Evaluation of the California Statewide Smart Thermostat Time of Use Pilot

A Report for Pacific Gas and Electric, Southern California Edison, and San Diego Gas & Electric

Submitted by Evergreen Economics

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Graphic Summary

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Design

Evergreen Economics compared **three groups** of low-income customers on the time-of-use (TOU) rate

Quasi-Control

1. TOU rate transition only

Treatment

2. TOU rate and smart thermostat without eco+

3. TOU rate and smart thermostat *with* eco+

Goal: This pilot aimed to understand if smart thermostats were a useful tool in transitioning low-income customers to a time of use billing rate.

Study Challenges: Difficulty recruiting customers into pilot leading to low participation. Delayed activation by Ecobee of eco+ feature (which shifts usage to non-peak periods) on thermostats. Inability to activate eco+ feature on all thermostats.

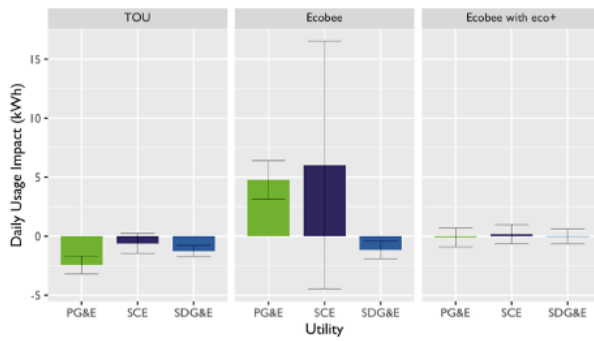
Methodology

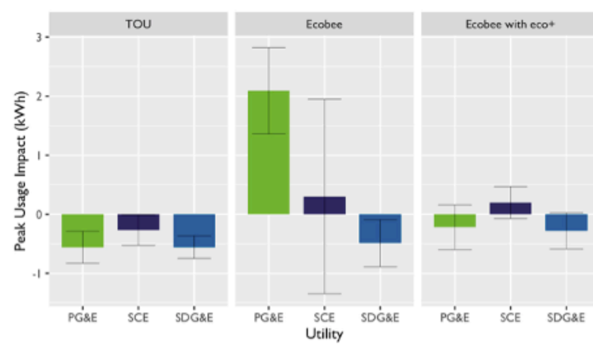
- Customer Segmentation
- Billing Analysis
- Three web surveys (before pilot, after summer, end of pilot)

Findings

Estimates of Pilot Program Savings

The TOU rate alone lead to customers lowering their overall energy usage during the peak period and throughout the day. Some of these savings were cannibalized by use of a new smart thermostat. There were some savings associated with the eco+ feature.

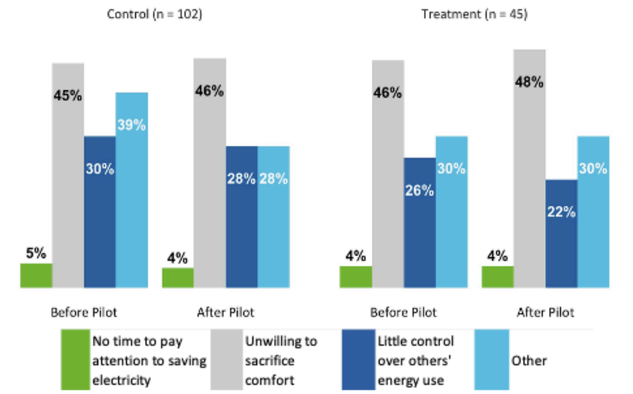




Group	PG&E		SCE		SDG&E	
	Treat-ment	Con-trol	Treat-ment	Con-trol	Treat-ment	Con-trol
1. Transitioned to TOU	88	96	86	82	48	81
2. Ecobee installed	40	n/a	36	n/a	42	n/a
3. eco+ connection	15	n/a	32	n/a	34	n/a

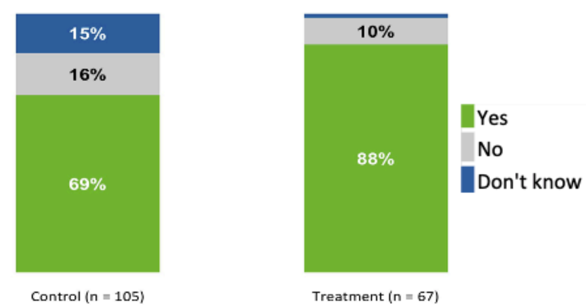
Increase in Usage Associated with Increase in Comfort

Participants who installed smart thermostats increased their comfort, which may explain some of the increase in energy usage.



Increased Awareness of Rate Change for Treatment Group

The treatment groups were more likely to be aware of the change in rate compared to the control group, suggesting that participation in the smart thermostat pilot helped households learn about the transition to the TOU rate.



1 Executive Summary

At the request of the California Public Utilities Commission (CPUC), the three California electric investor-owned utilities (IOUs) each ran a year-long pilot focused on identifying how to ease the transition to a time of use (TOU) rate for low-income customers. The TOU rate is meant to encourage residential customers to shift their usage away from the hours when the most electricity demand on the grid occurs.

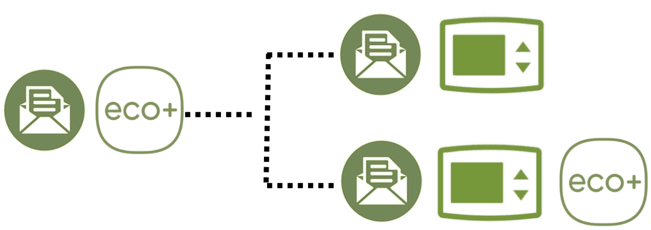
Pilot Methodology: This pilot aimed to understand if smart thermostats were a useful tool in transitioning low-income customers to a time of use billing rate. Evergreen Economics was hired to evaluate this pilot. Customers were recruited into the pilot by the IOUs and were told they would be placed in one of two groups:

1. **(Quasi) Control group:** Customers in this group were transitioned to a time of use rate, and kept their current thermostat. This is considered “quasi” control group as they still received the treatment of a rate change.
2. **Treatment group:** Customers in this group were transitioned to a time of use rate, with installation of Ecobee smart thermostats enabled with an “eco plus” (eco+) feature to automate energy savings during the peak period.

All pilot participants were given bill protection, which will credit any amount of payment over what would have been billed on the old tiered rate at the end of the full year of participation. Evergreen then randomly assigned customers to either a matched control or treatment group.

In late January and early February of 2019, customers were told which group they were assigned to and were transitioned to the new rate at the start of their monthly billing cycle. The IOUs hired implementation contractors to install smart thermostats and educate customers about the thermostat functions.

In the late summer of 2019, the thermostat manufacturer notified the study team that the eco+ functionality had not been included in the pilot thermostats, meaning that customers had not been automatically shifted away from heating and cooling usage during the peak TOU hours for the majority of the pilot period. This fractured the treatment group into two distinct sets of pilot participants after one group had eco+ pushed to their devices.



2a. Treatment group with smart thermostat (no eco+)

2b. Treatment group with smart thermostat *and* eco+ enabled

While this compromised Evergreen's research, Evergreen were able to perform analysis on the small period of time (August through November 2019) when eco+ was enabled, though this unfortunately limited Evergreen from reviewing a full year of customer interaction with this technology.

Analysis Methodology: Before customers were told if they were in the control group or the treatment group, they were asked to respond to an initial web survey that provided a baseline for self-reported thermostat usage and attitudes towards saving energy in their home.

Customers were surveyed again in the early fall of 2019, after they had received at least two warm-season bills, and then again in February of 2020, after nearly a full year of pilot participation. These surveys had many of the same questions, meant to track changes in attitude and behavior over time. The final survey included questions to assess treatment group satisfaction with the thermostat and impressions from the full year of pilot participation.

Evergreen Economics analyzed hourly advanced metering infrastructure (AMI) energy usage data to see how energy usage changed across the entire day, and during the peak period in particular. In interpreting the impact and process findings together, Evergreen identified conclusions that cover the TOU rate change and the additional impact of offering a smart thermostat, with and without eco+. At the end of the study, there were a total of 398 pilot participants.

TOU Rate

The move to the TOU rate, on its own, lowered energy usage, though only around half of these savings occurred during the peak period (for both SCE and SDG&E customers). For PG&E customers, one-quarter of the savings attributed to the move to the TOU rate occurred during the peak period.

Participant survey responses indicated that they had a general understanding of the TOU rates and that heating and cooling were the largest energy uses in their homes. Almost all respondents were able to correctly identify when energy costs the most (during the peak period for their IOU), but when respondents described when they thought their own homes used the most energy, their responses did not always align with the peak period. Customers were only able to accurately estimate when their home used the most energy between 47 and 73 percent of the time.

Close to half of customers reported that they wished they had been told more about the TOU rate before the pilot started and were particularly interested in **additional information on the rate, including the best times to use appliances**.

TOU Rate *with* a Smart Thermostat (no eco+)

The addition of the smart thermostat allowed low-income pilot participants to improve comfort in their homes, increased their awareness of the TOU rate, and gave them more control via smart devices, but was not beneficial in reducing peak and daily energy usage for PG&E and SCE participants. SDG&E participants with smart thermostats managed to further reduce energy use beyond their counterparts who did not receive the smart thermostats. Participants were generally satisfied with their thermostat when asked at the end of the pilot.

For PG&E customers, Evergreen saw a statistically significant increase in energy usage both in the peak period and daily, attributed to use of the smart thermostats. For SCE customers, the same was true, though this finding was not statistically significant. When Evergreen looked at SCE customers only in the summer, it appeared that thermostats were utilized to reduce air conditioning (AC) usage, though their overall change in energy usage was less than what Evergreen observed in the control group (i.e., TOU rate with no smart thermostat). In the winter, SCE customers were less likely than in the summer to see reduced usage from the thermostats. Across all seasons, this resulted in an increase in energy usage for SCE customers who had the smart thermostat installed, though this was not statistically significant.

SDG&E participants with the smart thermostats were able to save more energy than their counterparts in the control group who had kept their own manual and programmable thermostats and were moved to the TOU rate. They were able to save more energy in the winter, but also saw summer reductions compared to the control group.

There are two findings that may help to explain why the smart thermostat increased treatment group energy usage relative to the control group:

- **All pilot participants reported that the main hurdle standing in their way of saving additional energy is an unwillingness to sacrifice comfort in their home**. The new thermostat may have allowed them to better manage comfort in their home. Both control and treatment group participants reported that they had a preference for manually adjusting their thermostats though this may have meant different things to each group, depending on the functionality of their thermostats.
- The control group was less sure that they knew bill changes were attributable to the TOU rate. **This suggests that the participants with a smart thermostat may have been more likely to attribute a change in their bills to the TOU rate.**

Treatment group participants were initially told that their thermostats were already being “smart” and modifying their usage during the peak hours, though this was untrue through July of 2019.

This may have made them feel like they did not need to make as many changes on their own, during the peak period or in general.

The control group was more likely to report using their appliances less frequently to avoid the peak period during the summer months. While this was not statistically significant, it may indicate that the **control group was more likely to take action in non-cooling related ways in absence of the smart thermostat,** whereas the **treatment group may have been more likely to have interpreted the smart thermostat offering as more of a one-stop solution to the change in rate.**

The smart thermostat alone (and in the absence of eco+) is likely not a valuable program tool for reducing peak usage, though it can help improve customer awareness of the TOU rate and improve customer comfort.

TOU Rate *with* a Smart Thermostat *and* eco+

In the period when Evergreen were able to analyze customers with eco+ enabled on their smart thermostats, Evergreen did not detect any statistically significant energy savings on the average day that could be attributed to the smart thermostat with eco+, relative to the control group.

There was a sudden drop in energy use at 4 p.m. for SDG&E participants with eco+ enabled, which was then sustained into the remainder of the peak period. SDG&E participants may have lowered their energy usage beginning at the start of the peak period as a reaction to large summer bills (SDG&E had steeper rates compared to the other IOUs), or customers may have been re-educated or reminded about the peak period when eco+ was pushed to their smart thermostats. This may have also been easier for customers to do without sacrificing comfort, given that SDG&E participants live in a more temperate climate. SCE participants also seemed to have the majority of their energy usage mid-day, compared to PG&E and SDG&E customers who used more energy in the evening hours.

Nearly all of the survey respondents who answered all three surveys aligned with the participants that had eco+ enabled in August. Responses from this group show that they were **not widely confident in the thermostat's ability to help them control their energy bills, or help them lower their energy use.**

2 Introduction

The three largest California electric investor-owned utilities (IOUs) were directed in Decision 16-11-022 as modified by Decision 17-12-009 to propose a plan to implement a pilot that examines interventions that may help low-income, high-usage customers reduce their energy use as they adapt to time of use (TOU) rates. These program interventions include programmable communicating thermostats (PCTs), alternative pricing mechanisms, and mobile phone applications. The electric IOUs developed variations of the pilot, each using a treatment and control group of low-income customers who are willing to move to a TOU rate with a total of up to 1,600 pilot participants. The three pilot variations differ in the key ways shown in Table 1. Individually, each pilot will allow for comparisons within each IOU's low-income high-usage populations in warmer climate zones.

Table 1: IOU Pilot Differences

IOU	Past Program Participation	Climate Zones*	Total Targeted Participants
SCE	ESA before summer 2017 + high usage CARE customers + general CARE (signed up or verified)	14 and 15	• 150 treatment • 150 control
PG&E	ESA between summer 2013 and summer 2017	11 to 14	• 150 treatment • 150 control
SDG&E	ESA before summer 2017 + high usage CARE customers	All	• 500 treatment • 500 control

* Building climate zones as defined by the California Energy Commission (CEC)
https://ww2.energy.ca.gov/maps/renewable/building_climate_zones.html

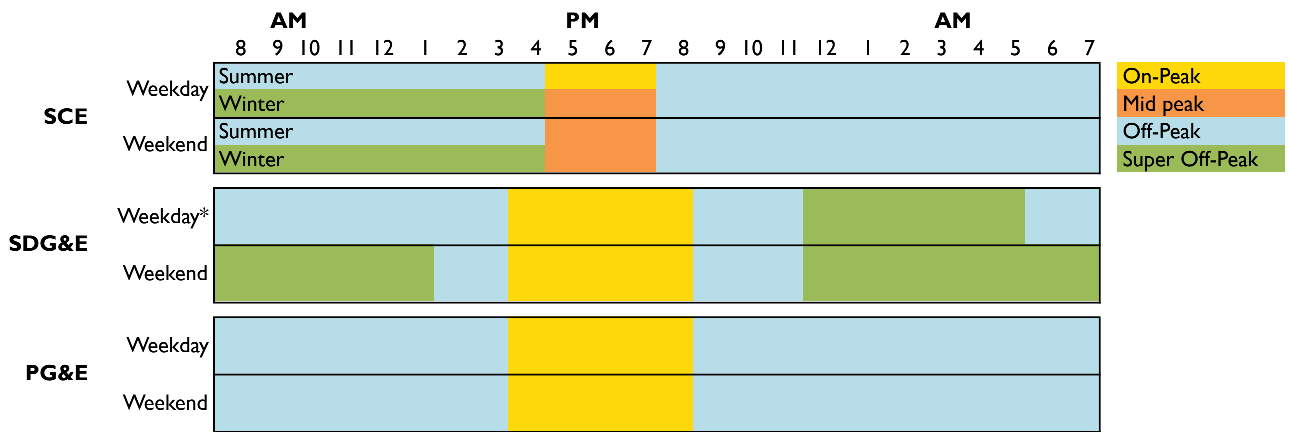
The IOUs recruited customers who had already participated in a low-income program. Altogether, the participants were required to:

- Receive electric service (gas optional);
- Own their home with no plans to move during the study period;
- Have and use central cooling (central air conditioning [AC] or heat pump);
- Have wireless internet in their home, and
- Not yet be on a TOU rate plan or have a connected PCT.

Over the course of the research, the total participant group dropped due to issues with thermostat installation and challenges re-contacting customers. These challenges are further explained in Appendix C and D.

Figure 1 demonstrates IOU differences in peak periods for the TOU rates applicable to this pilot. SDG&E and PG&E have on-peak hours between 4 PM and 9 PM, while SCE has peak from 5 PM to 8 PM with different rates for weekdays and weekends. The on-peak charges ($/kWh) for SCE and SDG&E are much larger than PG&E, relative to off-peal hours.

Figure 1: Time of Use Peak Period Difference Across IOUs



**Plus super off-peak from 10 a.m. to 2 p.m. in March and April*

In the summer of 2019, Ecobee announced that the thermostats used in this pilot study had not been running the Peak Relief functionality that was designed to help customers adjust to TOU rates. Ecobee pushed an updated version of Peak Relief (eco+) to a majority of the thermostats installed through the pilot, but this further fragmented the treatment group. It also greatly shortened the period that treatment customers experienced the Peak Relief functionality (now "eco+") during the full run of the pilot.

2.1 Study Objectives

This evaluation approach is designed to meet the following study objectives:

1. Conduct a load impact analysis that includes load shifting profiles, and gross energy and demand savings impacts.
2. Survey pilot participants to understand their experience and opinions of how the smart thermostat impacted their usage, especially during TOU periods. Evergreen asked demographic, behavioral, attitude, and knowledge questions to help contextualize Evergreen's findings in the load impact analysis.
3. Combine survey data with the customer usage data to further explore the relationship between customer self-report and demographic characteristics with usage patterns.
4. Understand if smart thermostats are a useful tool for low-income customers in transitioning to a TOU rate.
5. Identify beneficial messaging for future marketing or educational materials.

3 Methodology

3.1 Assign Treatment and Control Groups

The three IOUs recruited customers into the Low Income Programmable Communicating Thermostat (PCT) Time of Use (TOU) Pilot, letting them know that they would be moved to the TOU rate, and that they may or may not receive a PCT.

As required for a true randomized control trial (RCT) design, Evergreen randomly assigned these customers to either a treatment group or a control group. Prior to the assignment, Evergreen grouped customers into similar categories based on energy usage, average load shape, and possibly location (if needed). The Advanced Metering Infrastructure Customer Segmentation (AMICS) model framework (discussed in further detail below) was very useful in this regard, as an initial binning process allowed Evergreen to identify similar customers and group them together based on average energy use and load shapes (through the *k*-means cluster analysis).[1] Once similar customers were grouped in this manner, the randomized selection between the treatment and control groups was be completed.

3.1.1 Verify Pilot Eligibility

The IOUs recruited a total of 764 customers into the pilot, well below the initial target of 1,600. This was in part due to recruitment challenges documented in Appendix C and D.

Evergreen verified criteria used during utility recruitment with the utility billing data and measure incentive records, where feasible. A total of 34 customers were screened out of the initial IOU recruitment pool because they did not meet all of these eligibility criteria (for example, six had previously received incentives for PCTs, and one was already on a TOU rate). The IOU recruitment relied on customer self-report, which was not always sufficient to confirm eligibility for participation in the pilot.

An additional 36 customers opted out of the pilot prior to Evergreen's analysis. The remaining 694 customers were randomly assigned to the treatment and control groups (Table 2).

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[1] In effect, clustering automatically groups customers with similar hours of energy usage and magnitude of usage. This process identifies groups of customers with relatively homogenous patterns in energy usage, without relying on customer characteristics that are often not tracked (or not regularly updated) by the IOUs.

Table 2: Pilot Customer Recruitment and Screening

	PG&E	SCE	SDG&E	Total
IOU Recruitment Eligibility	Prior/current low-income program participation in climate zones 11-14		Prior/current low-income program participation	
Customers Targeted	300	300	1,000	1,600
Customers Recruited	414	174	176	764
Screened Out by Evergreen (not eligible)	25	0	9	34
Opted Out	36	0	0	36
Remaining	**353**	**174**	**167**	**694**

3.1.2 Customer Segmentation

Prior to the random assignment of customers into the control and treatment groups, Evergreen sorted customers into similar categories based on their average load shape in the pre-period and other characteristics. Evergreen used the AMICS model framework to identify similar customers and group them together based on their energy usage to improve the matching between the treatment and control groups.

Evergreen created different customer segments for each IOU (listed below) due to the variations in eligibility criteria, sample size, and pre-period load shapes across IOUs. The segments were chosen to minimize the baseline model error (as measured by repeated cross validation holdout tests) and group customers with similar potential for savings from the TOU pricing and/or PCTs, while also minimizing the number of customers isolated by the segmentation method (that is, solo customers without peers to enable a post-period comparison).

- PG&E: 5 daily energy usage (magnitude) groups and 7 normalized load shape clusters (hours-of-use)
- SCE: 2 eligibility categories (i.e., prior participation in the Energy Savings Assistance program) and 11 load shape clusters (magnitude and hours-of-use)
- SDG&E: 2 climate zone groups and 11 load shape clusters (magnitude and hours-of-use)

For the daily energy usage groups, Evergreen assigned customers to one of five bins according to their average daily energy usage in the pre-installation period, such that each bin contained roughly the same total kWh usage. The number of customers in each bin varied, with the highest energy usage bins containing the fewest customers. This binning strategy isolated customers who are atypical, reducing error in the model without removing these customers from the analysis.

The load shape clusters for each IOU were made up of customers with similar hours of use, identified by *k*-means clustering, such that each customer segment contains a subset of customers with similar hours of energy use during the pre-installation period. The benefit of cluster analysis is that similar customers are grouped automatically from the AMI data, rather than relying on customer characteristics that are often not tracked (or not regularly updated) by the IOU. Some customers have relatively flat load shapes with little change in energy usage throughout the day, while others exhibit a steep increase in energy usage in the morning and afternoon hours until they reach a peak in the evening and drop back down.

3.1.3 Random Assignment

Once similar customers were grouped in this manner, the randomized selection between the treatment and control groups could be completed. Specifically, Evergreen randomly assigned 50 percent of the customers in each IOU customer segment to the treatment group or the control group. In a few cases, Evergreen manually shifted customers with no peers (that is, those assigned to a segment with only n=1 customer) to the opposing groups to maintain a balance between the groups. Table 3 provides a side-by-side comparison of the average pre-period energy usage, low-income program participation, and home characteristics based on IOU program, billing, and customer information system data.

Table 3: Attributes of Control and Treatment Group

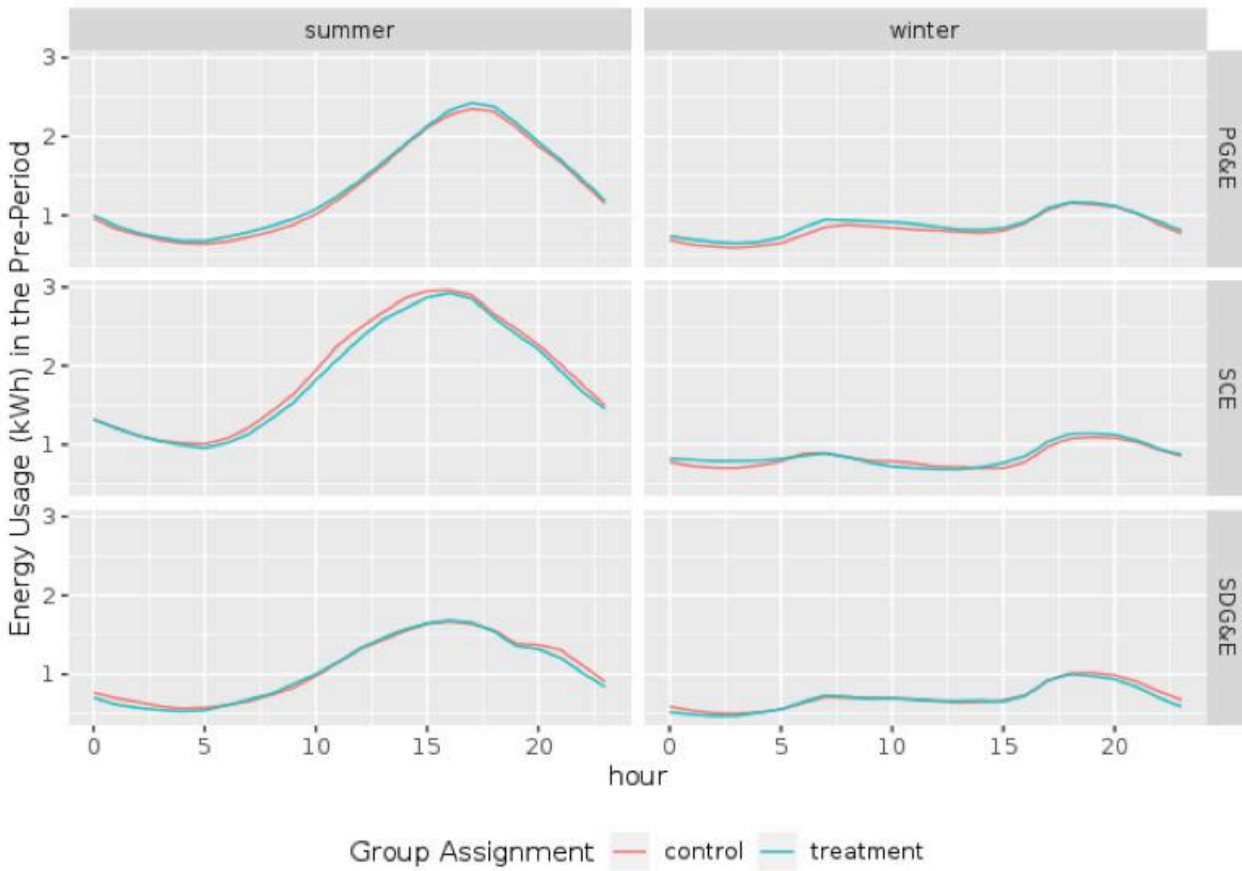
	PG&E		SCE		SDG&E	
	Control	Treat	Control	Treat	Control	Treat
N	176	177	87	87	84	83
Avg. daily kWh	23	24	28	28	19	19
Avg. kWh during peak hours	2.1	2.2	2.7	2.7	1.5	1.5
Avg. summer-shoulder ratio*	1.9	1.9	2.9	2.6	1.7	1.8
Avg. fixed-effects baseline**	0.49	0.49	0.63	0.63	0.42	0.42
% participated in ESA	100%	100%	8%	6%	27%	39%
% enrolled in CARE - late 2018	84%	84%	48%	54%	93%	88%
Avg. home square-footage	1,632	1,712	1,721	1,686	not available	not available
Avg. home built year	1982	1980	1986	1988	not available	not available
Avg. total CDD for the year	1,789	1,783	3,266	3,062	1,246	1,257
Avg. total HDD for the year	2,788	2,779	2,049	2,159	1,789	1,775

*Average hourly kWh in summer (months 6-8)/average hourly kWh ratio in shoulder months (11, 2-3). The concept is that the larger ratio is indicative of high HVAC usage, and thus more potential savings from a thermostat or AC program.

** Estimated baseline kWh, customer fixed-effects coefficients from a simplistic regression model using a full year of pre-period days (on days with defined temperatures). kWh ~ alpha + hdd + cdd.

Figure 2 shows the average kWh energy usage during the summer and winter months, by customers assigned to the control (pink) versus the treatment (blue) group prior to any program intervention. The overall kWh energy usage (scale) and shape differ across the three IOUs, but in both seasons, the control and treatment groups appear well matched. This is especially important during the summer peak hours, when Evergreen expects to see the largest impact from the TOU rates and/or PCTs.

Figure 2: Average Load Shape of Treatment and Control Group by Season and IOU



3.2 Customer Surveys

Evergreen designed and implemented a total of six web surveys over the course of the evaluation. This included three surveys for each study group (control and treatment) on three separate occasions: before the pilot began, after summer bills were received, and then in February 2020 after almost a year of participation in the one-year pilot.

For the first survey, Evergreen sent pilot participants both a postcard and an email that contained a unique link to a web survey before alerting them of their placement in the control or treatment group. Evergreen offered an incentive of a $25 to $50 gift card to either Target or Walmart (varied by IOU) for completing the first web survey.

Table 4 shows the initial IOU incentives along with the incentives planned for the three surveys. Respondents to all three surveys received an additional “kicker” incentive in some cases, as shown.

Table 4: Incentives by IOU and Treatment vs. Control Group

	PG&E		SCE		SDG&E	
	Treatment	Control	Treatment	Control	Treatment	Control
Initial IOU Incentive	Thermostat	None	Thermostat	$100	Thermostat	$100
First Survey	$50	$50	$25	$25	$25	$25
Second Survey	$50	$50	$25	$25	$25	$25
Third Survey	$50	$50	$25	$25	$25	$25
Survey "Kicker"	$50	$50	N/A	N/A	$25	$25
Final Incentive	N/A	N/A	N/A	$100	N/A	N/A
Total Possible	**$200**	**$200**	**$75**	**$275**	**$100**	**$200**

In Table 5, Evergreen presents the survey response rate over the course of the study. Columns labeled "n" include the total number of respondents that received surveys. There was a significant drop in the number of surveys sent to customers between the first and second survey due to participants dropping out of the study after learning their group assignment or after possible participants were unwilling to sign release forms. Attrition during this period of the study is discussed thoroughly in the interim findings memo included as Appendix D.

Table 5: Survey Response Rate

	First Survey			Second Survey			Third Survey		
	Completed	n	Response Rate	Completed	n	Response Rate	Completed	n	Response Rate
PG&E	**93**	**354**	**26%**	**77**	**142**	**54%**	**80**	**142**	**56%**
Control	66	176	38%	49	99	49%	55	99	56%
Treatment	53	178	30%	28	43	65%	25	43	58%
SCE	**93**	**174**	**53%**	**34**	**123**	**28%**	**36**	**123**	**29%**
Control	34	87	39%	19	87	22%	23	87	26%
Treatment	29	87	33%	15	36	42%	13	36	36%
SDG&E	**104**	**167**	**62%**	**67**	**133**	**50%**	**83**	**133**	**62%**
Control	55	84	65%	41	84	49%	56	84	67%
Treatment	49	83	59%	26	49	53%	27	49	55%
Total	**290**	**695**	**42%**	**178**	**398**	**45%**	**199**	**398**	**50%**

Table 6 shows how many of the respondents to the third survey had responded to the prior two surveys, allowing Evergreen to analyze responses and how they changed over the course of the pilot.

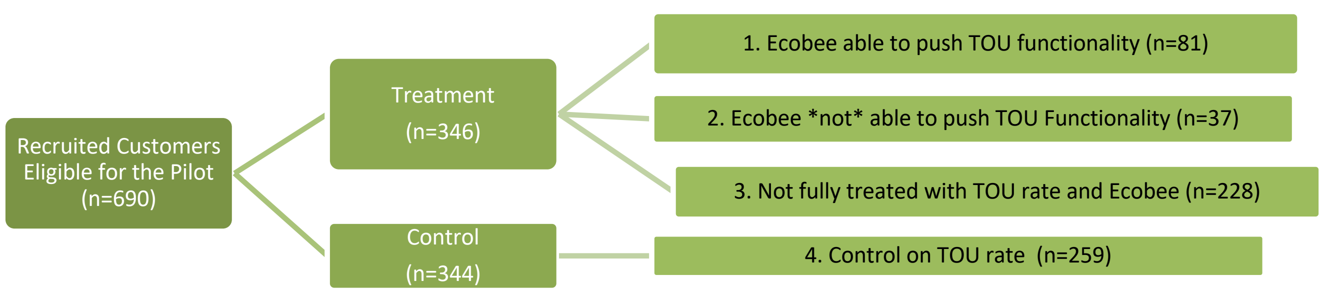
Table 6: Percentage of Respondents from Third Survey that Responded to All Three Surveys

	Completed All Three Surveys	n	Response Rate
PG&E	**46**	**80**	**58%**
Control	30	55	55%
Treatment	16	25	64%
SCE	**18**	**36**	**50%**
Control	12	23	52%
Treatment	6	13	46%
SDG&E	**45**	**83**	**54%**
Control	33	56	59%
Treatment	12	27	44%
Total	**109**	**199**	**55%**

3.3 Billing Analysis

Evergreen conducted an analysis of pre and post participation load and billing data to estimate potential energy and bill savings associated with TOU-enabled PCTs. Pilot participants were randomly assigned to two balanced groups: treatment and control. Each of these two groups fractured into varying levels of treatment or control, as shown in Figure 3.

