 20% likely experienced some kind of accuracy problem during Phase 1 that led to billing errors. These problems resulted from spotty data coverage, submeters going offline for a period of time, and a server software malfunction that caused time shifts in the data for some submeters. All three of these events caused delays in billing and some resulted in erroneous bills being delivered to customers. For Phase 2, Nexant recommends that additional submeter accuracy testing be conducted using a threshold of +/- 1% in order to improve billing accuracy and reduce the number of billing disputes with participants. This testing would preferably be done in a laboratory setting prior to installation to avoid the difficulties and limitations associated with measuring accuracy in the field and should include tests to ensure that submeter clocks are capable of proper time synchronization with IOU AMI systems. New metering standards and testing protocols related to submeters currently being developed by the National Institute of Standards and Technology (NIST) and the California Division of Measurement Standards may be able to be leveraged as a guide for best practices.

In addition to analyzing the processes, customer experiences, and accuracy that were specific to Phase 1, Nexant also surveyed non-submetered PEV customers to analyze customer preferences for different submetering features and identify factors that are likely to drive future uptake of submetering. This analysis showed that the type of submetering plan, magnitude of charging cost savings, and type of submeter installation—e.g., plug-in, mobile, professionally installed submeter or submeter plus Level 2 charger—are the most important factors that influence submetering adoption decisions. In the context of the survey, about 40% of survey respondents said that they would sign up for the submetering arrangement offered during Phase 1. For submetering to be attractive, a minimum amount of charging savings of 30 to 45% is needed and installation costs need to be kept low. Depending on the price differentials established for the opt-out TOU rates that will be rolled out to residential customers beginning in 2019, submetering plans with charging savings of 30-45% may be difficult to offer.

Installation cost, service provider, and charging information comprise a second tier of attributes that affect submetering adoption decisions. A mobile metering option was particularly popular among SDG&E respondents (+49% enrollment impact) and PG&E respondents (+41%), but had less of an impact on SCE respondents (+31%). While there was a preference for the utility or the PEV manufacturer to play the role of service provider, this was less pronounced for PG&E respondents than the other two IOUs. Nexant recommends offering additional submetering plans and pricing structures in Phase 2 along with exploring partnerships between MDMAs and IOUs as a way to provide more seamless service to the customer and achieve stronger brand equity.

Appendix A Question Bank and Guide for MDMA/IOU interviews

A.1 IOU Interviews

A.1.1 IOU role and responsibilities

- What changes to utility operations were required in order to carry out Phase 1 (i.e., enrolling customers in EV TOU tariffs, billing, project management, etc.?)
- How many FTE were required to support the Phase 1 Pilot?
- Briefly describe the day to day operations required to support Phase 1.
- Assuming Phase 2 proceeds as planned, how will operations have to change to accommodate more customers?

A.1.2 Costs

- What costs (operations, administrative, customer service, etc.) were experienced in providing submetering service? (Focus on categories of costs, we can ask for specific numbers via data request.)
- How would the costs of submetering scale with larger customer participation?
    - Are there any economies of scale associated with providing billing for submetering? (Another way to ask this would be to ask about the breakdown of fixed vs. variable costs for the MDMA.)

A.1.3 Pilot Enrollment

- Did customers reach out to you with questions about the pilot before enrolling? What did they ask you about and how did you respond?
- If your company was entirely responsible for getting customers enrolled in the pilot, how would they go about offering submetering as a service?

A.1.4 Relationship with MDMAs and Customers

- Describe your day to day interactions with the MDMAs (i.e., data transfer process, quality assurance, problem resolution process… common issues and resolution processes).
- Were there any issues that occurred during the pilot that required resolution of customer complaints or questions? What were they?
- What (if any) restrictions were there about how you interacted with customers during the pilot regarding submetering?
- Walk me through the process of how usage data is recorded by the submeter, transferred to the IOU, and then incorporated into a customer's bill.
    - Need details here, so don't be afraid to get into the weeds and spend some significant time.

A.1.5 Subtractive Billing Processes

- What internal preparations needed to be made in order to allow for subtractive billing?
    - What other departments of each IOU needed to be involved in these preparations?

        - Approximately how many IOU staff were involved in the pilot in any capacity?
    - What types of preparation entailed fixed costs versus variable?
- What was the most challenging aspect of the pilot from your perspective (processing enrollments, coordinating with MDMAs, developing billing procedures, etc.)?

