Pacific Gas and Electric Company

EPIC Final Report

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Project	*EPIC 1.22 – Demonstrate Subtractive Billing With Submetering for EVs to Increase Customer Billing Flexibility*
Reference Name	***EPIC 1.22 EV Submetering*** ***EPIC 1.22 Plug-In Electric Vehicle Submetering Pilot (PEVSP)***
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A.	Application
ANSI	American National Standards Institute
CEA	Customer enrollmet agreement
CPUC	California Public Utilities Commission
D.	Decision
DER	Distributed Energy Resource
EPIC	Electric Program Investment Charge
EV	Electric Vehicle
EVSE	Electric Vehicle Service Equipment (charging station)
GHG	Greenhouse Gas
IOU	Investor-Owned Utility
MCOR	Multiple Customer of Record
MDMA	Meter Data Management Agent
MDMS	Meter Data Management System
NEM	Net Energy Metering
PF	Power Factor
PEV	Plug-In Electric Vehicle
PEVSP	Plug-In Electric Vehicle Submetering Pilot
PG&E	Pacific Gas and Electric Company
SCE	Southern California Edison Company
SCOR	Single Customer of Record
SDG&E	San Diego Gas & Electric Company
TD&D	Technology Demonstration and Deployment
TOU	Time-of-Use

1 Executive Summary

This report documents the achievements, highlights, and key learnings of EPIC 1.22 – *Demonstrate Subtractive Billing with Submetering for EVs to Increase Customer Billing Flexibility* as reported in the EPIC Annual Report, also referred to as EPIC 1.22 –EV Submetering or Plug-In Electric Vehicle Submetering Pilot (PEVSP).

Enabling submetering for EVs is an approach to separately meter EV charging load with the goal of saving EV owners money on charging costs while better aligning EV charging with periods of low electricity demand. The technology examined in this report is focused on light-duty passenger vehicles, however, submetering can be applied to other vehicle types and potentially other Distributed Energy Resources (DER).

Subtractive billing paired with submetering utilizes charging data from submeters, embedded in or associated with EV charging stations, and subtracts it from a customer's standard utility bill. Submeters are electronic systems that measure the amount of electricity flowing to a device, which in this case is an EV charging station. This system allows utilities to offer a customer one electric rate for their EV charging, and a different rate for their primary source of load. A more detailed description of subtractive billing is provided in Section 4.1 and in Figure 4-1.

1.1 Issues Addressed

EPIC 1.22 aimed to address the following issues:

- First, most charging locations do not yet have utility revenue-grade submeters installed to collect charging data;
- Second, Investor-Owned Utilities (IOU) do not have the capability to receive third-party submetered data and automatically subtract it from a customer's bill; and
- Third, the strengths and weaknesses of submetering as an approach to EV charging are not well understood.

1.2 Key Objectives

The primary objective of EPIC 1.22 was to demonstrate the use of EV submetering within an Electric Vehicle Service Equipment (EVSE) to provide EV owners access to electricity at a less expensive electric rate—without having to install an additional utility meter to an existing service. In addition, EPIC 1.22 assesses the EV customer demand and benefits of a Plug-In Electric Vehicle (PEV) submetering arrangement, as well as evaluates billing integration costs to enable EV submetering at scale.

1.3 Project Activities, Results and Findings

This report provides details on the methods, findings and lessons learned from five tasks associated with the project:

- Task 1: Identify Service Offerings and Business Processes for participating utilities and the MDMAs and document the data flows involved with submetering (Section 4.1);

- Task 2: Assess Submeter Accuracy by analyzing the electrical accuracy of submeters in the field and via a laboratory study (Section 4.2);
- Task 3: Analyze the Customer Experience via a set of surveys (Section 4.3);
- Task 4: Assess Customer Billing Issues (Section 4.4); and
- Task 5: Estimate the Cost Savings of Submetering (Section 4.5).

1.4 Key Findings and Lessons Learned

The key findings from this project, which draw on studies conducted as part of the California Statewide PEV Submetering Pilot,[1] are as follows:

- Adding equipment from third-party vendors, and creating a more complex data flow path that involves MDMAs, increases the number of failure points and increases likelihood that billing data will be delayed or inaccurate, which also leads to customer dissatisfaction.
- A more reliable network than residential Wi-Fi should be utilized for billing-quality data.
- At least three major categories of accuracy problems were found:
    - **Time Shifting Issues**, which occurred when the timing of a submeter's charging information did not match the timing of the logger or the whole-house bill.
    - **Recording Issues**, which occurred when a submeter did not record an instance of charging.
    - **Magnitude Issues**, which occurred when the magnitude of the charging load recorded by the submeter did not match the magnitude of the charging load recorded by the logger.
- Once customers signed up for the submetering pilot, there was broad satisfaction with the service (see Section 4.3.2), however, this was undercut by the 10% of participants who dropped out before the end of the pilot, usually due to inaccurate or delayed bills, or due to a lack of savings on their electricity bill.
- A survey of EV owners who were not part of the pilot (see Section 4.3.4), conducted in 2016, found that there is strong interest in the concept of submetering if participants could save at least 30% on EV charging costs. The same study also showed that EV owners were far more likely to trust their utility as a provider of charging services as compared to an independent vendor.

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[1] For more information, please see Section 2.2 of this report and the California Public Utilities Commission (CPUC) webpage on Plug-In Electric Vehicle (PEV) Submetering: http://www.cpuc.ca.gov/general.aspx?id=5938.

- A survey of customers with billing issues (see Section 4.3.3), found that 38% of those who complained to PG&E did so because of problems with billing data provided by the MDMAs. An additional 18% of customers in the pilot were frustrated by conflicts between the submetering pilot and other demand response programs that they participate in. Inquiries to other utilities[2] participating in the pilot were driven by confusion over customer enrollment status and by delayed bills caused by unreliable MDMA data transfer to the utilities.
- A study of cost savings performed by an independent evaluation firm as part of the California Statewide PEV Submetering Pilot found that installing a charging station with a submeter saved customers $374 over installing a second utility-grade meter. The major costs for installing a Level 2 charger are the service panel and related wiring and vary greatly by location.
- A study of cost savings performed by an independent evaluation firm as part of the California Statewide PEV Submetering Pilot found that a customer could save $319 per year relative to the tiered rate by enrolling on a whole-house rate for PEV charging without investing in any type of separate metering. $58.79 is the incremental annual savings associated with the separate meter enabled rate. While the results above may represent the average customer in SCE's moderate climate region, they are not specific to PEV owners, who may have different energy use patterns.
- Based on preliminary estimates from the three participating IOUs, the utilities would each have to invest $3,000,000 to $5,000,000 to modify their customer billing systems to integrate submetering data from third-party vendors and generate a subtractive bill for EV charging.
- The approach to subtractive billing tested in this pilot is not yet ready to serve millions of customers across the state of California, given the data accuracy and billing issues experienced.

1.5 Conclusion

In summary, the results of EPIC 1.22 have led PG&E to determine that third-party submeters cannot provide the reliability and data accuracy required for retail billing, and that there is currently no path to production for such a use. This determination is based on the empirical assessment summarized in this report:

- Charging stations with submeters were not sufficiently accurate as demonstrated by both in-field data and independent lab tests.
- The MDMAs were unable to reliably receive data from the EVSE and were unable to transfer billing data to the IOUs in a timely or accurate manner. A more reliable network than residential Wi-Fi should be utilized to transmit charging data. In addition, MDMAs need to

[2] The three utilities who participated in the California Statewide PEV Submetering Pilot were PG&E, SCE, and SDG&E.

demonstrate their ability to reliably manage usage and billing data before this approach can be scaled to serve the state of California.

- The customer benefits in terms of saving on charging equipment are modest when compared to installing a separate utility grade meter and the upgrades required to accommodate third-party submeter data. For many customers, a whole-house TOU electric rate is likely sufficient to produce bill savings, independent of any submetering.

2 Introduction

This report documents the achievements, highlights, and key learnings of EPIC 1.22 – *Demonstrate Subtractive Billing with Submetering for EVs to Increase Customer Billing Flexibility*. This project is also referenced as the Plug-In Electric Vehicle Submetering Pilot (PEVSP) and hereafter as EPIC 1.22 – EV Submetering.

2.1 EPIC Program Regulatory Background

The CPUC passed two decisions that established the basis for the EPIC Program. The CPUC initially issued Decision (D.) 11-12-035, *Decision Establishing Interim Research, Development and Demonstrations and Renewables Program Funding Level,*[3] which established the Electric Program Investment Charge (EPIC) on December 15, 2011. Then, on May 24, 2012, the CPUC issued D.12-05-037, *Phase 2 Decision Establishing Purposes and Governance for Electric Program Investment Charge and Establishing Funding Collections for 2013-2020,*[4] which authorized funding in the areas of applied research and development, Technology Demonstration and Deployment (TD&D), and market facilitation. The CPUC defined TD&D as "the installation and operation of pre-commercial technologies or strategies at a scale sufficiently large and in conditions sufficiently reflective of anticipated actual operating environments to enable appraisal of the operational and performance characteristics and the financial risks associated with a given technology."[5]

The decision also required the EPIC Program Administrators[6] to submit Triennial Investment Plans to cover three-year funding cycles for 2012-2014, 2015-2017, and 2018-2020. On November 1, 2012, in Application (A.) 12-11-003, PG&E filed its first triennial EPIC Application, requesting $49,328,000 including funding for 26 Technology Demonstration and Deployment Projects. On November 14, 2013, in D.13-11-025, the CPUC approved PG&E's EPIC plan, including $49,328,000 for this program category. On May 1, 2014, PG&E filed its second triennial plan for the period of 2015-2017 in EPIC 2 Application (A.14-05-003). CPUC approved this plan in D.15-04-020 on April 15, 2015, including $51,080,200 for 31 TD&D projects.[7]

[3] http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/156050.PDF.

[4] http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/167664.PDF.

[5] CPUC D.12-05-037, p. 37.

[6] Pacific Gas and Electric Company (PG&E), San Diego Gas & Electric Company (SDG&E), Southern California Edison Company (SCE), and the California Energy Commission (CEC).

[7] In the EPIC 2 Plan Application (A.14-05-003), PG&E originally proposed 30 projects. Per CPUC D.15-04-020 to include an assessment of the use and impact of EV energy flow capabilities, Project 2.03 was split into two projects, resulting in a total of 31 projects.