Figure 3: Pilot Participant Treatment and Control Groups after the Program Intervention



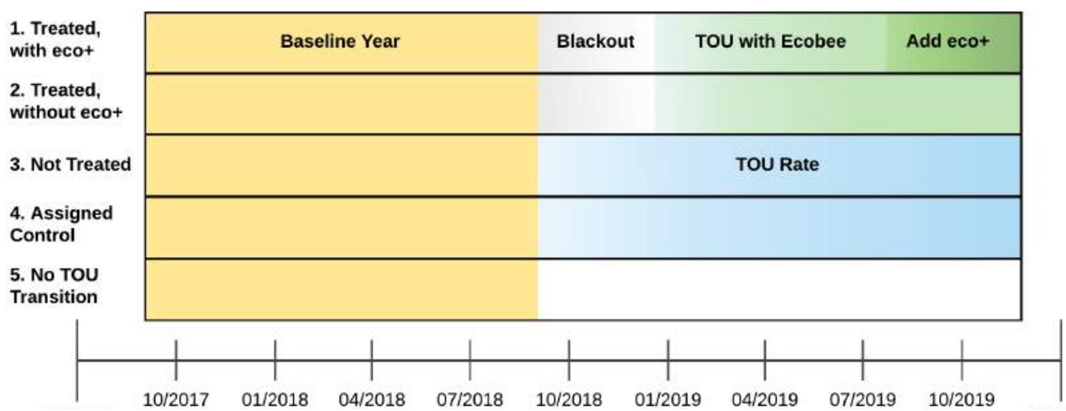
There are now four groups of pilot participants:

1. Treatment participants who installed the smart thermostat in early 2019, and received the full TOU functionality by the end of August 2019;
2. Treatment participants who installed the smart thermostat in early 2019, but will never receive TOU functionality due to connectivity issues;
3. Treatment participants who were not fully treated because they were not moved to a TOU rate or unable/unwilling to have the smart thermostat installed; these customers were either moved to a TOU rate without the device or dropped from the program by the IOUs;

4. Control group participants who were moved to the TOU rate.

Evergreen's original research plan assumed a full year of baseline and post-period data from the full treatment and control groups. Figure 4 provides the revised pilot program timeline by participant group. Due to delays in recruitment and limitations in scheduling the Ecobee PCT installations, the program intervention was completed between December 2018 and January 2019 (instead of October 2018, as originally planned).[2] The eco+ TOU-optimization feature was enabled for a subset of the customers with Ecobee PCTs (group 1) between July and August 2019. In order to accommodate reporting deadlines set by the CPUC, Evergreen was required to cut off data collection on November 30, 2019; hence, Evergreen has less than a full year of observations after the program intervention. In order to balance the baseline and reporting periods, Evergreen restricted the baseline period utilized in the regression models to the same time period in the prior year; the end of 2018 will be treated as a blackout period. The impacts of Ecobee and eco+ TOU-optimization functionality can only be estimated for the post-period observed in the data. Annualized impacts of eco+ TOU-Optimization are not feasible unless the pilot were to be extended through the summer months of 2020.

Figure 4: Program Intervention Timeline by Group



For the treatment group with PCTs (groups 1 and 2), the time between the TOU rate switch and the Ecobee PCT installation will be a blackout period for the analysis. Those customers who were assigned to the treatment group but never received a PCT (group 3) received the same intervention as those assigned to the control group (group 4). However, these customers were offered an Ecobee PCT but were unwilling or unable to receive a PCT, which makes them systematically different from groups 1, 2, and 4. The fifth group shown in Figure 4 contains customers who were randomly assigned to the treatment group or the control group, but were never transitioned to a TOU rate (e.g., they moved). There is no program intervention to assess in

[2] The TOU, Ecobee, and eco+ activation dates vary across customers. The Ecobee PCTs were installed between December 18, 2018 and January 18, 2019. eco+ was activated between July 18, 2019 and August 30, 2019.

group 5, but they can still be utilized in the baseline models because Evergreen has already verified that they are eligible to participate in the program.

3.3.1 Database

PG&E, SCE, and SDG&E recruited 764 low-income customers to participate in the pilot. Evergreen received customer account details and a full year of hourly interval AMI billing data for each customer prior to any program intervention, from September 2017 to August 2018. A total of 694 participants were assigned to the treatment or the control group as described in Section 3.1.

Evergreen received additional post-period data after adoption of TOU rates and installation of thermostats. This post intervention data again included customer account characteristics and hourly interval AMI billing data, from September 2018 to November 2019. Table 7 provides a detailed view of how the sample fractured after the original assignments.

There were some customers originally assigned to the pilot for which Evergreen did not receive post intervention data. There were issues with PG&E transitioning customers to TOU rates due to an inability to collect signature forms confirming acceptance of the terms of the pilot. Only 53 percent of customers recruited for the pilot by PG&E were transitioned to a TOU rate, compared to 97 percent from SCE and 94 percent from SDG&E. There were difficulties with implementation of PCT installations for the treatment group across all three IOUs, due to a wide range of issues such as installation scheduling logistics, incompatible home wiring, and customer refusal to accept the smart thermostat. For PG&E specifically, there was a challenge in getting customers to sign agreements with the utility. This is further detailed in Appendix D.

In August of 2019 the study team was notified by Ecobee that none of the thermostats installed had the correct software that would allow for automated load shifting away from the IOU's peak periods. Ecobee made efforts to update this software on each pilot thermostat though they were unable to do this to each and every thermostat.

Table 7: Fractured Treatment and Control Groups by IOU

	PG&E		SCE		SDG&E	
Group	**Treatment**	**Control**	**Treatment**	**Control**	**Treatment**	**Control**
Assigned	176	173	87	87	83	84
Received post-period AMI	176	173	87	87	53	84
Transitioned to TOU rate	88	96	86	82	48	81
At least six months of post data	87	95	82	77	46	79
Ecobee installed	40	n/a	36	n/a	42	n/a
eco+ connection	15*	n/a	32	n/a	34	n/a

*Evergreen determined active eco+ thermostats using data shared by an Ecobee file dated September 6th, 2019. At two later dates (October 2019 and March 2020) Ecobee provided additional information regarding four thermostats that were later activated. These four thermostats are excluded from our analysis.

Table 8 provides an overview of the resulting sample available for Evergreen's analysis. Evergreen defined the baseline year (i.e., pre-period) as the time between October 2018 and the first program intervention (TOU activation or Ecobee installation). The post-period begins after all relevant program interventions are completed for an individual customer. For groups 1 and 2, any dates that fall between TOU activation and Ecobee installation were excluded from the analysis. In late August 2019, Ecobee notified PG&E there was an additional defect impacting only PG&E installations (half of the thermostats received by PG&E were not set up correctly by Ecobee), which prevented 24 of the installed thermostats from accepting firmware upgrade over the cloud. A matching algorithm was utilized to identify a subset of the control group (group 4) that appears similar to the treated customers with thermostats installed (groups 1 and 2) during the baseline period; see Appendix E for details. The timeline of the control group was further restricted to match that of the treatment group prior to the difference-of-difference calculation of program impacts.

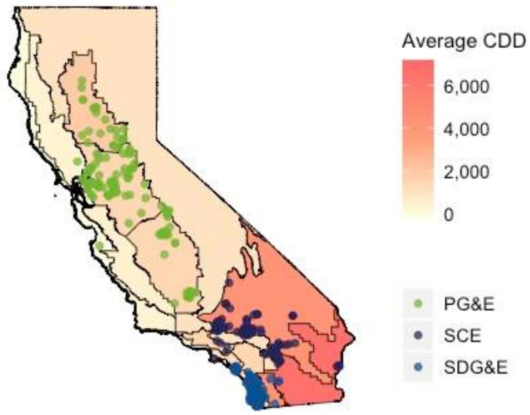
Table 8: Final Analysis Sample by Pilot Intervention and IOU

		Control	Treatment	
Group		Group 4	Group 1+2	Group 2
Intervention		TOU	TOU with Ecobee	TOU, Ecobee, eco+
Post-Period Timeline		Oct 2018 - Nov 2019	Dec 2018 - Aug or Nov 2019	Dec 2019 - Nov 2019
Number of Customers	PG&E	95	40	15
	SCE	77	36	32
	SDG&E	79	42	34
	Total	**251**	**118**	**81**

The IOUs also provided Evergreen with hourly weather data from 60 distinct weather stations, spanning all service territories from September 2017 through November 2019. Across all stations and dates required for the analysis, 96 percent of days contained a full 24 hourly observations. Evergreen merged these weather data with the billing records, using the IOUs' preferred weather station for each customer service account or determining the nearest station.

Figure 5 provides a map showing the geographic spread of the pilot participants by utility. The lines provide the boundaries of the California CEC Building climate zones. Each zone has been shaded with the annual cooling degree-days (CDD), with the hottest regions in red. Most of the participants from PG&E and SCE are inland, while many of SDG&E's participants are located along the coast. Many of the SCE participants are located in CZ14 and CZ15, the two hottest climate zones in California. These participants have a greater need for cooling throughout the year. PG&E and SDG&E customers are located in much milder climate zones, that have much lower cooling needs. The geographic distribution of participants is displayed below in Figure 5, along with the average annual CDD for the climate zone [3].

Figure 5: Pilot Participants by Utility and Climate Zone



The IOU customer account details allowed Evergreen to identify 134 customers (19%) that were enrolled in a demand response program during the pilot deployment. These programs include a direct load control AC switch program and a voluntary load reduction incentive program (with optional enabling technologies). To avoid attributing peak load reductions to the pilot that are actually caused by concurrent participation in these other programs, Evergreen excluded all observations on event days for customers enrolled in an existing demand response program.[4] It was not necessary to remove these customers from the analysis entirely, because these programs will only impact their energy usage during events.

3.3.2 AMI Customer Segmentation Model

In this task, Evergreen analyzed AMI interval billing data for the pilot participants from each of the IOUs. Evergreen used the AMI Customer Segmentation (AMICS) modeling approach to estimate the energy savings attributable to the Ecobee smart thermostat and eco+, independent of the transition to TOU rates.

The AMICS model has been used successfully in several residential applications to date and has produced very accurate estimates of load shapes, along with very detailed (i.e., hourly) estimates of program impacts. In 2018, Evergreen used the AMICS model to estimate impacts for SCE's

[3] Average annual degree-days for reference city within climate zone: https://www.pge.com/includes/docs/pdfs/about/edusafety/training/pec/toolbox/arch/climate/california_climate_zones_01-16.pdf

[4] While we do acknowledge that the pilot interventions may have increased the peak load reduction that participants were able to achieve during events, teasing out the savings of concurrent programs was outside the scope of this study.

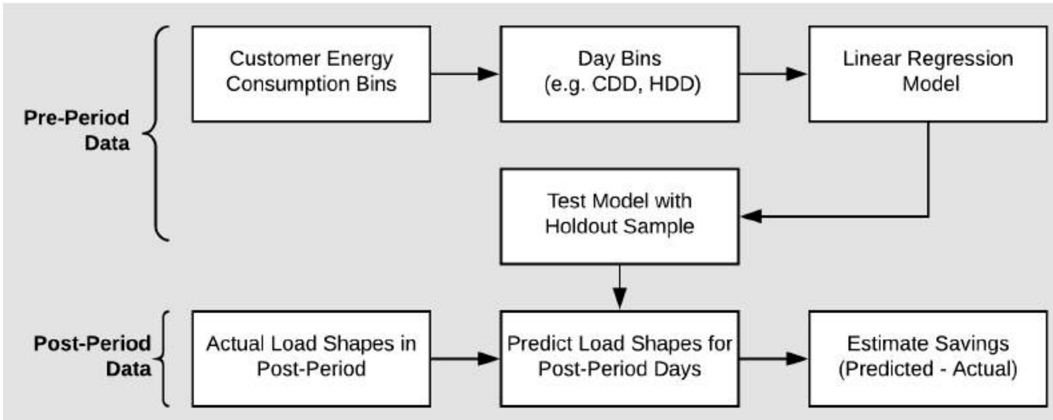
Optimized Connected Thermostat Project, and much of that work will be directly applicable to this evaluation. This project involved smart thermostats in California and had a very limited sample size (n=314), providing very promising indications that the model can be applied very effectively to the current pilot and address some of the potential study limitations (e.g., small sample sizes, lack of additional control groups). Evergreen's previous research for the IOUs has demonstrated that the AMICS modeling approach produces similar results to a traditional fixed effects billing regression model at the *program* level, while also providing the time of day the savings occurred.[5] This is not a proprietary "black box" method, but rather a series of simple linear regressions that are estimated with open source statistical software (R and PostgreSQL).

A unique step in the AMICS modeling approach is segmenting the AMI data into thousands of distinct segments (bins), as shown in Figure 6. Each bin contains interval energy use data for customers (from the treatment and control groups) with similar energy usage patterns on days with specific weather conditions. Binning the data and then estimating separate regression models for each bin limits the variation (across customers and days) for which each model must account. The AMICS approach produces a portfolio of daily energy-use load shapes and savings estimates, representing how each customer uses energy when experiencing specific (actual or expected) weather conditions.

In the second stage, the model is tested against a holdout sample of customers that were excluded from the original model estimation. If the model can predict the load shape for the holdout sample with sufficient accuracy (preferably within 1%), then Evergreen proceed with the third stage, which involves predicting load shapes for the post period and then comparing them with actual energy use. In this case, Evergreen has two separate phases of the post-period to assess: 1) Ecobee installation with TOU rate plan enrollment and 2) eco+ TOU-optimization activation. The same pre-period baseline model can be applied to each of the post-period phases.

[5] The AMICS approach has been extensively tested and shown to accurately estimate energy savings for residential and commercial customers participating in HVAC programs, multifamily whole building retrofit programs, and home energy reports programs (both recipients and controls). In each study, repeated holdout testing was conducted to demonstrate the model's ability to make reasonable and consistent load shape predictions across the diverse sample of customers and days.

Figure 6: AMICS Model Overview



The customer segmentation and billing regressions within the AMICS approach can be customized for each IOU to address differences across the IOUs with respect to variations in program design, customers recruited, and climate. This includes using different variables in the segmentation and/or regression models to reflect program variations. Details on the final segmentation method and regression specification are detailed in Appendix E Section 5.1.1. The post-period analysis will account for differences in weather conditions across the three IOUs, with peak savings corresponding to each IOU's peak period definition (e.g., summer weekdays from 4 p.m. to 9 p.m.).

Model Validation

To validate the model's ability to make reasonable predictions, Evergreen conducted a holdout test using only pre-period data. This involves randomly selecting 30 percent of the customers in Evergreen's data as a holdout sample, defining the bins and estimating the model using the remaining 70 percent, and finally using the model results (from the 70 percent sample) to predict energy usage for the holdout. This is sometimes referred to as a *cross-validation* exercise.

If the holdout test reveals customer or day bins with high prediction error, Evergreen can adjust the binning criteria (e.g., the number of load shape clusters) to refine the segmentation and then repeat the holdout process to confirm improvement.[6] The iteration process continues with small variations to the AMICS binning criteria until the model prediction error stops showing significant improvement. If multiple binning strategies result in similarly low prediction errors, the simplest model is selected for ease of interpretation.

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[6] We consider a segmentation approach successful if the resulting AMICS model is able to separate patterns in energy usage from the simple random noise of individual observations, as measured by our holdout validation tests. This must be balanced with a need for easy interpretation, as the model results by customer segment will be used to provide insights into the characteristics of customers that were able to achieve the greatest energy savings.

The results of one such holdout test are shown in Figure 7, comparing the predicted pre-period load shape from the model (red line) of customers from each IOU to the actual pre-period load shape for the holdout sample (blue line). When the model is preforming well, the two lines will overlap. The holdout test relies exclusively on pre-period data so that any differences between the predicted and actual energy usage can be attributed to model error, not to program savings. Evergreen specified a separate AMICS model for each of the IOUs, but the predictions for the control group and treatment group are based on the same AMICS model—these two groups were nearly identical in the baseline period, prior to the program intervention. Provided the limited modeling samples by IOU (n=214 for PG&E, n=110 for SCE, and n=92 for SDG&E) and a single year of baseline data, this is a strong result. In most cases, the model predictions track closely to actual load between 4 p.m. and 9 p.m., when Evergreen expect the largest pilot impacts (reduced peak energy usage) will occur.

Figure 7: Holdout Sample in Pre-Period, Actual vs. Predicted Usage by IOU

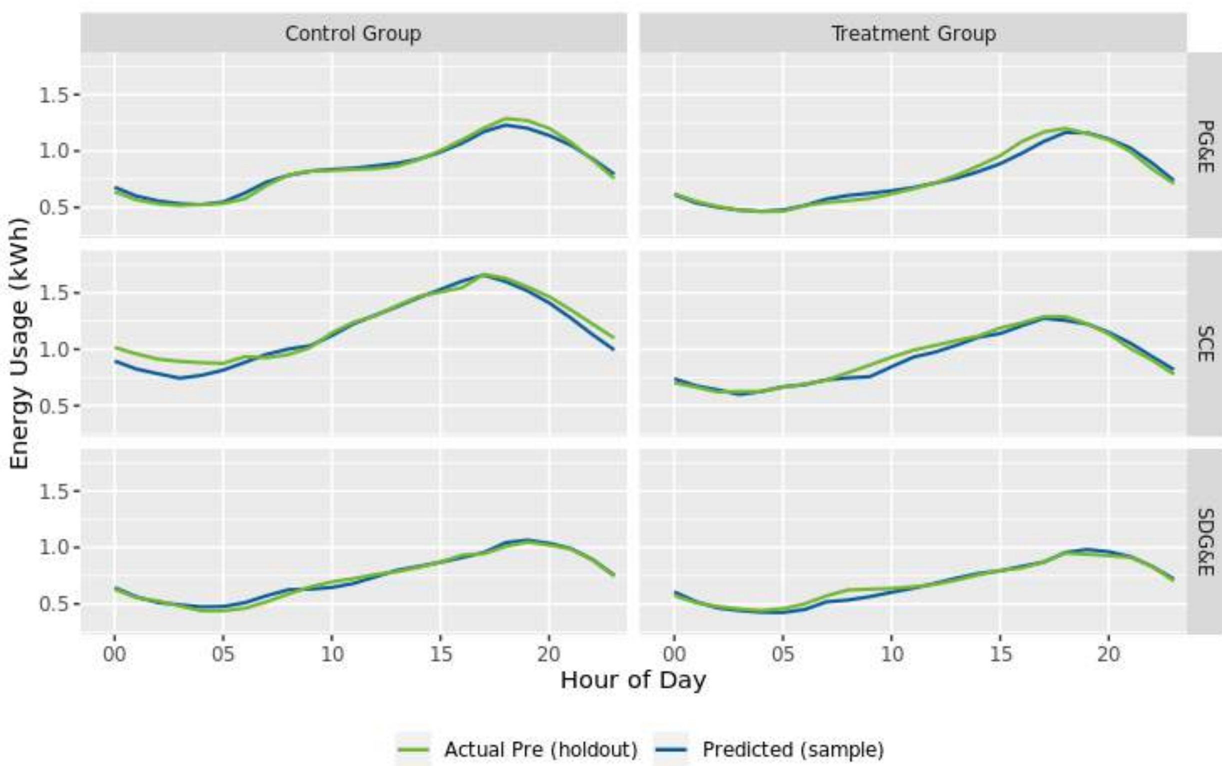

Table 9 provide some statistics characterizing the results of the holdout test with Evergreen's baseline model specification for the treatment and control groups by IOU.

Table 9: Summary of Baseline Model Holdout Test Results

IOU	Group*	Holdout N	Normalized Mean Bias Error (NMBE)	Root Mean Square Error (RMSE)
PG&E	Treatment	13	-0.6%	0.69
	Control	35	0.2%	0.68
SCE	Treatment	12	-1.6%	0.78
	Control	30	-3.7%	0.93
SDG&E	Treatment	15	-1.2%	0.58
	Control	24	1.1%	0.59

* This test was limited to customers that successfully participated in the pilot. This means that they were 1) assigned to the treatment group, transitioned to a TOU rate, and installed an Ecobee PCT, or 2) were assigned to the control group and transitioned to a TOU rate.

Post-Period Load Shapes and Savings

Once Evergreen was confident that the AMICS model accurately predicted the pre-period consumption for the observations in Evergreen's holdout sample, Evergreen re-estimated the model using the full sample (no holdout) to take advantage of all available data. Evergreen then used the model to predict what the load shapes would have looked like (for each customer segment on each day) in the post-period if the program pilot had not existed. Evergreen then compared these predicted load shapes to actual energy consumption over the same period to determine the total change from the pre- to post-period while controlling for any differences in weather and day type.

The control group allowed Evergreen to distinguish any naturally occurring changes from those caused by the program (difference-of-differences) for each type of customer and day (i.e., within each bin).

The main output of this task was a series of load shapes demonstrating the results of the pre-period holdout tests and post-period changes with hourly program impacts (i.e., savings). As the preceding graphs suggest, the load shapes obtained from the AMICS model allowed Evergreen to determine if there is load shifting occurring as a result of the pilot, which is one of the research objectives of this evaluation.

Acknowledgement of Limitations

The small pilot sample posed significant limitations for the regression analysis. A large number of observations are needed for a regression model to separate patterns in energy usage from random noise (e.g., meter measurement error, unusual events). This concern will apply to any regression model, not just the method Evergreen selected. However, **the holdout test demonstrates that the AMICS model is able to produce reasonable load shape estimates when limited to an even smaller sample (the 70% of customers remaining after the 30% holdout sample was excluded, or n=214 for PG&E, n=110 for SCE, and n=92 for SDG&E), thereby**

validating the use of this method. The final model predictions are based on the full sample (n=321 for PG&E, n=174 for SCE, and n=137 for SDG&E), increasing the number of observations available to the model and improving the accuracy of its predictions. The error bounds on the post-period load shape predictions and corresponding savings estimates reflect the remaining uncertainty in the AMICS load shape predictions.

Another limitation of this study is that the balance between the treatment and control groups was disrupted by the fractured treatment (e.g., failed Ecobee installations, Ecobee without eco+). However, the segmentation aspect of the AMICS approach is especially valuable in situations such as this. To build the model, Evergreen defined a series of customer segments that contain customers with similar baseline energy usage (i.e., magnitude of energy usage and hours of use). Many of these customer segments contain households from both the treatment and control groups. In effect, the segmentation phase identifies customers from the control group who are most similar to the treated customers based on the segmentation criteria, akin to comparison group selection. In this way, **segmentation accomplishes the same goal as matching**.

If a customer segment does not contain both treatment and control groups, the post-period changes are omitted from the difference-of-differences calculation. This is by design; **Evergreen can only assess program savings for the treated customers that have peers in the control group that will allow for a valid comparison in the difference-of-differences**. All but four customers in the treatment group had at least one well-matched comparison site in the control group.[7] However, not all of these matches had perfect overlap in post-period weather conditions and day types; some customer-days are thus omitted from the calculations of savings for the Ecobee above and beyond the TOU rate.

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[7] All 40 treated customers from PG&E and 42 from SDG&E had well-matched comparison sites in the control group. Unfortunately, 4 of the 36 treated customers from SCE (11%) did not have any well-matched comparison sites; these customers had especially high peak period energy usage. By chance, none of the highest energy users assigned to SCE's control group were successfully transitioned to the TOU rate, and were thus dropped from the pool of customers avalible for selection into the matched comparison group for the post-period analysis.

4 Findings

This section includes both process and impact findings. The process findings cover results from the three surveys and the impact findings cover the billing analysis.

4.1 Process Findings

In this section, Evergreen share findings from the three surveys that occurred over the course of the pilot. Results were analyzed across all three surveys:

- January 2019, before respondents were notified of their assignment as either treatment and control groups
- November 2019, after customers on the pilot had received their summer bills
- February 2020, after nearly a full year of participating in the yearlong pilot.

A total of 109 respondents completed all three surveys. The response rate for each survey, across each group (control, treatment, IOU) ranged from 26 to 67 percent.

Some questions were asked across all three surveys in order to track changes in perceptions over time, and some questions were asked just once (in the first survey, or a latter survey if participants did not respond to the first survey) in order to understand demographic information such as the existence of certain equipment in the home or prior thermostat usage.

Where Evergreen present results that identify perceptions over the course of the study, Evergreen only include results where respondents participated in all three surveys. Evergreen also excluded respondents that initially took the first survey but later decided to leave the pilot either because they did not like the group they had been placed in (treatment or control) or because they did not sign the correct release forms to participate in the pilot.

In this section, Evergreen cover the types of customers that participated in the pilot and include information on how they understand household energy use, how they use heating and cooling, and what types of items they have that use energy in their home. Following the respondent background, Evergreen cover experiences with the time of use (TOU) rate and with thermostats, as well as findings relevant to educational materials and strategies for a program similar to this pilot.

4.1.1 Respondent Background

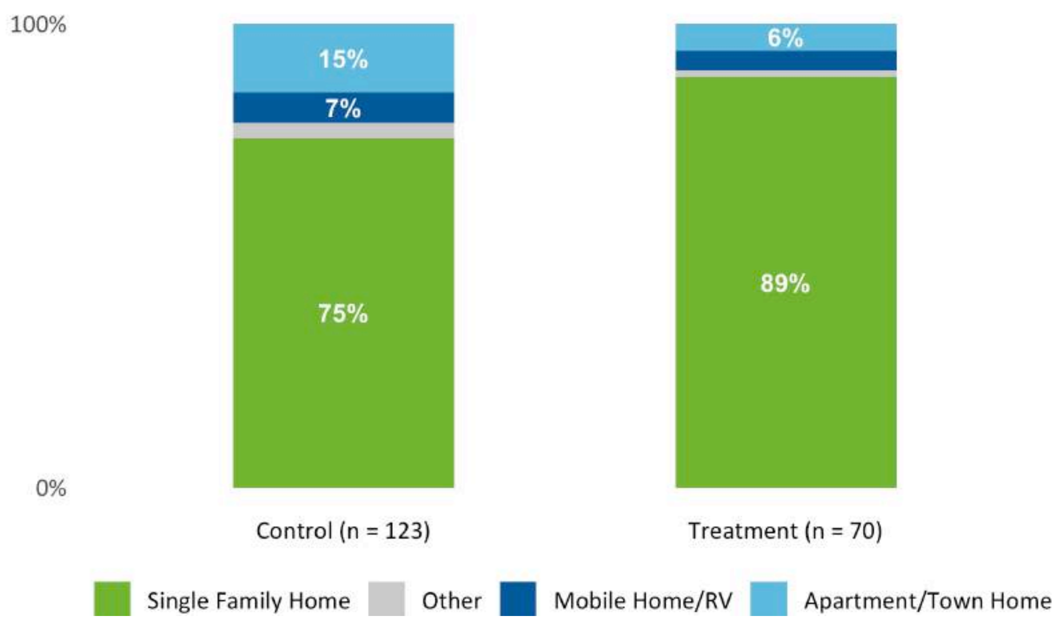
The majority of respondents (98% of the treatment group and 97% of the control group) stayed in their same household across the course of the pilot. Respondents from the treatment group who moved and had the program thermostat installed all left the thermostat in their prior household, and have thus been excluded from survey analysis. The same is true of the three control group participants who moved from their homes and are no longer considered part of the pilot.

Respondents in the treatment and control groups were similar in a number of ways:

- They had slightly more than one thermostat on average, before the study (an average of 1.06 thermostats for the control group and 1.11 for the treatment group).
- Before the study, over half of the participants in both groups reported owning a programmable thermostat (73% of the treatment group and 66% of the control group).
- Similar percentages reported having equipment that could contribute to higher bills.
- They both had similar and education levels, approximately three people in each home over the entire year, and 14 to 16 percent of respondents had an additional resident in the summer.

One area where the control and treatment groups *did* differ was in the likelihood that they lived in an apartment or townhome. There was a slightly higher amount of control group participants who reported living in apartments or townhomes (Figure 8).

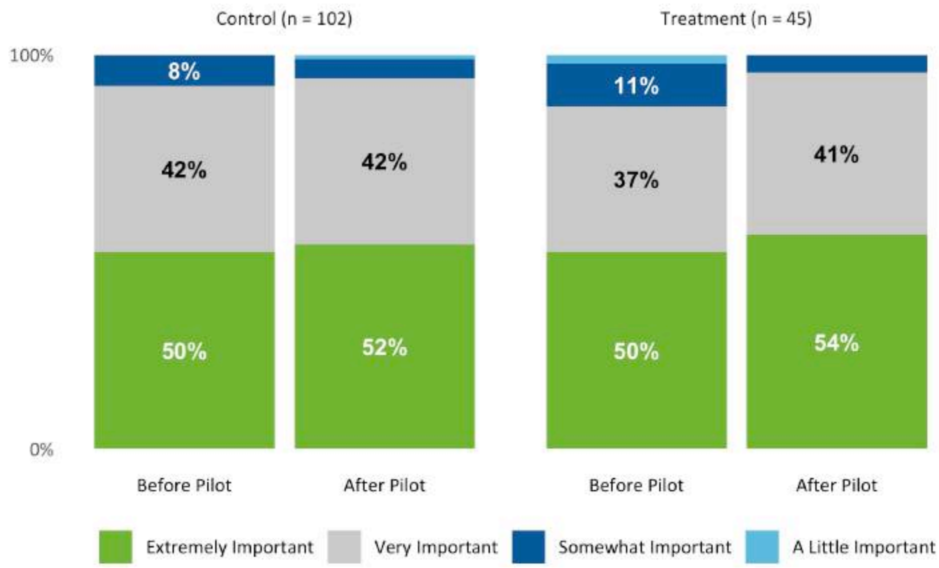
Figure 8: Reported Home Type, Control vs. Treatment Groups



4.1.2 Attitudes Towards Energy

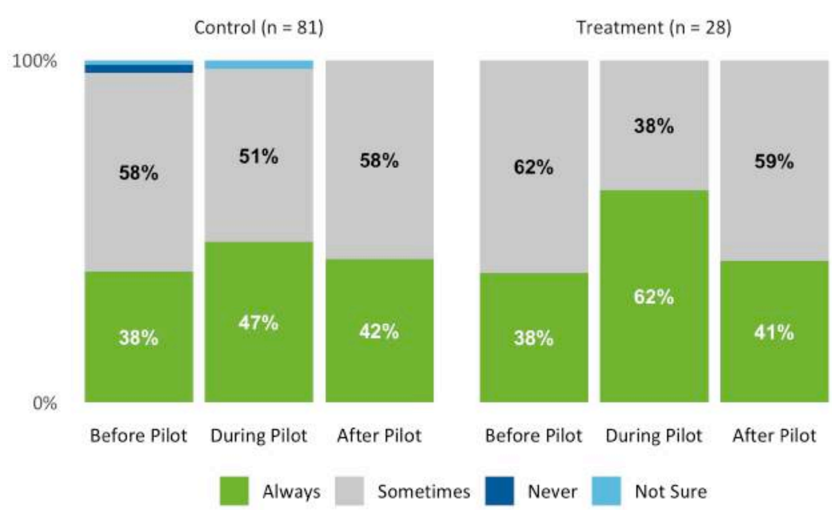
Before and after the pilot, Evergreen asked respondents about the importance of saving energy in their household. Nearly all respondents across the control and treatment groups reported that they felt that it is very or extremely important. After the pilot, as shown in Figure 9, the treatment group was more likely to report that they felt saving energy is extremely or very important, though this difference is not statistically significant. These results are broken out by IOU in Figure 9.

Figure 9: Reported Household Views on the Importance of Energy Efficiency Before and After Pilot



Almost 100 percent of respondents in both groups stated that they were sometimes or always doing everything they could to conserve energy when asked before, during, and after the pilot. These attitudes may have implications on their willingness to do more to save energy during peak periods or overall. While Figure 10 shows that respondents across both groups were more likely to say they were doing everything they could do all of the time in the summer (when AC loads are greater and likely when they had seen their highest bills), this is not a statistically significant jump or difference between the two groups. These results are broken out by IOU in Appendix A.

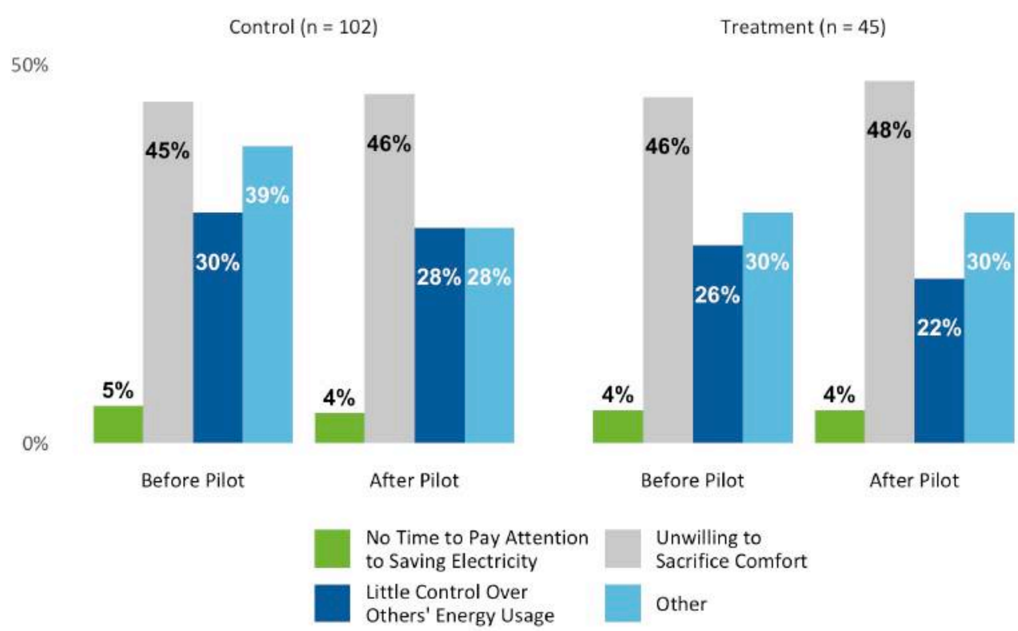
Figure 10: Reported Household Views Doing Everything They Can to Save Energy Before, During and After Pilot



Participants were asked about perceived factors that prevented them from saving more electricity in their homes. Almost half of participants in both groups stated that an unwillingness to sacrifice comfort in their homes was the main factor that prevented them from saving more energy. Comfort levels are often related to heating and cooling and may explain why Evergreen saw customers with the smart thermostats increase usage that ended up offsetting savings from the TOU rate. Evergreen will discuss this further in Section 4.2. If half of respondents (Figure 11) are not willing to sacrifice comfort, they may not be willing to reduce their usage during peak billing hours.