A.1.6 Issue Resolution

- What types of customer-related issues (if any) did you run into during the pilot (enrollment, billing complaints, de-enrollment, customer education, etc.)?
    - How were the issues resolved?
    - Were there any instances in which you were contacted by customers with questions about their bills related to the submetering? If yes, please provide the details of each interaction…what the issue was and how it was resolved or not.
    - How could these issues be mitigated during Phase 2?
- What specific MDMA-related issues did you experience during the pilot? (data transfer, technology problems, etc.)
    - How were the issues resolved?
    - How could they be mitigated during Phase 2?

A.1.7 Miscellaneous

- If you already have submetered EV-TOU rates (PG&E definitely does), how have you marketed those rates to customers? Do you actively market those rates?
- Do you have the ability to disconnect electric service at the primary meter for customers receiving submetering services?
- Based on your experience in Phase 1, what minimum technical standards do you think are necessary (if any) to allow for submetering? Have them explain why not having a standard would be costly or problematic.
- What are the biggest lessons you learned from Phase 1 that can be applied to Phase 2?

A.2 MDMA Interviews

Questions	Relevant MDMAs
Costs	
What are the costs associated with providing submetering service and who (MDMA or customer) is responsible for paying each type of cost in the pilot? (Focus on categories of costs, we can ask for specific numbers via data request)	All
How many FTE were required during Phase 1? How many FTE do you expect to need for Phase 2?	All
Describe the fee structure offered to customers for the submetering service (i.e., one time installation cost, monthly flat fee, monthly fee related to usage, etc.)	All
Business Model and Processes	

Questions	Relevant MDMAs
Describe your day to day interaction with each of the IOUs during the course of the pilot? How enrollment was handled, how about data transfer, how about bill complaints?	All
What (if any) restrictions were there about how you were allowed to interact with customers as an MDMA?	All
What benefits (if any) did you emphasize in marketing materials or communications with customers? Alternatively, if you were approached by customers, what motivations did they share with you about why they were interested in submetering?	All
Did you actively market submetering services to new customers? If not, what challenges do you foresee in marketing submetering to the broader EV-owning population?	All
Describe the process involved in enrolling customers in submetering and installing their submeters	
What was the most challenging aspect of the pilot in terms of enrolling customers in EV-TOU rates?	All
What was the most challenging aspect of the pilot in terms of getting submeters installed (reaching customers, coordinating with IOUs, developing technology, etc.)?	All
Walk me through the process of how usage data is recorded by the submeter and then transferred to the utility for billing.	eMW, NRG
How often do you routinely communicate with pilot participants? Describe the content of these communications.	Ohm, eMW
What is the business case for MDMA submetering beyond the pilot? What are the revenue streams for the MDMA? What kind of customer-MDMA business models do you think could be beneficial for both parties?	All
Service and Technology Innovations	
Are you currently offering any services through the pilot other than access to submetered TOU rates for PEV charging? (Level 2 charging, access to public charging network, customer software/apps that allow for information feedback on bills/charging behavior)	All
Looking forward, do you see your company offering submetering as a stand-alone service, or as one piece of a larger, more diverse service offering (which may or may not be related only to PEVs)? What other services do you contemplate offering related to the submetering business?	All
Where do charger/submetering technology have room to grow? What are the biggest challenges with the technology?	eMW, NRG
Issue Resolution	
What types of customer-related issues (if any) did you encounter during the pilot? (enrollment, charging performance, de-enrollment, customer education, etc.) How were the issues resolved?	All
What specific IOU-related issues did you experience during the pilot? How were the issues resolved?	All

Appendix B Participant Survey Instrument

The survey instrument used to assess customer experience during Phase 1 is presented below. The survey was administered online and highlighted sections represent programming notes.

B.1 About your plug-in electric vehicle (PEV)

1. How many PEVs do you own? _______
2. Please list the make, model and year of your PEV(s) (number of rows to fill in is equal to the answer provided in Q1):

Make	Model	Year	Month and year of lease/purchase	Miles driven in a typical weekday (M-F)

3. Please describe how often you typically charge your PEV away from home (drop downs, customers can fill in up to three rows):

Days per week	Charger Type	Avg. Duration
0 days 1 day 2 days 3 days 4 days 5 days 6 days 7 days Not sure	DC Fast Charging Level 2 Charging Not sure	Less than 1 hour Between 1 and 2 hours Between 2 and 3 hours Between 3 and 4 hours More than 4 hours Not sure

B.2 About your submetering service

4. How did you learn about the PEV submetering pilot? (Check all that apply)
   - ▫ Contacted by (insert MDMA name)
   - ▫ Contacted by my utility
   - ▫ Auto dealer
   - ▫ PEV rebate website
   - ▫ Internet search. What terminologies or topics did you search for? ____________
   - ▫ A neighbor or friend
   - ▫ Electric Vehicle Group
   - ▫ Other ____

5. How important was each of the following aspects of submetering in deciding to sign up for the pilot?

	Extremely important	Somewhat important	Somewhat unimportant	Not important at all
Ability to charge my vehicle more quickly				
The cost of the vehicle charger				
Ability to pay a lower rate for electricity used by my PEV				
The monthly service charge				
The ability to control the charging station from my smart phone				
The safety and reliability of the charging station				
Ability to measure the amount of electricity my vehicle is using				
The availability of an incentive for the PEV meter				
Other (please insert)				

6.