Pursuant to PG&E's approved 2015-2017 EPIC plan, PG&E initiated, planned and implemented EPIC 1.22 - *EV Submetering* project. Through the annual reporting process, PG&E kept CPUC staff and stakeholders informed of progress. The following is PG&E's final report on this project.

2.2 California Statewide PEV Submetering Pilot Regulatory Background

In July, 2011, the CPUC issued D.11-07-029 which ordered the three major California-based IOUs[8] to develop a protocol to allow submetered usage from EV chargers to be billed separately from the remainder of residential customers' total usage, as measured by the IOU's meter. This is referred to as subtractive billing.[9]

The Decision also stipulated the IOUs may not participate in the EV charging or submetering market.[10] On November 19, 2013, the CPUC issued D.13-11-002 modifying the PEV Submetering Protocol requirements set forth in D.11-07-029 by adopting a CPUC Energy Division staff Plug-In Electric Vehicle Submetering Roadmap for a two-phase pilot. The Statewide PEVSP project was managed by PG&E, but included both SCE and SDG&E as participants. Funded primarily through the EPIC Program, the project started on October 31, 2014 and concluded on September 1, 2018. A third-party evaluation firm conducted the studies for each phase. More information on the regulatory background of the PEV Submetering Program and the related technical reports can be found on the CPUC website: http://www.cpuc.ca.gov/general.aspx?id=5938.

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[8] The three California IOUs who participated in the Statewide PEV are Pacific Gas and Electric Company (PG&E), Southern California Edison Company (SCE) and San Diego Gas & Electric Company (SDG&E).

[9] Subtractive billing is a process where usage data from a submeter is subtracted from the usage data collected by the utility. This allows the load measured by the submeter to billed separately from the customer's overall bill. Please see Section 4.1 for a diagram and more details on subtractive billing.

[10] See CPUC D.11-07-029 and D.13-11-002, which set the parameters for the Pilot Studies. According to D.13-11-002, IOUs are not permitted to serve as MDMA in Phase 1; however, in Phase 2, this role was opened to the IOUs, although none served in that role.

3 Project Summary

As the adoption of EVs continues to accelerate in California, EV charging patterns will become an increasingly important factor in the state's electricity system. In January 2018, Governor Brown signed Executive Order B-48-18, which sets a goal of 5 million Zero Emissions Vehicles on the road in California by 2030. Next 10, a San Francisco-based think tank, finds that the state will likely meet or exceed the goal, but that charging infrastructure is not "keeping pace" with the rapid growth in EVs.[11]

EVs can provide benefits to the state in the form of lower greenhouse gas (GHG) emissions. However, in a future where EVs make up a significant share of California's vehicle fleet, charging loads will need to be monitored and managed to avoid exacerbating system peaks or negatively impacting grid reliability. Time-of-Use (TOU) pricing of electricity is one effective tool to ensure the bulk of EV charging occurs during periods of low system demand.

Currently, PG&E customers can access EV TOU rates in one of two ways—either by enrolling their entire house or facility onto a TOU rate, or by installing a separate meter dedicated to EV charging. Using submeters embedded in, or associated with, charging stations or other equipment presents a third approach that provides greater flexibility—however, this relatively new technology presents several key issues.

3.1 Issues Addressed

There are several issues addressed in this project. First, most charging locations do not yet have utility revenue-grade submeters to collect charging data. Second, IOUs do not have the capability to receive third-party submetered data and automatically subtract it from a customer's bill. Third, the strengths and weaknesses of submetering as an approach to EV charging are not well understood. This project is intended to address these issues by evaluating the use of submetering data for subtractive billing.

3.2 Objectives

The primary objective of EPIC 1.22 is to demonstrate the use of third-party EV submetering to provide EV owners access to electricity at a less expensive electric rate—without having to install a new separate utility meter for the purpose. In addition, EPIC 1.22 assesses EV customer demand and customer experience with submetering, as well as evaluates billing integration costs to enable EV submetering at scale.

The underlying technical assessment for this report was conducted as part of a two-phase EPIC pilot project managed by the CPUC with the participation of PG&E, SCE, SDG&E and a small group of third-party vendors who supply EV charging stations and related data services. These vendors were collectively called Meter Data Management Agents (MDMA). The *California Statewide PEV Submetering Pilot* was designed to test the implementation of third-party EV submetering solutions via

[11] See Next 10's The Road Ahead for Zero-Emission Vehicles in California for more detailed statistics: http://next10.org/zev.

MDMAs, and to evaluate the customer experience for both residential and commercial customers. A third-party firm with expertise in evaluation conducted the studies and published the final reports.

3.3 Scope of Work and Project Tasks

To meet the above objectives, the underlying pilot study was conducted in two phases. Phase 1 of the pilot, which was a small scale study involving 241 customers (out of a maximum allowed pilot size of 1,500) across California, began in early 2014 and results were published on April 1, 2016 in the *California Statewide PEV Submetering Pilot—Phase 1 Report*. In Phase 1, MDMAs offered charging stations with submeters to customers who were fully responsible (Single Customer of Record or SCOR) for paying all electricity consumption (including the submetered consumption) at their service location.

Phase 2 of the pilot, which included 434 customers across the state, began in early 2017 and results were made public in May 2019 in the *California Statewide PEV Submetering Pilot—Phase 2 Report*.[12] In Phase 2 of the pilot, the main objective was to evaluate the submetering process with a focus on customers who are billed as Multiple Customers of Record (MCOR). MCOR customers often live in multifamily housing or are commercial tenants who sublease.

Due to the timelines of the California Statewide PEV Submetering Pilot and the complexities of getting agreement from the multiple parties required in MCOR situations, MDMAs were unable to enroll any customers of this type, and thus only the SCOR scenario was evaluated in this study. The MDMAs, who were responsible for recruiting customers into the pilot project, reported that it was too complicated and time consuming to find, vet, and sign MCOR customers. According to the Phase 2 evaluation study, the MDMAs stated that gaining approval from the property owner and/or manager, and gathering signatures from MCOR, was too time consuming given the timelines of the pilot project.

Although the Phase 2 study did not include MCOR customers, it did examine a larger group of customers (434 submeters across the state out of a maximum of 1,500). In addition, stakeholders made improvements to the enrollment process, back-end data flow, and evaluation methods.

Table 3-1 summarizes the enrollment in each phase by IOU.

Table 3-1: Enrollment in Phase 1 and Phase 2 Pilot Studies

IOU	Phase 1 Enrollment	Phase 2 Enrollment
PG&E	132	240
SCE	92	151
SDG&E	17	58
Total	241	434

[12] Most of the participants in Phase 2 were new to the study; however a small number also participated in Phase 1. Participants in Phase 2 had to reapply to the program and were not automatically carried over.

Although certain components of these two studies are similar, the Phase 2 evaluation study built off the work done in the Phase 1 study and used improved evaluation methods. The California Statewide PEV Submetering Pilot studies were written by an independent evaluation firm with the participation of the three IOUs. This EPIC report synthesizes findings from the Phase 1 and Phase 2 evaluation reports, which are both available in full from the CPUC Plug-in Electric Vehicle (PEV) Submetering website.

3.4 Tasks and Milestones

To satisfy the objectives of EPIC 1.22, PG&E established the following tasks for this report:

- Task 1: Identify Service Offerings and Business Processes for participating utilities and the MDMAs and document the data flows involved with submetering (Section 4.1).
- Task 2: Assess Submeter Accuracy by analyzing the electrical accuracy of submeters in the field and via a laboratory study (Section 4.2).
- Task 3: Analyze the Customer Experience via a set of surveys (Section 4.3).
- Task 4: Assess Customer Billing Issues (Section 4.4).
- Task 5: Estimate the Cost Savings of Submetering (Section 4.5).

The results for reach task are detailed in the following section.

4 Project Activities, Results, and Findings

The EV submetering study consists of five major tasks as outlined above. This section presents the methods, results and observations, and lessons learned for each of the five tasks. As discussed above, to complete the empirical studies that underlie the analysis in this EPIC 1.22 report, the CPUC and the IOUs retained a third-party independent evaluation firm who conducted the work.

4.1 Task 1: Identify Service Offerings and Business Processes

Because subtractive billing via submetering relies upon a relatively new set of technologies and processes, the project team first identified and described the service offerings and business processes used by the IOUs and MDMAs, and then documented the data flows between the two sets of stakeholders.

4.1.1 Technical Development and Methods

The evaluators reviewed publicly available data on the MDMA service offerings and then conducted qualitative stakeholder interviews with the MDMAs and the participating IOUs. Based on information from these entities, the evaluation firm described the service offerings of the MDMAs, and documented the subtractive billing data flow between the utilities and MDMAs.

4.1.2 Results and Observations

In this project, the IOUs were responsible for processing enrolled customers, setting up separate submeter service accounts, performing subtractive billing for participations, and providing customer support.

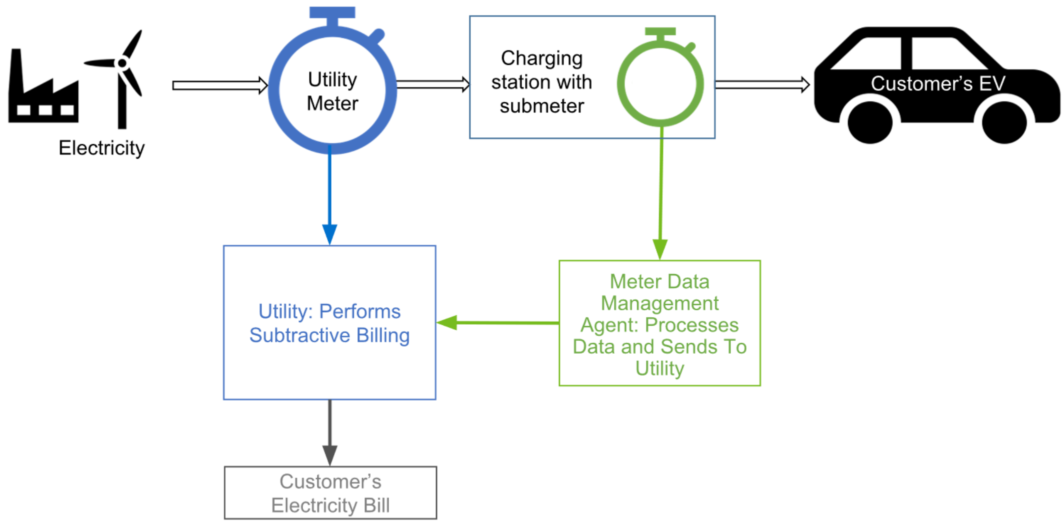
To accomplish these tasks, the IOUs worked with a small group of MDMAs, who marketed the pilot to customers, provided charging stations, enrolled customers, and provided data from the submeters, which were either associated with or embedded in the charging stations that they provided to customers.