Other factors that prevented participants in the control group from saving more electricity included health issues (n=8), older or non-energy efficient appliances (n=8), and older homes with poor insulation (n=2). The treatment group reported similar factors including health issues (n=3) and older or non-energy efficient appliances (n=2).

Figure 11: Limitations to Saving Energy Before and After Pilot

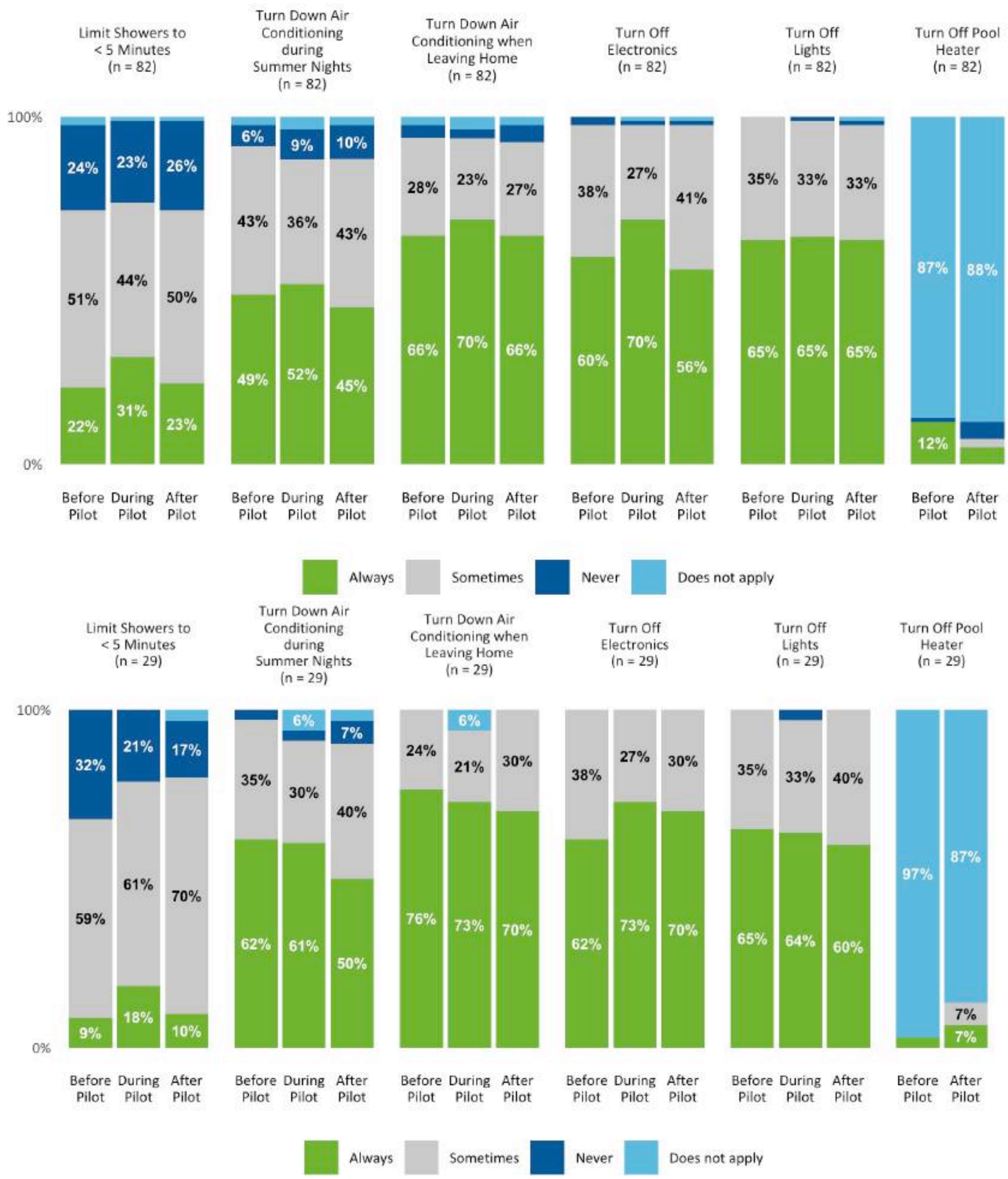


To get additional detail on what respondents were doing to save energy before, during, and after the pilot, Evergreen asked them about how often they do a set of five activites.

Limiting showers was the least popular activity amongst both the control and treatment groups, followed by turning down the air conditioner during summer nights.

Figure 12 shows that the control group reported taking on more energy efficient actions after the summer months (during the pilot), and the treatment group respondents reported doing slightly less as the pilot progressed. These changes over time are not statistically significant, nor are the differences between the control and treatment groups.

Figure 12: Frequency of Energy Savings Activities Before, During, and After Pilot, by Control (top) and Treatment (bottom) Groups



4.1.3 Understanding of Household Energy Use

Part of the intention of delivering a smart thermostat alongside the transition to TOU rates is meant to signal that heating and cooling are significant users of energy during peak hours. Customers were aware that the thermostat offer was a possibility even before the pilot started. From the very beginning of the pilot, customers in both the control and treatment groups ranked cooling methods such as AC and fans as the items in their home that use the most energy (Table 10 and Table 11).

Table 10: Ranking of Items That Respondents Believe Use More (lower number) or Less Energy by Season, Before and After Pilot, Control Group

Household Appliance	Before Pilot		After Pilot - Summer		After Pilot - Winter	
	Average	**n**	**Average**	**n**	**Average**	**n**
Cooling (AC/Fans)	2.62	99	1.75	99	8.22	99
Heating	4.01	94	7.08	97	2.15	97
Refrigerator	4.09	99	3.58	99	4.03	99
Lighting	5.33	99	4.93	99	4.30	99
TV	5.52	99	5.07	99	5.14	99
Water Heating	5.76	99	4.29	99	3.82	99
Pool/Spa Equipment	6.47	19	4.27	15	5.87	15
Oven	6.66	99	6.68	99	5.87	99
Laptop / Cellphone Chargers	7.29	99	6.69	99	6.59	99
Other (Personal/Business Equipment)	4.13	99	9.42	99	9.62	99

Table 11: Ranking of Items That Respondents Believe Use More (lower number) or Less Energy by Season, Before and After Pilot, Treatment Group

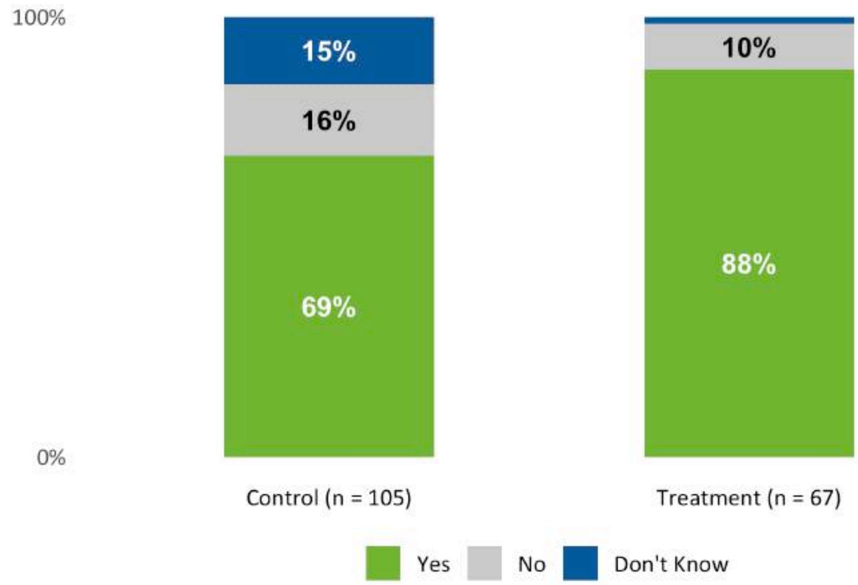
Household Appliance	Before Pilot		After Pilot - Summer		After Pilot - Winter	
	Average	**n**	**Average**	**n**	**Average**	**n**
Cooling (AC/Fans)	2.21	43	1.56	43	8.44	43
Heating	3.69	42	7.50	42	2.05	42
Refrigerator	4.23	43	3.95	43	4.28	43
Lighting	5.26	43	4.58	43	4.28	43
TV	5.93	43	4.74	43	4.74	43
Water Heating	5.09	43	3.91	43	3.47	43
Pool/Spa Equipment	2.67	3	2.00	7	3.29	7
Oven	6.93	43	6.72	43	5.74	43
Laptop / Cellphone Chargers	7.67	43	7.07	43	7.00	43
Other (Personal/Business Equipment)	4.35	43	9.81	43	9.98	43

4.1.4 Experience with Time of Use Rate

Understanding of the Time of Use Rate

At the beginning of each survey, Evergreen asked respondents if they recalled switching to a new rate in the beginning of 2019. For this question, Evergreen did not specify the *type* of rate they were switched to because Evergreen later wanted to test their knowledge of the difference in rates. The treatment group was much more likely to be aware of the change in rate (this is statistically significant at the 90% level), suggesting that the additional treatment of the thermostat (or extra effort needed to schedule installation) may have helped them to be aware of (and possibly react to) a change in rate (Figure 13).

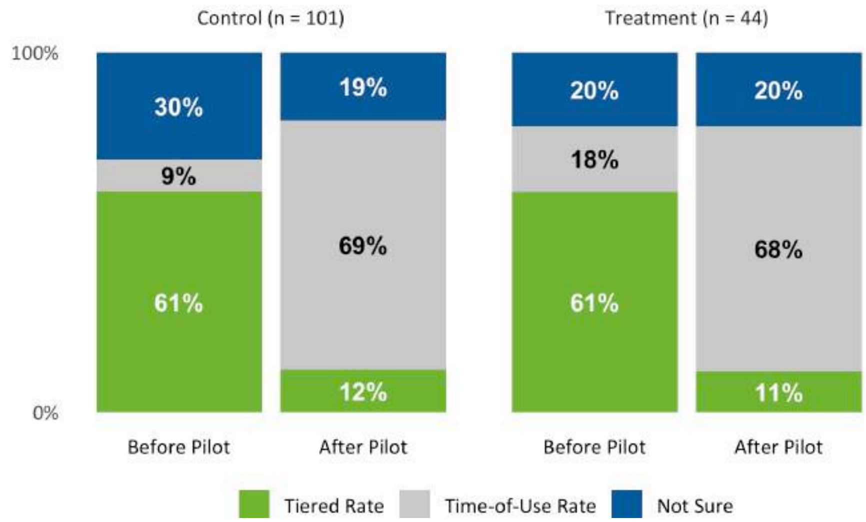
Figure 13: Awareness of Rate Change by Control and Treatment Group



Throughout the remainder of this research, when reporting on questions specific to the TOU rate, Evergreen do not include the respondents who did not know or did not recall their rate changing in the beginning of 2019 in Evergreen's analysis.

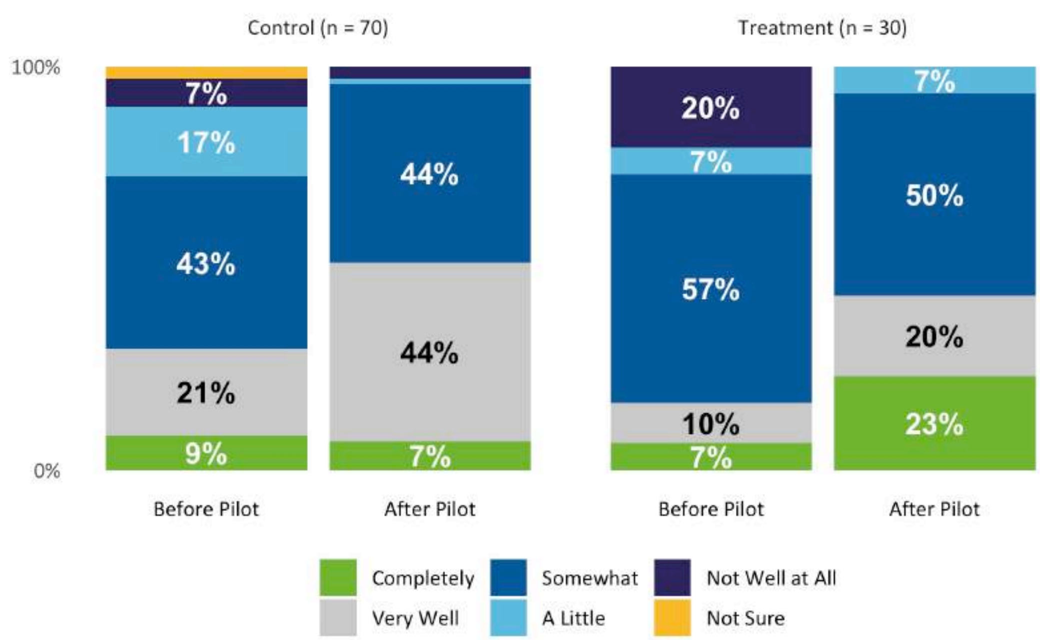
To understand if respondents were changing any behavior *in reaction to* the TOU rate, Evergreen first wanted to test respondents' awareness of their current rate before the pilot (tiered) or after the pilot (time of use). In general, nearly 20 percent of respondents were unaware of what type of rate they were on, and close to 70 percent of respondents knew they were on a TOU rate by the time the pilot ended. Depending on the group, 9 to 18 percent of respondents already thought they were on the TOU rate before the pilot started (Figure 14).

Figure 14: Awareness of Current Rate by Control and Treatment Group



Of respondents who *knew* that they were on the TOU rate, it appears that the full year of participation in the pilot increased their self-reported understanding of the rate amongst both the control and treatment groups. This increase is statistically significant amongst the control group but not amongst the treatment group, likely due to the smaller sample size. Figure 15 shows responses to the question "How well do you understand the time of use rate?" While it appears that the control group and treatment group started with varied understandings of the rate, these differences are not statistically significant.

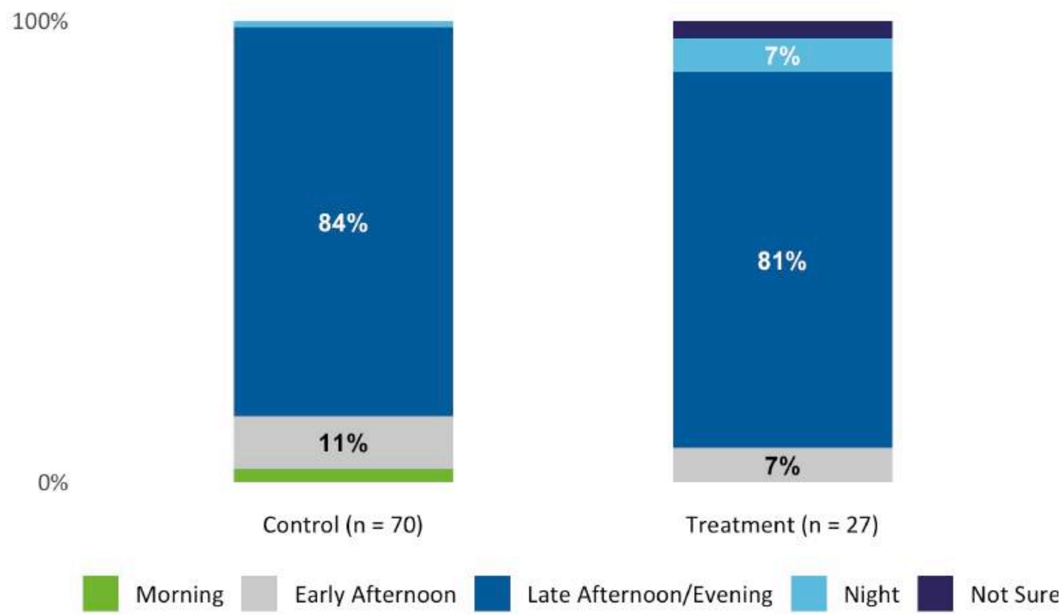
Figure 15: Level of Understanding of Time of Use Rate Before and After Pilot, Control vs. Treatment Group



At a later point in the second of three surveys, Evergreen asked respondents who reported seeing their bill increase or decrease compared to the two prior years and understood that they were on the TOU rate, how well they felt they understood the rate. The intent of this question was to understand the impact of getting these higher or lower bills on customers interpretation of their understanding of the time of use rate. Since nearly all respondents reported at least some change in their bill compared to the prior year, it is not surprising that these results also showed that the majority of respondents thought they understood the bill somewhat, very well, or completely.

After the summer months of the pilot, Evergreen asked respondents about when they think energy costs the most during the summer. The majority of respondents (all of whom were aware that they were on the TOU rate) gave a response that seemed to reflect an understanding of the rate (Figure 16).

Figure 16: Awareness of When Energy Costs the Most During the Summer, in Fall of 2019, by Control and Treatment Groups



While customers seemed aware of when energy *costs* are the highest, this did not always align with when their reported *usage* was the highest. Despite an awareness that energy cost was the highest in the evening, a smaller proportion of respondents reported that their own home used the most energy during that time (Figure 17, compared to Figure 16) which may suggest that some respondents either do not agree that they use the most energy during the utility-identified peak time, or that they feel unable to shift their usage out of the peak hours.

While Figure 17 shows that over the course of the pilot, an increased percentage of the treatment group reported that they use the most energy in the evening. This difference is not statistically significant.

Figure 17: Understanding of When Households Use the Most Electricity Before and After Pilot, Control vs. Treatment Group

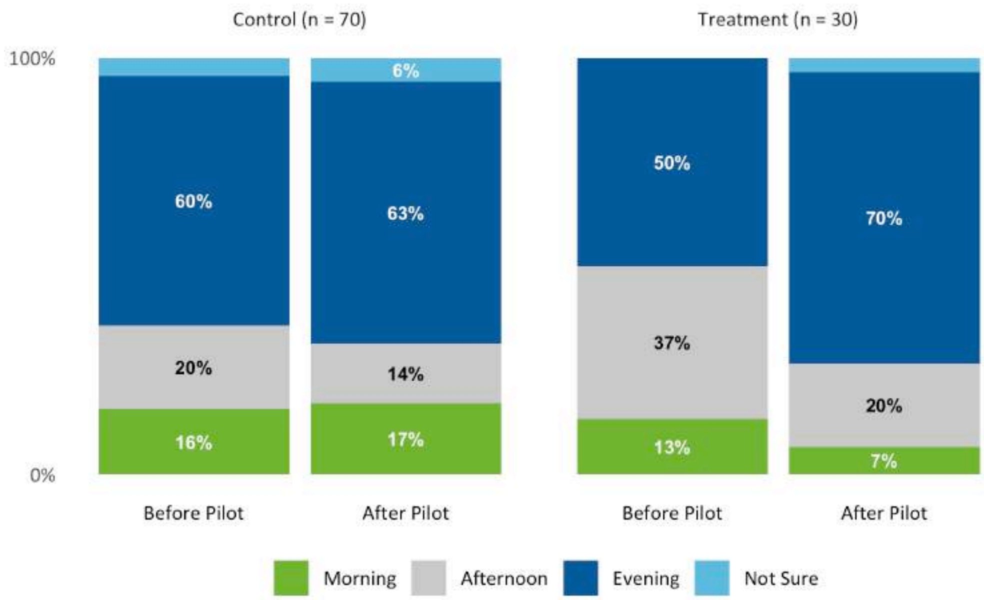
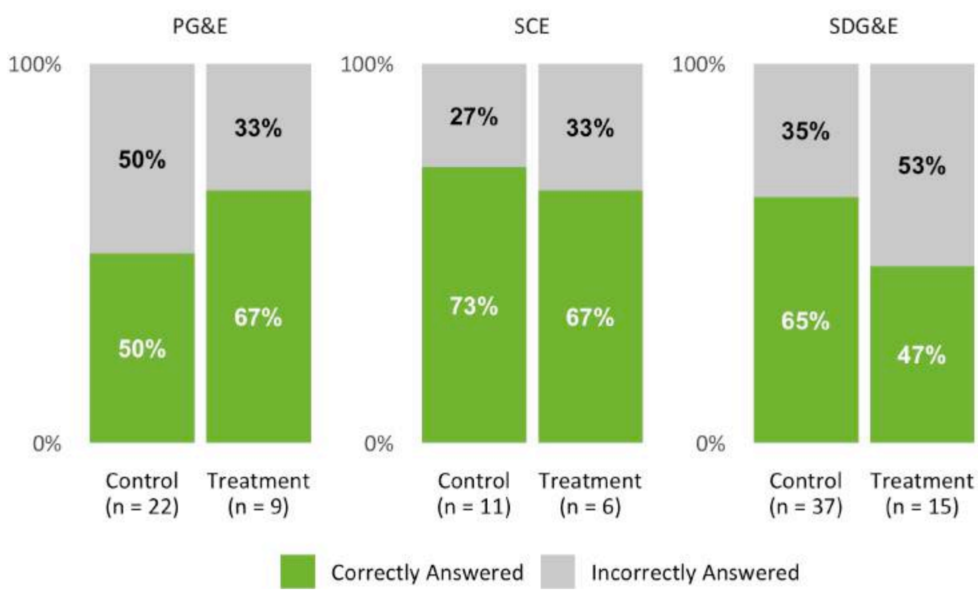


Figure 18 shows the actual usage in the baseline period for pilot participants, using AMI energy usage data provided by the utilities. Participants were not very successful in identifying when their households use the most energy when Evergreen compared responses to the full period of billing data. Depending on the IOU, customer success in accurately describing their peak usage window ranged from 47 to 73 percent as shown in Figure 18.

Figure 18: Accuracy of Self-Reported Time of Household Use Compared to Actual Household Use

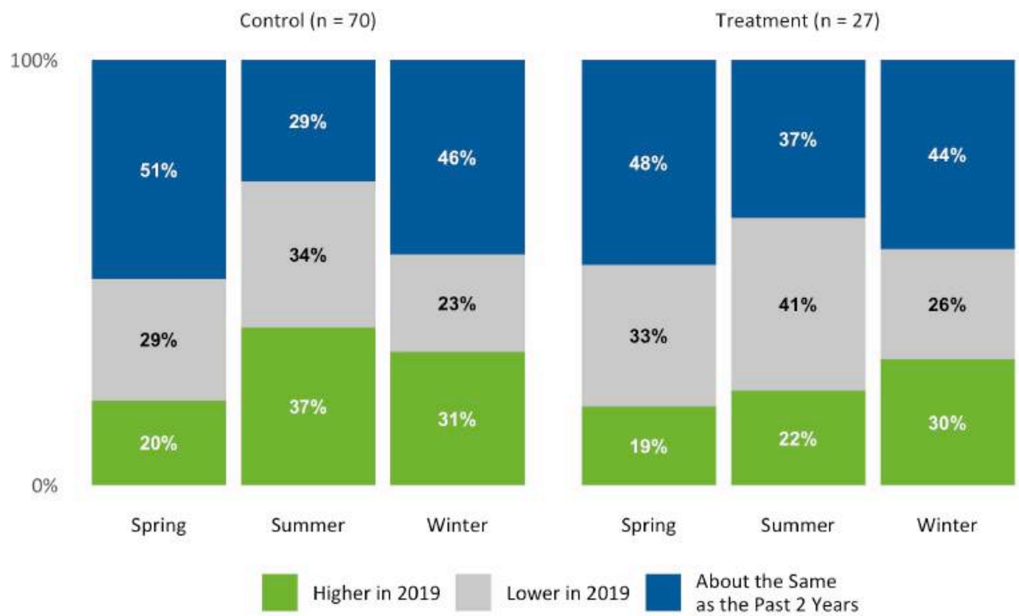


Bill Impacts of the Time of Use Rate

Right after the summer months, Evergreen asked respondents to report if they had seen their bills go up or down in the pilot period, compared to the prior two years. Evergreen asked them about three periods of time: Spring (March to May 2019), Summer (June to August 2019), Winter (December 2018 to February 2019).

Figure 19 shows that respondents were more likely to notice a bill change in the summer compared to the winter or spring months, likely due to cooling load. Interestingly, the treatment group had a large portion of respondents (41%) who thought that their bills during the summer of the pilot were lower than they had been in prior years. This may be due to an inability to recall bills from the past two years. This information is broken out by IOU in Appendix A.

Figure 19: Respondent Interpretation of Bill Change During Pilot Compared to Prior Two Years of Those Aware They Were on TOU

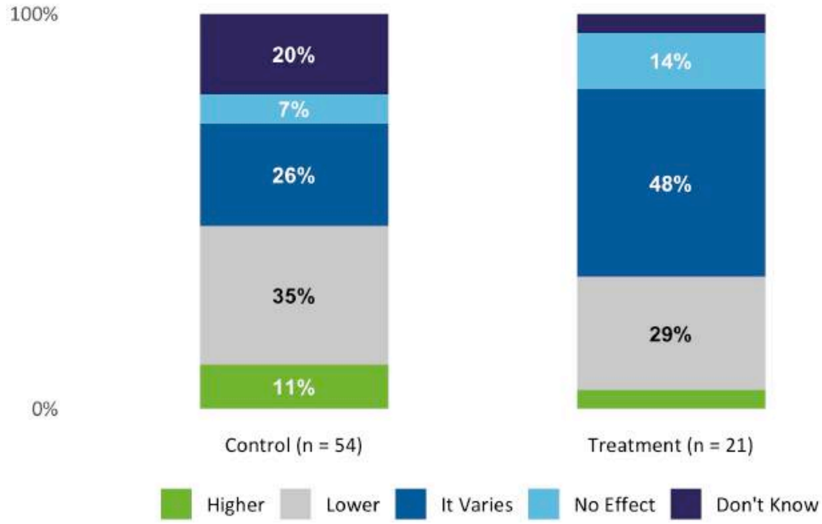


Of the respondents who reported seeing their bill increase or decrease during one or more seasons in 2019 compared to 2018 (before the pilot), respondents were asked about the impact of the TOU rate on their bill change. Each respondent group (treatment vs. control) had different responses regarding if the TOU rate made their bill higher, lower, or varied (Figure 20). The treatment group was more confident in their ability to identify the impact of the TOU rate compared to the control group, which was more likely to report that they did not know (statistically significant).

Evergreen know from prior research that evening usage (and thus peak charges) generally increase in the summer with cooling loads during time of use, and decrease in the winter months, which may be the reason for respondents reporting that the effect of the TOU rate on their bill differs

(Figure 20). Evergreen report more on how customers responded to the TOU rate by changing behaviors in the next section.

Figure 20: Overall Impact on Utility Bills Attributed to Time of Use Rate, of Control and Treatment Group Respondents Who Knew They Were on Time of Use Rate



Responding to the Time of Use Rate

To further identify what respondents did in reaction to the TOU rate, Evergreen asked what helped them reduce energy usage during the peak billing periods. Responses below only include respondents who were aware that they were on the TOU rate.

A much higher proportion of the control group reported not using appliances or lights (80%) compared to the treatment group (60%), though likely because of small sample size; this is not statistically significant. Surprisingly, modifying cooling and heating was rarely mentioned. This finding aligns with what Evergreen saw in the impact evaluation, specifically with PG&E where Evergreen saw a cut back in energy usage during the day amongst the control group.

Table 12: What Respondents Reported as Helping Them Save the Most Energy During TOU Peak Periods, of Those Aware They Were on TOU Rate

Control Group (n=70)	Treatment Group (n=30)
○ 56 of 70 mentioned not using appliances or lights (laundry and dishwashers were the most frequently mentioned appliances, but people also mentioned lights and stovetops) ○ Being aware of peak/off-peak times in general – 8 of 80 ○ Seven people did not have anything to say.	○ Not using appliances or lights (e.g., laundry [almost all of this group mentioned laundry], dishwasher, dryer, EV charger – 1 person, AC, pool filter – 1 person) – 18 of 30 ○ Being aware of peak/off-peak times in general – 8 of 30 ○ Thermostat (eco+ feature specifically) – 2 of 30 ○ Two people did not think anything was helpful.

Satisfaction with the Time of Use Rate

One way to understand satisfaction with the TOU rate is to see if respondents would recommend the rate to a neighbor or friend. When Evergreen looked at satisfaction this way, almost all respondents regardless of whether they were in the control or treatment groups said they were at least somewhat likely to recommend it to a friend.

Evergreen received somewhat similar results when Evergreen measured satisfaction another way. Close to 75 percent of respondents reported that they were somewhat to extremely satisfied with the TOU rate. Of the respondents that reported being less than satisfied, Evergreen asked them to report on what would have made them more satisfied. The most common response was that they expected to see savings on this rate but that ended up not being the case (Table 13).

Table 13: What Would Have Increased Customer Satisfaction with the TOU Rate?

Control Group (n=15)	Treatment Group (n=7)
○ 9 of 15 said that they did not see the amount of savings that they expected ○ 5 of 15 said that they did not like the peak times ○ 1 of 15 was concerned about how the rate would affect switching to solar in the future	○ 5 of 7 said that they did not see the amount of savings they expected (some people said that their bills even went up) ○ 1 of 7 did not like the how the Ecobee thermostat worked ○ 1 of 7 said they did not pay much attention to anything

4.1.5 Experience with Thermostats

In addition to testing how low income customers adjust to a TOU rate, this pilot tested if those who were given a smart thermostat had an easier transition to the TOU rate. Respondents in the treatment group were given an Ecobee thermostat with the intent that each thermostat would have a program installed on it which would help shift usage away from peak hours. In reality, this feature “eco +” was not added to thermostats until seven or eight months after the start of the pilot (August and September 2019). This error may have caused treatment group participants to already think their thermostats were working behind the scenes through the summer to help shift their energy usage during the peak hours.

Thermostat Attrition

Before analyzing the treatment group and their experience with the Ecobee thermostat specifically, it is important to understand who this group of respondents represents. In order to narrow down the treatment group for this analysis, Evergreen excluded:

- Any respondents who were assigned to the treatment group but rejected the offer of a thermostat.

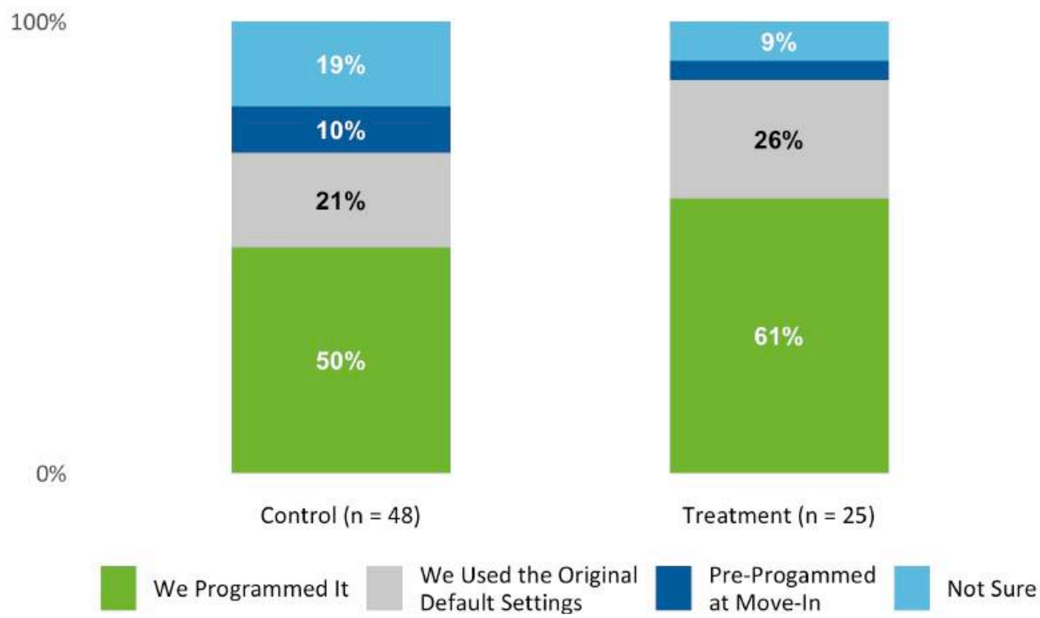
- Any respondents who believed that their thermostat was no longer installed and working. Evergreen did, however, include respondents who responded that they did not know if their thermostat was installed and working because they can still explain how they used their thermostat.
- Three respondents who did not end up having eco+ on their Ecobee thermostat (according to data from Ecobee), in order to keep the group consistent.