Q6a. Which of the following best describes the price structure of electricity specifically for your PEV?

- Same price for all hours of the day
- More expensive during peak period and less expensive during off-peak period

Q6b. Which of the following best describes the price structure for electricity used for the rest of your home?

- Same price for all hours of the day
- More expensive during peak period and less expensive during off-peak period

7. When you enrolled in the PEV submetering pilot, were you aware that a time-of-use (TOU) rate for your whole house (including your PEV) was available to you from (Insert IOU Name)?
   - Yes
   - No
   - Not sure

IF Q7= "NO" OR "NOT SURE", SKIP TO Q9

8. Why did you choose submetering over a rate that applies to your whole house? (Check all that apply)
   - My bills are lower with submetering
   - Submetering was recommended to me by ______________________________
   - I received an incentive for the PEV meter
   - Other ____

9. Have you accessed any data collected by your submeter during the pilot?
   - Yes
   - No
   - Not sure

IF Q9 = "NO" OR "NOT SURE", SKIP TO Q12

10. What type of data did you access?
    - Electricity usage
    - Cost
    - Emissions
    - Other ____

11. What tools or technologies did you use to access the data?
    - Website
    - Smart phone app
    - On-board vehicle display
    - Other ____

B.3 Customer Service

12. How would you rate your overall satisfaction with your submetering service?
    - Extremely satisfied
    - Somewhat satisfied
    - Neither satisfied nor dissatisfied
    - Somewhat dissatisfied
    - Extremely dissatisfied

IF Q12 = "NEITHER SATISFIED NOR DISSATISFIED", SKIP TO Q15

IF Q12= "EXTREMELY SATISFIED" OR "SOMEWHAT SATISFIED", SKIP TO Q14

13. Please explain your dissatisfaction with your submetering service briefly below.

SKIP TO Q15

14. Please explain your satisfaction with your submetering service briefly below.

15. Please rate the following aspects of your submetering service.

	Excellent	Very good	Good	Fair	Poor	No experience
Scheduling the installation of the meter or charging station						
The installation appointment						
Signing up for the PEV rate with (insert IOU name)						
Accuracy of the PEV portion of your bill						
Customer service provided by (insert IOU name) after PEV rate started						
Customer service provided by (insert MDMA name) after the meter or charging station was installed						
Safety of my charging station						
Accuracy of the measurement of electricity used by my PEV						
Reliability of my charging station						
Ability to control my charging station remotely						
Access to information about whether and when my vehicle is charging remotely						

16. Have you experienced any technical problems with your charging station?
    - ▫ Yes
    - ▫ No
    - ▫ Not sure

If Q16 = "NO" OR "NOT SURE", SKIP TO Q19

17. Please describe the technical problem(s) you experienced below:

18. How satisfied were you with the resolution of the technical problem(s)?
    - ▫ Extremely satisfied
    - ▫ Somewhat satisfied
    - ▫ Neither satisfied nor dissatisfied
    - ▫ Somewhat dissatisfied
    - ▫ Extremely dissatisfied
    - ▫ The problem(s) is/are still unresolved

19. Have you experienced any billing problems associated with your submetering service?
    - ▫ Yes
    - ▫ No
    - ▫ Not sure

IF Q19 "NO" OR "NOT SURE", SKIP TO Q22

20. Please describe the billing problem(s) you experienced below:

21. How satisfied were you with the resolution of the billing problem(s)?
    - ▫ Extremely Satisfied
    - ▫ Somewhat satisfied
    - ▫ Neither satisfied nor dissatisfied

- Somewhat dissatisfied
- Extremely dissatisfied
- The problem(s) is/are still unresolved

22. Do you use a timer to control when your PEV charges?
    - Yes, always
    - Yes, most of the time
    - Yes, but not very often
    - No, never

23. What improvements would you like to see in your submetering service?

24. Would you participate in another pilot related to PEVs?
    - Yes
    - No
    - Not sure

25. Would you be interested in participating in a second phase of the current pilot where you would receive a bill for your EV charging from (Insert MDMA Name)?
    - Yes
    - No
    - Not sure

End of Survey Recruitment for logger installations:

Proposed Wording:

There may be additional opportunity for you to participate in a $150 paid study. If such an opportunity were to become available, a Nexant staff member will contact you to schedule an appointment so that an engineer can visit your home to install a data logging device near your submeter. The appointment will take about 45 minutes and you will receive a $100 Visa Gift Card. About two months later, the engineer will return to retrieve the device. At that time, you will receive a $50 Visa gift card. The second appointment usually takes less than 45 minutes.

