REPORT

2015 Load Impact Evaluation for Pacific Gas & Electric Company's SmartAC™ Program

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Prepared for
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1 Executive Summary

This report documents the ex post and ex ante load impact evaluation of Pacific Gas and Electric's (PG&E) SmartAC™ Program for the year 2015. SmartAC is an air conditioning cycling program that involves the installation of load control devices (primarily switches[1]) on central air conditioners (AC) at residential and small and medium business (SMB) premises. When a SmartAC event is called, the control devices limit the duty cycles of AC units, thereby reducing demand. SmartAC customers are also allowed to participate in PG&E's critical peak pricing program, SmartRate™. For these dually enrolled customers, PG&E cycles participants' air conditioners during the SmartRate peak period from 2 to 7 PM on all days when critical peak pricing is in effect.

SmartAC events can be called under a variety of conditions when peak demand reductions are needed, including for testing purposes that support measurement and evaluation (M&E) of the program. Events can occur at any time of day between May 1 and October 31, for up to 6 hours per event and a maximum of 100 hours per season. Events are typically called in late afternoons on hot summer days. No localized emergency events were called in 2015; however, 11 test events were called for subsets of the population and are discussed in detail throughout this report. Nine of the 11 SmartAC event days were also event days for SmartRate.

Residential customer enrollment at the end of summer 2015 consisted of almost 169,000 control devices belonging to 152,000 customers. Small- and medium-sized business (SMB) customer enrollment was around 9,000 control devices for close to 5,000 premises. Approximately 37,000 customers with nearly 41,000 devices were dually enrolled in SmartAC and SmartRate. Historically, SmartAC and SmartRate events have often overlapped. Ex post impact estimates for dually enrolled customers are reported in the evaluation of the SmartRate program, but dually enrolled customers are included in the aggregate ex ante estimates for SmartAC contained in this report since they contribute to the maximum load reduction capability of the program.

1.1 Residential Ex Post Load Impacts

In 2015, M&E test events were called on 11 days between June 25 and September 11 under a variety of circumstances. More than half of the events included hours after 6 PM and an event was also called on a weekend (August 15) for the first time. For two events (June 25 and August 17), PG&E called multiple test events at different times of the day to increase the number of hours for which load impacts could be estimated. Two of the events (August 15 and September 8) did not coincide with SmartRate events, which allowed load impacts for SmartAC-only and dually enrolled customers to be compared.

Table 1-1 shows the estimated load impact from 4 to 5 PM for the 2015 test events. The table focuses on 4 to 5 PM because those hours were most common across events and allow the estimated load impacts to be compared to each other without any confounding due to time-of-

[1] The program formerly offered switches and programmable communicating thermostats (PCTs), but PCTs are no longer offered. Eighteen percent of the devices on SmartAC are PCTs that still remain in operation throughout the service territory.

day effects. The overall average impact from 4 to 5 PM was 0.51 kW per customer, or about 20% of the whole house load.

Table 1-1: Summary of Ex Post Load Impacts for 4–5 PM on 2015 Event Days

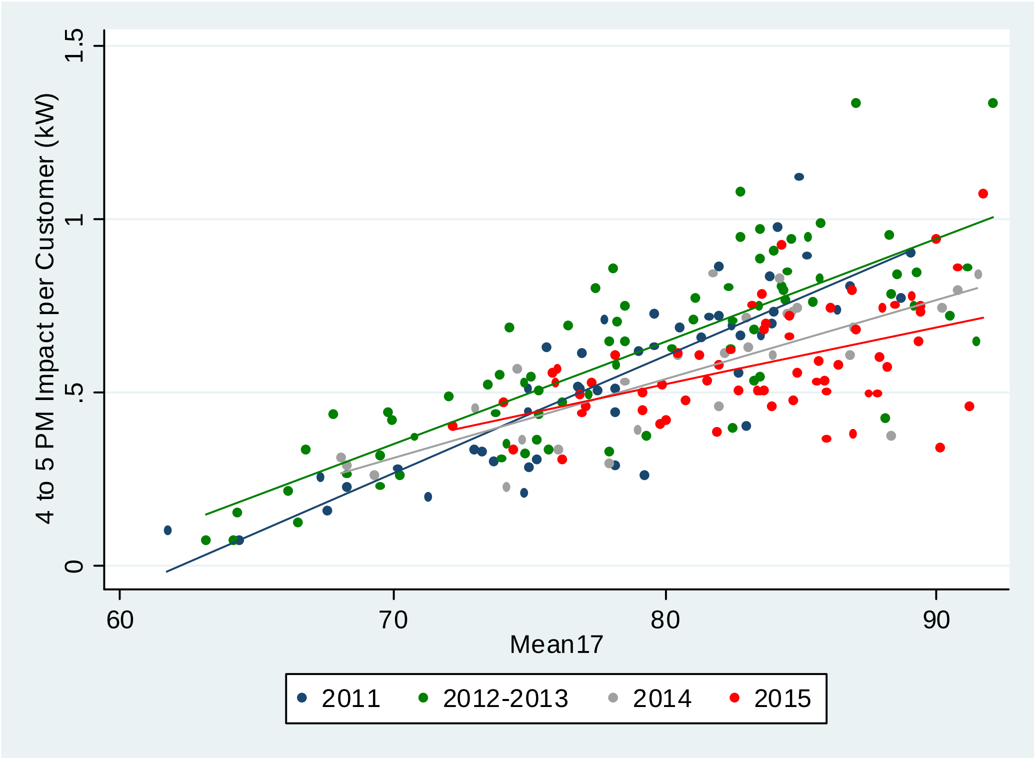
Event Date[2]	SmartRate Day	Weekend Event	Ref Load (kW)	Avg. Impact (kW)	% Impact	Avg. Temp (°F)
6/25	Yes	No	2.53	0.57	23%	97.3
7/1	Yes	No	2.45	0.40	16%	94.5
7/28	Yes	No	2.42	0.49	20%	98.5
7/29	Yes	No	2.90	0.66	23%	99.3
8/15	No	Yes	2.20	0.39	18%	96.6
8/17	Yes	No	2.85	0.63	22%	99.1
9/9	Yes	No	2.57	0.50	19%	100.3
9/10	Yes	No	2.79	0.53	19%	99.2
9/11	Yes	No	2.52	0.45	18%	95.9
Avg.	**N/A**	**N/A**	**2.58**	**0.51**	**20%**	**97.9**