Evergreen did include in analysis three respondents who reported that their thermostats were online and working, despite a report from Ecobee suggesting that they were offline. Evergreen made this decision assuming that Ecobee's data were from a single point in time, and that the respondent had a better idea of the operationality of their thermostats.

How Thermostats are Used

Before the pilot began, there were no statistically significant differences in how the control and treatment group programmed their existing thermostats (Figure 21). In general, 50 percent or more of the survey respondents reported programming their thermostats.

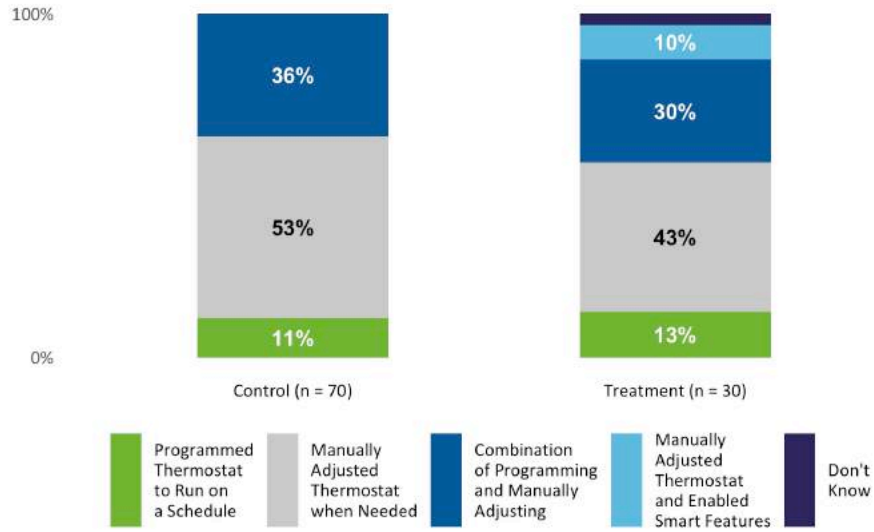
Figure 21: How Respondents Programmed (or Did Not Program) Thermostats Before Pilot



Thermostat Usage During the Pilot

At the end of the pilot, Evergreen asked respondents to report how they used their thermostats over the past year. The treatment group was given an additional response option of being able to enable smart features, though only 10 percent of the treatment respondents reported taking such action. There were no significant differences in how the two groups reported interacting with their thermostat, suggesting there was a similar preference for programming and manually adjusting the thermostat across both the treatment and control group respondents Figure 22**.**

Figure 22: How Respondents Reported Interacting with Their Thermostat Over the Pilot Year



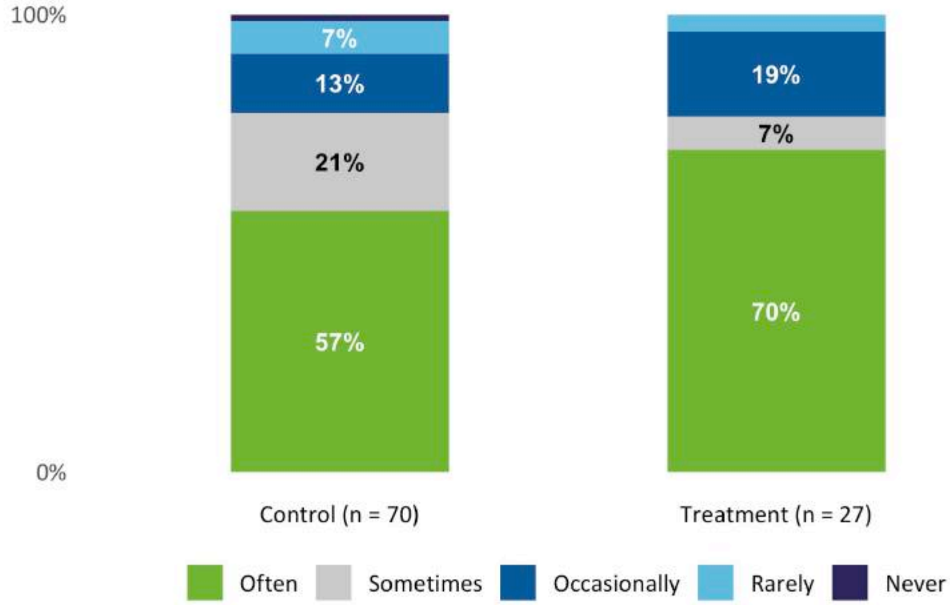
Despite nearly 83 percent of respondents in the treatment group reporting that they interacted with their thermostats *other than* programming a schedule, when Evergreen asked respondents if they ever adjusted the thermostats away from the initial settings, 46 percent reported that no, they did not adjust their thermostat. When looking at the group that said no or do not know in response to the question about adjusting the thermostats, Evergreen see that the majority of each of these response groups reported manually adjusting their thermostats. It is possible that they interpreted the question as asking about adjusting away from the initial settings in a more permanent way. This would explain the difference in responses to these two questions.

Table 14: How Smart Thermostats were Used

How Thermostat Was Used	Yes (n=4)	No (n=11)	Don't Know (n=8)
Programmed Thermostat to Run on a Schedule	20%	18%	13%
Manually Adjusted Thermostat When Needed	20%	45%	63%
Combination of Programming and Manually Adjusting Thermostat	60%	27%	13%
Manually Adjusted Thermostat and Enabled Smart Features	0%	9%	13%

To further understand if customers with the Ecobee (the treatment group) interacted with their thermostats differently during the pilot than participants in the control group (with non-smart thermostats), Evergreen asked participants about how they interact with their thermostat by personally making adjustments to the thermostat to avoid using electricity during peak hours (Figure 32). While it appears that the treatment group reported adjusting their thermostat "often" more than the control group, this difference is not statistically significant. "Often" was clarified to mean almost daily in the survey question.

Figure 23: How Often Respondents Reported Personally Adjusting Thermostat to Avoid Using Electricity During the Peak Time of Day After Summer of Pilot (Q70)



Those who reported adjusting their thermostat occasionally or more often were asked about what actions they took to avoid the higher cost of energy during peak hours (Table 15). The treatment group was more likely to adjust the thermostat in some way (62%) compared to the control group (47%). Though this difference is not statistically significant, it may indicate that the smart thermostat enabled the treatment group to make more adjustments to their temperatures than the control group. The control group was more likely to report limiting other appliance usage compared to the treatment group. This finding is not statistically significant, likely due to the small sample size.

Table 15: Of Those Who Adjusted Thermostat at Least Once a Month or More, Self-Reported Actions to Avoid the Higher Cost During Peak Hours (Q71)

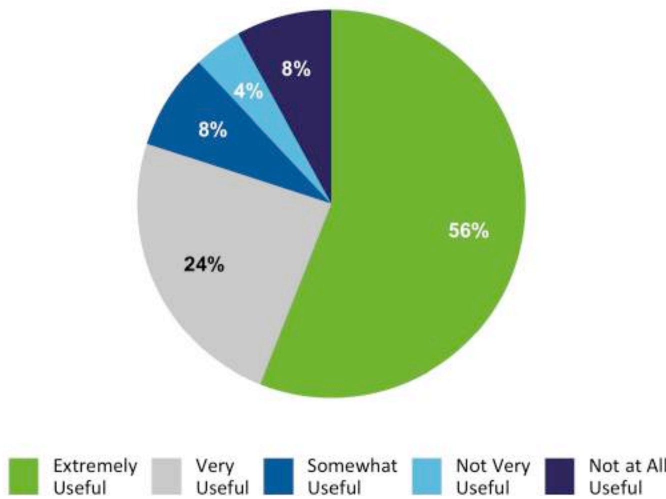
Control Group (n=64)	Treatment Group (n=26)
○ Adjust heating/cooling temperature (n=30 of 64) ○ Limit other appliance use (washers, dryers, TV, etc.) (n=24 of 64) ○ Reducing energy in general (5 of 64) ○ 2 got evaporative coolers ○ 1 switched to LEDs ○ 2 did not have anything to say	○ 16 of 26 mentioned adjusting their thermostat in some way (e.g., turning off the heat/AC more often/during peak hours, using off-peak hours, lower temps in winter and higher temps in summer, etc.) ○ 4 of 26 used other appliances less often (dishwasher, washer, dryer) ○ Reducing energy in general (4 of 26) ○ 2 of 26 had nothing to say

Use of Smart Devices

The majority (93%) of the treatment group respondents reported having had a smart phone or an internet connected device. Of this group, nearly half (48%) of the respondents reported that they always or mostly control the Ecobee thermostat with their smart phone or internet connected device. Only 16 percent of respondents said that they never use their smart device.

Excluding the treatment group respondents who never use their smart device to control their thermostat, respondents found the smart device very or extremely useful for controlling their thermostat (80%, Figure 24).

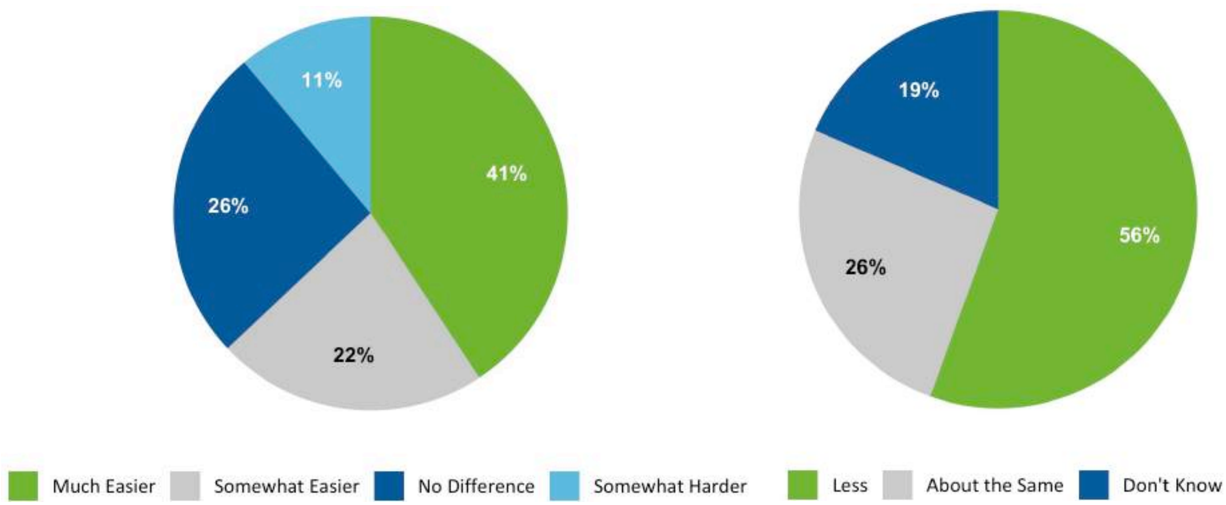
Figure 24: Usefulness of the Ability to Control Thermostat from Smart Phone



Satisfaction with Smart Thermostat

In general, respondents with eco+ installed on their thermostat (almost all treatment group respondents) were not widely confident in the thermostat's ability to help them control their energy bills or help them lower their energy use, or on the existence of eco+. Respondents who reported either an increase or decrease in their bills compared to the past two years were asked if they found that the new thermostat made their ability to control bills easier or harder than their prior thermostat (Figure 25). Sixty-three percent of respondents found the thermostat made it somewhat to much easier to control their bills, while 11 percent reported finding it harder. Just under half of respondents reported either that they think they use about the same amount of energy with the smart thermostat or that they did not know. No one thought that the new thermostat increased their energy usage.

Figure 25: Thermostat Impacts on Ability to Control Energy Bills and Thermostat Impacts on Energy Bills (n=27)



The respondents who were confident that the thermostat contributed towards lowering their energy bill attributed it to the ease of seeing and controlling the temperature settings (Table 16).

Table 16: Why Respondents Thought the Smart Thermostats Impacted Their Ability to Control Their Energy Bills

More Ability to Control Energy Bills (n=15)	About the Same Ability to Control Energy Bills (n=9)
○ The ability to control their thermostats remotely/when they are not at home (5 of 15) ○ More conscious of energy use (2 of 15) ○ Thermostat made it easier to see and control the temperature settings (3 of 15) ○ eco+ features (3 of 15) ○ 2 had nothing to say	○ They do not use it too much (3 of 9) ○ Consciously set temperatures (4 of 9) ○ 2 of 9 did not have anything to say

Despite only slightly over half of respondents thinking that that the thermostats helped them to control their energy bills, slightly more respondents (67%) responded that yes, "the thermostat was a useful tool for shifting energy usage to off-peak, less expensive times." These results only include respondents who were aware that they were on the TOU rate.

Evergreen asked respondents to explain why they did or did not think the thermostat was useful for shifting to off peak hours. The main reason that respondents found the thermostat useful was that it was easy to control temperature settings, especially remotely or from a smartphone (Table 17). Evergreen checked to see if responses differed by the type of thermostats that respondents were used to having; amongst those who found it useful or not useful, there was a similar percentage of customers with programmable versus manual thermostats before the study.

Table 17: Why Respondents Did or Did Not Think The Thermostat Was a Useful Tool for Shifting Energy Usage to Off-Peak Hours

Yes, Useful (n=18)	No, Not Useful (n=6)
○ Easy to control temperature settings (especially remotely/from smartphone) (10 of 18) ○ Thermostat made it easier to see and control the temperature settings (4 of 18) ○ More conscious of energy use (1 of 18) ○ 3 of 18 did not have anything to say	○ People adjusted their thermostats manually and used their thermostats when they felt like they needed them (6 of 6) ○ 1 of 6 said that the Ecobee settings were unreliable and thus did everything manually

Evergreen's ability to interpret customers' experiences with eco+ is limited due to eco+ not being enabled until August of 2019 or later. Only 21 percent of customers recall noticing that the thermostat automatically adjusted to help them save energy and money during the time of day when energy is more expensive. 33 percent of the 24 respondents reported that they did not know, and the remaining 46 percent reported that they were not aware.

Evergreen then asked customers about eco+ specifically by name and described that it is designed to help save them money when energy costs the most by automatically adjusting the temperature set-point during peak usage times. Evergreen also noted that eco+ would be displayed on their thermostat. Of the 24 respondents who answered the question, all of whom had the feature installed, only half of the respondents reported that the eco+ function was currently working on their thermostat. This again suggests that there was rather low awareness of the eco+ feature among those who had it installed.

Overall Satisfaction

Overall satisfaction with the thermostat provided through this pilot was high (89% of respondents reported that they were at least somewhat satisfied with the thermostat), despite the mixed reviews of the thermostat's ability to help shift usage and avoid peak hours. Regardless of the usefulness of the thermostat, it may have been seen as a nice offering that was paired with the TOU rate transition. When Evergreen followed up with those who were either neutral or not satisfied, one person said it did not work well (specifically that it runs too long in the morning), one person said it was not as user friendly as their old standard thermostat, and one person said they did not use it much.

Evergreen asked customers to compare their new thermostat directly to the thermostat that they had before the pilot. Table 18 shows what respondents liked more and less about the pilot-provided thermostat. The majority of respondents reported that there was nothing they liked more about their prior thermostat (77%), and respondents touted that the pilot thermostat was better in that it allowed them to control the device when not at home (22%) and from their smart device (22%).

Table 18: Features of the Thermostat That Respondents Liked More or Less Than Their Original Thermostat (n=27)

Better with the Pilot Thermostat	Worse than the Prior Thermostat
○ Ability to control the app when not at home (6 of 27) ○ Ability to control the app from their own smart device (6 of 27) ○ Easy to use and understand (6 of 27) ○ Touch screen/digital features (4 of 27)	○ 21 of 27 did not have anything they disliked ○ 3 of 27 said that it was more complicated than their old systems ○ 2 of 27 did not like the limited temperature ranges (e.g., cannot set AC higher than 80 degrees) ○ 1 of 27 said it was hard to program with their smartphone

4.1.6 Beneficial Messaging for Future Emails or Marketing

To understand how to improve education about the TOU rate, Evergreen asked respondents who were aware they were on the TOU rate what they wished they knew about the rate before they started the pilot (Q20). Over half of both the treatment (19 of 30) and control groups reported that there was nothing else they wish they would have known. Of the remaining participants, Table 19 shows what each group was interested in learning. The most common request for both groups was additional information on the rate, including the best times to use appliances.

Table 19: Additional Desired Information for the Time of Use Rate (n=27)

Control (n=33)	Treatment (n=11)
○ Also interested in more rate information (13 of 33), e.g., off peak times, best times to use appliances, how could changing your thermostat by a degree or two decrease your energy costs, how to maximize savings in the summer, etc. ○ Interested in seeing comparisons with their past energy bills in terms of how much they saved when they were on the new rate (9 of 33) ○ People were also confused about what the rate was (4 of 33) ○ Importance of sticking to the timeframe (2 of 33) ○ One person wished they had an automated thermostat, one person wished the rate was available sooner, and three people complained about the rate	○ 7 of 11 remaining (disregarding the 19 above) said that they wish they would have known more about the numbers (e.g., the summer and winter rate details, details about the costs during the new rate, how the costs would fluctuate, and one person asked for statistical models that discussed different rate plans ○ 1 person wanted to know when they used the most energy, 1 person was still unclear about what the rate was (although they understood they were on the new rate), and 2 people complained about their thermostats

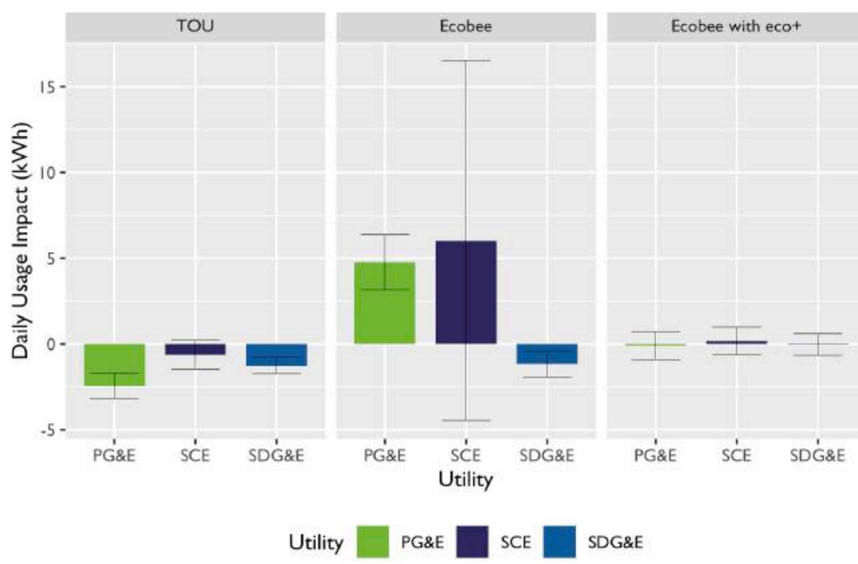
4.2 Impact Findings

This section provides Evergreen's estimates for the energy savings experienced by customers that can be attributed to the LI TOU PCT Pilot program interventions, based on the AMICS models, by IOU. Evergreen start by comparing just the TOU rate and the TOU rate with the smart thermostat, and then address the eco+ feature.

Figure 26 provides an overview of Evergreen's estimated incremental impacts, as an average change in daily kWh across the full post-period, for each of the program interventions by utility.[8] The error bars indicate the bounds for a 95 percent confidence interval around each estimate. The TOU rate led to reduced energy usage for all three IOUs, but this change was only statistically significant for PG&E and SDG&E. The incremental impact of the smart thermostat without eco+ (Ecobee) was an increase in energy usage for PG&E and SCE, but a further reduction in energy usage (i.e., savings) for SDG&E.

For all three IOUs, the Ecobee with eco+ activated had a very small and insignificant impact on energy usage. It appears that the eco+ feature does help avoid an increase in energy usage that often occurs with the Ecobee on its own. However, it is important to provide a caveat for these findings with a reminder that the Ecobee and Ecobee with eco+ impacts are based on a limited timeframe and smaller sample than the TOU impacts. The impacts of these limitations are addressed later in this section.

Figure 26: Estimated Daily Usage Impact (kWh) of Pilot Program Interventions by IOU



[8] The Ecobee impact provides an estimate for the *incremental* impact of installing an Ecobee on a customer's energy usage, not the *combined* impact of installing an Ecobee during the transition to a TOU rate (i.e., TOU + Ecobee).

Figure 27 provides a similar comparison of program impacts by IOU, this time focusing on the utility peak-period (4 to 9 p.m. for PG&E and SDG&E, 5 to 8 p.m. for SCE). The TOU rate led to statistically significant reductions in energy usage on average during the peak period for all three IOUs. The incremental impact of the smart thermostat without eco+ (Ecobee) was a large increase in energy usage for PG&E and a small and insignificant increase for SCE, versus a further reduction (i.e., savings) for SDG&E. For all three IOUs, the Ecobee with eco+ activated had a small and insignificant impact on energy usage. It appears that the eco+ feature also helped customers from PG&E avoid an increase in peak-period energy usage that commonly occurred with the Ecobee on its own. Again, the Ecobee peak impact estimates are based on a limited timeframe and smaller sample than the TOU impacts.

Figure 27: Estimated Peak Usage Impact (kWh) of Pilot Program Interventions by IOU

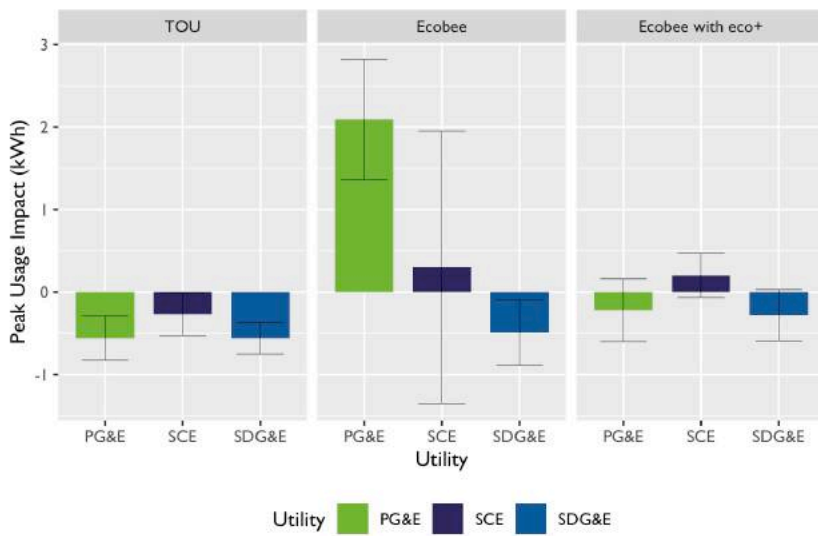


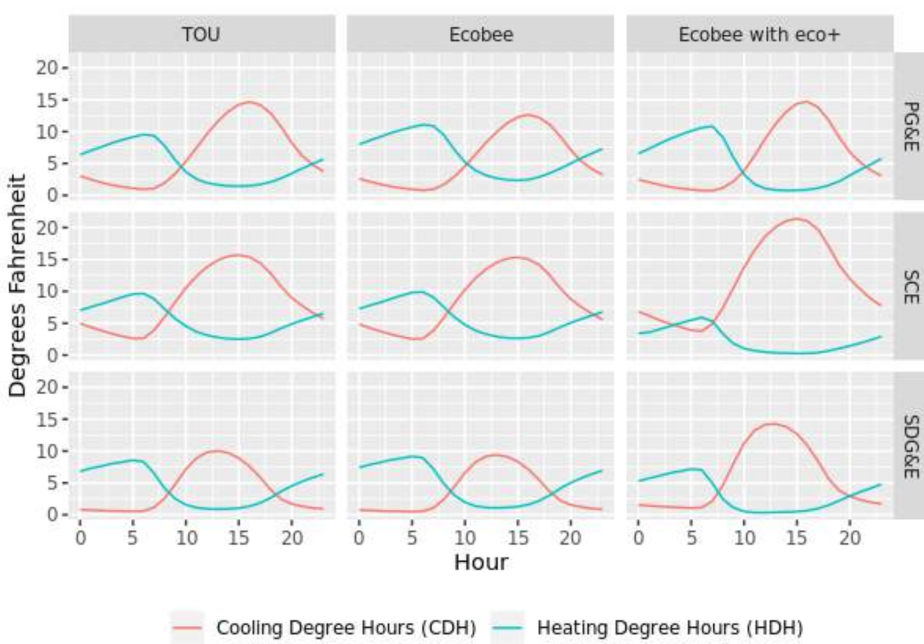
Table 20 provides the estimated impacts of the Ecobee with and without eco+ on customer bills, as a cost per day. This is based on Evergreen's estimated kWh impacts and the current TOU rate schedules by utility, season, and hour. Most participants will likely think of the program impact in terms of changes in their bill, not directly considering their energy usage in kWh. SDG&E customers who installed the Ecobee smart thermostat saved an average of $0.79 per day, with larger bill reductions in the winter months of $0.91 per day, whereas PG&E customers spent an average of $0.80 more after installing the Ecobee, with an increase of around $0.34 in the summer and $1.03 in the winter. Participants from SCE had much more erratic bills with the Ecobee, with bill increases of $2.42 per day in the summer that were offset by reductions in the winter months of $2.20 per day. The impact of the Ecobee with eco+ was much more mild, within $0.10 per day of the bill costs experienced by customers who were transitioned to the TOU rate without a smart thermostat. Keep in mind that the three IOUs have different rate structures (e.g., ratio of on-peak to off-peak rates, complexity of rate schedule by seasons and day type) and weather conditions. The purpose of this table is to translate the energy savings impacts into bill impacts experienced by the customers, to aide the comparisons.

Table 20: Estimated Impact of Pilot Program Interventions on Customer Bills ($/day)

Estimated Bill Impact		PG&E	SCE	SDG&E
Ecobee	Average Day in Post-Period	$0.80	-$0.66	-$0.79
	Summer Day	$0.34	$2.42	-$0.54
	Winter Day	$1.03	-$2.20	-$0.91
Ecobee with eco+	Average Day in Post-Period	$0.03	-$0.09	$0.04

Figure 28 provides the average heating and cooling load for the average customer on the average day in the post-period for each of the program interventions (TOU, Ecobee, and Ecobee with eco+) by utility. The post-period for the TOU impact estimate is based on a full year of AMI data, with a wide range of heating and cooling needs. SCE customers experienced the most extreme weather conditions of the IOUs with an average of 8.7 CDD and 5.7 HDD, whereas SDG&E customers experienced the most temperate weather conditions with an average of 3.9 CDD and 4.4 HDD. Even though the post-period for the Ecobee is less than a full year (approx. Jan – Nov 2019), Evergreen have a similar balance of heating and cooling load reflected in this post-period, when compared to the full year of post-period in the TOU impacts. Therefore, it is unlikely that the timeline limitation has significantly biased the Ecobee impact estimate. The post-period of the Ecobee with eco+ (approx. July-Nov 2019) has more cooling and less heating (except in the case of PG&E) and more cooling load than the Ecobee without eco+. Therefore, the impact estimate for eco+ should be interpreted more as a summer or summer/fall estimate. SCE customers had the highest cooling needs during the eco + post-period, with an average of 11.7 CDD and only 2.4 HDD; whereas PG&E and SDG&E averaged 5.9 CDD with 5.0 and 3.2 HDD, respectively.

Figure 28: Average Daily Cooling and Heating Loads Reflected in the Post-Period Impacts



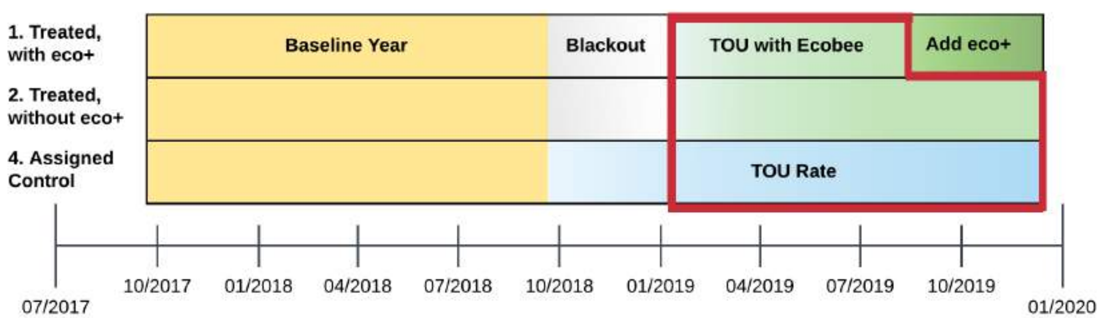
4.2.1 TOU and Ecobee Impacts

Table 21 provides an overview of the pilot participants who are depicted in this analysis. Figure 29 provides a visual representation of the analysis timeline, with the post-period outlined in red. In this case, the post-period is defined as the time period after each customer was transitioned to the TOU rate; for the treatment group, Evergreen must further refine this to exclude the blackout period before the Ecobee installation and any observations after the activation of eco+.[9] The AMICS model was estimated on a full year of baseline data from every customer, but since the treatment group did not have the Ecobee installed for a full year, the post-period difference-of-differences will be limited to the time frame of the treatment group. Therefore, the timeline depicted in this analysis is between the initial program intervention (i.e., the transition to a TOU rate, with the addition of an Ecobee for the treatment group) between September 2018 and January 2019, and the end of the post-period on November 30, 2019 or activation of eco+. Evergreen has between 77 and 95 customers in the control group and 36 and 42 customers in the treatment group, depending on the IOU.

Table 21: Post-Period Analysis Sample by Pilot Intervention and IOU

		Control	Treatment
Post-Period Timeline		Oct 2018 - Nov 2019	Dec 2018 - Aug or Nov 2019
Number of Customers	PG&E	95	40
	SCE	77	36
	SDG&E	79	42
	Total	**251**	**118**

Figure 29: Post-Period Timeline for TOU, Ecobee and eco+ Impacts

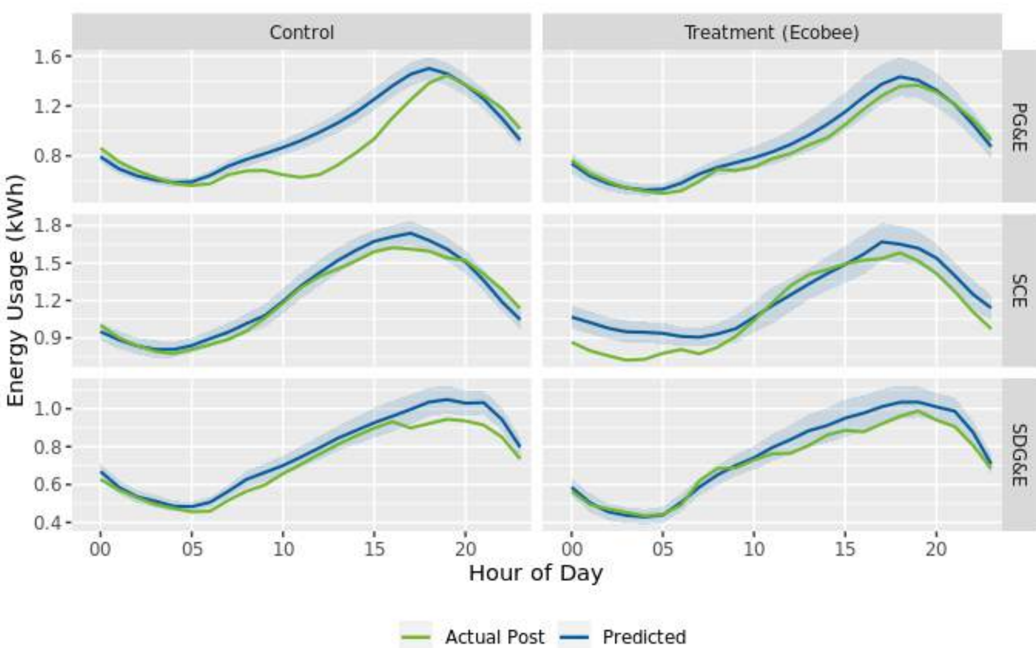


[9] We have provided estimates of the combined impact of the Ecobee with eco+ in the next section (4.2.2). This section focused on the impact of the Ecobee without eco+. Though this was not part of the original pilot plan, we ended up with a large number of customers with nearly a full year of an Ecobee on a TOU rate without eco+, enabling Evergreen to conduct this analysis. The results improve our understanding of the device's impact on energy usage when a specialized program like eco+ is not available or not functioning correctly on the device.

Figure 30 shows the post-period predicted load shape (blue) with the actual post-period load shape (green) across all customers who participated in the pilot (i.e., transitioned to a TOU rate and installed an Ecobee if they were assigned to the treatment group). This prediction is based on the pre-period consumption model and post-period weather data; it represents the expected load shape for these customers in absence of program pilot participation. The error of each hourly prediction is depicted as a 95 percent confidence interval in the shaded area around each estimate. Whenever the actual post-period load shape (green line) falls outside the predicted post-period load region (blue area), this indicates that a statistically significant change was observed during that hour.