If such an opportunity were to become available, would you like a Nexant staff member to contact you?

- Yes, OK to contact me. – Name: _____________ Phone: ______________
- No thanks, I'm not interested

Appendix C Adaptive Choice Survey Methodology

A choice based survey measures the impact of different variables, or attributes, on respondent preferences. In the research design, the product or program being tested is decomposed into a set of attributes, each of which has different mutually exclusive options or levels. As an example, color may be an attribute and the levels could be red, yellow, or green. A product or program design, or concept, is composed of one level option of each defined attribute. A respondent is asked to evaluate each concept,[86] revealing preferences for each attribute level. In classic discrete choice modeling (DCM) conjoint design simply includes a series of choice tasks, asking the respondent to choose a preferred concept from a choice set. The choice sets presented include concepts evenly balanced across each attribute level. For example, if an attribute has three levels, each level will be presented in one third of the concepts. Regression analysis can then be used to determine the incremental impact of each attribute and level on each respondent's tendency to prefer one design over another.

The choice based surveying methodology used for this study was Adaptive Choice-Based Conjoint (ACBC). ACBC is a methodology well vetted in the field of decision science in use since the mid-2000s. As its name indicates, ACBC is adaptive in nature. Core to the ACBC methodology is the tailoring of choice sets to each respondent's underlying preferences. This means that a respondent is only evaluating concepts that are personally relevant. While this means that some levels are shown more often than others, those that are shown are more relevant to the respondent, enabling more choice data to be collected on those levels that have a greater impact on respondent preferences.

The ACBC methodology includes four tasks that serve to tailor the conjoint exercise to each respondent's relevant consideration set. These four tasks are:

- **The "Build-Your-Own" task**: Respondents select their preferred level for each (pre-selected) attribute to design their own preferred submetering offer;
- **The screening task**: Respondents are shown several program offers that are similar to but different than their preferred offer and asked to indicate which offers they might consider (the "consideration set"). This screens out program characteristics that are unacceptable and identifies characteristics that are requirements for adoption of the program in the eyes of individual respondents;
- **The choice task or tournament task**: Respondents are shown a series of screens with a set of program offers, similar to DCM choice tasks. The offers shown are those that were classified as acceptable possibilities in the screening task. On each screen respondents must choose the preferred offer from these possibilities. Differences between offers are visually highlighted to help the respondent focus on the differences when choosing between offers; and
- **The calibration task**: Respondents are shown and asked to rate their adoption likelihood for the offer they selected in the "Build-Your-Own" task, for an unacceptable offer, and for the offer they preferred among all those shown in the choice task. This helps identify the intensity of preferences between acceptable and unacceptable offers.

[86] Depending on the methodology, a respondent can be asked to evaluate designs in a variety of ways, including indicating a preferred design among a set of designs, indicating a relative preference using a scale, etc.

The first benefit of this adaptive design is a technical one. Creating a design that is focused on relevant parameters means preference data can be collected for more attributes across a smaller sample (or alternatively, fewer choice sets) than is necessary for DCM.[87] Design efficiency is greatly improved with ACBC because the choice sets are dynamically adapted to include concepts that are ever more similar and relevant to the respondent, honing in on and testing relative respondent preferences. The second benefit of an adaptive design is behavioral. Enabling the respondent to focus on a more relevant, tailored choice set also eases the cognitive task of evaluating different concepts—both by reducing the quantity of choice sets as well as by better engaging the respondent.

C.1 Conjoint design

A conjoint design is defined by the product or program attributes to be tested and the potential levels, or options, for each attribute. The PEV submetering ACBC design consisted of the six attributes[88] summarized in Table C-1. The attribute description column shows the definitions that were provided for respondents during the education section of the survey before the ACBC. These attributes were carefully selected to ensure that the design addressed key research questions, covering the research topics of submetering business model, additional services, submeter installation and cost, and charging savings.