To enroll, customers were required to fill out a customer enrollment agreement (CEA)[13] with their MDMA who would submit it to the utility. In most cases, customers paid for a licensed professional to install the EVSE with a submeter; in certain locations, the EVSE and submeter could be plugged in and hung on the wall. When the customer charged their EV, the submeter in the charging station tracked the power consumed by the EV and recorded a stream of charging data.

[13] CEAs were similar for each IOU and contained: terms and conditions, a list of eligibility criteria, a description of the duties and obligations of the participant and IOU, and a form to provide information. CEAs could be rejected by the IOU if customers did not meet the eligibility criteria or if the CEA had missing or incorrect information. IOUs often worked directly with customers to resolve issues; in some cases, CEAs with issues were sent to the MDMA for resolution.

Figure 4-1 depicts these relationships for a SCOR who is responsible for paying for all of the electricity consumption at a premises.[14]

Figure 4-1: Activities and Responsibilities for Submetering Stakeholders



The charging station sends data to the MDMA, using the customer's home Wi-Fi network. The MDMA organizes the data and then sends it to the IOU by way of secure electronic file transfer. The IOU uses this data stream, in conjunction with the standard meter data they receive from the customer's utility meter via the SmartMeter™ Network, to calculate a whole-house charge and a separate EV charge. The IOU combines all information into a final bill and sends it to the customer via their standard customer management system.

Participating customers in both phases were primarily residential customers living in a single family home; one exception was in Phase 2 when a condominium homeowner's association (billed at a commercial rate) registered as a multi-family SCOR customer.[15]

4.1.3 Lessons Learned

The number of stakeholders involved in signing up customers to a program increases the likelihood of errors and can decrease customer satisfaction as applicants may not be sure whom to contact regarding a problem. Although stakeholders made improvements over the course of the pilot, the enrollment process sometimes led to confusion and delays in enrollment for customers.

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[14] Master metered premises were not eligible for Phase 1 of the pilot. Additional flow charts depicting the SCOR and MCOR relationships are available in Appendix D of the California Statewide PEV Submetering Report—Phase 2.

[15] The homeowner's association case was not included in the logger-based accuracy study, but was included in the customer surveys and other portions of the study.

In addition, the data transfer process was problematic. Submeter charging data was sometimes delayed, likely due to communication issues between the customer's charging station and the MDMA (See Section 4.2 Task 2: Assess Submeter Accuracy). When billing data from the MDMAs was delayed, this caused customers to miss the benefits of submetered rates, and sometimes led to late bills; both of these factors caused customer dissatisfaction. These delays frustrated customers, as detailed in Task 3: Analyze the Customer Experience.

Overall, the business processes were new and required customization, which led to labor intensiveness and room for error. Task 1 resulted in the outlining of processes and data flows for enabling fully automated participant sign-up, data editing, verification, validation and billing.

4.2 Task 2: Assess Submeter Accuracy

In order for submetering to be successful from both a business and a customer satisfaction perspective, submetering data from the MDMAs must be on-time and accurate so that IOUs can bill customers appropriately. The accuracy of the submeters was evaluated using two different techniques:

- By taking field measurements of customer installations using data loggers; and
- By testing two samples of charging stations from each MDMA in a third-party laboratory setting.

In Phase 1, an accuracy threshold of ±5% was set for the submeters when installed on customer premises. This threshold was the result of negotiations among the stakeholders and was a compromise to allow the development of charging station technology.

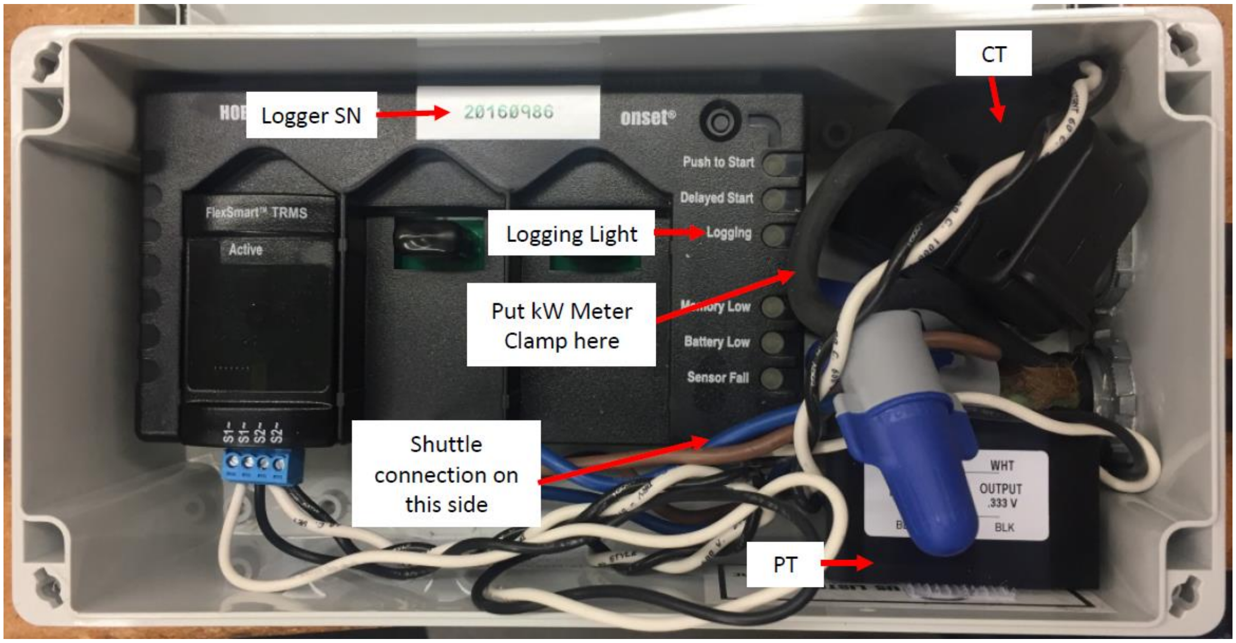
In Phase 2, again based on stakeholder discussions, the submeter accuracy threshold was set to ±2% in the field and ±1% in a laboratory setting. The accuracy threshold was allowed to be less stringent in the field, consistent with the standards set by the American National Standards Institute (ANSI).

For comparison, PG&E utility grade meters must meet an accuracy standard of ANSI C.12.20 class ±2% in the field and ±0.5% in a laboratory setting.

4.2.1 Technical Development and Methods

To carry out the in-field testing, a third-party evaluation firm contacted customers to ask if they would allow loggers to be installed. Using a technical contractor, the evaluators installed loggers on the premises of all 58 customers who replied yes. Loggers are external devices that can measure the electric load on circuits to within ±0.5%. These devices can also assess the timing accuracy of the charging stations. The Phase 2 logger is shown in Figure 4-2; similar devices were used in the Phase 1 study.

Figure 4-2: Example of a Logger



Loggers were installed in the field on a rolling basis (i.e. as soon as possible after recruitment) by field engineers, hired by the evaluator, who have experience with the installation and recovery of data logging equipment. The loggers were put in place for 7-10 days in each location. The evaluators chose this duration to ensure that multiple charge cycles over a given week could be observed at each location.

In Phase 2, loggers were set to record data in 5-minute intervals. This interval was selected to provide greater resolution than the 15-minute intervals that are now standard for the large IOUs' primary meters.

Because the Phase 2 logger study showed that only 5.2% of the charging stations passed the most stringent accuracy threshold of the study, the CPUC and evaluator determined to conduct a laboratory study of the submeters used in the Phase 2 pilot. Six charging stations (two samples from each of the MDMAs) were submitted to a third-party electrical testing laboratory. The lab simulated the charging load of an EV and then precisely measured the electricity flowing through the charging stations. More details on the logger and lab test procedures and protocols can be found in the Phase 1 and Phase 2 PEV technical reports.

4.2.2 Results and Observations – Logger Study

Several statistical techniques were used to generate a range of figures and tables depicting the accuracy issues for both the logger-based study and for the laboratory study. To formally test the similarities between the submeter measurements and logger readings, an equivalence testing approach with a threshold of 2% was used in two distinct ways.

The first was to use a paired t-test approach. A paired t-test is a statistical test used to compare the means of two different samples where observations in one sample are paired with observations in a second sample. This approach consists of two separate tests, one of the null hypothesis that the submeter mean is at least 2% less than the logger mean and the second of the null hypothesis that the submeter mean is at least 2% greater than the logger mean. The results of the equivalence tests for each submeter are shown in Table 4-1.