Compared to past years, the average impacts observed in 2015 have declined after factoring in differences in the average temperature across event days. Figure 1-1 plots historical impacts for 4 to 5 PM and the average temperature from midnight to 5 PM (referred to as “mean17”) at the LCA level for all events going back to 2011.[3] The relationship between impacts and mean17 is approximately the same for 2011-2013, but impacts for 2014 and 2015 events are noticeably lower after controlling for temperature. This decrease can be explained by a combination of declining reference loads, poor performance of ExpressStat PCTs, and operability malfunctions related to the device paging network.

2 The June 30 and September 8 events are not included in this table because they were called from 7 to 8 PM and 1 to 3 PM, respectively.

3 Because 2013 only had 1 event that included 4-5 PM, it was combined with 2012 for the purposes of the graph.

Figure 1-1: Impact vs. Temperature for 4–5 PM Load Impacts during 2011–2015 Events



Comparing the load impacts within different segments of the SmartAC population produced several important findings pertaining to the heterogeneity of demand response capabilities. Dually enrolled customers provided smaller load reductions than SmartAC-only customers, as did multi-family customers when compared to single-family customers. In terms of the impacts associated with different device types, LCR switches performed best while the ExpressStat PCTs did not produce any measureable load reductions. Finally, customers recruited into the SmartAC program using a new, targeted marketing strategy provided larger load reductions than existing customers on both an absolute and relative basis.

1.2 Residential Ex Ante Load Impacts

Ex ante load impact estimates represent the expected average and aggregate load impacts that would occur during a SmartAC event under normal (1-in-2) and extreme (1-in-10) weather conditions if all customers were called simultaneously. Impacts were estimated for two sets of normal and extreme weather, one corresponding to PG&E peak operating conditions and the other corresponding to the California Independent System Operator (CAISO) statewide peak operating conditions.

Table 1-2 shows the average ex ante impact estimates for the residential SmartAC population in 2015 over the resource adequacy window from 1 to 6 PM. These estimates include the contribution of dually enrolled customers. For the 1-in-2 PG&E weather year, the highest estimated impact is on the July peak day, with an average load reduction of 79 MW and a peak hourly impact of 100 MW. For a 1-in-10 weather year, the July peak day again shows the highest impacts, with a mean impact during the five hour event window of 94 MW and a maximum hourly impact of 114 MW. Under CAISO 1-in-2 conditions, the peak month changes from July to June, with mean and peak hourly impacts of 72 and 91 MW, respectively. Under 1-in-10 CAISO conditions, the peak month is July with a mean aggregate impact of 88 MW and a peak of 109 MW.