Table C-1: Conjoint Design Parameters

Attribute	Attribute Description (provided during the education section)
Submetering plan	A submetering plan could be structured in different ways that would give you access to different benefits (electricity discount vs flat monthly fee).
Charging info & control	Because the submeter collects your charging information, a submetering plan could also provide you with information about your charging habits and allow you to program or otherwise control your charging.
Service provider	Submetering could be provided by your utility, your EV manufacturer, or an independent company.
Submeter installation	In order to qualify for a submetering plan you would need to have a submeter installed to measure the electricity used by your EV. A submeter could be installed in a few ways and may or may not require installation by a qualified contractor.
Installation cost	A submetering plan might include an installation charge between $150 and $300.[89]
Charging savings	Percent of your monthly charging cost[90]

87 See http://www.sawtoothsoftware.com/support/technical-papers/adaptive-cbc-papers/cbc-vs-acbc-comparing-results-with-real-product-selection-2009, which compares sampling requirements for CBC versus adaptive CBC (ACBC) and concludes that the adaptive nature of ACBC leads to the sample size needs being as much as 30% lower for ACBC. Therefore if a 500 sample is needed for CBC a 350 sample could be sufficient for ACBC.

88 Technically speaking, compensation was tested as two attributes: compensation type and compensation amount. In the pre-conjoint importance rating questions only the former was evaluated.

89 This was followed by a question assessing preference for upfront versus monthly payment.

Table C-2 summarizes the levels tested for each attribute. A complete definition of each level was provided to respondents throughout the conjoint exercise via hover text.[91] Note that charging savings—communicated as a percent of the respondent's estimated monthly charging cost—was not tested with discrete levels during most of the adaptive conjoint exercise. Instead, the adaptive design allowed for testing a range of feasible charging savings. The one exception to this was the "Build-Your-Own" task in which respondents were asked to select from attribute levels to design their preferred option. In this task the savings levels in brackets below were associated with each plan type, reflecting that different plan options might be able to offer differing levels of charging savings. It is important to note that while not all customers who enroll in a submetering rate will experience such savings, this feasible range was intended to represent average savings and a broad range was test to enable assessment of a broad range of potential future savings. This approach was taken in lieu of testing specific rate design components—e.g., peak hours, off-peak discount—which might drive savings to allow for more flexibility in assessing the impact on enrollment and to ensure the applicability of research findings to a future state when there is uncertainty around the specific design of default residential rates—or typical rates used by PEV owners.

Table C-2: Conjoint attributes and levels

Attributes	Levels
Submetering plan	Flat monthly fee (charge anywhere) [25% savings]
	Flat monthly fee (charge at home) [35% savings]
	Electricity discount [45% savings]
	Electricity discount + grid services [60% savings]
Charging Info & Control	Bill only
	Info
	Info + control
Service provider	Utility [logo used]
	Car brand name [logo used]
	Independent EV charging company
Submeter installation	Simply plug-in
	Mobile (in-car)
	Meter (pro-install)
	Meter (pro-install) + Level 2 charger (Additional installation cost of $600 or $12/mo for 60 months)
Installation cost	None

[90] Tailored cost estimate piped in for each respondent.

[91] visible by hovering one's mouse over the level names

Attributes	Levels
	$150 (or $3/mo for 60 months)
	$300 (or $6/mo for 60 months)
Charging savings	Continuous between 16% and 81%

C.2 Adaptive Conjoint Analysis

The choice data collected with a choice based conjoint exercise is simply the composition of each set of concepts shown to each respondent and the choices the respondent made given those concepts. Data collected with an ACBC also includes the following selections made during the course of the survey:

- The composition of the concept designed by the respondent in the "Build-Your-Own" task;
- Any attribute levels denoted to be "Must-have" or "Unacceptable" during the screening task;
- The composition of the concept ("winning concept") that was most preferred during the tournament task; and
- Stated enrollment likelihood for four concepts: the BYO concept, the winning concept, and two other concepts from the screening task—an offer denoted to not be a possibly and an offer denoted to be a possibility.

While all of these data points may be of interest on their own, their primary use is to develop a choice model for each respondent.[92] A choice model includes an estimated impact for each parameter (each level of each attribute) on the likelihood to choose a particular concept design over alternatives. In the context of the PEV submetering survey, a choice model was used to estimate a respondent's preference for a particular submetering plan design concept. Using a choice model it is possible to model a respondent's relative preference, or preference share, between concept alternatives and the option to not select any concept (the "none" option). Preference shares across all modeled alternatives add up to 100% and represent the likelihood with which a respondent will prefer (or select in the survey) each option relative to the others.

It is important to note that preference share is not the same as enrollment likelihood because in a simulated survey setting there is a tendency to overstate the likelihood of actually selecting a concept. To make preference share more reflective of real world choices, it is often tied to actual observed data. Alternatively, preference shares can be compared on a relative basis and differences can be interpreted as relative changes in enrollment likelihood or relative enrollment impact. Either method usually consists of establishing a baseline concept. For the PEV submetering study, this would be the submetering plan design most typical among plans offered in the field pilot. Once a baseline is established, preference share for the baseline can be compared to preference share for other modeled concepts.