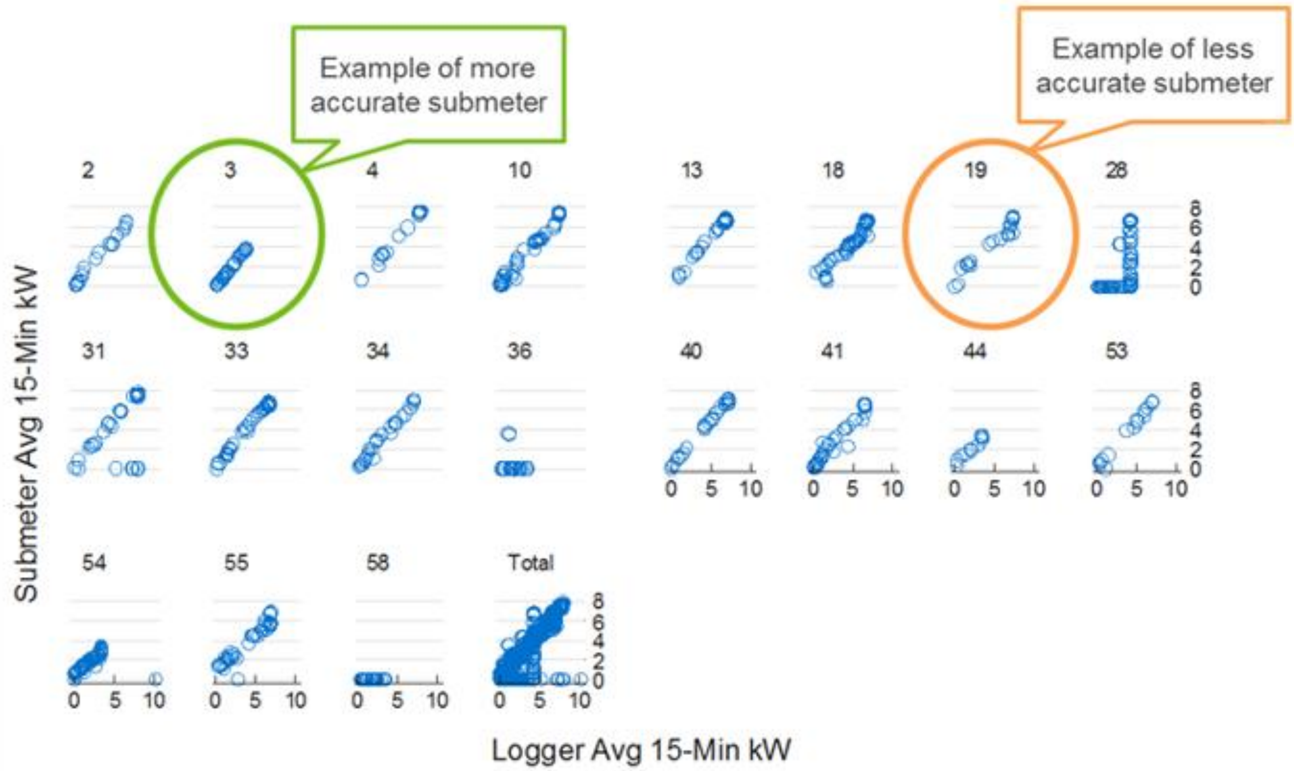
At the 15 minute level, only 5.2% of submeters in Phase 2 study met the most stringent accuracy threshold of ±2%. In order to determine if the submeters were reasonably close to the target, the analysis was repeated using daily consumption levels rather than the 15 minute level. This relaxed constraint allowed for minor deviations between 15-minute intervals to net-out on a daily basis. However, even at the daily level, only 9.6% of submeters in the Phase 2 study were able to stay within the ±2% accuracy threshold.

Table 4-1: Equivalence Testing Results for Submeter Accuracy All Vendors by Utility

	PG&E	SCE	SDG&E	Avg. Pass Rate
Percent customers passing (15-min kw intervals +/- 2%)	15.8%	0.0%	0.0%	5.2%
Percent customers passing (Daily kw intervals +/- 2%)	31.3%	0.0%	0.0%	9.6%

Figure 4-2 shows the comparisons for each submeter in the form of scatter plots for a set of submeters reporting to PG&E. Each 15-minute interval is represented in the figure by a blue circle. When submeters and loggers agree, these graphs will show a straight 45-degree line. Deviations from the 45 degree line represent inaccuracies. The Y-axis in the graphs represent the submeter average 15-minute kW, and the X-axis represents the logger readings for the same time interval.

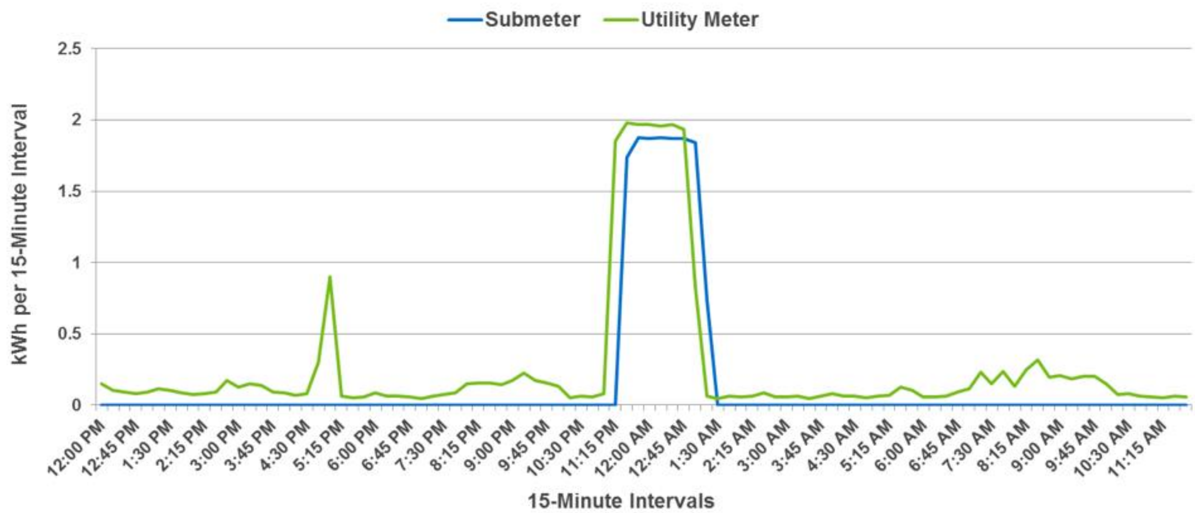
Figure 4-2: Submeter Measurements vs. Logger Readings, Phase 2 Pilot



Given the small percentage of submeters that passed even the less stringent daily accuracy test, the CPUC and evaluator recommended sending two samples of each MDMA's equipment to third-party laboratory testing.

Visualization of time shifting issues is presented in Figure 4-3. This figure visually compares charging load over time as measured by a submeter against the charging load as measured by the utility meter. Figure 4-3 shows the submeter was not time synchronized to the utility meter. This results in a discrepancy between when the utility meter shows charging begins (at approximately 11 p.m.) and when the submeter shows that charging begins (at approximately 11:15 p.m.). Although this issue was fixed, time-synchronization issues are a potential source of submeter inaccuracy.

Figure 4-3: Time Shift in Usage Data Between Submeter and Utility Meter

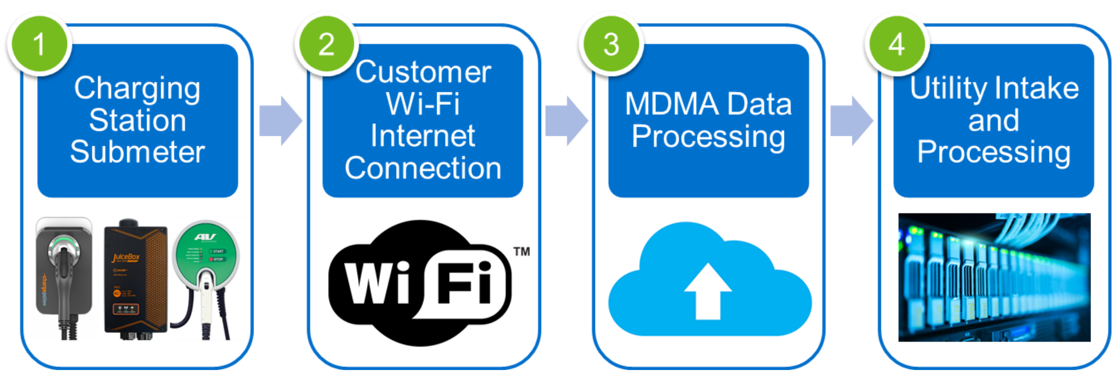


4.2.3 Source of Inaccuracies

Customer Wi-Fi Internet Connection provides a high-level overview of the data flows between the submeter and the utility in order to provide visibility into potential sources of the inaccuracies. The potential sources for inaccuracies are organized by each step in the diagram. The decision to laboratory test the submeters was not part of the original test plan for the project. It came about when the third-party evaluator discovered that the submeters were not meeting the field performance standard (i.e., ±2% error) and brought it to the CPUC's attention.

The tests from the third-party laboratory were carried out to independently to help isolate the sources of inaccuracies. The field testing relied on data that passed through all four steps in Figure 4-4 Although laboratory testing also relied on Wi-Fi, in the lab environment a high quality connection was established to remove this source of failure. Consequently, the laboratory testing was able to identify issues that were contained to steps 1 and 3 of the submeter systems.

Figure 4-4: Data Flow Diagram



4.2.4 Charging Station Submeter

Laboratory testing confirmed accuracy issues remained, even when the complications of customer Wi-Fi and utility data intake were removed. However, the lab testing still relied on retrieving charging data from the MDMA's online portal. This, in turn, required the data to be transmitted to the MDMA's cloud-based system and presumably processed in some way before being transmitted to the online portal.

Without a direct diagnostic output from the charging station, it is impossible to determine with complete certainty if the accuracy issues are from the submeter, data processing and storage, or both. Inclusion of a diagnostics tool in future submeter models, such as a light that blinks after every 1 kWh of electricity consumed may help isolate accuracy issues.

4.2.5 Customer Wi-Fi Internet Connection

The potential intermittency of customer Wi-Fi was another possible source of data issues. Some charging stations may only store a day of data and customer Wi-Fi, in certain circumstances, can become disconnected for a longer period of time. If this occurs, the submeter is not able to send charging data to the MDMA. A lack of charging data can lead to inaccurate customer bills or a loss of savings to the customer if only part of a billing cycle is recorded.

For example, one brand of EVSE charging station had 24 hours of on-charging station data storage, whereas another brand can store up to 90 days of interval data. Based on these on-charging station storage capacities, if the Wi-Fi connection was down for more than 24 hours, there is a potential for data loss.

Based on the evaluator's acuracy analysis, there were instances where the data loggers indicated charging was taking place, but there was not any registered consumption from the submeters. These instances may be indicative of issues that interrupt communication between the charging station and the cloud-based server.

4.2.6 MDMA Data Processing

Another potential failure point is the MDMAs' data processing, storage, and transmission systems. When the evaluator inquired about the MDMAs' internal data flows and handling practices, the MDMAs responded that their internal processes are proprietary. Without insights to the specific data related processes, it is impossible to determine if any of the accuracy issues are a result of data processing errors. During Phase 2, one MDMA and the IOUs encountered systematic data handling and process related challenges which required the MDMA to re-label data intervals from end time to start time and properly set the 15-minute intervals. This issue was resolved and resulted in improved data quality.