The AMICS model finds statistically significant reductions in the whole-building energy usage of the control group across all three IOUs (i.e., green line falls below blue shaded area). The model also detected changes in the energy usage of the treatment group, with increases in energy usage during some of the morning hours and decreases during some evening hours. As the treatment group received two program interventions, further analysis is required to tease out the changes in load shape caused by the Ecobee installation (prior to eco+ activation) from the TOU rate itself.

Figure 30: Actual Post-Period Load vs. Baseline Model Predictions by IOU



As the control group only received one program intervention and the model predictions account for any differences in weather, Evergreen can attribute any change in the load shape of the control group to the TOU rate, shown in Table 22. The largest savings attributed to the TOU rate were seen in the control group from PG&E, with average daily energy savings of 2.4 kWh or 10 percent, followed by SDG&E with 1.3 kWh and SCE with 0.6 kWh savings. However, most of these savings exhibited by PG&E occurred outside the peak hours of 4 to 9 p.m. (with 0.6 kWh savings during these peak hours), while closer to half of the savings exhibited by the control group from SCE and SDG&E occurred during peak hours. This may be due to differences in the TOU educational materials, end use equipment, and other differences across the IOUs.

Table 22: Changes in Energy Usage (kWh) Attributed to the TOU Rate, by IOU

		Average Daily Energy Usage				Peak Hours**	
IOU	N Customers*	Predicted	Actual Post	Change (kWh)	Change (%)	Change (kwh)	Change (%)
PG&E	95	23.5	21.1	-2.44 ± 0.75	-10%	-0.56 ± 0.27	-7%
SCE	77	29.6	29.0	-0.61 ± 0.85	-2%	-0.27 ± 0.26	-4%
SDG&E	79	18.4	17.1	-1.26 ± 0.48	-7%	-0.56 ± 0.19	-9%

* Refers to the number of customers in the control group, who were transitioned to the TOU rate without any additional program interventions.

** Peak is 4 to 9 p.m. for PG&E and SDGE or 5 to 8 p.m. for SCE.

Figure 31 shows estimated hourly change in kWh by group for a difference-in-differences estimation of the impact of an Ecobee, with error bars depicting 95 percent confidence intervals. The difference-in-differences between the control and treatment groups are performed within each customer-day segment and then weighted by the number of observations in the treatment group during the post-period. This helps to control for any known differences in the composition of customers and weather conditions in the control and treatment groups.[10]

The customers in the control group (in orange) reduced their energy usage during the morning hours of 6 a.m. to 11 a.m. after starting the TOU rate; these are off-peak hours. This indicates that the control group customers are taking action to reduce their energy usage; these actions are not limited to the peak period. Both the control group and treatment group from all three IOUs reduced their energy usage during peak hours after being transitioned to the TOU rate. However, the relative changes observed in the control and treatment groups differ across the three IOUs. As the control group provides Evergreen's best estimate of the change that the treatment group would have experienced transitioning to the TOU rate without the Ecobee, this will influence Evergreen's conclusions about the incremental impact of the Ecobee.

[10] This comparison is restricted to customer and day segments that were observed in the post-period with both treatment and controls. This restriction excludes some observations, as 15 percent of treatment customer-days in the post-period had no similar customers and/or days in the control group during the post-period. This is a result of the fractured groups, where many customers did not complete their assigned program interventions (Section 3).

Figure 31: Comparison of Post-Period Changes by Group and IOU

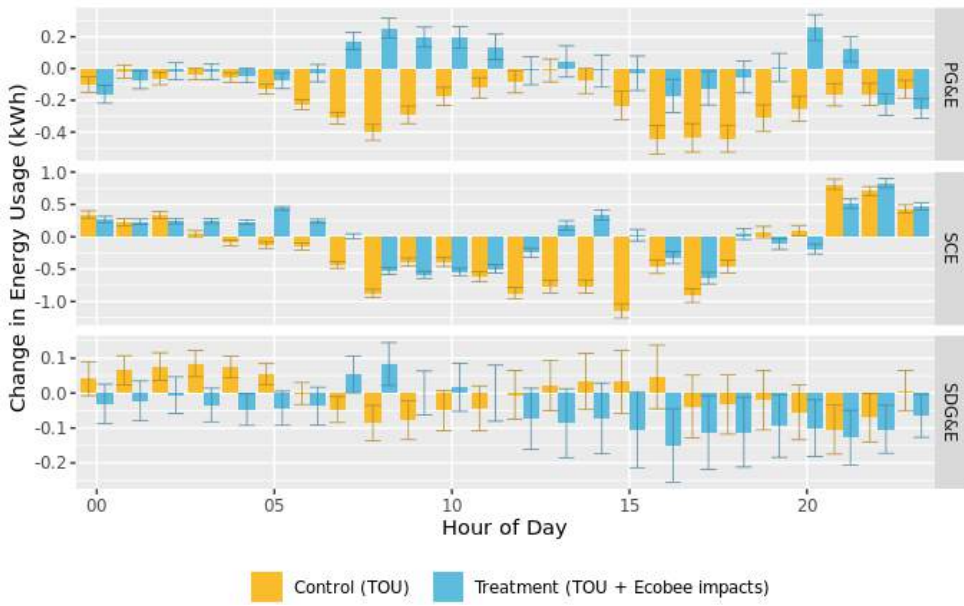
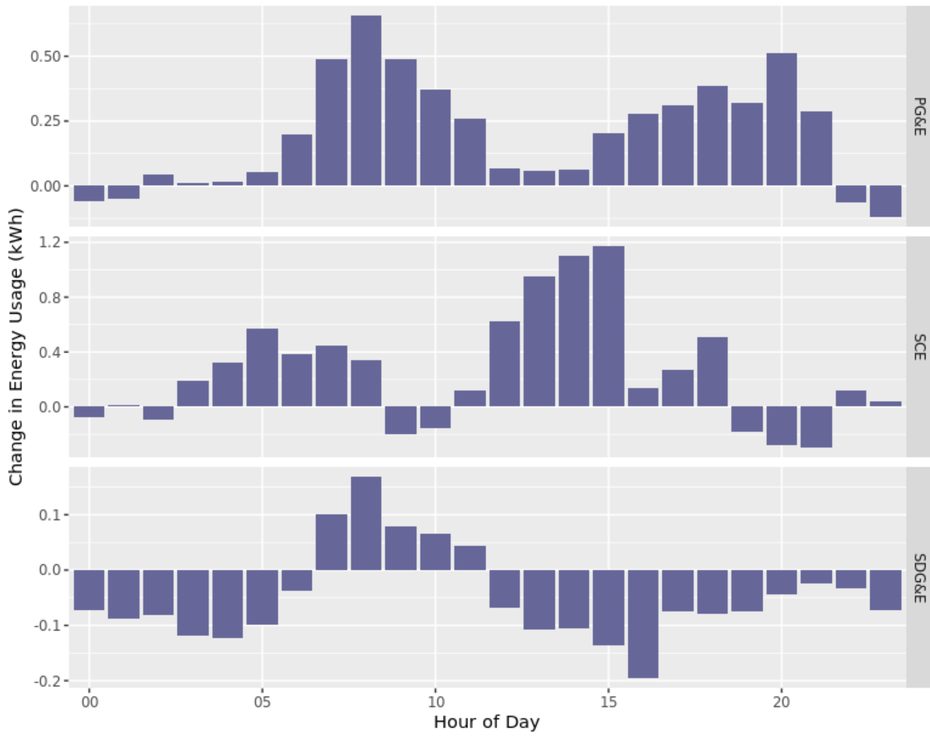


Figure 32 shows Evergreen's estimate of the hourly incremental impact of the Ecobee. This is based on the difference-in-differences between the control group and treatment group. None of the Ecobees included in this analysis had eco+ enabled, so these changes are associated with the default settings and built-in features of the Ecobee (e.g., programmable schedule, remote controls). Evergreen sees a similar pattern in Ecobee impacts from PG&E and SCE, where the Ecobee is associated with an increase in energy usage in the morning and either afternoon or evening hours. There are only a few hours where Evergreen sees any reductions (i.e., savings) associated with these smart thermostats. SDG&E exhibits a very different trend, where the Ecobee increased energy usage from 6 a.m. to 11 a.m., but led to savings during all other hours, including the peak hours. The customers, building stock, smart thermostat installers, and educational materials differ across the three IOUs, but the technology was the same.

Figure 32: Estimated Incremental Impact of Ecobee



The Ecobee impact is estimated as the difference between the total change observed in the treatment group and the change observed in the control group.

Table 23 provides a summary of these changes by IOU. Increases in energy usage are shown in red, while savings (i.e., reductions in energy usage) are shown in black. A 95 percent confidence interval is provided for the estimated impact of the Ecobee. Figure 33 and Figure 34 present these same estimated impacts in a visual form, with bars to represent the incremental impacts of the TOU rate and Ecobee, which combined, account for the change observed in the treatment group.

Evergreen found a statistically significant increase in energy usage on the average day attributed to the Ecobees for PG&E and a statistically significant decrease in energy usage for SDG&E. During the peak hours, Evergreen found statistically significant savings attributable to the Ecobees from SDG&E, significant increases from PG&E, and no significant changes from SCE. During the peak hours, while on the TOU rate, the thermostats often had impacts in the opposite direction of the TOU rate (i.e., offsetting the TOU impacts). The TOU rate lowered usage during the peak period across all three IOUs, then the smart thermostat offset this with an increase in usage during the peak period for PG&E and SCE. Over the course of the day, this same trend was observed.

Table 23: Changes in Energy Usage (kWh) Attributed to the Ecobee, by IOU

	N Treated Customers*	Average Day				Peak Hours**			
		Total Change (in treat)	TOU Impact (in control)	Ecobee Impact (difference)	Ecobee %	Total Change	TOU Impact	Ecobee Impact	Ecobee %
PG&E	40	0.09	-4.69	4.77 ± 1.61	15%	0.04	-2.06	2.09 ± 0.73	16%
SCE	36	0.62	-5.41	6.03 ± 10.50	7%	-0.90	-1.21	0.30 ± 1.65	2%
SDG&E	42	-1.27	-0.10	-1.17 ± 0.75	6%	-0.70	-0.21	-0.49 ± 0.40	8%

* Refers to the number of customers in the treatment group, who were transitioned to the TOU and installed the Ecobee smart thermostat.

** Peak is 4 to 9 p.m. for PG&E and SDGE or 5 to 8 p.m. for SCE.

Figure 33: Changes in Daily Energy Usage (kWh) Attributed to the Ecobee, by IOU

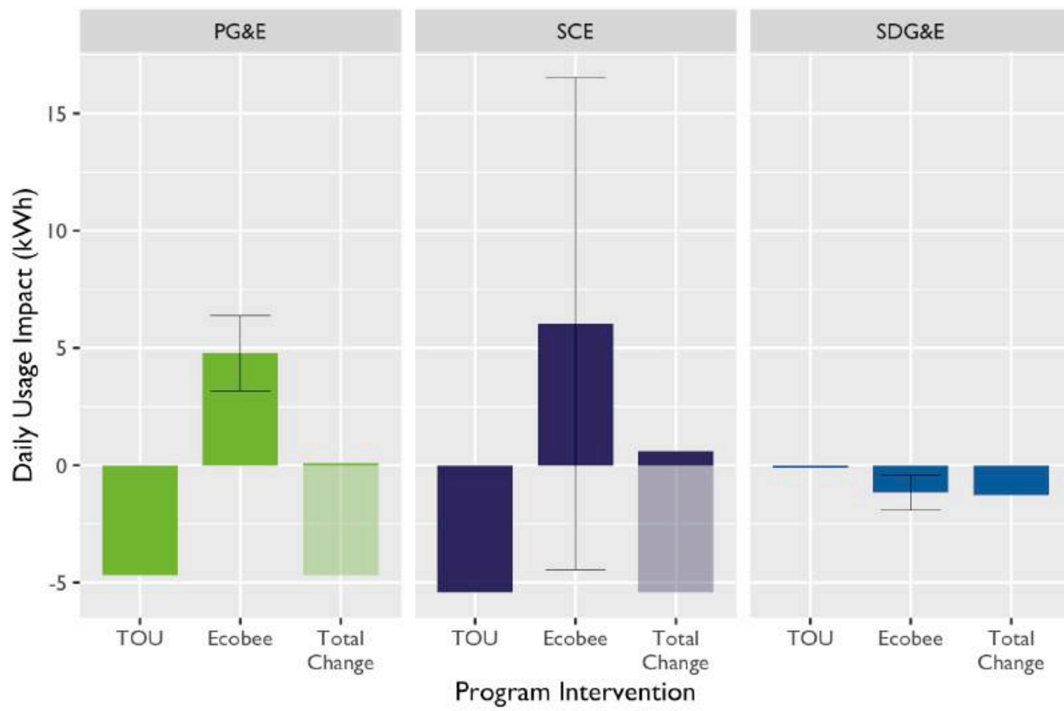
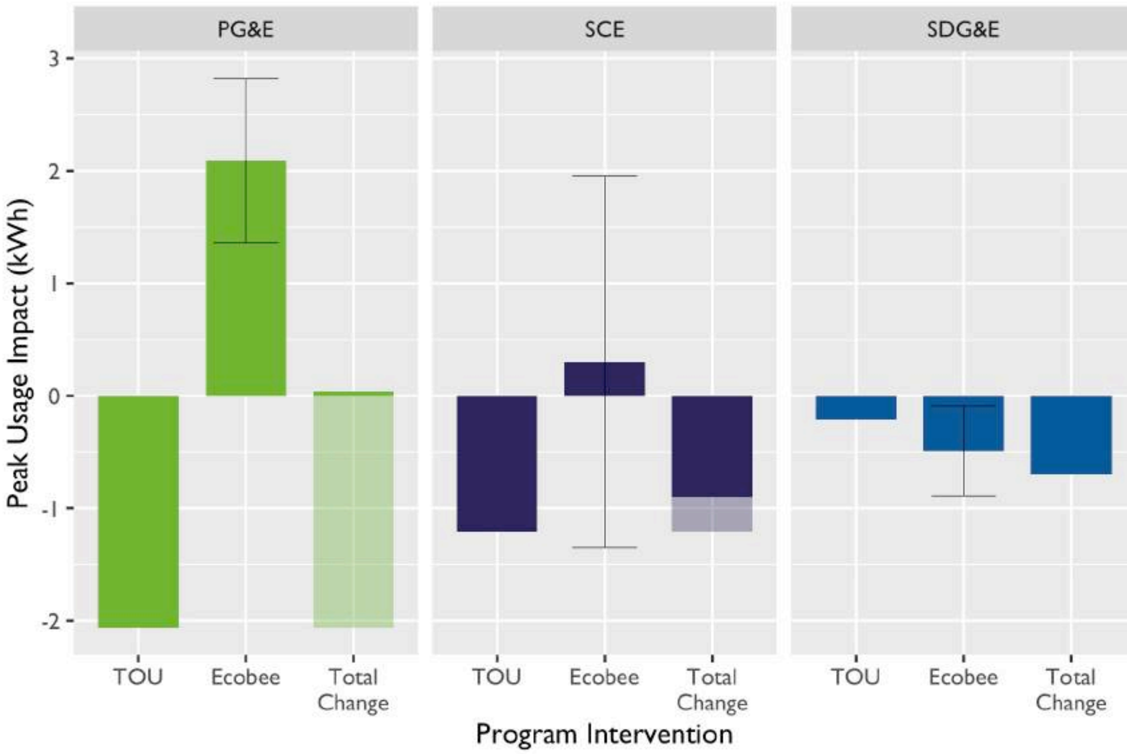


Figure 34: Changes in Peak Energy Usage (kWh) Attributed to the Ecobee, by IOU



To help understand how the smart thermostats were being used throughout the year, Evergreen looked at impacts for the two main HVAC seasons: summer and winter. Figure 35 shows Evergreen's estimated hourly change in kWh by group, with error bars depicting 95 percent confidence intervals around each estimate. The most interesting finding is in the control group (TOU rate only) from SCE. These customers reduced their energy usage from 7 a.m. until 7 p.m. during the summer months, but then increased their energy usage during this time period in the winter months. The treatment group did reduce their energy usage during the day for both seasons, but exhibited larger reductions in the summer months. These findings suggest that SCE's customers are more willing or able to cut back on usage during the summer than in the winter.

Figure 36 shows Evergreen's estimate of the hourly incremental impact of the Ecobee based on the difference-in-differences between the changes observed in the control group (TOU only) and treatment group (TOU with Ecobee) by season. For customers from SCE, the Ecobee led to an increase in energy usage during summer months and a decrease in usage during winter months relative to the TOU rate on its own. This inconsistent benefit across the two main HVAC seasons helps to explain the statistical insignificance of the overall Ecobee impact results for SCE.

Figure 35: Comparison of Post-Period Changes by Group and IOU, by Season

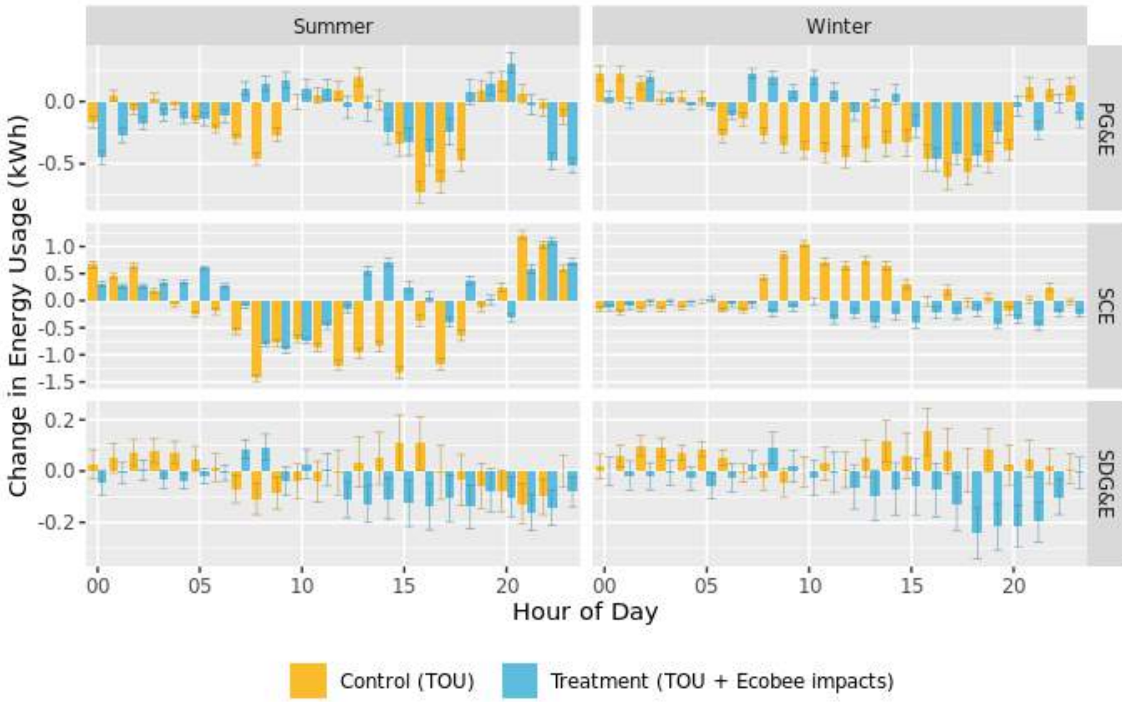
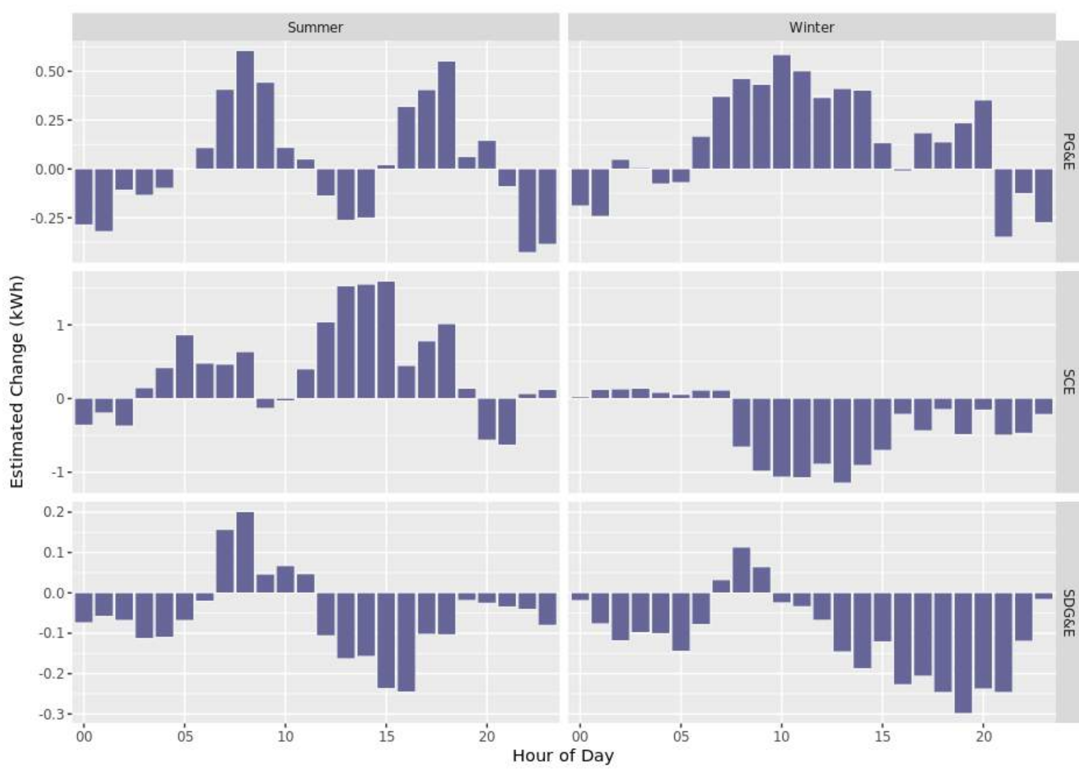


Figure 36: Estimated Incremental Impact of Ecobee, by Season



4.2.2 Ecobee with eco+ Impacts

As mentioned earlier, eco+ was only installed and activated in the Ecobee thermostats for a short period towards the end of the pilot, for only 69 percent of treatment group participants. This limited Evergreen's ability to fully assess the value of eco+ as it did not cover the entire summer period, and it did not cover the entire treatment group as originally intended. Despite these limitations, Evergreen did investigate any eco+ impacts in the portion of the post-period when eco+ was active.

Table 24 provides an overview of the pilot participants who are depicted in this analysis. Figure 37 provides a visual representation of the analysis timeline, with the post-period outlined in red. In this case, the post-period is defined as the days **between the activation of eco+ in July-August 2019 and the end of the post-period on November 30, 2019**. The post-period is defined as the time period after the customers who were assigned to the treatment group had the eco+ TOU functionality activated on their Ecobee. The AMICS model was estimated on a full year of baseline data from every customer (with controls for weather and seasonality), but since the treatment group only had the eco+ feature activated for three to four months, the post-period difference-of-differences is limited to the time frame of the treatment group. Evergreen have between 77 and 95 customers in the control group and 15 and 34 customers in the treatment group, depending on the IOU.

Table 24: eco+ Analysis Sample by Pilot Intervention and IOU

		Control	Treatment
Intervention		TOU	TOU with Ecobee and eco+
Post-Period Timeline		June 2019 - Nov 2019	July or Aug 2019 - Nov 2019
Number of Customers	PG&E	95	15
	SCE	77	32
	SDG&E	79	34
	Total	**251**	**81**

Figure 37: Post-Period Timeline for Ecobee with eco+ Impacts

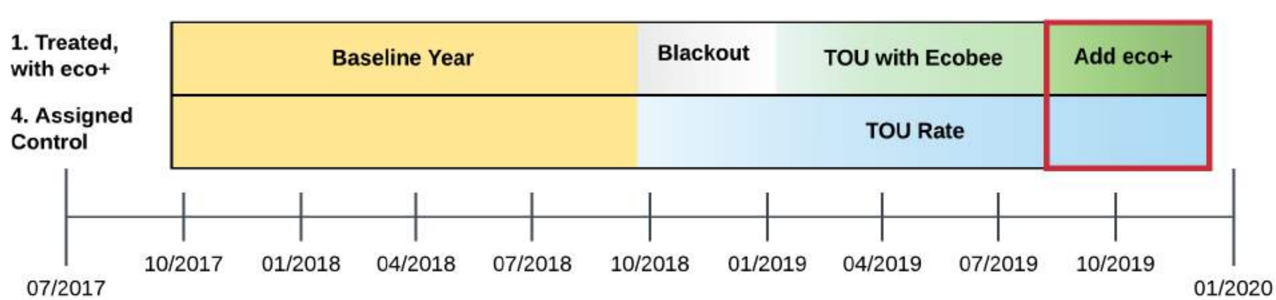


Figure 51 compares the post-period predicted load shape (blue) with the actual post-period load shape (green) for customers in the control group and the subset of the treatment group who activated the eco+ feature on their Ecobee. This prediction is based on the pre-period consumption model and post-period weather data from July to November 2019; it represents the expected load shape for these customers in absence of the program interventions. The error of each hourly prediction is depicted as a 95 percent confidence interval in the shaded area around each estimate. Whenever the actual post-period load shape (green line) falls outside the predicted post-period load region (blue area), this indicates that a statistically significant change was observed during that hour.

The AMICS model finds statistically significant reductions in the whole-building energy usage of the control group for PG&E during the morning and afternoon hours (i.e., green line falls below blue shaded area), followed by an increase in energy usage at night. The changes in the treatment group appear more erratic, likely due to the small sample size (n=15, 32, and 34 for PG&E, SCE and SDG&E respectively) and limited timeframe. Both groups from SDG&E show a sudden drop in energy usage at 4 p.m. that is maintained after peak hours until 11 p.m.

Figure 38: Actual Post-Period Load vs. Baseline Model Predictions by IOU After eco+

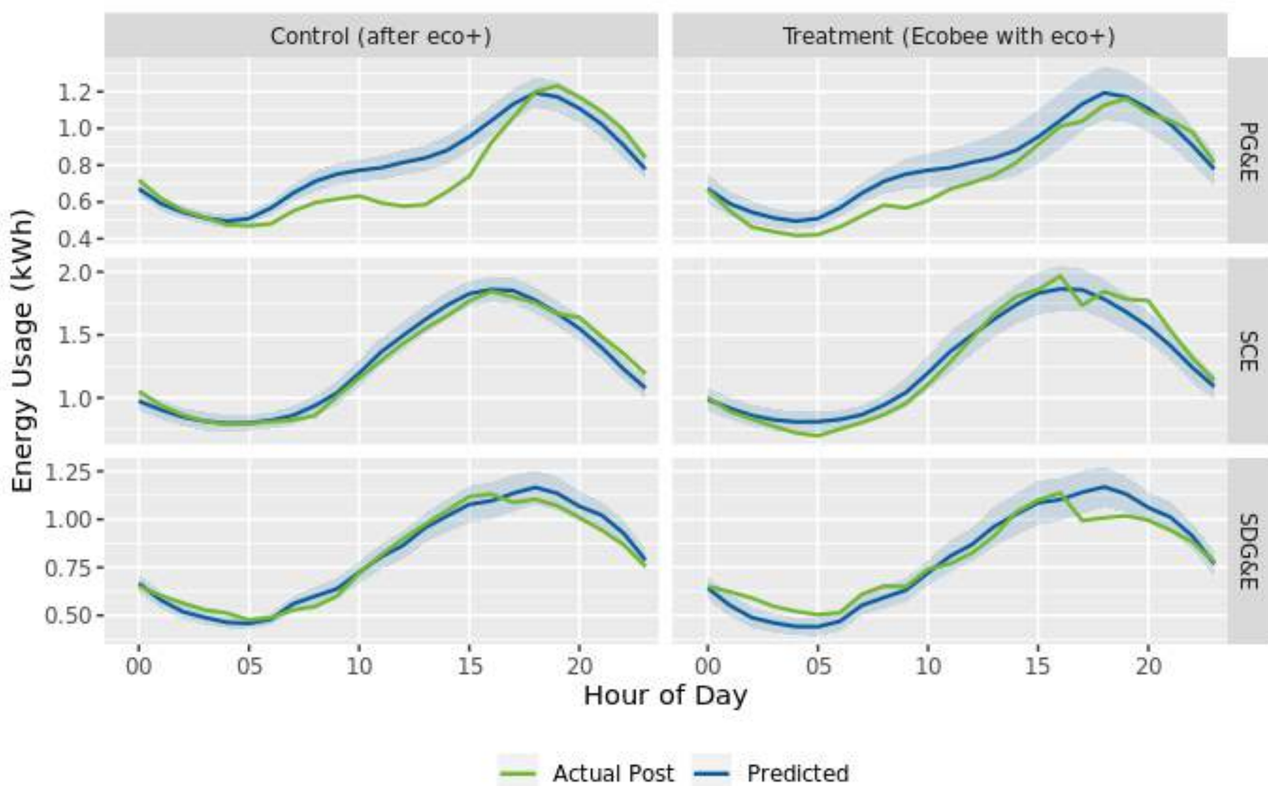


Figure 39 shows the estimated hourly change in kWh by group for a difference-of-differences estimation for the impact of an Ecobee with eco+ enabled, with error bars depicting 95 percent confidence intervals around each estimate. Again, the difference-in-differences between the control and treatment groups were performed within each customer-day segment and then weighted by the number of observations in the treatment group during the post-period to control for any known differences in the composition of customers and weather conditions in the control and treatment groups.[11]

Both the control group and treatment group from SDG&E reduced their energy usage during the peak hours after being transitioned to the TOU rate, though not all of these changes were statistically significant. As the control group provides Evergreen's best estimate of the change that the treatment group would have experienced transitioning to the TOU rate without the Ecobee, Evergreen are most interested in the relative difference between the control group and treatment group.

Figure 39: Comparison of Post-Period Changes after eco+ Enabled by Group and IOU

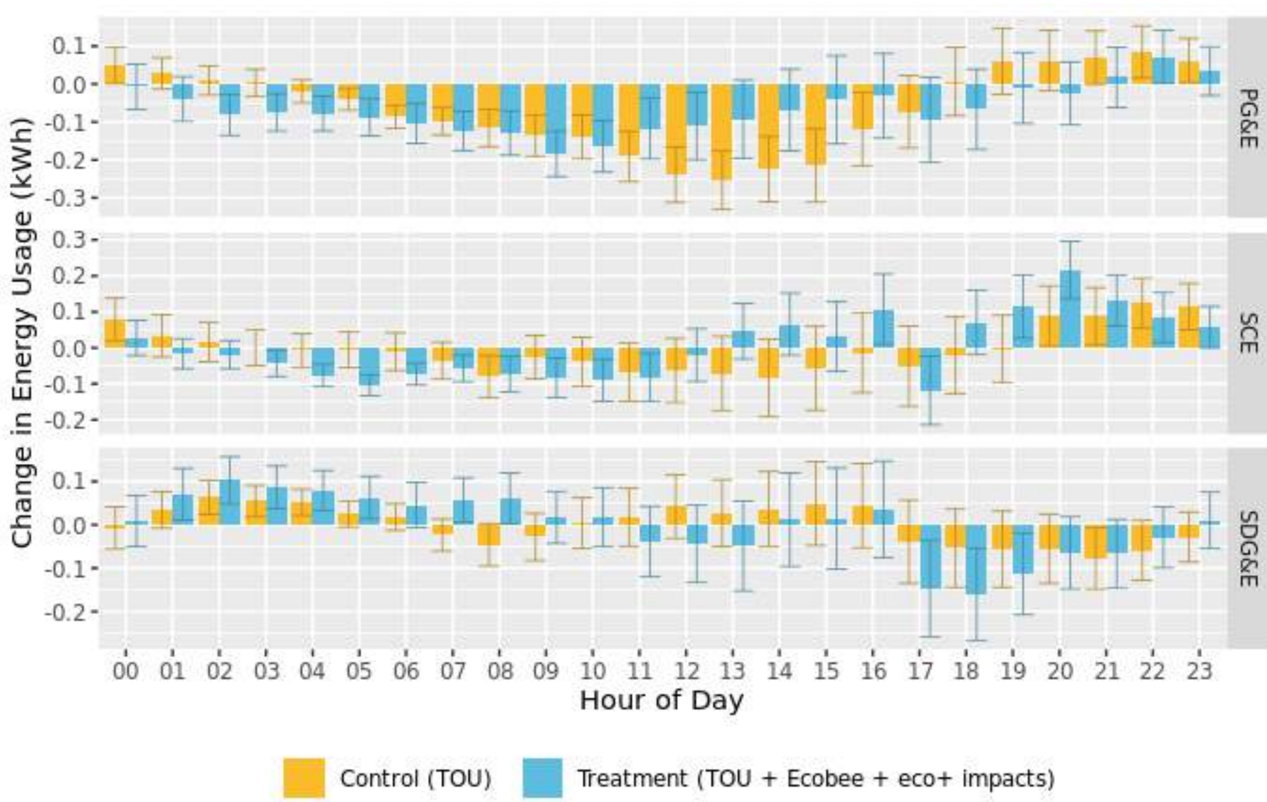
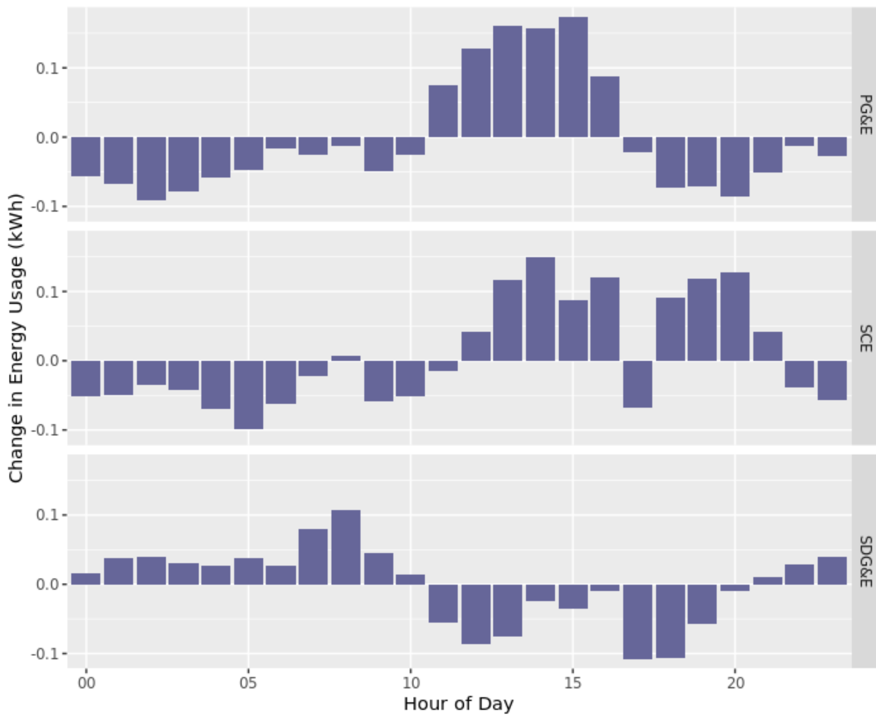


Figure 40 shows Evergreen's estimate of the hourly incremental impact of the Ecobee with eco+. This is based on the difference-in-differences between the control group and treatment group. The

[11] This comparison is restricted to customer and day segments that were observed in the post-period with both treatment and controls. This restriction excludes some observations, as 3 percent of treatment customer-days in the post-period had no similar customers and/or days in the control group during the post-period.

customers who installed the Ecobee and activated eco+ from PG&E exhibited the most consistent improvements, with reduced energy usage from 5 p.m. until 10 a.m., though most of these savings are offset by increases in usage between 11 a.m. and 4 p.m. Unfortunately, customers with an Ecobee and eco+ from SCE increased energy usage from 12 p.m. until 9 p.m., relative to the control group.