[92] The exception to this is the "Must-have" or "Unacceptable" data, which is used dynamically during the survey to design more relevant choice sets.

Fundamentally, a choice model is constructed using logistic regression analysis. For an aggregate choice model, it is common to use a multinomial logit function (or similar model) to determine the average impact of each parameter on the decision to choose a concept. This would produce the average impact across respondents. However, different classes of respondents and even different individual respondents may have very different choice models from the average. That is to say that an individual's preferences may be very different than the average preference across respondents. Because of this, using an aggregate model to predict preferences for a set of individuals will introduce error to the extent that each individual's preferences differ substantially from the average.

An alternative is to produce a choice model which captures individual differences, resulting in a separate set of parameter impacts for each respondent. This method, called Hierarchical Bayes (HB), makes the critical assumption that each respondent's preferences for a given parameter come from a distribution of the overall population's preference for that parameter—or attribute level. By making this assumption, the estimation method can link all respondent's preferences for a particular attribute together and provide respondent-level impact estimates that are derived in part from population-level estimates—also called utility values as they represent the value a respondent accords to a parameter. This results in more precise estimates of each respondent's utility values.[93]

The adaptive software used to implement the ACBC[94] study has built in HB estimation capabilities[95] and was used to produce parameter estimates. The output of the HB estimation is a set of utility estimates for each respondent for each attribute level and for the "none" option.[96] The units of these utility estimates are log odds ratios and their values represent the contribution a particular attribute level has towards the total utility of a given concept. As mentioned earlier, a concept is composed of one level for each attribute and the total utility for a concept is the sum of the utilities for the relevant level of each attribute.

To calculate the preference share for a given concept, the total utility for the concept is exponentiated—because it represents the log of an odds ratio—and compared to the odds ratio of other alternatives. These alternatives usually include the "none" option, may also include other concepts, and in general should be a reasonable representation of the real world choice that is being modeled. For example, in a consumer product situation there may be a choice between two well-known brands, a generic brand, (each with specific parameters) and "none." For a customer option such as a submetering plan the only real choice with which a customer may be faced is whether or not to participate, given a single program option—as opposed to

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93 Note that the HB modeling assumes that respondent parameter preferences are related and normally distributed. Because, of this respondent level models are different but related, rather than completely separate and unrelated.

94 The software used was the ACBC module from Sawtooth Software, the industry standard for adaptive conjoint studies. Sawtooth Software has many modules and is widely used for surveying.

95 For more technical background see https://www.sawtoothsoftware.com/download/techpap/hbtech.pdf

96 The "none" option represents a respondent's tendency to choose nothing among a set of concepts. A key input to the estimation of this parameter is the respondent's tendency to indicate that concepts are not a possibility in the screening task. The estimation is further refined using the respondent's stated enrollment likelihoods given during the calibration task.

whether or not to participate given multiple plan options[97]. In this case, only the preference shares for two options would be modeled: the choice to enroll in the program and the choice to not enroll in the program.

Equation 1 and Table C-3 detail how preference share would be calculated for the dual-alternative scenario described above. This equation could be extended to multiple options in two ways. In a pure preference share method, exponentiated utilities for other alternatives would simply be added to the denominator. This represents the respondent's preference for one alternative, given a set of alternatives. The disadvantage of this method is that the preference share for a given concept is dependent upon the number of concepts modeled, since adding additional concepts to the denominator reduces the relative value of the preferred concept.

Equation 1: Calculation of Preference Share for a Concept

$$\text{Preference share}_{(\text{concept}|\text{none})} = \frac{e^{U_{\text{concept}}}}{e^{U_{\text{concept}}} + e^{U_{\text{none}}}}$$

$$\text{Where } e^{U_{\text{concept}}} = \textstyle\sum_1^n U_{A_{i,l}}$$

Table C-3: Definition of Variables for Calculation of Preference Share

Variable	Definition
U	Utility value
U_{concept}	Total utility of the concept
U_{none}	Utility of the "none" option
$A_{i,l}$	Level of the i^{th} attribute in the concept
n	Number of attributes

In the second method, a two-step decision process is modeled. Initially, the concept with the highest utility is selected among all modeled alternatives—not including the "none" option. This represents the respondent's preferred concept. Then, the preference share is calculated for the preferred concept given the "none" alternative. This represents the respondent's likelihood of actually selecting that concept over selecting nothing at all and means that a preferred concept will always have the same preference share, regardless of the number of inferior alternative concepts also being modeled. In practical terms, this method assumes a two-step choice process starting with the identification of a preferred concept, followed by a final decision on whether to choose that concept or nothing at all.[98]

[97] Though this may also be a plausible scenario

[98] The two options described for calculating utilities are applicable only when modeling two or more submetering offers that are available side-by-side. Nexant created a simulator tool as a supplement to this report that includes such scenarios and uses the two-step approach to calculate utilities.