4.2.7 Utility Intake and Processing

Once the data was received by the utilities, it was processed with various levels of automation. PG&E provided the evalutor with the original raw data files it received from the MDMAs and the data files merged with PG&E's whole premise consumption data to assist the evaluator in isolating accuracy issues. The evaluator compared the data sets and confirmed that PG&E's data handling processes preserved the integrity of the data provided by the MDMAs.

4.2.8 Results and Observations – Third-Party Laboratory Study

For the laboratory study, two charging stations from each of the MDMAs were sent to an independent third-party laboratory[16] based in the United States. This facility conducted a range of tests using a simulated EV charging load that allowed them to precisely measure the amount of power being sent through the circuits of the charging station and compare this power usage with that of the embedded submeter.

To prepare for the study, a customized test plan was developed by electrical engineers affiliated with the three IOUs and the independent evaluation firm and designed to simulate the conditions that charging stations may face in the field. The tests include varying voltage and Power Factor (PF) with respect to the utility electrical supply to the charging stations, and varying duration of charging cycles for the EVs.

The tests that the laboratory ran included a standard suite of load conditions designed to simulate various load profiles that the device is likely to face in use. The exact tests used are detailed in the appendix of the Phase 2 report.

The standard was set at ±1% for compliance with the acceptance accuracy standard for the bench testing conducted by the independent lab Test results from the independent lab indicate that all three submeters integrated into the three manufacturers charging stations were not in compliance with the ±1% accuracy standard for bench testing. A redacted[17] copy of the report provided by the lab is contained in Appendix G of the Phase 2 report.

The best performing submeter was only compliant on one-third of the tests, and the compliance rate was lower for the other two submeters; the best performing submeter was compliant with the accuracy standard in 14 of the 42 tests conducted on each charging station. Tests were conducted at two (2) load levels, full load and 1% of full load; two (2) levels, unity and 50%, with the exception of one MDMA unit which would not operate at PF levels below 81% at full load. Multiple voltage levels were also used for the range of tests with both high and low load levels and PFs to simulate the widest range of conditions the chargers might operate at in the field. While an insufficient numbers of tests at each load, PF, and voltage were conducted to determine the statistical significance of each of the three manipulated variables on the test results, some patterns were observed.

Table 4-2 below shows the independent lab test results for the charging stations with submeters by vendor. Approximately 54% of all the tests results showed that the submeters would result in

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[16] The independent lab testing was conducted by MET Labs, based out of Baltimore Maryland. Results were provided in a report titled "TEL99908-PGE ALL TESTS USC Rev 1" delivered to the evaluator on November 1, 2018.

[17] The details of the specific test results are confidential. Non-redacted versions were provided to the utilities and CPUC for review. The MDMAs each received a copy of the report where their specific tests were not redacted so they could review their own results.

undercharging customers for energy deliveries by at least 1%, with 29% of the tests meeting the accuracy standard; the remaining 43% of the test results showed registration errors greater than 1% that would overcharge customers for the energy delivered to the charging station.

Table 4-2: Submeter Accuracy Test Results From Independent Lab

Charging Station	% of Tests in Compliance
Vendor A	33% (14 of 42)
Vendor B	4.8% (2 of 42)
Vendor C	26.2% (11 of 42)

4.2.9 Lessons Learned

Based on the field and additional laboratory testing, the submeters included in this pilot did not meet the accuracy standard of ±1% for acceptance testing in the laboratory or ±2% in the field.

Laboratory testing has identified accuracy issues in the submetering system, which includes the submeter and the cloud data processing. Intermittency of customer Wi-Fi appears to be the driver for data intervals where field loggers recorded charging and the submeters did not. The errors resulting from missing submeter data are significantly larger than the errors identified in the laboratory setting that were isolated to the submeter systems.

From a review of the technical reports, PG&E determined that subtractive billing failures were created primarily by three kinds of issues:

- **Time Shifting Issues**, which occurred when the timing of a submeter's charging information did not match the timing of the logger or the whole-house bill;
- **Recording Issues**, which occurred when a submeter did not record an instance of charging; and
- **Magnitude Issues**, which occurred when the magnitude of the charging load recorded by the submeter did not match the magnitude of the charging load recorded by the logger.

The instance of a logger reading greater than its corresponding submeter was most common, followed by the submeter failing to record an instance of charging. In summary, it was found that the submeters tested as part of this demonstration study were not nearly accurate enough to supply dependable revenue-grade billing information—and this outweighs any potential benefit that might accrue to the customer.

Involving an additional third-party in the subtractive billing process (the MDMAs) creates additional potential for data discrepancies that complicates troubleshooting. The pilot conditions present obstacles to scaling subtractive billing to a statewide scale. There is a need to develop submetering accuracy standards, including standards for end-to-end data delivery.

4.3 Task 3: Analyze the Customer Experience

Task 3 presents findings from three surveys administered by the evaluator as part of the Phase 2 study. In general, the customer experience surveys found broad satisfaction with the submetering pilot: 66% of surveyed participants in the Phase 2 pilot reported being extremely satisfied and 26% reported being somewhat satisfied. The majority of satisfied participants said that the ability to pay a lower rate and reduce their electricity bill was the most important reason for satisfaction. The Phase 2 pilot also provided customers up to $400 in incentives in the form of discounted charging stations provided by the MDMAs.

However, 2% reported being somewhat dissatisfied and 2% reported being extremely dissatisfied with inaccurate bills or higher billing costs being the top reasons for dissatisfaction. In addition, 10% (42 participants) withdrew from the Phase 2 pilot after they had started the program, but prior to completion. Ten of those customers completed a survey designed to discover their reasons for leaving the pilot prematurely. Of those who withdrew, 6 said they were dissatisfied with the submetering service, while 3 said they were satisfied and 1 was ambivalent.

The remainder of this section provides greater detail on how Task 3 was accomplished and provides more information from the surveys that were part of this task.

4.3.1 Technical Development and Methods

The respondent's knowledge of submetering and perceptions of the pilot study was assessed using four survey instruments: one that was part of the Phase 1 pilot, and three that were part of the Phase 2 pilot; because the Phase 2 results are more recent and comprehensive, these results are presented first.

All Phase 2 pilot participants were contacted immediately after enrolling in the pilot with a request to complete a participant survey (the Welcome Survey) in June 2017. Participants then received an additional survey request in May 2018 at the end of the pilot (the Post Pilot Survey).

The first survey instrument, the Welcome Survey, consisted of 34 questions. This survey assessed motivations for participating, knowledge of submetering and demographic information. It was sent via email and United States Mail to 434 customers of the three IOUs participating in the pilot, and 372 responded for an 86% response rate. Those who completed the survey received a $25 check. The number of surveys sent and the response rate by IOU is shown in Table 4-3.

Table 4-3: Phase 2 Participant Survey Response Rates by IOU – Welcome Survey

IOU	Surveys Sent	Surveys Completed	Response Rate
PG&E	240	200	83%
SCE	136	125	92%
SDG&E	58	47	81%
Total	**434**	**372**	**86%**

A second survey, The Post Pilot Survey with 29 questions, was sent to those who stayed in the pilot at the end of 12 billing cycles (approximately a year) and followed the same recruitment strategy as the Welcome Survey. This survey went out to 392 pilot project customers and was returned by 314 for an 80% completion rate.

The third survey was the Unenrolled and Prospective Participants Survey, which included 58 questions. This survey went out to two groups of customers: 14 prospective participants (returned by 4 for a 29% response rate) and 20 unenrolled participants (returned by 10 for a 50% response rate).

Additionally, to better understand why customers may have reacted negatively to the submetering pilot experience, a separate survey was sent to customers who either withdrew from the pilot while it was underway (unenrolled participations) or did not complete the enrollment process (prospective participants).

Further details on the design and administration of the survey instruments is contained in Section 3 of the Phase 1 and Phase 2 evaluation reports. The remainder of this section presents the survey results associated with the focus areas described previously.

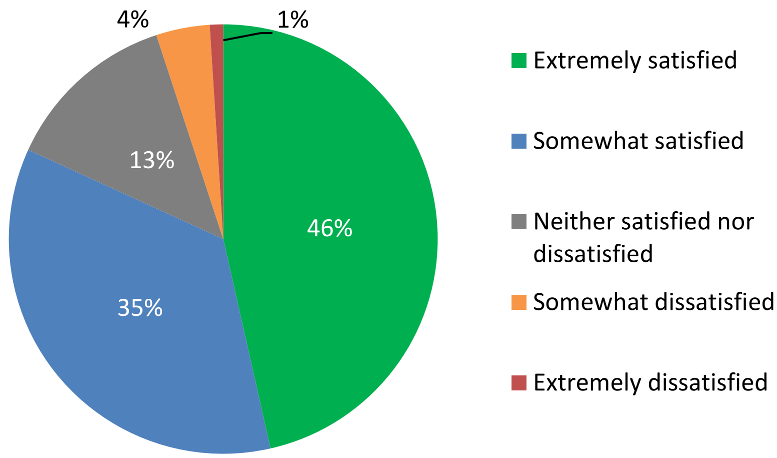
4.3.2 Welcome and Post-Pilot Results

The Welcome and Post Pilot surveys were analyzed together to assess participants' knowledge of behavior around charging their EVs, knowledge of submetering, understanding of the program and of related issues, and experiences with the program. The three most important motivations for enrolling in the Phase 2 pilot were the following:

- Ability to pay a lower rate for electricity used by the PEV;
- The availability of an incentive for the PEV submeter; and
- A discount of approximate $400 on the cost of vehicle charging station.