Table 1-2: 2015 Residential SmartAC Ex Ante Load Impact Estimates by Weather Year and Day Type (Event Period 1–6 PM)

Weather Year	Day Type	Mean Hourly Per Customer Impact (kW)	Max. Hourly Per Customer Impact (kW)	Aggregate Mean Hourly Impact (MW)	Aggregate Max Hourly Impact (MW)
1-in-2 PG&E	Typical Event Day	0.49	0.61	73.8	92.3
	May Peak Day	0.29	0.39	43.8	60.0
	June Peak Day	0.49	0.61	74.6	93.2
	July Peak Day	0.52	0.66	78.8	100.0
	August Peak Day	0.48	0.61	73.2	92.2
	September Peak Day	0.45	0.57	68.5	86.3
	October Peak Day	0.18	0.27	26.4	40.8
1-in-10 PG&E	Typical Event Day	0.56	0.69	85.0	105.0
	May Peak Day	0.49	0.61	74.1	92.1
	June Peak Day	0.57	0.71	86.0	107.7
	July Peak Day	0.62	0.76	93.9	114.4
	August Peak Day	0.58	0.71	87.7	107.6
	September Peak Day	0.48	0.60	72.7	91.4
	October Peak Day	0.39	0.50	58.6	75.7
1-in-2 CAISO	Typical Event Day	0.39	0.51	59.7	77.4
	May Peak Day	0.25	0.35	37.5	53.5
	June Peak Day	0.48	0.60	72.4	90.8
	July Peak Day	0.42	0.54	63.8	81.9
	August Peak Day	0.36	0.48	54.7	72.1
	September Peak Day	0.32	0.43	47.8	65.0
	October Peak Day	0.21	0.31	31.5	46.6
1-in-10 CAISO	Typical Event Day	0.49	0.62	74.4	93.1
	May Peak Day	0.37	0.49	56.8	74.2
	June Peak Day	0.45	0.57	68.4	86.9
	July Peak Day	0.58	0.72	87.9	108.6
	August Peak Day	0.53	0.65	79.4	98.6
	September Peak Day	0.41	0.53	61.8	79.3
	October Peak Day	0.31	0.41	46.2	62.4

1.3 SMB Ex Ante Load Impacts

The SMB segment of the SmartAC program has been closed to new customers for several years. No M&E test events have been called for this group since 2011. The ex ante estimates presented in this report are based on the average impacts per device estimated in the 2011 evaluation, adjusted for customer attrition.

Table 1-3 shows the average ex ante load reductions for the SMB population for the resource adequacy window from 1 to 6 PM. For the 1-in-2 PG&E weather year, the highest estimated impacts occur on June and July peak days with an average impact of 2.6 MW and a peak hourly impact of 3.0 MW. July has the highest impacts for the 1-in-10 weather year, with an average event window impact of 3.1 MW and a peak hourly impact of 3.6 MW. Under CAISO conditions, June and July have approximately the same forecasted 1-in-2 impacts (2.4 MW average, 2.8 MW peak), but July has the highest 1-in-10 impacts (3.0 MW average, 3.5 MW peak).

Table 1-3: SMB SmartAC Ex Ante Load Impact Estimates

Weather Year	Day Type	Mean Hourly Per Customer Impact (kW)	Max. Hourly Per Customer Impact (kW)	Aggregate Mean Hourly Impact (MW)	Aggregate Max Hourly Impact (MW)
1-in-2 PG&E	Typical Event Day	0.61	0.72	2.5	3.0
	May Peak Day	0.39	0.46	1.6	1.9
	June Peak Day	0.62	0.73	2.6	3.0
	July Peak Day	0.62	0.73	2.6	3.0
	August Peak Day	0.61	0.71	2.5	2.9
	September Peak Day	0.53	0.63	2.2	2.6
	October Peak Day	0.30	0.36	1.2	1.5
1-in-10 PG&E	Typical Event Day	0.70	0.82	2.9	3.4
	May Peak Day	0.66	0.78	2.8	3.3
	June Peak Day	0.71	0.83	2.9	3.4
	July Peak Day	0.74	0.87	3.1	3.6
	August Peak Day	0.72	0.84	3.0	3.5
	September Peak Day	0.58	0.69	2.4	2.8
	October Peak Day	0.47	0.55	1.9	2.2
1-in-2 CAISO	Typical Event Day	0.49	0.59	2.0	2.4
	May Peak Day	0.38	0.45	1.6	1.9
	June Peak Day	0.58	0.68	2.4	2.8
	July Peak Day	0.57	0.67	2.3	2.8
	August Peak Day	0.45	0.53	1.8	2.2
	September Peak Day	0.43	0.51	1.7	2.1
	October Peak Day	0.30	0.36	1.2	1.5

Weather Year	Day Type	Mean Hourly Per Customer Impact (kW)	Max. Hourly Per Customer Impact (kW)	Aggregate Mean Hourly Impact (MW)	Aggregate Max Hourly Impact (MW)
1-in-10 CAISO	Typical Event Day	0.65	0.77	2.7	3.2
	May Peak Day	0.48	0.57	2.0	2.4
	June Peak Day	0.56	0.66	2.3	2.7
	July Peak Day	0.72	0.84	3.0	3.5
	August Peak Day	0.68	0.79	2.8	3.2
	September Peak Day	0.51	0.60	2.1	2.5
	October Peak Day	0.42	0.50	1.7	2.0

1.4 Operability Analysis

For the first time since 2012, a robust operability analysis was conducted using switch data collected from a random sample of installed devices to analyze the physical condition of installed LCR switches and to evaluate their performance during events. Field technicians from GoodCents (SmartAC implementer) performed the fieldwork required for the analysis, which included physical inspections of approximately 900 installed load control switches in the Bay Area and Central Valley and downloading operating data from switches that were properly connected.