C.3 Assessing Statistical Significance of Adaptive Conjoint Analysis

The simplest type of regression analysis, an ordinary least-squares (OLS) linear regression, has straightforward and relatively well known measured of statistical significance, namely:

- **P-values for each parameter estimate:**[99] the probability that an estimate is different from zero only due to random chance. One minus this number is the "confidence level" of the estimate and a commonly accepted confidence level is 95%, the confidence level is a gradient and a 94% confidence level is still indicative of reasonable confidence in an estimate.

- **R-squared for the model**: the percentage of observed variation that is explained by the model. Adjusted r-squared, a similar statistic, also adjusts for degrees of freedom (including the number of model parameters).[100] There is no commonly accepted significance cutoff for interpreting R-squared or adjusted R-squared, and the interpretation depends on the amount of inherent variance in the variable being modeled. A value below 25% is considered small (though not necessarily indicative of an invalid model) and a value of 50% can actually be indicative of statistically valid predictive power in many situations.

Because of the complexity of a logistic regression, such as a choice model, the assessment of statistical significance or model accuracy is not as straightforward as it is with linear models. That said, several measures can be used in the design and analysis process to ensure a model has statistically valid and significant predictive power.

- **Standard error of parameter estimates**: While the HB estimation method has the advantage over aggregate logistic regression analysis of including individual level variation, logistic regression does have a useful purpose. In particular, an aggregate model can be used to produce standard errors for parameter estimates. This is particularly useful in the research design phase to ensure that the sample size and number of parameters planned should produce statistically significant results. This analysis is done by running an aggregate model (such as an aggregate logit model) on randomly generated data.[101] Since the data is randomly generated parameter estimates are not expected to be different from zero.[102] In other words the choice impact of two alternatives should be no different than random chance (or a 1:1 ratio). While there is no commonly accepted cutoff for standard error values in this context, 0.05 is an empirical target value recommended by the creators of the ACBC software[103] though levels below 0.10 are still deemed acceptable. The technical interpretation of a 0.05 standard error

99 Derived by plotting the ratio of an estimate and its standard error on a normal distribution

100 $R^2 = 1 - \frac{SS_{residual}}{SS_{total}}$, where SS is the sum of squares of the difference between estimates and observations.

$Adjusted\ R^2 = 1 - \frac{(1-R^2)(N-1)}{N-p-1}$, where R^2 is the non-adjusted R^2, p is the number of parameters, and N is the sample size

101 While it is also possibly to use an aggregate model to estimate parameters using actual data once it is collected, such estimates will necessarily differ from HB estimation results, due to the fundamental differences in the two models. Therefore it is not recommended to interpret the values of such aggregate estimates other than to confirm that standard errors are still small.

102 and therefore a p-value interpretation cannot be used since it a test for whether a value is significantly different from zero

103 According to Sawtooth Software, which has observed hundreds of studies, models with parameter estimates at or near 0.05 tend to be more stable and have better predictive power, based on external validation

from randomly generated data is that it represents a variation of +/- 2.5%[104], well in the range of statistically significant validity. A parameter estimate standard error of 0.05 on actual (not randomly generated data) would represent an even lower variation.

- **Root likelihood error**: The error used to evaluate the precision of a choice model for an individual respondent is called root likelihood (RLH) error[105] and represents the accuracy of an individual respondent's choice model in predicting the actual choices that respondent made in the choice exercise. This statistic must be interpreted in the context of the choice task structure. For example, if three alternatives were presented in each choice task, a random chance model would have correctly predict choice about one third of the time, or an RLH value of 0.33. If a choice model has an RLH value of, say 0.67 (correctly predicting choice two thirds of the time) it can be said to be twice as accurate as a random chance model.
- **Percent certainty:**[106] Percent certainty represents the percent of variability in actual choices that is explained by a logistic model. This makes it similar in interpretation to an adjusted R-squared statistic for OLS regressions, with the important distinction that values are typically lower than for R-squared or adjusted R-squared. While there is no commonly accepted threshold for statistical significance, values from 0.2 to 0.4 (or 20% to 40% certainty) represent "excellent model fit" according to the creator of the statistic.[107]
- **Standard error of preference share estimates**: The above three statistics assess either aggregate estimates for parameter utilities (as with aggregate logit standard errors) or predictive power of the model on a whole but not of individual utility estimates (RLH and Percent Certainty). An option for assessing the statistical validity of utility estimates derived using HB estimation is estimating the standard error of preference share[108] estimated across respondents. This provides an assessment of the variation in