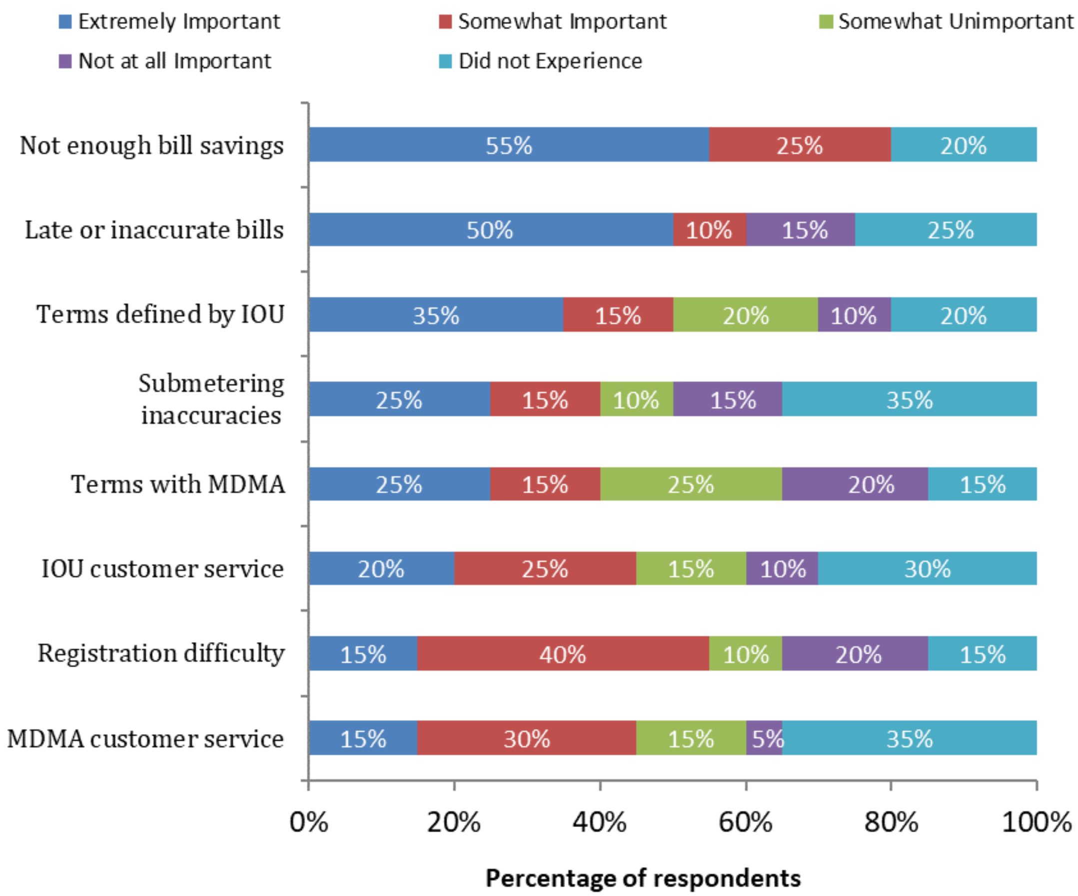
Several questions towards the end of the post-pilot survey dealt with the topic of customer satisfaction in Phase 2. A majority of customers (81%) said that they were "extremely satisfied" or "somewhat satisfied," while 5% of respondents rated their level of satisfaction as "somewhat dissatisfied" or "extremely dissatisfied." The remaining 13% responded as "neither satisfied nor dissatisfied with the program as they had experienced it thus far. Figure 4-5. Presents the frequency of responses:

Figure 4-5: Overall Customer Satisfaction With Submetering Service (Phase 2)



Of the 20 customers who reported being at least somewhat dissatisfied with the pilot, the majority of respondents (55% and 50%) rated "not enough bill savings" and "late or inaccurate bills" as extremely important reasons for their dissatisfaction. Notably, only 15% of respondents rated "Registration difficulty" as extremely important, but 40% rated it somewhat important, leaving registration difficulty to be the third most important reason for dissatisfaction as measured by those who rated it at least. A breakdown of the reasons for dissatisfaction is presented below in Figure 4-6.

Figure 4-6: Reasons for Dissatisfaction With the Phase 2 Pilot



4.3.3 Unenrolled and Prospective Study Results

Forty-two participants who unenrolled from the Phase 2 pilot prior to its conclusion were contacted. Of those who unenrolled, 60% were at least somewhat dissatisfied with their submetering service, while 30% were at least somewhat satisfied, and 10% were ambivalent.

Of the 10 customers who completed the unenrolled survey from Phase 2 of the Pilot, the majority of respondents (60%) rated "not enough bill savings" as an extremely important reason for their decision to un-enroll, and another 20% rated it as somewhat important for a top-2 box score of 80%.

The second most important driver of unenrollment is "Other billing problems" with a top-2 box score of 50% and the third most important driver is "Errors resulting from submeter accuracy" with a top-2 box score of 40%. A breakdown of the reasons for un-enrollment is presented below in Table 4-4.

Table 4-4: Importance of Factors in Deciding to Unenroll From the Pilot (Phase 2)

How important was each of the following aspects in contributing to your un-enrollment from the pilot?	Not Important at All	Somewhat Unimportant	Somewhat Important	Extremely Important	Top 2 Boxes
Not enough bill savings	0%	10%	20%	60%	80%
Other billing problems	13%	0%	0%	50%	50%
Errors resulting from submeter accuracy	10%	0%	0%	40%	40%
Late or inaccurate bills	10%	10%	10%	30%	40%
IOU customer service	30%	0%	20%	20%	40%
MDMA customer service	20%	0%	20%	10%	30%
Other technical problems	14%	0%	0%	29%	29%
Other non-technical or billing problems	0%	0%	0%	17%	17%
No longer have an EV	10%	0%	0%	0%	0%

A total of four customers did not complete the enrollment process while another 63 did not sign a CEA. A breakdown of reasons provided for not completing, or starting (in the case of those that did not sign a CEA), the enrollment process is provided in Table 4-5. The write-in response (e.g., the respondent selected "Other (please explain)" for their reason) has the largest Top-2 box score of 72%. The second most important reason was "The enrollment process was complicated" as indicated by its Top-2 Box score of 69%. The third most important was "I didn't think I would save enough with the rate offered" which has a Top-2 box score of 57%.

Table 4-5: Reasons for Not Completing or Beginning the Enrollment Process (Phase 2)

How important was each of the following aspects in your not completing enrollment for the pilot?	Not Important at All	Somewhat Unimportant	Somewhat Important	Extremely Important	Top 2 Boxes
Other (please explain)	28%	0%	0%	72%	72%
The enrollment process was complicated	21%	10%	48%	21%	69%
I didn't think I would save enough with the rate offered	27%	16%	30%	27%	57%
I would have wanted to stay on the rate for more than 12 months	45%	19%	22%	13%	36%
I didn't want to limit my charging on weekday afternoons / evenings	52%	18%	22%	7%	30%
I didn't think the rate was compatible with my net metered PV solar production	60%	13%	10%	16%	27%
I didn't want to or couldn't un-enroll from other programs (auto-pay, demand response, etc.)	54%	21%	7%	18%	25%
I didn't qualify for the pilot for another reason (please explain)	68%	13%	6%	13%	19%
I don't usually charge my car at home	73%	16%	6%	4%	10%

Table 4-6 provides more detail on what respondents wrote if they selected "Other (please explain)" on the survey. For those who provided details, the most common explanation was that the customer did not want one of the qualifying charging stations, while the second-most common reason was the risk of not qualifying for the project and thus not gaining the incentive, but having to purchase a charging station nonetheless. Another three respondents expressed concern with the cost of the eligible EVSEs.

Table 4-6: Stated Reasons for Not Completing Enrollment

Reason	Count
Did not want qualifying charging station	5
Risk of not qualifying	3
Cost of eligible charging station	3
Missed deadline	2
Already on TOU rate	1
Couldn't use existing charging station	1
External cost factor	1
Net metering conflict	1

4.3.4 Non-Pilot EV Owners Study

Drawing off a study carried out as part of the Phase 1 pilot project, over 8,000 residential EV users who were not part of the pilot project and who lived across California were asked to participate in a survey about submetering. The survey ran in February and March of 2016 and ultimately included responses from about 200 PG&E customers (and 626 in total).

This study found that 41% of PEV owners said they would be willing to enroll in a submetering system similar to that in the Phase 1 pilot that provided substantial savings of approximately 30% on the cost of electricity for EV charging. It is important to note that this figure likely suffers from “hypothetical bias” that often exists with stated preference surveys. Hypothetical bias is generally positive, meaning that survey respondents would be prone to overstate their true likelihood of enrolling in submetering. The earliest adopters of EVs may also be more willing to adopt a submeter than a broader population due to their “first-mover” nature.

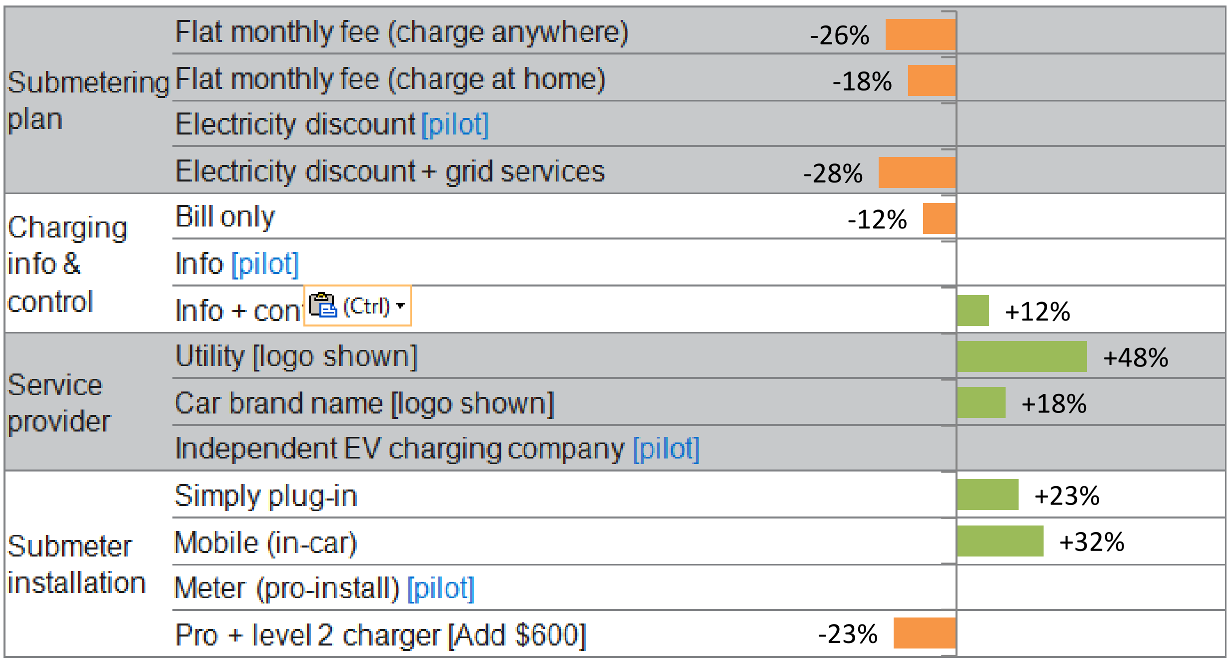
The most important factors driving customer interest in submetering include the business model of the submetering plan, the amount of charging savings, and saving money on the purchase and installation of a home charging station.