Figure 40: Estimated Incremental Impact of Ecobee with eco+ Enabled



The Ecobee with eco+ impact is estimated as the difference between the total change observed in the treatment group after eco+ and the change observed in the control group during the same timeframe. Table 25 provides a summary of these changes by IOU. Increases in energy usage are shown in red, while savings (i.e., reductions in energy usage) are shown in black. A 95 percent confidence interval is provided for the estimated impact of the Ecobee. Evergreen did not detect any statistically significant energy savings on the average day attributed to the Ecobees with eco+. During the peak hours, Evergreen found statistically significant increases attributable to the Ecobees with eco+ from SCE, and no significant changes from the other two IOUs. Figure **41** presents these same estimated impacts in a visual form, with bars to represent the incremental impacts of the TOU rate and Ecobee with eco+, which combined, account for the change observed in the treatment group.

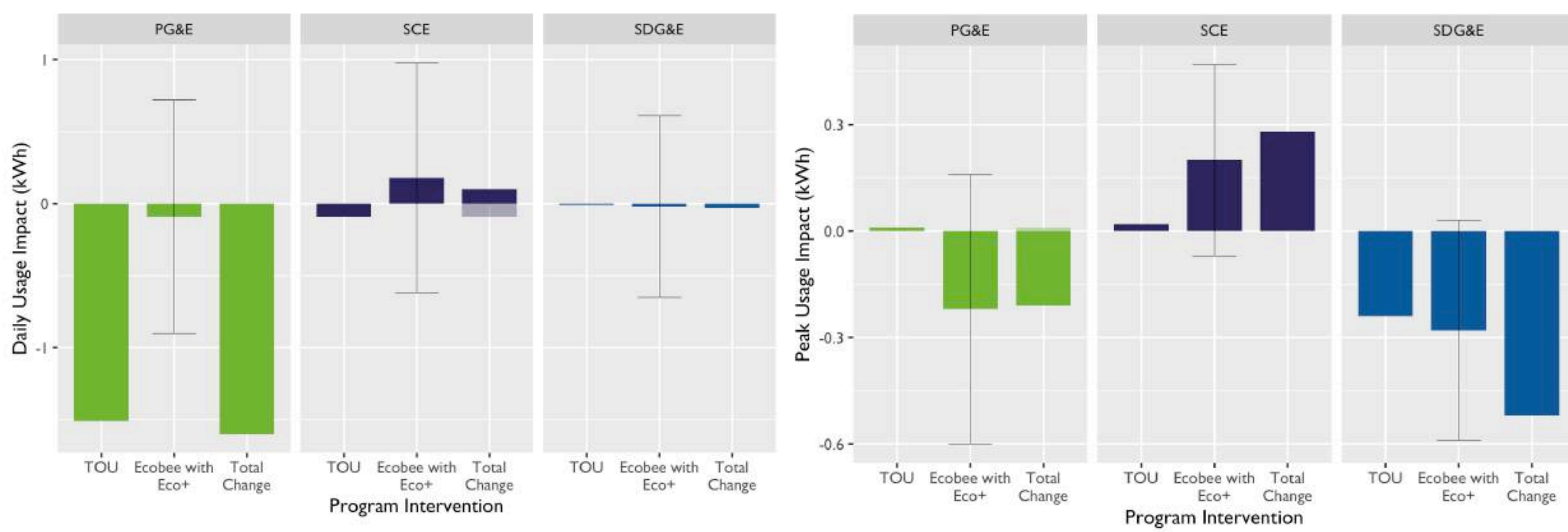
Table 25: Changes in Energy Usage (kWh) Attributed to the Ecobee with eco+, by IOU

	N Treated Cust-omers*	Average Day				Peak Hours*			
		Total Change (in treat)	TOU Impact (in control)	Ecobee eco+ Impact (difference)	Ecobee eco+ %	Total Change	TOU Impact	Ecobee eco+ Impact	Ecobee eco+%
PG&E	15	-1.60	-1.51	-0.09 ± 0.81	0.5%	-0.21	0.01	-0.22 ± 0.38	3%
SCE	32	0.10	-0.09	0.18 ± 0.80	0.6%	0.28	0.02	0.27 ± 0.27	4%
SDG&E	34	-0.03	-0.01	-0.02 ± 0.63	0.1%	-0.52	-0.24	-0.28 ± 0.31	4%

* Refers to the number of customers in the treatment group who were transitioned to the TOU rate, installed the Ecobee smart thermostat, and successfully activated the eco+ feature.

* Peak is 4- to 9 p.m. for PG&E and SDGE or 5 to 8 p.m. for SCE.

Figure 41: Changes in Daily Energy Usage and Peak Energy Use (kWh) Attributed to the Ecobee with eco+



5 Conclusions

This study looks specifically at low-income customers who often face higher energy burdens and aging housing stock. At the beginning of the pilot, most respondents thought they were already doing everything they could to save energy some to all of the time, suggesting they did not think they had many remaining opportunities to save additional energy, regardless of rate.

Customers also reported that they were less likely to take actions that were comfort related (such as shorter showers and turning down the AC at night) compared to actions such as turning off lights and electronics, and comfort was the most commonly chosen reason for not being able to save energy.

Conclusions below cover the TOU rate change and the additional impact of offering a smart thermostat with and without eco+.

TOU Rate Change

Half of the savings attributed to the TOU transition occurred during peak hours for SCE and SDG&E; this percentage was lower for PG&E, with most of those customer energy savings attributable to the TOU transition *outside* of the peak period of 4 to 9 p.m.

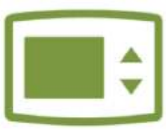
Survey responses from customers reflected a general understanding of the TOU period, as well as of the items in their home that use the most energy:

- Almost all respondents know *when* energy costs the most, it does not always align with when they think their own household uses the most energy.
- Respondents were aware of the peak hours of the day and that heating and cooling were the most energy intensive items in their home. This was consistent at the beginning and end of the pilot.

Respondents were split about wishing they had been told more about the TOU rate before the pilot started. Over half of respondents reported there was nothing else they wanted to know, and of the remaining half, the most common request was for **additional information on the rate, including the best times to use appliances**.

Smart thermostats seem to cannibalize savings from transitioning to the TOU rate. **Smart thermostats without eco+ did not provide consistent and significant benefits to low-income customers**. The exception is SDG&E customers, whose peak reductions and average daily kWh both improved with the smart thermostat.

- PG&E customers likely used the thermostat to improve comfort year round. Evergreen saw a statistically significant increase in usage attributed to the smart thermostat amongst PG&E participants both during the peak period and across all hours of the day.
- SCE customers did not use the thermostat to cut AC usage (they had more AC usage than the control group, but still represented a reduction compared with the pre-period year) but did use the thermostat to save energy in winter (less heating). On an annual basis, this was reflected as an overall increase in kWh.
- SDG&E customers used the thermostat to save more energy in the winter (reduced heating) than in the summer (reduced AC), but did cut back in both seasons (beyond what the control group could do).



Smart Thermostats

Smart thermostats allow customers to better control comfort. An unwillingness to sacrifice comfort was the most common reason chosen for not saving additional energy. This, alongside the increased ability to modify thermostat set points with a smart device/phone may have contributed to this cannibalization of savings from the TOU rate.

If increased awareness of the TOU rate is more important to the IOUs than the cannibalization of savings, it may make sense for the IOUs to offer thermostats; otherwise, they will see more savings with the TOU rate alone:

- The treatment group was more likely to be aware that their rate changed, suggesting that **the thermostat is useful if increased awareness of the TOU rate is important to the IOUs**.
- Similarly, respondents in the control group were more likely to report that they did not know if the TOU bill was the reason for any observed change in their bills over the course of the year. This suggests **that the participants with a thermostat may have been more likely to attribute a change in their bills to the TOU rate**.

Respondents were **very satisfied with the thermostat** (89 percent were at least somewhat satisfied), and respondents **appreciated the ability to control their thermostat with their smart phone or smart device**.

Sixty-three percent of respondents reported that the thermostat made it easier to control their bills, while 11 percent found it more difficult. This interpreted ease may be due to the ability to control set points through a smart device.

Both treatment and control group respondents reported that they had a preference for programming and manually adjusting the thermostat, suggesting that **most treatment group customers modified the default settings**. This aligns with what Evergreen found in the impact results, where thermostats seem to be used more to increase comfort than to shift usage off of peak hours.

Comparing the control and treatment respondents who reported that they modify their thermostat set points and settings, **the control group was more likely to report using their appliances less frequently to avoid the peak period during the summer months**. While this was not statistically significant, it may indicate that the **control group was more likely to take action in non-cooling related ways in absence of the smart thermostat,** whereas the **treatment group may have been more likely to have interpreted the thermostat offering as more of a one-stop solution to the change in rate.** This interpretation may have been due to their impression that the thermostat was set up to adjust off peak hours, though in actuality this feature was not installed until three-quarters of the way through the year-long pilot.

Unfortunately, a manufacturer error in programming the devices prohibited Evergreen from having a full year of information to assess the impact of eco+. Evergreen were, however, able to assess the short time period that eco+ was enabled (July through November 2019), and also review the impact of the smart thermostat without eco+ on participants' ability to adapt to TOU.

Smart Thermostat & eco+

In general, respondents with eco+ installed on their thermostat were **not widely confident in the thermostat's ability to help them control their energy bills or help them lower their energy use**, or on the existence of eco+ or a similar feature.

Evergreen did not detect any statistically significant energy savings on the average day attributed to thermostats with eco+.

Both the control and treatment group at SDG&E showed a sudden drop in energy usage at 4 p.m., which was maintained through the peak period, suggesting they may be well-educated on the TOU rate.

Appendix A: Survey Results by IOU

Table 1: Type of Energy Using Equipment for Control Group Survey Respondents by IOU

Group	Object	PG&E	SCE	SDG&E
Control - Percentages	Well	10%	13%	0%
	Shop Equipment	14%	21%	7%
	Pool Pump	14%	15%	11%
	Medical Equipment	21%	21%	10%
	Jacuzzi, Hot Tub, or Heated Pool	16%	0%	20%
	Irrigation Pump	3%	13%	2%
	Electric Vehicle Charger	10%	5%	3%
Control - Counts	Well	63	38	61
	Shop Equipment	63	38	61
	Pool Pump	71	37	67
	Medical Equipment	63	38	61
	Jacuzzi, Hot Tub, or Heated Pool	71	37	67
	Irrigation Pump	63	38	61
	Electric Vehicle Charger	63	38	60

Table 2: Type of Energy Using Equipment for Treatment Group Survey Respondents by IOU

Group	Object	PG&E	SCE	SDG&E
Treatment - Percentages	Well	15%	9%	3%
	Shop Equipment	11%	22%	15%
	Pool Pump	9%	12%	18%
	Medical Equipment	18%	15%	6%
	Jacuzzi, Hot Tub, or Heated Pool	6%	24%	12%
	Irrigation Pump	3%	3%	6%
	Electric Vehicle Charger	7%	3%	8%
Treatment - Counts	Well	33	33	33
	Shop Equipment	33	33	34
	Pool Pump	33	33	33
	Medical Equipment	33	33	33
	Jacuzzi, Hot Tub, or Heated Pool	33	33	33
	Irrigation Pump	33	33	33
	Electric Vehicle Charger	27	32	34

Table 3: Reported Household Views Doing Everything They Can to Save Energy Before, During and After Pilot, by IOU

Group	Time Period	Response	PG&E	SCE	SDG&E
Control	Before Pilot	Always	35%	46%	38%
		Sometimes	56%	54%	62%
		Never	6%	0%	0%
		Don't Know	3%	0%	0%
	During Pilot	Always	44%	38%	53%
		Sometimes	53%	62%	44%
		Never	0%	0%	0%
		Don't Know	3%	0%	3%
	After Pilot	Always	32%	46%	50%
		Sometimes	68%	54%	50%
		Never	0%	0%	0%
		Don't Know	0%	0%	0%
		Total Control N	**34**	**13**	**34**
Treatment	Before Pilot	Always	62%	0%	54%
		Sometimes	29%	100%	46%
		Never	0%	0%	0%
		Don't Know	0%	0%	0%
	During Pilot	Always	71%	0%	62%
		Sometimes	29%	100%	38%
		Never	0%	0%	0%
		Don't Know	0%	0%	0%
	After Pilot	Always	36%	0%	54%
		Sometimes	64%	100%	46%
		Never	0%	0%	0%
		Don't Know	0%	0%	0%
		Total Treatment N	**14**	**2**	**13**

Table 4: Understanding of Current Rate Before and After the Pilot, by IOU

Group	Time Period	Response	PG&E	SCE	SDG&E
Control	Before Pilot	Tiered Rate	49%	69%	70%
		Time-of-Use Rate	20%	6%	0%
		Not Sure	32%	25%	30%
	After Pilot	Tiered Rate	15%	19%	7%
		Time-of-Use Rate	54%	69%	84%
		Not Sure	32%	13%	9%
		Total Control N	**41**	**16**	**40**
Treatment	Before Pilot	Tiered Rate	53%	88%	58%
		Time-of-Use Rate	18%	13%	21%
		Not Sure	29%	0%	21%
	After Pilot	Tiered Rate	0%	25%	16%
		Time-of-Use Rate	53%	75%	79%
		Not Sure	47%	0%	5%
		Total Treatment N	**17**	**8**	**19**

Table 5: Respondent Interpretation of Bill Change During Pilot Compared to Prior Two Years of Those Aware they were on TOU (Q61, Q62, Q63)

Group	Time Period	Response	PG&E	SCE	SDG&E
Control	Spring	Higher in 2019	18%	55%	11%
		Lower in 2019	32%	18%	30%
		About the same as the past two years	50%	27%	59%
	Summer	Higher in 2019	41%	73%	24%
		Lower in 2019	27%	9%	46%
		About the same as the past two years	32%	18%	30%
	Winter	Higher in 2019	45%	36%	22%
		Lower in 2019	18%	18%	27%
		About the same as the past two years	36%	45%	51%
		Total Control N	22	11	37
Treatment	Spring	Higher in 2019	22%	0%	21%
		Lower in 2019	22%	25%	43%
		About the same as the past two years	56%	75%	36%
	Summer	Higher in 2019	22%	25%	21%
		Lower in 2019	33%	75%	36%
		About the same as the past two years	44%	0%	43%
	Winter	Higher in 2019	56%	0%	21%
		Lower in 2019	11%	50%	29%
		About the same as the past two years	33%	50%	50%
		Total Treatment N	9	4	14

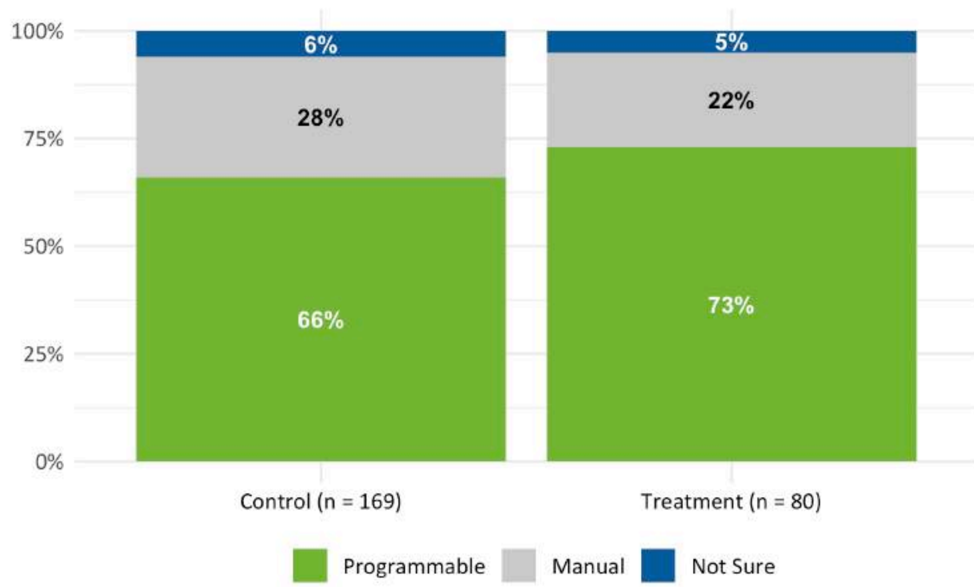
Appendix B: Additional Survey Results

Demographic Information

Before the pilot started, the control and treatment groups reported having roughly the same number of thermostats in their homes. The control group (n=159) reported having 1.06 thermostats, while the treatment group (n=79) reported having 1.11 thermostats. No one in either group reported having more than two thermostats

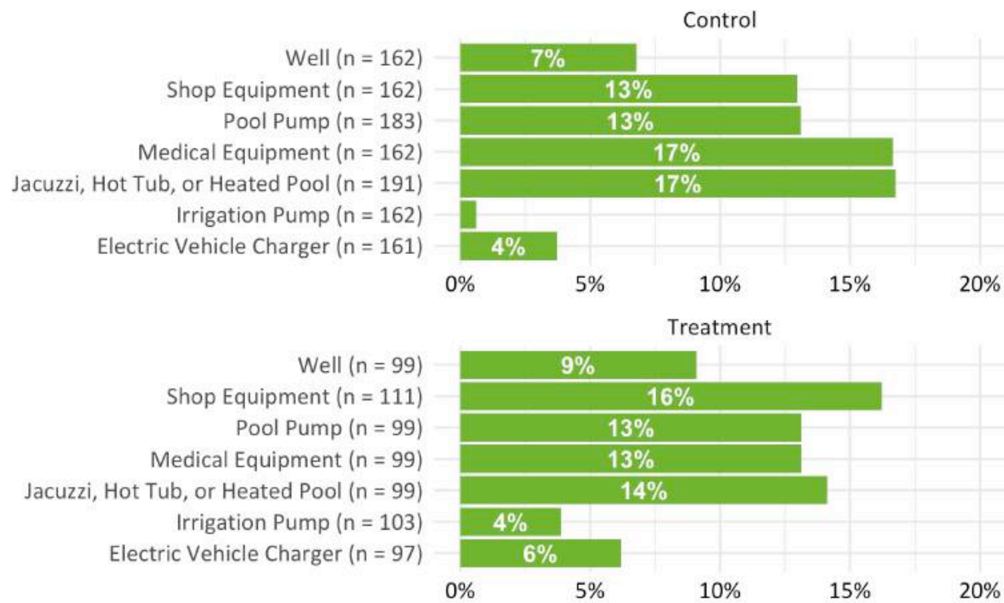
Figure 155 presents different types of thermostats in both the control and treatment groups before the implementation of the pilot. Over half of participants in both groups reported owning a programmable thermostat, while approximately a quarter of participants in both groups reported having a manual thermostat. The differences in thermostat types are not significant at the 90% level of confidence.

Figure 1: Type of Thermostat for Treatment and Control Group Survey Respondents Prior to Pilot



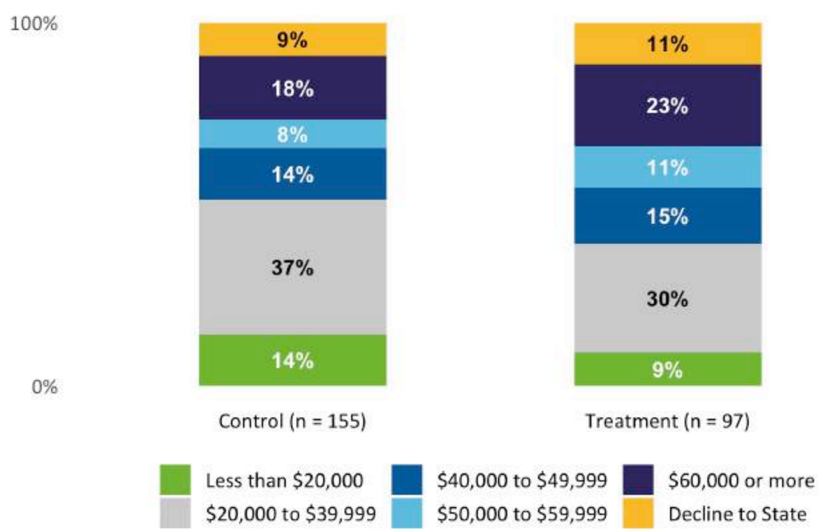
Across both groups, participants reported similar percentages of larger equipment that could contribute to higher energy bills. Differences between the control and treatment groups shown in Figure 256 are not statistically significant.

Figure 2: Type of Energy Using Equipment for Treatment and Control Group Survey Respondents



The control and treatment group gave similar responses (no statistically significant differences) in terms of income and education levels. The same was true for household composition (approximately three people in each home over the entire year) and in terms of additional residents in the summer (14 to 16% of respondents had an additional resident in the summer).

Figure 3: Reported Income Levels, Control vs. Treatment Groups



Evergreen asked respondents if the people who live in their home generally agree on the ideal temperature in their household. While the difference is not statistically significant, slightly more of the control group respondents reported this is the case (84%) compared to the treatment group respondents (75%).

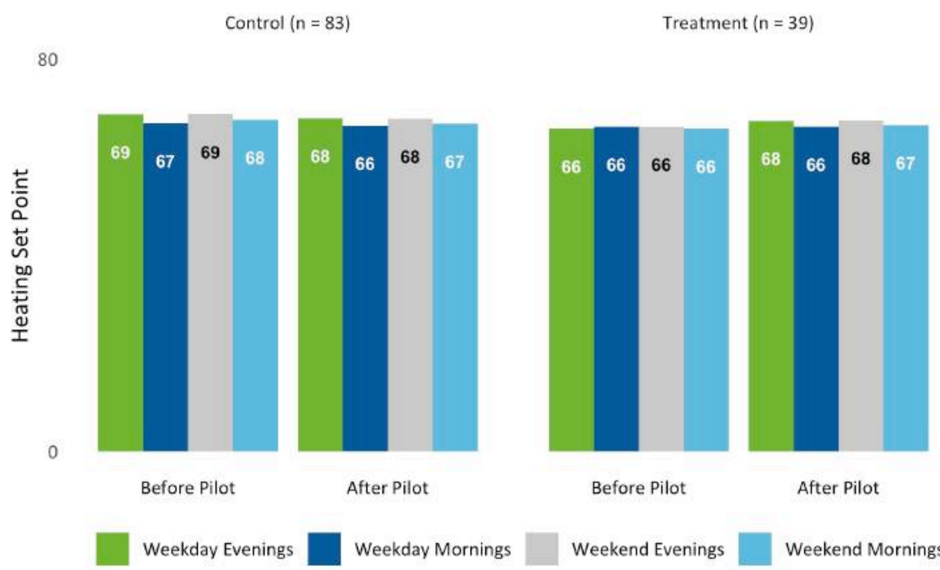
1.1.1 Use of Cooling and Heating

Evergreen asked respondents to report how they use and interact with heating and cooling to understand if there are any initial differences in the strategies between the control and treatment groups and also to see if they reported changing their behavior in regard to heating and cooling over the course of the pilot.

In regard to cooling set point, the way cooling is used, and supplemental cooling strategies, there were no significant differences between the treatment and control groups or in behaviors before or at the end of the pilot. The most common cooling strategy outside of central AC for both groups was ceiling fans. Additional information on cooling can be found in Appendix B.

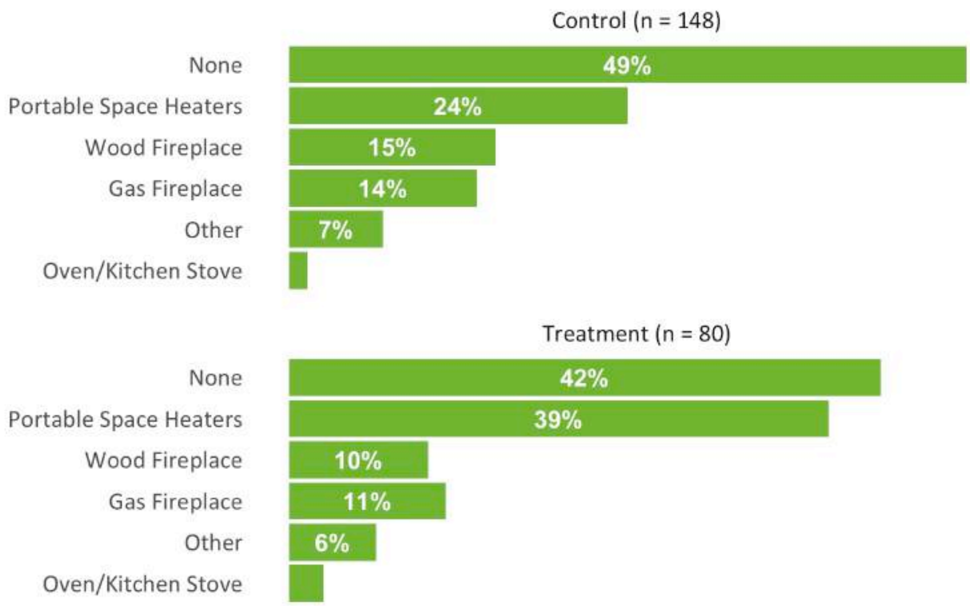
In regard to heating, over 93 percent of both the treatment and control groups had central heating in their homes. On average, across weekdays/weekends and mornings and evenings, the average reported set points were consistent (ranging from 66 to 69 degrees Fahrenheit). Customers in the control group were more likely to report that their set point was lower at the end of the pilot than before the pilot, whereas customers in the treatment group were more likely to report a higher average set point after the pilot. These differences are minor, but it may show that there is a slightly more active effort to lower set points (even slightly) amongst the control group.

Figure 4: Average Heating Set Point (in degrees Fahrenheit) at Different Types and Times of Day Before and After the Pilot, by Comparison and Treatment Groups



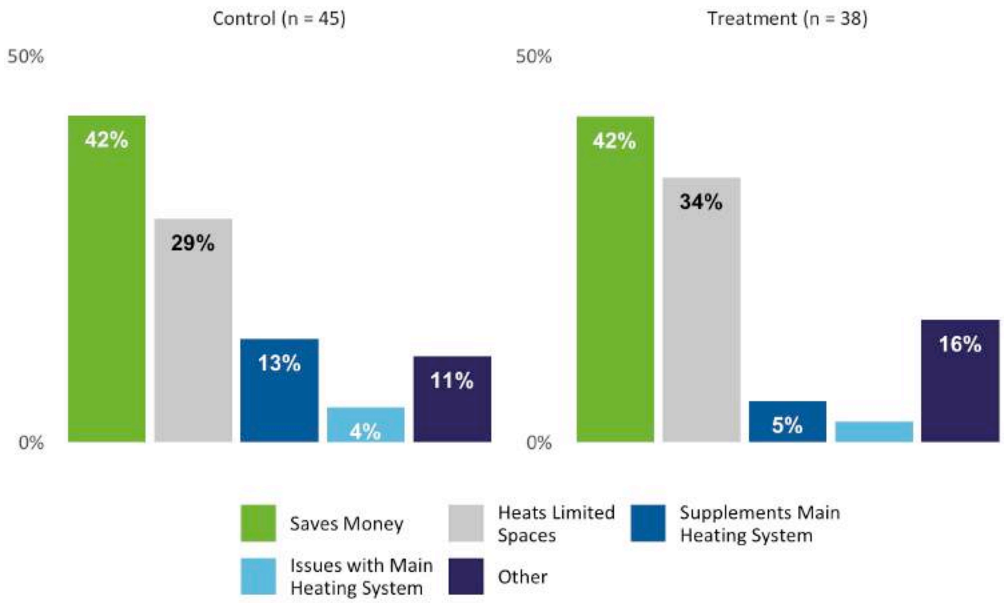
One interesting difference in heating strategies amongst the control and treatment group respondents was that the treatment group was much more likely to utilize portable space heaters compared to the control group. This difference is statistically significant.

Figure 5: Use of Non-Central Heating Systems by Comparison and Treatment Groups



In terms of *how* respondents report using space heaters, 42 percent of participants in both the treatment and control groups reported using space heaters in place of their central heating system in order to save money on their bill (Figure 618). There are no statistically significant differences in the responses between the treatment and control groups.

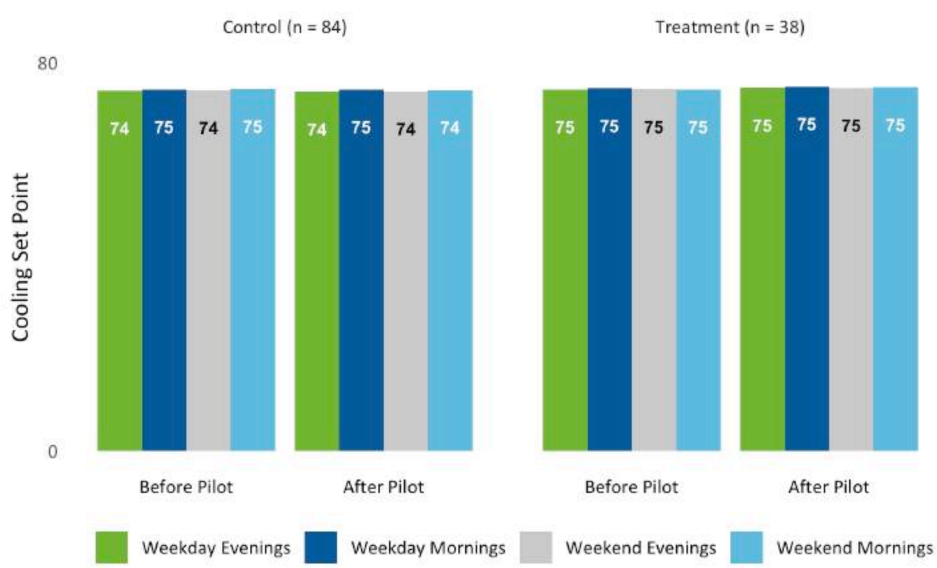
Figure 6: Reasons Why Participants Use Portable Space Heaters



Cooling

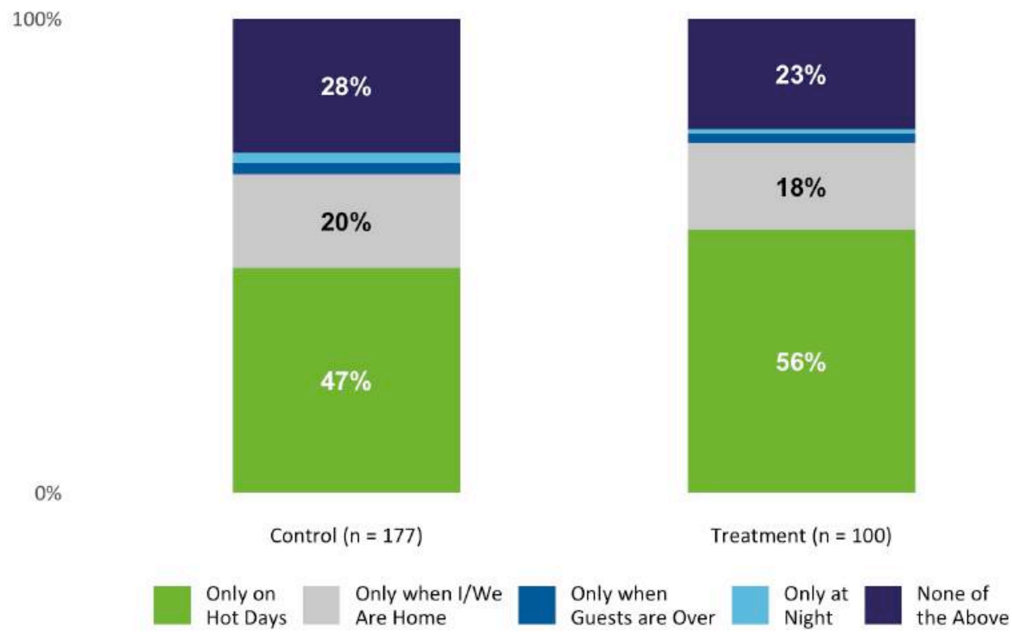
On average, across weekdays/weekends and mornings/evenings, the average respondent reported set points were very consistent at 74 or 75 degrees Fahrenheit (Figure 59).