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104 In log odds ratio terms, the preference share for a parameter when comparing two alternatives with equal probabilities (e.g. a 1:1 odds ratio, or what would occur with randomly generated data) is $\frac{e^{\log(\frac{1}{1})}}{e^{\log(\frac{1}{1})}+e^{\log(\frac{1}{1})}} = 50\%$, if the error an estimate is 0.05, the preference share is $\frac{e^{\log(\frac{1}{1})+0.05}}{e^{\log(\frac{1}{1})+0.05}+e^{\log(\frac{1}{1})}} = 51.25\%$. This represents a variation of 2.5% because $\frac{51.25\%-50\%}{50\%} = 2.5\%$. A parameter estimate standard error of 0.05 on actual (not randomly generated data) would represent an even lower variation. For example, for a log odds ratio of 2:1, the variation would be 1.0% because the estimate with no error would be $\frac{e^{\log(\frac{2}{1})}}{e^{\log(\frac{2}{1})}+e^{\log(\frac{1}{2})}} = 80\%$, the estimate with error would be $\frac{e^{\log(\frac{2}{1})+0.05}}{e^{\log(\frac{2}{1})+0.05}+e^{\log(\frac{1}{2})}} = 80.8\%$, and $\frac{80.8\%-80\%}{80\%} = 1.0\%$.

105 Root likelihood error is the geometric mean of the probabilities corresponding to the choices made by respondents, obtained by taking the Nk^{th} root of the product of the Nk probabilities. The best possible value of RLH is unity, achieved only if the computed solution correctly accounts for all the choices made in all tasks by all respondents.

106 Also called rho-squared or McFadden's pseudo R-squared. "Conditional logit analysis of qualitative choice behavior." McFadden. 1974.

107 Urban Travel Demand: A Behavioral Analysis. Domencich and McFadden. 1975. Reference to rho-squared appears in Chapter 5, Pages 122 onwards.

108 The preference share for a given concept is the output for which a choice model is designed. Therefore, it is most intuitive and accurate to interpret utility estimates through the preference share transformation, rather than directly. In addition, utility estimates for each attribute are designed to be used together in the full choice model. Analyzing a utility estimate separately from the full choice model will overstate the importance of or variation in that estimate. For example, to understand the importance of, say the first level of an attribute in a three attribute choice model, it is not entirely correct to simply analyze that level against the none option or against the other levels of that attribute. Instead, it is more appropriate to compare two concepts which include one level for each of the three attributes and between which the only difference is that one includes the first level of the first attribute and that the other includes, say the second level. This would be a more correct comparison of the relative preference for levels one and two of the first attribute.

preference share across respondents for given a concept specification. An intuitive way to conduct this analysis is to model preference share for the baseline (current state) concept against which all other concepts will be measured. Then the error across this preference share estimate for each respondent can be calculated.

All four of these methods were used when designing and analyzing the PEV Submetering ACBC study. The choice model (consisting of the attributes and levels tested) was designed to ensure statistical validity and predictive power of the model and analysis of the data collected also indicated that the choice model has strong predictive power as a whole, for individual parameter estimates, and for the three primary test cells—PG&E, SCE, SDG&E.

Table C-4 summarizes the results for each type of analysis described above. From the outset, the choice model was designed to ensure robust statistical significance—standard errors of all parameter estimates were below 0.10 and all but one were either at or near 0.05. Estimates within test cell subsets of the total sample were also statistically significant, even for smaller test cells with sample sizes close to 200. Measures of overall model predictive power (RLH and percent certainty) indicated that the choice model had excellent predictive power.

Table C-4: Results of Tests of Statistical Validity and Predictive Power for Choice Model

Statistic	Result	Interpretation
Standard error of aggregate logit utility estimates using random response data	Error estimates using 200 randomly generated responses were all under 0.10 (and for all levels but Charging Savings were between 0.040 and 0.069. For Charging Savings standard error was 0.098)	Less than 5% variation in aggregate parameter estimates using random data simulated to represent individual segments
Average root likelihood error of HB estimation	0.751	Choice model is more than twice as accurate as a random guess
Percent certainty	64% certainty	Excellent choice model fit
Standard error of preference shares across respondents	1.0% to 1.8% error for preference shares ranging from 36% to 88%	Vary little variation in parameter estimates. Implies a low p-value (below 0.01) and high statistical significance.