The contingent survey design allows the marginal effect of different attributes relating to participant experience to be tested. Figure 4-7 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.

The submetering plan attribute was intended to test the openness of EV 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.

Before answering these questions, 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 Phase 1 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.

Figure 4-7: Relative Impact on Enrollment Compared to Phase 1 Pilot: Business Model and Participant Experience Attributes



4.4 Task 4: Assess Customer Billing Issues

Inquiries that were made by customers to each of the IOUs for various kinds of help with issues pertaining to billing and the program in general were compiled and analyzed in order to further assess the customer experience, in Task 4.

4.4.1 Technical Development and Methods

This analysis is based on a request for billing inquiry data that was sent to each of the IOUs. Each of the IOUs tracked the received customer support inquiries that related to the submetering pilot project and then reported the findings to the evaluation firm in charge of drafting the California Statewide PEV Submetering Pilot reports.

4.4.2 Results and Observations

Each IOU tracked and categorized data differently; separate tables are provided for each utility. Customer inquiries received by PG&E (excludes unenrollment requests) are shown in Table 4-7. Issues with MDMA data, questions created by enrollment in a conflicting Demand Response program, and general inquiries to better understand the program were the most common inquiries.

Table 4-7: PG&E Customer Inquiries

PG&E Customer Inquiries	
Category	**Percent**
Issue with MDMA data (no or bad data)	38%
Customer enrolled in prohibited program (Rule 24, AP, BPP)	18%
Program clarity	10%
Customer satisfaction	8%
Communications	5%
Customer enrollment documentation incorrect or incomplete	5%
Customer issue	5%
PG&E process	5%
Technology Issue	5%
Total	**100%**

Note: Category percentages may not total 100% due to rounding.

The most common inquiries to SCE were for program enrollment status, general rate, and questions or complaints about late bills. The top sources of SCE customer inquiries related to the program are shown in Table 4-8.

Table 4-8: SCE Total Customer Inquiries

SCE Customer Inquiries		
Category	**Count**	**Percent**
Enrollment Status	31	46%
General Rate Info	10	15%
Delayed Bill	6	9%
Bill Accuracy	5	7%
Request to Change Rate	3	4%
Pilot Info	2	3%
Moving	2	3%
NEM Info	2	3%
General Info	2	3%
Eligibility	1	1%
View Bill Online	1	1%
Hardware	1	1%
Rebate	1	1%
Online Data Availability	1	1%
TOTAL	**68**	**100%**

Table 4-9 shows the customer inquiries received by SDG&E. The most common inquiries were requests to opt-out of the program; customers also made rate inquiries and general program inquiries. In total SDG&E, which is the smallest of the three utilities, received the fewest number of inquiries (9) about the pilot.

Table 4-9: SDG&E Rate Inquiries

SDG&E Customer Inquiries		
Category (Evaluator's Classification)	**Count**	**Percent**
Request to Opt-Out of Pilot Program	3	33%
Rate Inquiry	2	22%
General Program Inquiry	2	22%
Customer Enrolled in Prohibited Program (Rule 24, AP, BPP)	1	11%
Already Enrolled in TOU Rate	1	11%
Total	**9**	**100%**

4.5 Cost Estimates of Submetering

The cost of submetering for customers, MDMAs, and utilities is a critical area to analyze in any broader consideration of policy choices. This section presents cost comparisons of two approaches: Submetering using an EV charging station and installing a separate utility grade meter for EV charging. This section also presents preliminary cost estimates of upgrading utility infrastructure to provide submetering at state-wide scale. Without broader field and customer testing and commercial acquisition, PG&E is unable to provide any definitive cost estimates to deploy submetering for EV charging to existing EV customers or on a systemwide basis. The utilities provided a preliminary range of unit cost estimates for qualitative comparison of utility and third-party submetering costs based on available data, but the range of cost estimates is not credible for use in developing actual deployment cost estimates.

4.5.1 Customer Equipment Cost Estimates: Utility-Grade Meter vs. Charging Station With Submeter

One key motivation for submetering is to lower the cost of installing EV charging equipment to encourage the adoption of EVs. This section compares the costs of installing an EV charging station with a submeter against the main alternative: installing a second utility grade meter dedicated to EV charging.

To carry out this task, the evaluator requested cost estimates from the utilities on installing a second utility-grade meter. The evaluators then researched publicly available information to check the utility estimates. In addition, the evaluators used utility information and public information to generate estimates on the cost of installing an EV charging station with a submeter. They then created a cost comparison between these two approaches.

There are many possible configurations of charging equipment that can be installed at customer's premises.[18] It is important to note that most EVs contain the actual charging equipment within the vehicle. The charging stations discussed in this report provide greater convenience and additional services, such as the ability to remotely monitor or control EV charging—however, they are not strictly necessary.

The evaluators created multiple scenarios that are simplified here to compare these costs:

- Service Model 1: Installing a second utility grade meter and directly charging the EV
- Service Model 2: Installing a networked charging stations with embedded submeter

In both models, the evaluators assumed that the customer is starting with no existing PEV charging-related infrastructure or equipment. In either case, the primary costs to the customer include the labor, materials, and permits to install an additional circuit and associated equipment to connect the meter or charger to the electricity system within the premise. In the second scenario there are additional costs to install the charging station itself.

These costs can vary significantly based on location and the existing electrical configuration at a customer's premises. For example, labor costs are significantly higher in the San Francisco Bay Area as compared to the central valley. The configuration and location of existing wiring relative to the desired charging location can add significant differences to the cost as well. A range of costs is generated in the underlying technical reports, but, for the sake of simplicity, the average costs are presented in this report.

The IOUs estimate that the average cost to the customer under Service Model 1 is approximately $1,640. However, the cost could be lower than this estimate if the customer has existing wiring[19] or the cost could be significantly higher if, for instance, there is a detached garage distant from the main panel which would require trenching. The utilities stated they are aware of installation costs as high as $8,000 in extreme cases.

Service Model 2 includes all of the costs of a new circuit, but also includes the cost of purchasing and installing a networked charging station with submetering capability. The average cost for a charging station with integrated submeter in this pilot was $650 retail. Prices in the pilot ranged from $500 to $850 based on the brand and features.[20]

- The cost estimate of Service Model 1 (separate utility revenue grade meter) is $1,640

[18] See Section 4.6 of the California Statewide PEV Submetering Pilot – Phase 2 Report, which provides details on scenarios, and assumptions used in the cost estimates. The report will be available on the CPUC's website: http://www.cpuc.ca.gov/general.aspx?id=5938.

[19] An example would be if there was an existing 240V circuit to the garage not being used.

[20] Please see Section 4.6.2 of the Phase 2 report.

- The cost estimate of Service Model 2 (charging station with submeter) is $1,266
- This results in a cost difference of $374

Both installations require the addition of a circuit from either the primary or secondary panel to the charging location.[21] The primary difference between the two options is that installing a separate utility-grade meter requires the addition of a new panel and associated installation costs, whereas the submeter approach requires the purchase and installation of a charging station with an integrated submeter. From the customer's perspective, the charging station with submetering capabilities from Service Model 2 is generally the lower cost option.

4.5.2 Utility Cost Estimates: System Upgrades to Scale Submetering

Installing a utility-grade meter to separately meter PEV charging creates costs for the utility. These include the cost of the meter and any utility costs to install and maintain the second meter. The combined meter and labor costs ranged from $120 to $388, with an average cost of $219. Under the separate utility revenue-grade meter scenario the utilities already have billing systems and processes in place, so there are no incremental system costs to the utility.

Scaling third-party submetering to a state-wide scale also creates costs for the utility. The cost data presented below represents preliminary estimates created by the evaluation firm. Without broader field and customer testing and commercial acquisition, PG&E is unable to provide any definitive estimates of the costs to deploy submetering for EV charging to existing EV customers or on a systemwide basis.

Table 4-10 presents the one-time and recurring costs that are expected to be incurred by the utilities to achieve full-scale automated billing operations incorporating third-party submeter data. The average one-time cost per utility is approximately $4,200,000 and the expected annual recurring cost per submeter is approximately $200. The following sections provide the underlying details that were used to develop the estimates for the customer and utility perspectives.

Table 4-10: One-Time & Recurring Utility Cost of Submetering at Full Scale With Automation

Cost Type:	Cost Component	Average	Range
One-Time / Per Utility	Cost to Establish Protocols	$357,500	$215,000 to $500,000
	Updating Systems for Full Billing/Data Automation	$3,833,333	$3,000,000 to $4,500,000
	Total One-Time Cost to Utility	**$4,190,833**	**$3,215,000 to $5,000,000**
	Operations & Administration Labor Costs Per Submeter	$198	$50 to $346

[21] SCE recently implemented the Charge Ready Home Installation Rebate Program where residential customers can receive a rebate of up to $1,500 toward their out-of-pocket costs for the electrical upgrades and permitting fees necessary to allow installation of a Level 2 (240-volt) PEV charging station. The rebate does not cover the cost of the charging stations, but it will help cover the cost of installing and permitting the charging station.

Recurring / Per Submeter	**Total Annual Recurring Cost to Utility Per Submeter**	**$198**	**$50 to $346**

Utility costs fall within two categories: one-time costs, and annual recurring costs. The one-time costs include establishing the submetering protocols and updating the billing systems for third-party submeter data integration. Annual recurring costs include administrative labor costs to operate the program, address customer inquiries, and rebill customers for missing or incomplete data.