Figure 7: Average Cooling Set Point at Different Types and Times of Day Before and After the Pilot, by Comparison and Treatment Groups



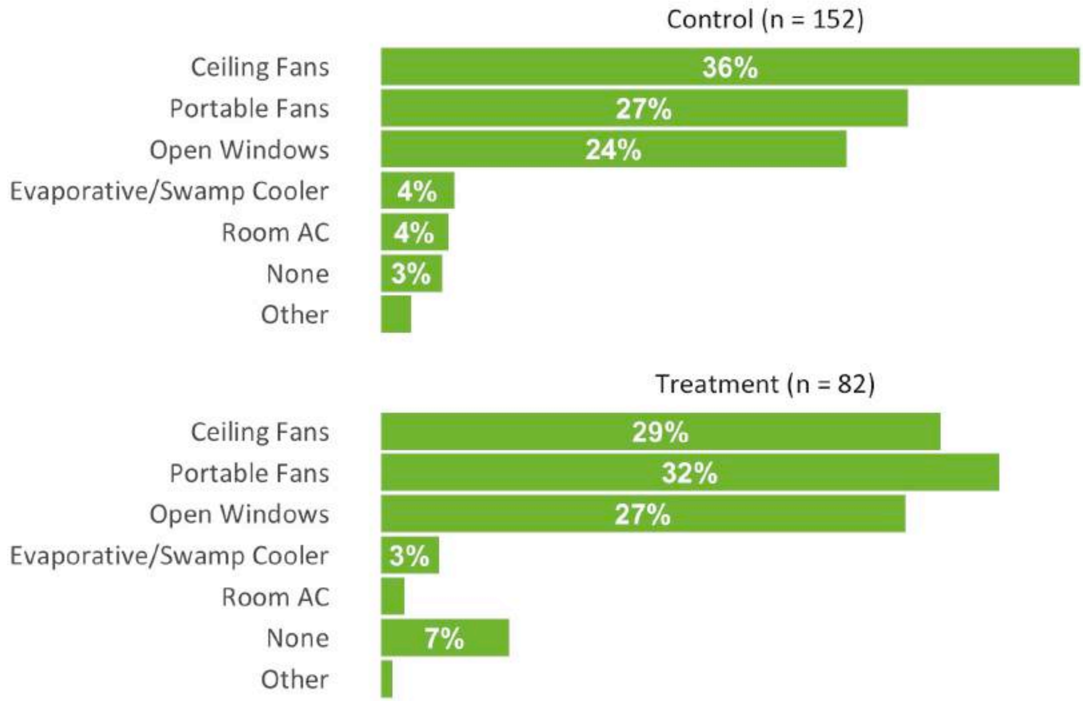
The treatment group respondents were more likely to report that they used their air conditioning only on hot days compared to the control group as shown in Figure 60, though this difference is not statistically significant.

Figure 8: How Air Conditioning is Used, Treatment vs. Control Group



There were no significant differences between the treatment and control groups with regards to how they use other methods of cooling. The most common non-Central AC strategies for both groups were ceiling fans and portable fans.

Figure 9: Use of Non-Central Cooling Systems by Comparison and Treatment Groups



Appendix C: Survey Questions

Survey Questions

	Question	Survey 1	Survey 2	Survey 3
2	Have you moved since January 2019? o Yes o No		x	x
3	When you moved, what did you do with the smart thermostat that had been installed in your prior residence? A) Took it and then installed it in my new home (or had it installed) B) Kept it, but have not installed it at my new residence [Ask control group questions] C) No longer have it [Ask control group questions] D) Don't know		x	x
4	Our records indicate that at the beginning of the program you were offered a smart thermostat from [IOU] that would be installed in your home. Do you recall this? o Yes o No		x	only if did not respond to Survey 2, only if refused treatment
5	[IF YES] Do you recall why you decided to not receive and install the smart thermostat? o Yes (please explain why)___________ o No o Don't know		x	only if did not respond to Survey 2, only if refused treatment
6	[If yes] How would you rate the usefulness of the instruction you got on your new thermostat? o Extremely useful o Very useful o Useful o Not very useful o Not at all useful		x	only if did not respond to Survey 2, only if refused treatment

	Question	Survey 1	Survey 2	Survey 3
7	Is the thermostat [IOU] gave you still installed and working? o Yes o No o Don't know		x	x
8	[If no or don't know] What happened to the thermostat? o Text [skip to end of orange questions]		x	only if did not respond to Survey 2
9	[if yes]Our records indicate that your thermostat is no longer online. Is there anything that has changed that you think may have caused the thermostat to no longer be online? o Text [skip to end of orange questions]		x	only if did not respond to Survey 2
10	In January 2019, you were switched to a new type of billing rate structure for your electric bill. Do you recall this? o Yes o No [Thank and terminate] o Don't know [thank and terminate]		x	x
11	Now that you have been on the time-of-use rate for almost a year, we want to know how likely you'd be to recommend the rate to a friend or neighbor. o extremely likely o somewhat likely o likely o not likely o not very likely			x
12	How satisfied are you with the time-of-use rate overall, compared to the billing structure you were on in 2018, before this pilot? o extremely satisfied o somewhat satisfied o neither satisfied nor unsatisfied o not satisfied o not at all satisfied			x
13	[if less than somewhat satisfied ask] What would have made you more satisfied with the new rate? [free response]			x

	Question	Survey 1	Survey 2	Survey 3
14	** NEW ** [for treatment group] Which of these statements best describe how you used your thermostat over the past year? A. I manually adjusted the temperature whenever I was uncomfortable (use a nob/buttons on the thermostat or in the app as needed) B. I programmed the thermostat to certain temperatures for each day and time (rarely changed settings, just kept it on a schedule) C. I enabled the "smart" features to learn my schedule and temperature preferences (let it make adjustments on its own) D. Combination of A and B E. Combination of A and C F. Don't know			x
15	[for control group] Which of these statements best describe how you used your thermostat over the past year? A. I manually adjusted the temperature whenever I was uncomfortable (use a nob/buttons on the thermostat or in the app as needed) B. I programmed the thermostat to certain temperatures for each day and time (rarely changed settings, just kept it on a schedule) C. Combination of A and B F. Don't know			x
16	[If had smart thermostat] How satisfied are you with your Ecobee smart thermostat? o extremely satisfied o somewhat satisfied o neither satisfied nor unsatisfied o not satisfied o not at all satisfied			x
17	[if less than somewhat satisfied ask] What would have made you more satisfied with your Ecobee thermostat? [free response]			x

	Question	Survey 1	Survey 2	Survey 3
18	[If had thermostat] Thinking over the whole past year, was the Ecobee thermostat a useful tool for shifting your energy usage to off-peak, less expensive times? (list hours dependent on utility)? Yes No Don't know			x
19	Why do you say that?			
20	Looking back, what do you wish you knew about the rate before you started on it?			
21	When do you think your household uses the most electricity? a. Morning b. Afternoon c. Evening d. Not sure	x		x
22	When do you think electricity use is highest in your neighborhood? a. Morning b. Early afternoon c. Late afternoon d. Evening/night e. Not sure	x		x
23	Does anyone in your household regularly use any medical equipment that plugs in and uses electricity? a. Yes b. No c. Not sure	x	x	first timers only

	Question	Survey 1	Survey 2	Survey 3
24	Does your household have a well? a. Yes b. No c. Not sure	x	x	first timers only
25	Does your household have an irrigation pump? This is different than your standard irrigation system. a. Yes b. No c. Not sure	x	x	first timers only
26	Does your household have a pool pump? a. Yes b. No c. Not sure	x	x	x
27	Does your household have a Jacuzzi, hot tub, or heated pools? a. Yes, but it's shared amongst households b. Yes, just for my household c. No d. Not sure	x	x	x
28	Does your household have any shop equipment such as air compressors or power tools that you use often? a. Yes b. No c. Not sure	x	x	first timers only
29	Does your household have a plug-in electric vehicle charger? a. Yes b. No c. Not sure	x		first timers only

	Question	Survey 1	Survey 2	Survey 3
30	How important is saving electricity to your household? a. Extremely important b. Very important c. Somewhat important d. A little important e. Not at all important	x		x
31	Do you think you do everything you can to save electricity (such as open windows in the summer, line dry clothes, only run full loads of laundry, take shorter showers)? a. Always b. Sometimes c. Never d. Don't know	x	x	x
32	Which of the following would you say keep you from saving more electricity in your home? Which are true for you? (select all that apply) a. I don’t want to sacrifice comfort in my home b. I don’t have time to pay attention to saving electricity c. I have little control over when others in my household use electricity d. Other: ____________	x		x

	Question	Survey 1	Survey 2	Survey 3
33	How often do members of your household do any of the following? Choose never, sometimes, always, or does not apply. [Will rotate a-e] In the summer we: a. Turn down or off the air conditioning at night during the summer months b. Turn down or off the air conditioning when you leave your home c. Turn off pool heater All year we: d. Turn off lights when not in use e. Turn off electronics like TVs and computers when no one is using them f. Limit showers to five minutes or less	x	x	x
34	How many thermostats do you have? 1 2 3 4+ Don't know [ask thermostat questions for each thermostat if >1]		x	first timers only
35	What type of thermostat do you have in your home? a. Manual (use a nob, or lever, or switch to adjust the heating or cooling temperature, cannot program) b. Programmable (allows you to set heating and cooling to come on at certain temperatures and even on certain days or times) c. Not sure	x	x	first timers only

	Question	Survey 1	Survey 2	Survey 3
36	[If programmable or not sure] Is your thermostat Wi-Fi enabled so that it can be connected to your home's Wi-Fi to take in weather data and adjust temperatures? a. Yes b. No c. Not sure	x	x	first timers only
37	[If programmable or not sure] Is it "smart" meaning that it can learn your behaviors and preferred temperature settings and make adjustments on its own? a. Yes b. No c. Not sure	x	x	first timers only
38	Approximately how old is your thermostat? a. less than 5 years b. 5 to 10 years c. More than 10 years d. Don't know	x	x	first timers only
39	[If programmable or not sure] Did you or someone in your home program your thermostat or are you using the original default settings? a. We programmed it b. We used the standard settings c. It was already programmed when we moved in d. Not sure	x		first timers only
40	Do you have central heating? a. Yes [CENTRAL HEATING=YES] b. No c. Not sure	x		first timers only

	Question	Survey 1	Survey 2	Survey 3
41	[If CENTRAL HEATING=YES] What temperature do you set your thermostat at for heating on [a weekday during the day/weekday during the evening/weekend during the day/weekend in the evening (question will be asked four times to cover each time period)] a. __ degrees (will be dropdown menu) b. Not sure	x		x
42	What cooling temperature do you set your thermostat to on [a weekday during the day/weekday during the evening/weekend during the day/weekend in the evening (question will be asked four times to cover each time period)] ? a. __ degrees (will be dropdown menu) b. Not sure	x		x
43	How do you use your AC? a. Only at night. b. Only on very hot days. C. Only when guests are over. D. Only when I/we are home. E. None of the above, we use it at varying times.	x	x	first timers only
44	Does everyone in your household agree on a temperature setting? a. We generally agree b. We disagree on the ideal temperature c. I live alone d. Don't know	x	x	first timers only

	Question	Survey 1	Survey 2	Survey 3
45	[If CENTRAL HEATING=YES] Besides your central heating system, do you use anything else to heat your home? Check all that you use: a. portable space heaters b. Fireplace c. Oven/kitchen stove d. Other _____________	x	x	first timers only
46	[If CENTRAL HEATING=YES] When would you typically use [response from prior question, asked for each response]? [will rotate options] a. When we don't want to use our central system in order to save money / keep our utility bill lower b. In addition to the main heating system since it doesn't provide enough heat c. Because the main heating system does not work well so we use this instead of the main heating system d. To heat just a limited space or single room where the central system doesn't work well e. Not sure f. Other________	x	x	first timers only
47	Besides your central cooling system, do you use or do anything else to cool your home? Check all that you use: a. portable fans b. Room AC c. Ceiling fans d. Open the windows e. evaporative cooler / swamp cooler f. Not sure g. Other _____________	x	x	first timers only

	Question	Survey 1	Survey 2	Survey 3
48	Which do you think uses the most electricity in your home in the summer? Please rank these from highest electricity use to lowest electricity use. (The order will be randomized for each participant) a. TVs b. Chargers for laptops and cellphones c. Oven d. Stovetop e. Refrigerator f. Cooling (AC and/or fans) g. Heating h. Lighting I. Heating water for washing clothes and dishes, and bathing j. pool/spa equipment k. other: (personal/business equipment such as table saws, workout machines, fish tanks) ______________	x		x
49	Which do you think uses the most electricity in your home in the winter Please rank these from highest electricity use to lowest electricity use? (The order will be randomized for each participant) a. TVs b. Chargers for laptops and cellphones c. Oven d. Stovetop e. Refrigerator f. Cooling (AC and/or fans) g. Heating h. Lighting I. Heating water for washing clothes and dishes, and bathing j. pool/spa equipment k. other: (personal/business equipment such as table saws, workout machines, fish tanks) ______________	x		x

	Question	Survey 1	Survey 2	Survey 3
50	When would you typically use [response from above question, asked for each response]? a. to save money / keep our utility bill lower b. When the central cooling system doesn't provide enough cool air c. Because the central cooling system does not work well so we use this instead d. To cool just a limited space or single room where the central cooling system doesn't work well e. Not sure f. Other________	x		first timers only
51	How are you currently billed for electricity? a. Tiered rate: My rate varies based on how much electricity I use, where I pay more for each unit of electricity I use above a certain amount. b. Time-of-use rate: My rate varies based on time of day, where I pay more during the time of day when overall demand for electricity is highest. c. I don't know	x		x
52	How well do you understand how you are billed for electricity? a. Completely b. Very well c. Somewhat d. A little e. Not at all f. Don't know	x		x

	Question	Survey 1	Survey 2	Survey 3
53	[if NOT SCE]: Do you live in a: a. Single family home – with no shared walls with neighbors b. An apartment/townhome/condo where I share walls with a neighbor c. A mobile home or RV d. Other_________	x	x	first timers only
54	[if NOT SCE, if prior question =B]: How many units would you estimate are in your building? a. 2 b. 3-5 c. 5-15 d. 16-50 e. 50+ f. Not sure	x	x	first timers only
55	What is the highest grade or year of school that you have completed? ? a. some primary or secondary school g. a high school diploma or GED h. some college I. a two-year college degree j. a four-year college degree k. an advanced degree	x	x	first timers only
56	How many people live in your home 12 months of the year, including any children? a. 1 b. 2 c. 3 d. 4 e. (scroll option with numbers up to 20)	x	x	first timers only

	Question	Survey 1	Survey 2	Survey 3
57	How many of those people are 18 or under? a. 1 b. 2 c. 3 d. 4 e. (scroll option with numbers up to 20)	x		first timers only
58	Do you have any additional people living with you during the summer for more than a month? This might include college students home for the summer or any other people who come to live with you in the summer. a. Yes b. No c. Don't know	x	x	first timers only
59	How many additional people live with you during the summer, for more than a month? a. 1 b. 2 c. 4 d. 5+	x	x	first timers only
60	Select the income range that best describes your household's 2017 income. a. Less than $20,000 b. $20,000 to $40,000 c. $40,000 to $50,000 d. $50,000 to $60,000 e. $60,000 or more f. Don't know g. Decline to state	x	x	first timers only

	Question	Survey 1	Survey 2	Survey 3
61	What was your energy cost like this past winter (December 2018 to February 2019)? Would you say they were higher, lower, or about the same in early 2019 as they were the past 2 winters? o Higher in 2019 o Lower in 2019 o About the same as the past 2 years (on average)		x	only if did not respond to Survey 2
62	What was your energy cost like this past spring (March to May)? Would you say they were higher, lower, or about the same in 2019 as they were the past 2 springs? o Higher in 2019 o Lower in 2019 o About the same as the past 2 years (on average)		x	only if did not respond to Survey 2
63	What was your energy cost like this past summer (June to August)? Would you say they were higher, lower, or about the same in 2019 as they were the past 2 summers? o Higher in 2019 o Lower in 2019 o About the same as the past 2 years (on average)		x	only if did not respond to Survey 2
64	[If more or less to winter, spring, summer questions] Why do you think your bills were different this year? [Text]		x	only if did not respond to Survey 2
65	Based on your understanding - energy cost the most during which set of hours in the summer? o Morning (1) o Early afternoon (2) o Late afternoon/evening (code time based on IOU) [4-9PM for SDG&E, 5-8 for SCE, 3-8 for PG&E- PG&E to confirm) (3) o Night (4) o Not sure (5)		x	only if did not respond to Survey 2

	Question	Survey 1	Survey 2	Survey 3
66	How well do you feel you understand the change from tiered billing to time-of-use rates for your electricity billing (called time-of-use)? O Extremely well o Very well o Somewhat well o Not very well o Not at all		x	only if did not respond to Survey 2
67	[If more or less to winter, spring, summer questions] How do you think the new rate system (time-of-use) has affected your energy bills? Do you think that the new rate system you're on has made your bills higher, lower, or had no effect compared to the old way you were billed? o higher o lower o no effect o it varies o doesn't know		x	only if did not respond to Survey 2
68	[If more or less to winter, spring, summer questions] How do you think the new thermostat's functioning has affected your ability to control energy bills? Do you think the new thermostat has made it easier, harder, or had no effect on your ability to control your energy bills compared to your prior thermostat? o harder o easier o no effect o it varies o doesn't know		x	only if did not respond to Survey 2
69	Do you recall your thermostat ever automatically adjusting to help you save energy and money during the time of day when energy is more expensive [will list utility specific hours]? o yes o no o doesn't know		x	only if did not respond to Survey 2

	Question	Survey 1	Survey 2	Survey 3
70	How often did you change how you use energy by personally adjusting your thermostat, to avoid the higher- cost time of day? o Often (almost daily) o Sometimes (at least once a week) o Occasionally (at least once a month) o Rarely o Never		x	only if did not respond to Survey 2
71	[If occasionally to often] What did you change to avoid the higher cost? [text]		x	only if did not respond to Survey 2
72	*Now I want to ask you about some of the features of your thermostat and how you use it.*		*x*	only if did not respond to Survey 2
73	Do have a smart phone or internet connected device? o Yes o No o Don't know		x	only if did not respond to Survey 2
74	[If yes] How often, if ever, do you control your thermostat using your smart phone or internet connected device? o I always control the thermostat using my smart phone or internet connected device o I mostly control the thermostat using my smart phone or internet connected device o I sometimes control the thermostat using my smart phone or internet connected device o I occasionally control the thermostat using my smart phone or internet connected device o I never control the thermostat using my smart phone or internet connected device		x	only if did not respond to Survey 2

	Question	Survey 1	Survey 2	Survey 3
75	[If yes] How useful did you find the ability to control your thermostat from your smart phone? o Extremely useful o Very useful o Somewhat useful o Not very useful o Not at all useful		x	only if did not respond to Survey 2
76	ECO+ is a thermostat function that is designed to help save you money when energy costs the most by automatically adjusting the temperature set=point during peak usage times. ECO+ would be displayed on your thermostat to let you know when it's in use. Is the ECO+ function currently working on your thermostat? o Yes o No o Don't know		x	only if did not respond to Survey 2
77	Overall, how much do you think the new thermostat has made it easier or harder for you to adjust to the new time-of-use rate, or has it made no difference? o Much easier o Somewhat easier o No difference o Somewhat harder o Much harder		x	only if did not respond to Survey 2
78	Why did you say [response from above]? o Text		x	only if did not respond to Survey 2
79	Have you ever adjusted the thermostat settings from the way they were set up when [IOU] installed the thermostat? o Yes o No o Don't know		x	only if did not respond to Survey 2

	Question	Survey 1	Survey 2	Survey 3
80	Now that you have the smart thermostat, do you think you use more, less, or about the same energy? o More o Less o About the same o Don't know		x	only if did not respond to Survey 2
81	[If more] How do you think the smart thermostat helped you save more energy?		x	only if did not respond to Survey 2
82	[If less] How do you think the smart thermostat caused you to use more energy?		x	only if did not respond to Survey 2
83	[If about the same] Why do you think it has not changed the amount of energy you used?		x	only if did not respond to Survey 2
84	Compared to your old thermostat, what do you like more about the new thermostat? [text]		x	only if did not respond to Survey 2
85	Compared to your old thermostat, what do you like less about the new thermostat? [text]		x	only if did not respond to Survey 2
86	Lastly, thinking of any changes you've made in using energy since you started on the new rate, What has helped the most for you to save energy during the peak period of 4 to 9 [will adjust based on IOU] when rates are higher?		x	x

Appendix D: Interim Findings Memo

MEMORANDUM

Date: April 30, 2019

To: IOU Low Income Programmable Communicating Thermostat Time of Use Pilot Study Team

From: Martha Wudka and Sarah Monohon, Evergreen Economics

Re: Interim Findings from first PCT TOU Pilot Study

This memo provides a summary of findings from the first of three surveys sent to participants of the Investor-Owned Utilities (IOU) Low Income Programmable Communicating Thermostat (PCT) Time of Use (TOU) Pilot conducted by Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E).

Each of the three IOUs created slightly different versions of the pilot that utilize treatment and control groups to assess if PCTs are a valuable tool to help low-income customers adjust to TOU rates. Both groups were moved to the TOU rate in the beginning of 2019, and the treatment group received a PCT and education on how to use it.

The first of three surveys was distributed in December 2018 and January 2019. This survey provides a baseline by which to assess if having a PCT has changed the way that low-income customers react to the TOU rates. A second survey will be conducted after participants experience at least two warm weather bills in the summer of 2019. The third survey will be conducted after the completion of the one-year pilot in early 2020. The customer survey results will be paired with an analysis of usage data to validate any changes in usage patterns that may have resulted from the pilot.

This memo includes four sections:

1. Methodology
2. Survey Attrition
3. Baseline Survey Results
4. Interim Findings

1 Methodology

The three IOUs recruited a total of 764 customers into the Low Income Programmable Communicating Thermostat (PCT) Time of Use (TOU) Pilot, letting them know that they would be moved to the TOU rate, and that they may or may not receive a PCT. Evergreen screened and assigned recruited customers into treatment or control groups, and then sent both groups the first survey.

1.1 Screening and Control and Treatment Group Assignment

The IOUs recruited customers who had already participated in a low-income program (see first row of Table 1). Evergreen applied additional screening criteria to the IOU pool of recruits:

- Receive electric service (gas optional);
- Own their home with no plans to move during the study period;
- Have and use central cooling (central air conditioning (AC) or heat pump);
- Not yet be on a TOU rate plan or have a connected PCT; and
- Have wireless internet in their home.

A total of 34 customers were screened out of the initial IOU recruitment pool who did not meet all of these eligibility criteria (for example, six had previously received incentives for PCTs, and one was already on a TOU rate). An additional 36 customers opted out of the pilot prior to Evergreen's analysis. The remaining 695 customers were randomly assigned to the treatment and control groups (Table 1**Error! Reference source not found.**).

Table 1: Pilot Customer Screening and Assignments

	PG&E	SCE	SDG&E	Total
IOU Recruitment Eligibility	Prior low-income program participation in climate zones 11-14	Prior low-income program participation in climate zones 14-15	Prior low-income program participation	
Customers Recruited	414	174	176	764
Screened Out by Evergreen	25	0	9	34
Opted Out	36		0	36
Control	176	87	84	347
Treatment	178	87	83	348

Prior to the random assignment of customers into the control and treatment groups, we sorted customers into similar categories based on their average load shape in the pre-period and other characteristics. Evergreen used our Advanced Metering Infrastructure Customer Segmentation (AMICS) model framework to identify similar customers and group them together based on their energy usage to improve the matching between the treatment and control groups.

Evergreen created different customer segments for each IOU (listed below) due to the variations in eligibility criteria, sample size, and pre-period load shapes across IOUs. The segments were chosen to minimize the baseline model error (as measured by repeated cross validation holdout tests) and group customers with similar potential for savings from the TOU pricing and/or PCTs, while also minimizing the number of customers isolated by the segmentation method (that is, solo customers without peers to enable a post-period comparison).

- PG&E: 5 daily energy usage (magnitude) groups and 7 normalized load shape clusters (hours-of-use)
- SCE: 2 eligibility categories (i.e., low income program participation) and 11 load shape clusters (magnitude and hours-of-use)
- SDG&E: 2 climate zone groups and 11 load shape clusters (magnitude and hours-of-use)

For PG&E's daily energy usage groups, we assigned customers to one of five bins according to their average daily energy usage in the pre-installation period, such that each bin contained roughly the same total kWh usage. The number of customers in each bin varied, with the highest energy usage bins containing the fewest customers. This binning strategy isolated customers who are atypical, reducing error in the model without removing these customers from the analysis.

The load shape clusters for each IOU were made up of customers with similar hours of use, identified by *k*-means clustering, such that each cluster contained a subset of customers with similar hours of use during the pre-installation period. Cluster analysis is an unsupervised machine-learning algorithm designed to detect patterns in data.[1] The benefit of cluster analysis is that similar customers are grouped automatically from the AMI data, rather than relying on customer characteristics that are often not tracked (or not regularly updated) by the IOU. Some customers have relatively flat load shapes with little change in energy usage throughout the day, while others exhibit a steep increase in energy usage in the morning and afternoon hours until they reach a peak in the evening and drop back down.

Once similar customers were grouped in this manner, the randomized selection between the treatment and control groups could be completed. Specifically, we randomly assigned 50 percent of the customers in each IOU customer segment to the treatment group or the control group. In a

[1] The *k*-means clustering algorithm randomly assigns each customer's load shape to one of *k* clusters and then calculates the sum of the distance between each load shape and the centroid (i.e., average load) of the cluster to which it was assigned. Load shapes are then reassigned to the nearest cluster centroid, and the process is repeated until the variation within each cluster cannot be improved.

few cases, we manually shifted customers with no peers (that is, those assigned to a segment with only n=1 customer) to the opposing groups to maintain a balance between the groups. Table 2 provides a side-by-side comparison of the average pre-period energy usage, low-income program participation, and home characteristics based on IOU program, billing and customer information system data.

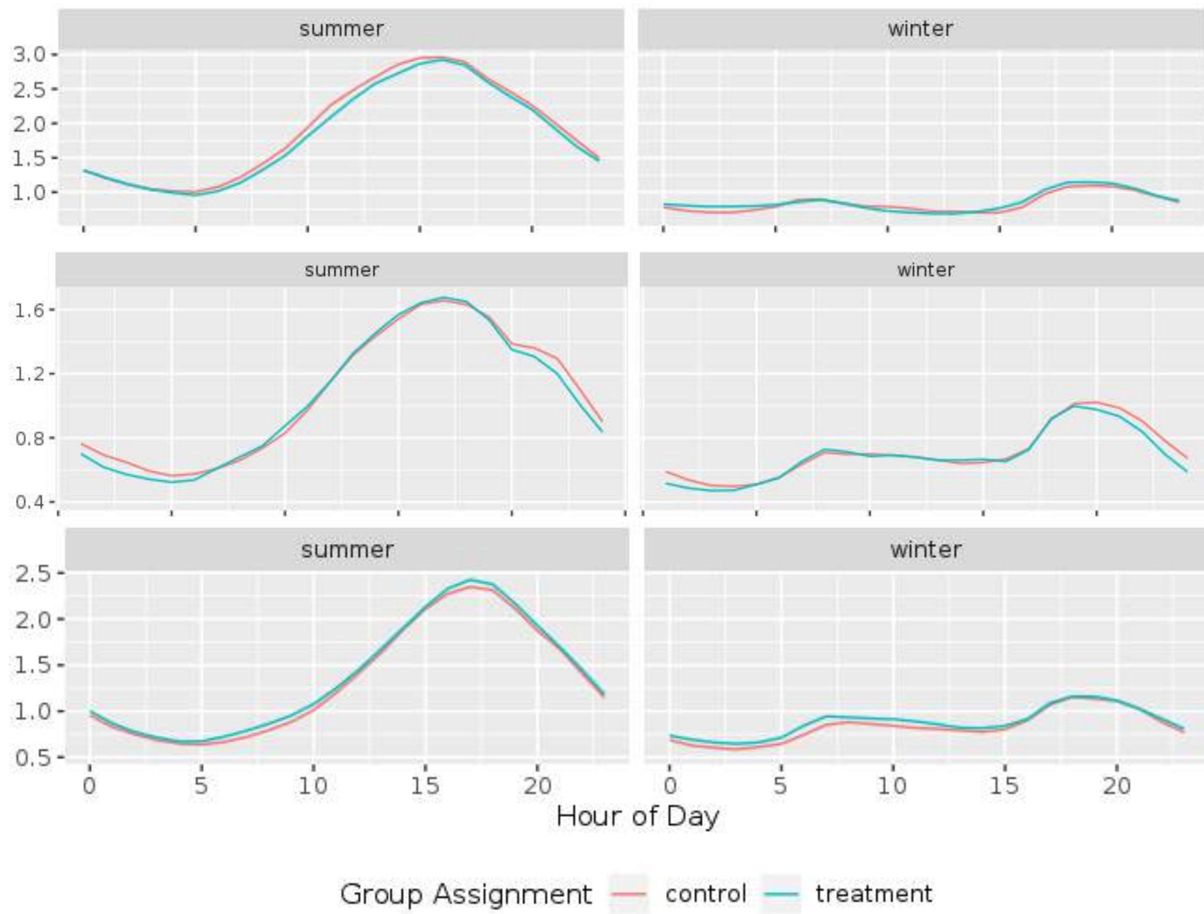
Table 2: Attributes of Control and Treatment Group

	PG&E		SCE		SDG&E	
	Control	Treat	Control	Treat	Control	Treat
N	176	177	87	87	84	83
Avg. daily kWh	23	24	28	28	19	19
Avg. kWh during peak hours	2.1	2.2	2.7	2.7	1.5	1.5
Avg. summer-shoulder ratio*	1.9	1.9	2.9	2.6	1.7	1.8
Avg. fixed-effects baseline**	0.49	0.49	0.63	0.63	0.42	0.42
% participated in ESA	100%	100%	8%	6%	27%	39%
% enrolled in CARE - late 2018	84%	84%	48%	54%	93%	88%
Avg. home square-footage	1,632	1,712	1,721	1,686	not available	not available
Avg. home built year	1982	1980	1986	1988	not available	not available

*Average hourly kWh in summer (months 6-8)/average hourly kWh ratio in shoulder months (11, 2-3). The concept is that the larger ratio is indicative of high HVAC usage, and thus more potential savings from a thermostat or AC program.
** Estimated baseline kWh, customer fixed-effects coefficients from a simplistic regression model using a full year of pre-period days (on days with defined temperatures). kWh ~ alpha + hdd + cdd.

Figure 1 shows the average kWh energy usage during the summer and winter months, by customers assigned to the control (pink) versus the treatment (blue) group prior to any program intervention. The overall kWh energy usage (scale) and shape differ across the three IOUs, but in both seasons, the control and treatment groups appear well matched. This is especially important during the summer peak hours, when we expect to see the largest impact from the TOU rates and/or PCTs.

Figure 1: Average Load Shape of Treatment and Control Group by Season and IOU (Top = SCE, Mid = SDG&E, Bottom = PG&E)



1.2 Survey Recruitment

Evergreen sent pilot participants both a postcard and an email that contained a unique link to a web survey before alerting them of their placement in the control or treatment group. We offered an incentive of $25 to $50 gift card to either Target or Walmart (varies by IOU) for completing the first web survey.

Table 3 shows the initial IOU incentives along with the incentives planned for the three surveys. Respondents to all three surveys will receive an additional “kicker” incentive in some cases, as shown.

Table 3: Incentives by IOU and Treatment vs. Control Group

	PG&E		SCE		SDG&E	
	Treatment	Control	Treatment	Control	Treatment	Control
Initial IOU Incentive	Thermostat	None	Thermostat	$100	Thermostat	$100
First Survey	$50	$50	$25	$25	$25	$25
Second Survey	$50	$50	$25	$25	$25	$25
Third Survey	$50	$50	$25	$25	$25	$25
Survey "Kicker"	$50	$50	N/A	N/A	$25	$25
Final Incentive	N/A	N/A	N/A	$100	N/A	N/A
Total Possible Incentive	**$200**	**$200**	**$75**	**$275**	**$100**	**$200**

A total of 286 pilot participants responded to the initial web survey (Table 4). Across all three IOUs, the average response rate was 54 percent.

Table 4: Number of Respondents to First Survey

		PG&E[2]	SCE	SDG&E	Total
Control and Treatment Assignments	Control	176	87	84	347
	Treatment	178	87	83	348
Respondents	Control	66	34	55	155
	Treatment	53	29	49	131

[2] The total number of surveys sent to PG&E pilot participants was lowered to 191 after 163 respondents who did not return a participation waiver were dropped from the pilot.

2 Attrition

Between the time that customers were recruited to the pilot and the time they were assigned to the treatment or control group, half[3] (51%) of the treatment group left the pilot. In this section we explain the reasons for this attrition from data provided by SCE and SDG&E.

The most common reason for the attrition of treatment group customers was that they stopped responding to follow up outreach from the pilot installation staff (18%) as shown in Table 5. Another fifteen percent of recruited pilot participants requested to cancel participation and 10 percent could not install the PCT due to incompatible wiring or HVAC equipment.

Table 5: Post Recruitment Attrition for Treatment Group (SCE and SDG&E)

	Percent of Treatment Group (n=170)
Completed PCT installation	**49%**
Did not move forward with pilot participation	**51%**
Did not respond to follow up communications	18%
Requested to cancel participation	15%
Equipment proved to be incompatible (wiring, HVAC)	9%
Already has PCT	5%
To be identified at a later date	5%

Table 6 expands upon the 15 percent of treatment group customers who requested to cancel participation. Amongst this group, the most common response (36%) was that they decided that they did not need a smart thermostat. The group that did not think they needed a thermostat reported that they “just like the regular one [they] have,” that they “don’t see the point when [theirs] works just fine.” Twenty percent were uninterested due to their age or health condition.

[3] Note that PG&E attrition data will be included at a later date. This section currently covers both SCE and SDG&E.

Table 6: Reasons for Request for Cancellation from Treatment Group (SCE and SDG&E)

	Percent (n=25)
Does not need a PCT	36%
Elderly or health related reason	20%
Moving	8%
Too complicated/tech averse	8%
Other/Unknown	28%

Part of the value of this pilot is understanding interest in this program amongst the targeted (low-income) population. Some of the attrition issues are valuable for future program consideration and some are irrelevant (such as moving between the time of recruitment and the pilot start date).

Attrition issues that should be considered for future program design are:

- Incompatible equipment in households (9% of treatment group customers);
- A general lack of desire for a PCT (9% of treatment group customers); and
- Elderly or health related reason for disinterest (5% of treatment group customers)

The attrition of pilot participants (which happened while the first survey was in the field) will also affect the ability to use results from this survey as a baseline going forward. Only 38 percent of the treatment group customers who took the initial survey stayed in the pilot. This means that Evergreen's results for the treatment group participants will only be able to be tracked overtime for a portion of the survey respondents.

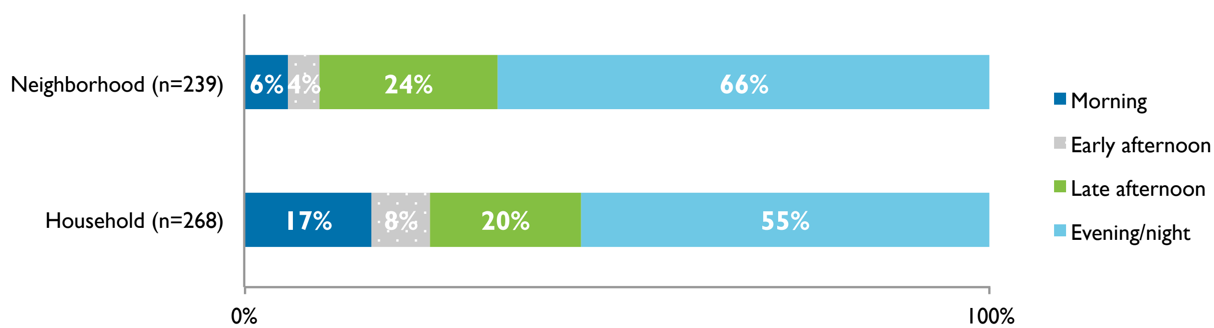
3 Baseline Survey Results

As mentioned previously, the first web survey of pilot participants provides baseline data on low-income customer perceptions of TOU rates and thermostat features, and their ability to reduce energy usage.

3.1 Perceptions of Time of Use and Rates

Customer awareness of when their energy usage is highest is important to the overall concept of TOU rates. We asked respondents when they think *their household* uses the most electricity, and then when electricity use is highest in *their neighborhood*. Excluding those who responded "not sure," the majority (55%) of respondents thought they used the most electricity in the evening. A greater fraction of respondents (66%) thought that their neighbors used the most electricity in the evening. This may indicate that a small fraction of respondents (11%) believe they are using electricity off-peak. At the end of the pilot we will compare survey responses to usage data to see if they are in fact more likely to use electricity off-peak.

Figure 2: When Respondents Think Household And Their Neighborhood Uses The Most Electricity (excluding "not sure" responses)



Respondents completed a ranking exercise for which they were given a randomized list of energy-using equipment to drag and drop in order of highest energy usage (with 1 being the highest, and 10 being the lowest). Cooling and heating were ranked as using the highest amount of energy, and chargers and the oven and stove were ranked as using the least amount of energy, according to respondents (Table 7), indicating they have a good understanding of the major energy-using end uses in their homes.

Table 7: Respondent Ranking of Energy Using Equipment From Highest to Lowest

Equipment	Mean
Cooling (n=273)	2.7
Heating (n=261)	4.0
Clothes washer/clothes dryer (n=273)	4.1
Refrigerator (n=273)	4.2
Lighting (n=273)	5.2
Water heating (n=273)	5.6
TVs (n=273)	5.6
Pool/spa equipment (n=45)	5.7
Oven/stove top (n=273)	6.5
Chargers (n=273)	7.6

3.2 Thermostat Features and Settings

Households often include multiple occupants who may or may not agree on the ideal temperature. Of the respondents who live with others (80%), 81 percent say that all occupants agree on the thermostat settings. The average air conditioning set point is 74 degrees (consistent across time of day), while average heating temperature set points varied very slightly between daytime (67 degrees) and evening (68 degrees).

On average, each household had 1.1 thermostats (n=278), with almost all respondents with multiple thermostats living in a single-family home. Having at least one thermostat was a qualification for participation in the pilot. The most thermostats any household had installed was three. Respondents reported that 71 percent of existing thermostats were programmable, 26 percent were manual, and 6 percent of thermostats were of an unknown type.

To assess customer understanding of thermostats, we asked respondents with programmable thermostats if their programmable thermostats were Wi-Fi enabled "so that it can be connected to a home's Wi-Fi to take in weather data and adjust temperature" or if it was "'smart meaning that it can learn behaviors and preferred temperature settings and make adjustments on its own."

Eleven percent of respondents with programmable thermostats reported that their existing thermostats were "smart;" 13 percent reported that they were Wi-Fi enabled (i.e., PCT). This indicates that there may be some confusion from customers (since PCTs were supposed to be screened out during the initial phone outreach), and that some respondents are not clear on the capabilities of their thermostats.

At least six of the respondents reported that thermostats that are "smart" are over five years old, and at least two of the respondent reported that thermostats that are Wi-Fi enabled are over 10 years old, indicating there is confusion on the customer side as to which thermostats denote eligibility for programs, since these technologies were not available ten years ago. Future outreach to potential pilot participants must include very clear information and descriptions of technologies to avoid any confusion among recruits. This will save time spent visiting ineligible homes for installation.

3.3 Reducing Energy Usage

Respondents were asked if they had certain equipment that may contribute to excessive electricity usage, or non-discretionary uses. This may impact how they choose to cut back during peak hours (if at all) in response to the new TOU rate. The decision to cut back electricity use might be a difficult one to make for customers who have medical equipment that needs to be powered.

Table 8: Unique Equipment in Household

Energy Using Equipment	Percentage of Respondents (n=285)
Medical equipment that plugs in and uses electricity	16%
Household Jacuzzi, hot tub, or heated pool	12%
Pool pump	11%
Well	8%
Irrigation pump	1%

We asked respondents about how important it is for their household to save electricity. This metric will be compared to future surveys to see if respondents perceive saving electricity to be more or less important after participating in a full year of the pilot study. Just above half of the respondents reported that saving electricity is "extremely important" to their household. An additional 38 percent reported that it was "very important," with just one respondent noting that it was "a little important."

We also asked respondents what keeps them from saving more electricity in their home. This question will allow Evergreen to compare responses across the next two surveys to see if perceived barriers to saving electricity changes after pilot program participation. Respondents provided a number of reasons that they are unable to save more electricity in Table 9. Note that the first three responses listed in the table were prompted, while the other responses are categories of unprompted write-in responses. Fewer than three percent of respondents reported having trouble saving energy because of either heating, building envelope issues, being elderly, being home during the day, or using the dryer rather than a clothesline.

Table 9: What Keeps Respondents From Saving More Electricity In Their Homes (multiple responses allowed)

	Percentage of Respondents (n=285)
Comfort (prompted)	43%
Control over others in the household (prompted)	33%
Do not have the time to pay attention to saving energy (prompted)	6%
AC-related	4%
Health	3%
Heating-related	3%

Another important baseline measurement is how respondents assess their efforts to save energy. We asked participants if they think they do everything they can to save electricity. Forty percent of respondents reported that they always do everything they can to save electricity (Table 10), but the remaining 60 percent of respondents believe there is more they could be doing. Future surveys will ask this question again to see if respondents still feel the same after pilot participation.

Table 10: Do Respondents Do Everything They Can To Save Electricity?

	Percentage of Respondents (n=285)
Always	40%
Sometimes	56%
Never	2%
Not Sure	1%

In order to be able to assess how valuable the smart thermostat is in helping customers adjust to time of use rates, we first asked about heating and cooling practices *before* the pilot. All pilot participants were required to have a central AC, and 95 percent reported having central heating. We asked respondents about what type of other heating and cooling devices they use to supplement their central systems.

Nearly 30 percent of respondents use portable space heaters to supplement their central heating system (Table 11). Across each of the top four supplemental heating types, respondents reported that the most common reason for using the supplemental heating source is when they do not want to use their central system in order to save money/keep their utility bill lower. Six percent of respondents with portable space heaters use them in the bathroom after showering. Those who use the oven or stove noted that they choose what type of meals to make based on the weather to benefit from the indirect heating that cooking produces.

Table 11: Supplemental Heating Usage

	Percentage of Respondents (n=285)
Portable space heater	28%
Gas fireplace	13%
Wood fireplace	11%
Oven/stove	2%
Wood stove	2%
Electric fireplace	1%

Respondents report using central AC minimally, even though many are located in climate zones with very hot summers. When given four options regarding when they use their AC, 50 percent reported that they only use it on very hot days. These are often days where supply becomes critical, meaning these customers have potential to lower peak usage to help with high load days. Twenty-nine percent of respondents said that it varies, suggesting that there may be room to shift usage after the transition to TOU rates for some pilot participants.

Low usage of AC may be related to the high usage of supplemental cooling methods, the most popular of which was ceiling fans (Table 12632 12). When asked why these cooling strategies were used, the most common response chosen across the board was “to save money/keep our utility bill lower.” In some cases, the method was used to supplement the cooling system or to get air circulating in the house.

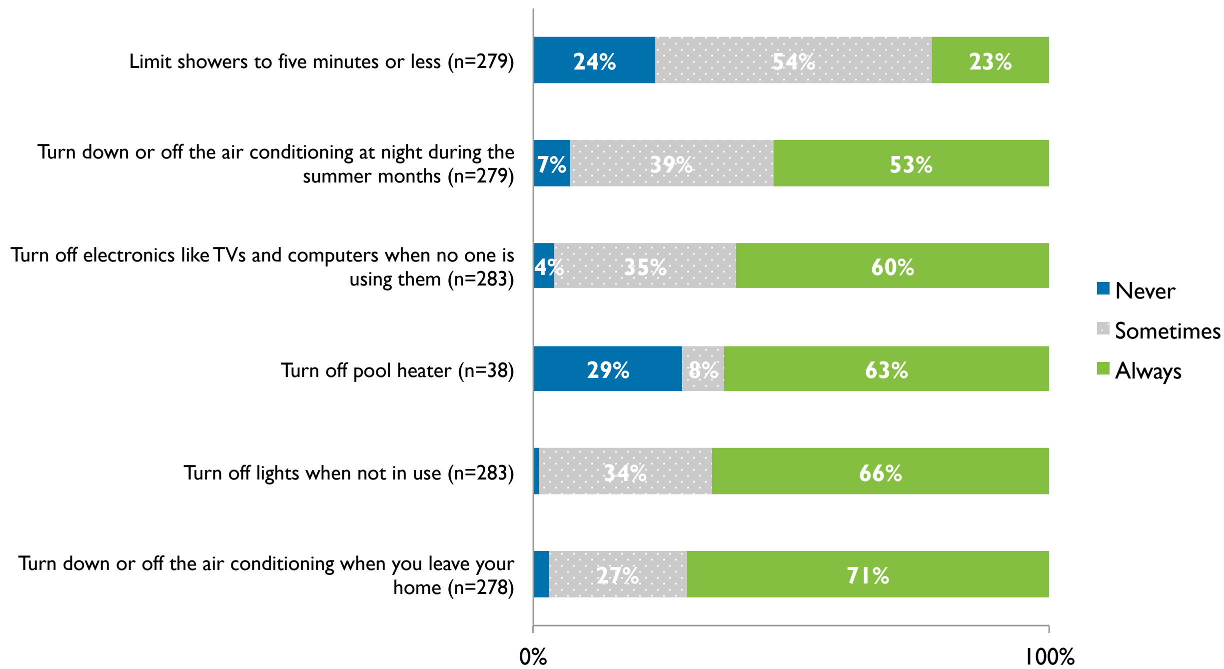
Table 126: Supplemental Cooling Usage*

	Percent of Respondents (n=285)
Ceiling fans	67%
Portable fans	57%
Open the windows	50%
Evaporative cooler/swamp cooler	7%
Room AC	6%
Whole house fan	1%
Evaporative cooler	0%

*Multiple responses allowed

We also asked respondents about behavioral energy efficiency actions that they could take and how often they do them. We expect that participants may take some of these actions in response to the application of the TOU rate, so this will be used as a baseline to see if energy efficiency behaviors change after the transition to TOU. There appears to be room for increased energy efficiency behaviors based on how often respondents take certain actions. Nearly 30 percent of respondents with their own pool never turn off the heater, and close to 50 percent of respondents always turn their AC down or off at night during the summer, leaving room for improvement for the remaining 50 percent of respondents.

Figure 3: Prompted Energy Efficiency Behavioral Actions Taken By Respondents (excludes 'does not apply')



4 Interim Findings

The baseline survey data provides information regarding how low-income customers currently view their energy usage and implications for future implementation of the program.

In designing a full-scale program, staff should be aware of barriers to participation including general lack of interest in PCTs, incompatible equipment in homes, and elderly or health related reasons for disinterest in the PCT offering.

Sixty percent of respondents think there is more they could do to save electricity but the possibility of AC savings may not be realized, given that 50 percent of respondents reported that they only use their AC on very hot days. Supplemental cooling is very popular, and survey respondents were very accustomed to turning on fans instead of using air conditioning.

Rebalancing the Control Group

The original balance of the treatment and control assignments did not remain intact due to lack of transition to a TOU rate, home wiring incompatibility with the Ecobee PCT, or customer refusal to allow installation. In order to estimate program impacts, it was necessary to rebalance the treatment and control groups with the remaining customers. Customers that were assigned to the treatment group but did not install an Ecobee PCT (group 3) were systematically different from the rest of the treatment group, and could not be incorporated into the control group.

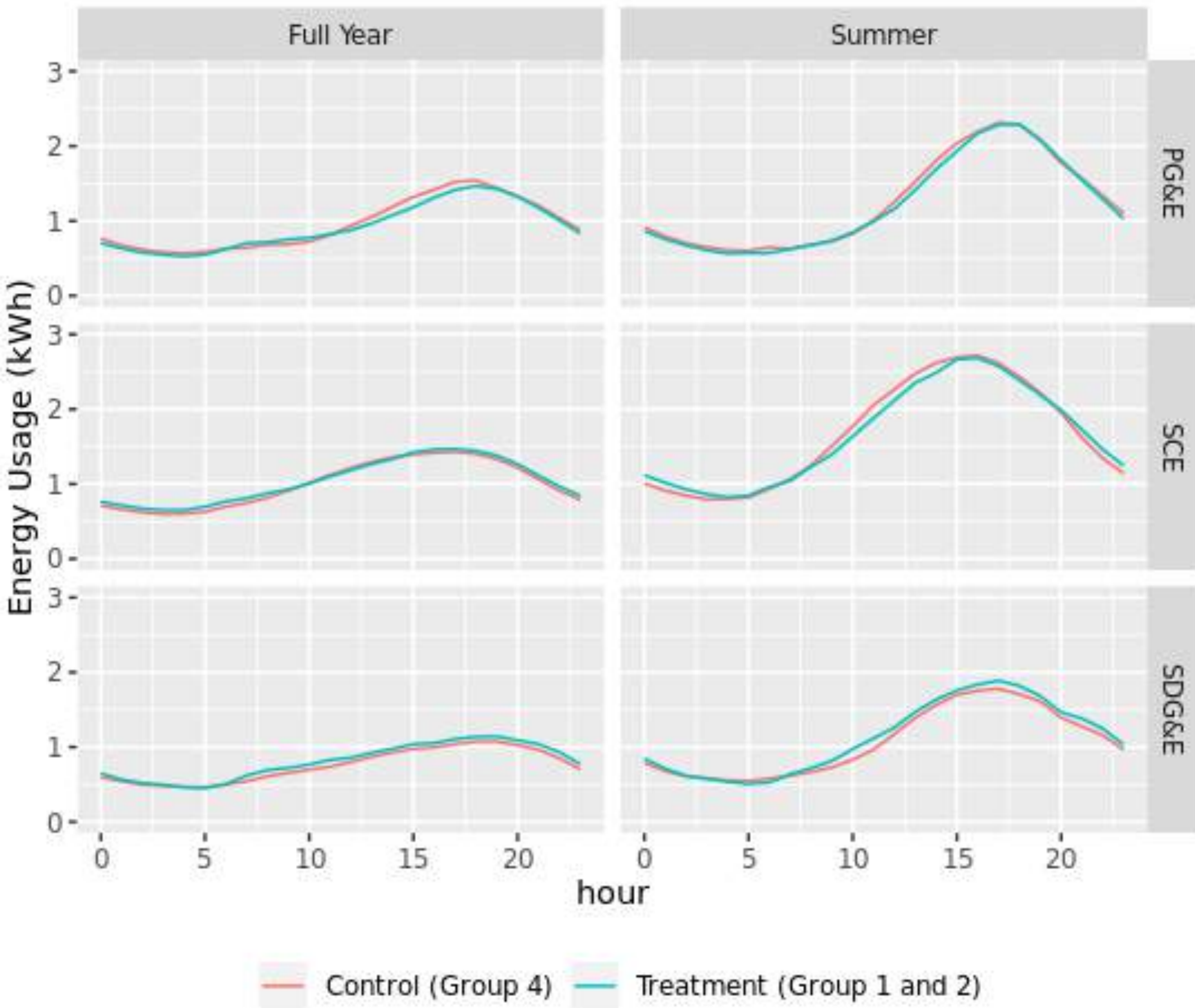
A matching algorithm was utilized to identify a subset of the control group (group 4) that appears similar to the treated customers with thermostats installed (groups 1 and 2) prior to the start of the pilot. The algorithm utilized a year of pre intervention data for each customer (prior to TOU activation date for group 4 and prior to the first intervention, the TOU activation or Ecobee installation). Each customer's average hourly consumption was determined for the full year and summer months only. This resulted in a profile of 48 hourly average consumption values (24 annual and 24 summer) for each customer.

Within each of the IOUs, each customer profile from groups 1 and 2 was compared to every profile within group 4; the sum of squares between the comparison 48 observations was calculated. A treatment customer's matched comparison is that with the lowest sum of squares. This results in matched comparisons that have similar usage over the course of the year, with additional focus on the summer months. All but four customers in the treatment group had at least one well-matched comparison site in the control group.[4] These customers had high summer peak consumption or Net Energy Metering (i.e., onsite generation offsetting consumption) that were not observed in any of the available controls.

The output of this work is a "matched comparison" group that will be used for analysis, rather than a randomized control group. The matched comparisons broken out by IOU are shown in Figure 106.

[4] An "adequate" match was defined as a pair with a sum of squared-errors less than 25. Four of the customers treated by SCE did not have any comparable customers in the control group with post-period data. There were comparable customers in the control group during the assignment process, but by chance, all of them dropped out of the pilot or were not transitioned to the TOU rate.

Figure 10: Average Load of Treatment Group and Matched Comparison



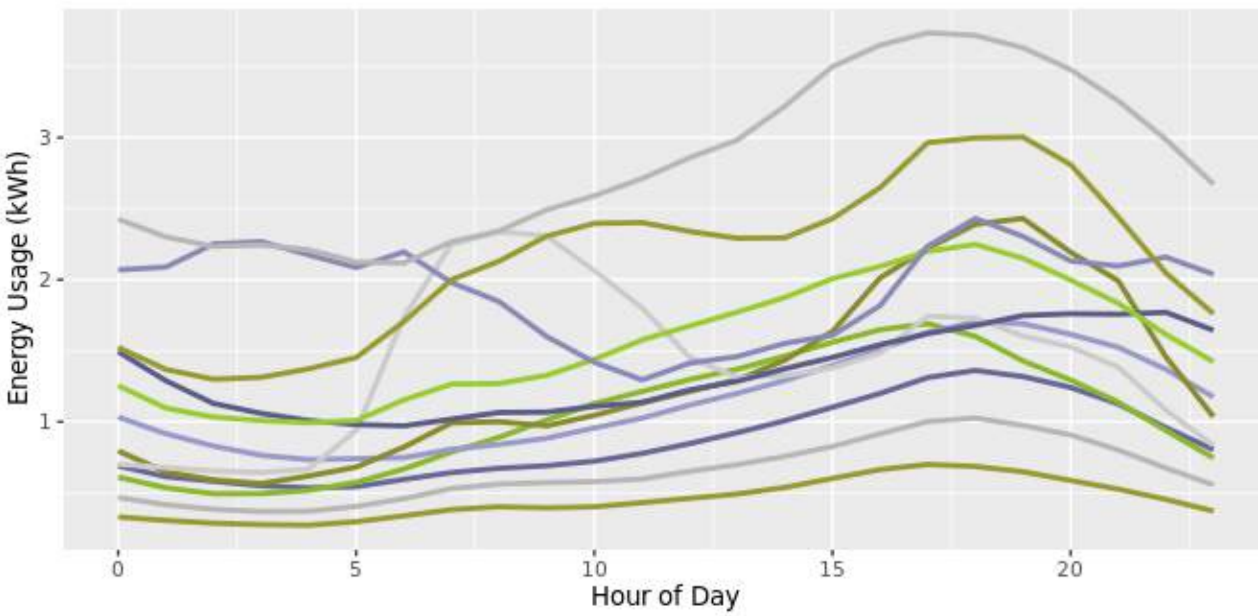
Details on AMICS Segmentation and Regression

Segmentation

A key step in the AMICS modeling process is segmenting customers based on the pre-period billing data. Similar customers are modeled together, increasing the number of observations within each bin. The additional observations improve the model's ability to separate out signals in energy usage from simple random noise.

The most successful customer segmentation approach Evergreen identified for the pilot across all three IOUs was segmenting by average annual load shape (magnitude and hours of use) during the pre-period. Evergreen used *k*-means clustering to identify the 12 unique load shape clusters shown in **Error! Reference source not found.**, each containing a subset of residential customers from PG&E with similar load shapes during the pre-period. Cluster analysis is a machine-learning algorithm designed to detect patterns in data.[5] The benefit of cluster analysis is that similar customers are grouped automatically from the AMI data rather than relying on customer characteristics that are not typically tracked (or not regularly updated) in utility databases. These load shape clusters help account for the differences in occupant schedules, energy-intensive equipment, peak demand hours, and other factors.

Figure 11: PG&E Load Shape Clusters



For SDG&E, Evergreen further segmented by climate zone. The building climate zones defined by the California Energy Commission may help to control for differences in the typical climate (including temperature, humidity, and wind) as well as housing stock (e.g., building type, vintage, existing equipment).[6]

In addition to the segmentation schemes described above based on customer characteristics, each day of the study period is also categorized in terms of its weather, day type, and season.

The weather bins are created by calculating cooling degree hours (CDH) for each hourly observation using a base temperature of 65 degrees Fahrenheit, and then taking the average of these hourly values to create a single cooling degree-day (CDD) value for each customer on each

[5] The *k*-means clustering algorithm randomly assigns each customer's load shape to one of *k* clusters and then calculates the sum of the distance between each load shape and the centroid (i.e., average load) of the cluster to which it was assigned. Load shapes are then reassigned to the nearest cluster centroid, and the process is repeated until the variation within each cluster cannot be improved.

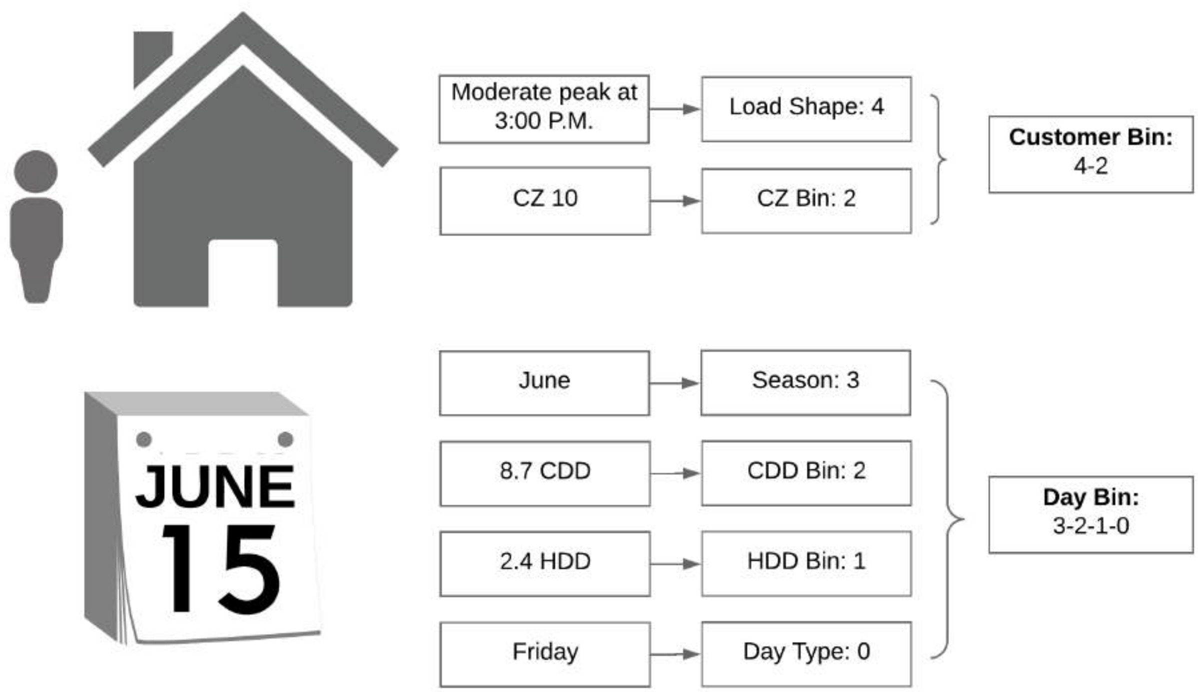
[6] A description of the CEC climate zones can be found at https://ww2.energy.ca.gov/maps/renewable/building_climate_zones.html

day (i.e., each "customer-day") in the study period.[7] These customer-days are assigned to a series of bins, each containing a range of six CDDs. This process is repeated to assign days to heating degree-day (HDD) bins, again using a base temperature of 65 degrees Fahrenheit. Segmenting days by their CDD and HDD in this manner explicitly incorporates temperature into Evergreen's model.

To control for the differences in energy usage across days with the same weather conditions, Evergreen also binned by day type and season. Weekends were assigned to day type 1, and weekdays were assigned to day type 0. The four seasonal bins are defined as winter (December-February), spring (March-May), summer (June-August), and fall (September-November).

Error! Reference source not found. provides an example of a single customer and day being binned. Each customer was assigned to just one customer bin, but because temperature and day type changes throughout the year, each customer has customer-days that were assigned to many different bins.

Figure 12: Customer-Day Segmentation Example



[7] A cooling degree-day (CDD) is a metric designed to measure the demand for energy required to maintain a comfortable temperature inside a building. It represents the number of degrees that the outdoor temperature exceeded an assumed baseline (in this case, 65°F), averaged across all hours in the day. By calculating this metric from hourly temperatures instead of daily averages, we can identify days that require some cooling during peak hours as well as heating in the early morning or evening.

The segmentation process has the following benefits for the pilot evaluation:

- Variation in CDD is controlled for in the bins so it does not need to be included as a variable in the model specification; the same is true for all other binning factors.
- Modeling customer-days allows Evergreen to exclude individual days from the database (e.g., demand response event days). Rather than limiting the analysis to customers with flawless data throughout the study period, Evergreen removes specific days with less than 24 consecutive hours of billing and weather data.
- Participants with no post-period observations are still useful when constructing models of the pre-period because they are simply a series of customer-days. These pre-period observations improve Evergreen's ability to produce reasonable load shape predictions for other customers in the same segment that do have post-period observations. Later in the analysis, customers with no post-period observations are automatically excluded from the impact estimates.

Baseline Load Shapes

Once the data were segmented, the AMICS model estimated an ordinary least squares (OLS) regression model for each customer-day bin, as shown in **Error! Reference source not found.**, with a single dummy variable for each hour of the day.

Equation 1: AMICS Regression

$$kWh_{i,t} = \beta_{0i}H00_{i,t} + \beta_{1i}H01_{i,t} + \beta_{2i}H02_{i,t} + \ldots + \beta_{23i}H23_{i,t} + \varepsilon_{i,t}$$

$$\begin{aligned} &Where: \\ kWh_{i,t} &= \text{Energy consumption, for customer in bin } i \text{ during hour } t \\ H00, H01, \ldots &= \text{Array of dummy variables (0,1) representing the hour of the day} \\ \beta_{0i}, \beta_{1i}, \ldots &= \text{Coefficients estimated by the model, for customers in bin } i \\ \varepsilon &= \text{Random error, assumed normally distributed} \end{aligned}$$

Unlike a traditional fixed effects regression model, which estimates a single set of slope coefficients for all customers and a y-intercept specific to each individual customer, the regression modeling approach employed by the AMICS model estimates a full unique set of slope coefficient estimates for each customer segment (i.e., climate zone and load shape cluster) for each day bin (weather and day type).

Computing Standard Errors

In the AMICS approach, Evergreen estimate individual regression models for thousands of customer-day segments, providing a kWh energy usage prediction for each hour.

Because the AMICS model is estimated using the pre-period data, Evergreen computed the relative variance for each hour of the day for each customer-day bin as the ratio of the variance to predicted hourly kWh usage. These relative variances are then applied to the post-period data to create confidence intervals for the model predictions of each hour of each customer-day in the post-period. With 24 hours per day and thousands of customer-day segments, Evergreen computed over 24,000 confidence intervals. For aggregated predictions, such as the annual and seasonal post-period load shapes, Evergreen used bootstrapping to estimate the relative variance for each hour, accounting for variation in the number of observations and relative kWh represented by each customer-day bin.

Any bias in the AMICS model predictions detected in the holdout validation test will be reflected in the error bounds on the predictions of post-period energy use and the corresponding savings estimates.