To establish the submeter protocols, each utility expects to incur costs ranging from $215,000 to $500,000. These costs include time for internal staff, stakeholder workshops, and potentially the need to hire external consultants to provide subject matter expertise. Cost estimates to update the data and billing systems range from $3,000,000 to $4,500,000 per utility.

These costs include but are not limited to:

- Establishing MDMA-accessible folder structures;
- Creating appropriate codes to identify the MDMAs, manufacturer and model codes, and meter type codes within the utility server infrastructure;
- Creating gateway for the Meter Data Management System (MDMS) to take in a flat file of interval usage data from the MDMAs;
- Developing processes for collecting the MDMA data and moving to a staging folder for aggregation and processing;
- Creating a new interface program that will pick up the MDMA-Reported Interval Data from the staging folder and review the data for acceptance or rejection;
- Transferring records passing validations to the MDMS gateway for consumption by the MDMS;
- Performing administrative tasks in support of the new submeters and validation, estimation, and editing rules;
- Developing and implementing enrollment and un-enrollment automation tasks;
- Developing rules for Net Energy Metering (NEM) billing; and
- Reconciling direct access and community choice aggregation processes within the billing system.

Several factors may affect the accuracy of the cost estimates that include but are not limited to:

- Protocols[22] That Establish the Data Standards: without issues such as data quality, format, and delivery frequency agreed upon, it leaves uncertainty regarding the design needs, and subsequent costs, for the system.
- Data quality From MDMAs: automation upgrades can be implemented, but they do not resolve the problem of inaccurate metering and MDMA data processing. If submeter energy usage continued to be inaccurate, that would result in a variety of customer complaints and costly resolution steps when scaled across all of a utility's systems (billing, call center, etc.).
- Timing: SCE and SDG&E are undergoing major billing system upgrades over the next few years. The timing of implementing the automation may affect the cost of the project due to the uncertainty related to costs expected several years out under systems that have not yet been implemented.

[22] A protocol could increase or decrease utility costs. SDG&E is currently more automated than the other utilities. If a protocol resulted in a different data format compared to what they currently use, they would incur costs to change their system to accept a different format.

- Potential Requirements for Inclusion Of Customer Facing Applications Like MyEnergy, FirstFuel, and Opower, or Rate Analysis Tools: Requirements for customer facing applications have not been established, and will add cost if they must be implemented.

The annual recurring costs varied significantly by utility. Estimates for these costs ranged from $50 per submeter up to nearly $350 per submeter per year. These costs include the utility program staff that will operate the program, along with charges for time from the billing and call center staff that will be supporting the operations. The variation in these costs may be attributable to how costs are allocated across organizations within a utility, the number of participating customers, and underlying assumptions regarding the frequency and type of interactions with customers. Data quality from the MDMAs, the need for customer facing applications, and the division of labor between MDMAs and utilities from a customer service perspective will also heavily influence the costs.

5 Value Proposition

The purpose of EPIC funding is to support investments in technology demonstration and deployment projects that benefit the electricity customers of PG&E, SDG&E and SCE. The primary objective of EPIC 1.22 is to demonstrate the use of EV submetering to provide EV owners access to lower cost electric rates—without having to install a new separately metered service. From a review of the independent technical reports associated with the California Statewide PEV Submetering Pilot project, PG&E finds that this is not a valid approach to monitoring or managing EV load and that third-party submetering does not provide substantial benefits to end users under the pilot conditions. Thus, the value proposition of this pilot was demonstrating that there is not presently a path to production for third-party submetering within charging stations.

5.1 Primary Principles

The primary principles of EPIC are to invest in technologies and approaches that provide benefits to electric ratepayers by promoting greater reliability, lower costs and increased safety. This EPIC project contributed to these primary principles in the following ways:

- **Greater Reliability**: Subtractive billing via third-party submetering has the potential to improve the monitoring and management of EV charging load, which can contribute to improved system reliability. However, EPIC 1.22 has shown that the demonstrated approach to EV submetering is not ready to scale to the entire state and thus these reliability benefits are not yet able to be realized.
- **Lower Costs:** The successful use of EV submetering via charging stations could reduce the cost of EV charging, however the costs savings—an average of $374 per installation—are modest as compared to installing a second utility-grade meter and may not produce any ongoing bill savings when compared to alternative TOU rates. At the same time, to scale submetering to customers across California will cost the utilities from $3,215,000 to $5,000,000 per utility.
- **Increased Safety**: EPIC 1.22 did not examine this issue.

5.2 Secondary Principles

EPIC also has a set of complementary secondary principles. This EPIC project contributes to the secondary principles of testing societal benefits and GHG reduction potential of new technologies by demonstrating that third-party submetering is not yet ready for statewide scale. However, PG&E supports the goal of making EV charging cheaper and easier. Creating a system that incentivizes EV charging could have the following benefits:

- Societal Benefits: The ability to cost-effectively submeter EVs could reduce the cost of EV charging and/or support the grid by charging off-peak. By making charging cheaper and easier, submetering could support state goals and objectives for EV utilization.
- GHG Emissions Reduction: Reducing the cost of EV ownership and/or charging could increase EV utilization, in turn reducing GHG emissions from fossil fuel vehicles.

5.3 Key Accomplishments

The key accomplishment of EPIC 1.22 is the determination that there is currently no path to production for third-party submetering under the project conditions. As outlined in Section 4, this approach to EV charging and submetering is error prone, complex, does not produce consistent savings for customers, and imposes costs on the ratepayers to change existing billing systems.

However, this finding does provide value to IOUs, ratepayers, and EV owners by demonstrating that proceeding with development of a third-party approach to EV submetering is not an effective course of action at this time and is not economically efficient. This finding may spur additional innovation within the EV charging space or collaboration with utilities to determine a path forward if customer demand necessitates.

Future innovation can build upon the accomplishments of EPIC 1.22, including the establishment of subtractive billing processes and the learnings around the challenges of integrating submetered data into IOU billing systems.

5.4 Key Recommendations

Given the modest cost savings for individual customers, and the high costs that third-party submetering creates for ratepayers, PG&E recommends that the IOUs and associated stakeholders:

- Examine alternative approaches to submetering that use different equipment and/or communications networks, as this study has shown that the demonstrated approach is error-prone.
- Perform additional studies to compare the costs and benefits of EV submetering against whole-house TOU rates. Given that most utilities in California are transitioning to TOU rates in the coming year or two, further analysis of how TOU rates affect EV charging is recommended.
- Develop standards for submeter accuracy, data transmission, and integration into utility billing systems in order to enable a path to production.

5.5 Technology Transfer Plan

A primary benefit of the EPIC program is the technology and knowledge sharing that occurs both internally within PG&E, and externally across other IOUs, the CEC and the industry. In order to facilitate this knowledge sharing, PG&E will share the results of this project in industry workshops and through public reports published on the PG&E website.

On June 24, 2019, the CPUC hosted a public PEV Submetering Workshop where results of this pilot were presented.

5.6 Adaptability to Other Utilities and Industry

This project was a joint California IOU effort and the findings of this project are relevant and adaptable to other utilities and the industry. The key finding, that submetering using third-party vendors is not yet ready for statewide scale, has several potential lessons for other utilities or locations that are considering this approach. As discussed above, the key points are that any future efforts in this direction should:

- Be based on submetering equipment that meets revenue-grade accuracy standards
- Utilize a robust communication standard that can withstand interruptions
- Include proper data verification and validation procedures to ensure the accuracy of subtractive billing

5.7 Data Access

Upon request, PG&E will provide access to data collected that is consistent with the CPUC's data access requirements for EPIC data and results.

6 Metrics

The following metrics were identified for this project and included in PG&E's EPIC Annual Report as potential metrics to measure project benefits at full scale.[23] Given the proof of concept nature of this EPIC project, these metrics are forward looking.

Table 6-1: List of Proposed Metrics and Potential Areas of Measurement (as applicable to a specific project or investment area)	**Reference**
1. Potential energy and cost savings	
h. Customer bill savings (dollars saved)	Section 4.5.4
4. Environmental benefits	
a. GHG emissions reductions (MMTCO2e)	Section 3

[23] 2015 PG&E EPIC Annual Report. Feb 29, 2016. http://www.pge.com/includes/docs/pdfs/about/environment/epic/EPICAnnualReportAttachmentA.pdf.

7 Conclusion

This report documented the achievements, highlights, and key learnings of EPIC 1.22 – *Demonstrate Subtractive Billing with Submetering for EVs to Increase Customer Billing Flexibility*. Based on the results of the tasks summarized in this report, PG&E has found that there is currently no path to production for third-party submeters embedded within EV charging stations.

Four primary findings from this project drive this conclusion:

- Charging stations with submeters were not sufficiently accurate as demonstrated by both in-field data and independent lab tests. Until hardware is available that meets PG&E's revenue-grade metering standards for accuracy, subtractive billing based on submetering cannot be deployed.
- The MDMAs were unable to reliably receive data from the EVSE and were unable to transfer billing data to the utilities in a timely or accurate manner. A more reliable network than residential Wi-Fi should be utilized to transmit charging data. In addition, MDMAs need to demonstrate their ability to reliably manage usage and billing data before this approach can be scaled to serve the state of California. In order to enable a path to production, PG&E recommends that stakeholders develop standards for submeter accuracy, data transmission, and integration into utility billing systems.
- The customer saves an average of $374 in one-time installation costs to separately meter their EV load. The average customer can save $378 a year on their bill by moving from a tiered rate to a separately metered rate. $319 of the annual savings could be realized by switching from a tiered rate to a whole-house TOU rate without installing a separate meter or submeter.
- The evaluator found that each of the three major IOUs would have to spend $3,215,000 to $5,000,000 on upgrades required to accommodate third-party submeter data, depending on the utility's system configuration. If the state desires alternative methods of calculating GHG credits for EV drivers, PG&E can help deliver such methods without revenue grade billing data. If the state wishes to enable customers to measure their EV charging loads with revenue grade accuracy, PG&E can develop a technology deployment plan to address such a desire, assuming there is sufficient customer demand.

PG&E is eager to continue supporting transportation electrification across the state and rising to meet both the needs of the state and PG&E's customers. PG&E will continue to do so in such a way that appropriately pairs a technology solution with the need it is designed to address. Cost, accuracy, and customer satisfaction are paramount to right-sizing these solutions.