In both the Greater Bay Area and Central Valley, most switches were present and appeared to be connected properly, while only a handful were missing, connected incorrectly, or dysfunctional because of other issues with the air conditioning unit. The percentage of switches with physical problems ranged from 2 to 12% and increased as a function of a switch's age. An analysis of the downloaded runtime data showed that switches failed to receive load control signals and reduce air conditioning usage for 10 to 25% of event hours. Similar to the physical inspections, older switch vintages were more likely to experience communications failures.

Combining the communication failure estimates with the physical connectivity failures gives a sense of the overall failure rates for switches of different vintages, which are shown in Table 1-4. For devices installed in 2007, the overall failure rate could potentially be as high as 34%, while failure rates for 2009 and 2011 are also potentially above 20%. For newer switches (2014 and 2015), the overall failure rate is less than 15% and is primarily due to communications failures.

Table 1-4: SmartAC Switch Failure Rates by Vintage

Switch Vintage	# of Switches in SmartAC Population	% of Total Switches	Physical Failure Rate	Communications Failure Rate	Overall Failure Rate[4]
2007	8,912	6%	11%	25%	33%
2008	44,132	30%	9%	10%	18%
2009	14,549	10%	11%	12%	22%
2010	17,643	12%	6%	10%	15%
2011	22,275	15%	11%	13%	23%
2012	8,827	6%	6%	10%	15%
2013	12,307	8%	4%	12%	16%
2014	10,765	7%	2%	10%	12%
2015	10,204	7%	3%	10%	13%
All	**149,615**	**100%**	**8%**	**12%**	**19%**

1.5 Recommendations

The 11 test events conducted in 2015 provided valuable insights into the performance of SmartAC. A key result of the ex post analysis is that there is a downward trend in average load impacts that was first apparent in 2014 and became exacerbated in 2015. The two causes of this trend that can be most easily addressed by PG&E are the failure of the ExpressStat PCTs and the decline in the operability of older switches. We recommend replacing ExpressStat PCTs and non-communicating older switches with new LCR switches[5] to improve performance in a cost-effective manner. A third potential cause of the reduced impacts is declining peak period usage for existing customers over time. An initial analysis of the usage of control customers from 4 to 5 PM on event days showed a declining pattern that mirrors the trend in average impacts. Potential explanations for this declining usage include increased solar adoption or increasing efficiency of air conditioning units in the SmartAC population due to customer churn. We recommend conducting additional analysis in the spring and early summer to better understand this result and assess PG&E's options for addressing it.

Several improvements were made to the ex ante methodology for 2015, including independent estimation of impacts for each hour in the resource adequacy window, a new model specification with lower prediction error, and a more granular approach to incorporating dually enrolled customers in the analysis. We recommend PG&E continue to call a large

4 To calculate the overall failure rate, it was assumed that the percentage of devices that are not connected correctly would be equally likely to experience communication failure as the population of properly connected devices (i.e., the two causes of failure are independent). To avoid double counting, the overlap of the two types of failure was subtracted from the sum of the individual causes.

5 PG&E is in the process of field testing new two-way communicating switches that leverage the AMI network, so these switches should be used if possible.

number of test events in future years to generate more useful data and further increase the robustness of the ex ante results.

2 Overview of SmartAC™ Program

PG&E's SmartAC™ program utilizes direct load control switches on central (split system or package unit) air conditioners (AC) and PCTs[6] at residential and SMB premises to reduce electricity demand during times of peak system usage. When a SmartAC event is called, the control devices limit the duty cycles of AC units, thereby reducing the amount of electricity used. Three device types have been deployed by PG&E to control AC units and each has different functional capabilities. LCR5000 and LCR5200 are both load control receivers (referred to hereafter as switches), which are attached to the outdoor AC unit. They control the duty cycle of the AC unit directly using one of several different algorithms. UtilityPro and ExpressStat PCTs are devices that can control the AC unit using either duty cycle control (like a switch) or by adjusting thermostat temperatures. All PCTs that are currently operational as part of SmartAC use duty cycle control. Table 2-1 shows the number of enrolled control devices by customer type, device type, and local capacity area (LCA) at the end of the 2015 program year.

Table 2-1: SmartAC Enrolled Customers and Active Control Devices at End of 2015 Program Year

Customer Class	Local Capacity Area	Enrolled Customers	PCTs (UtilityPro + ExpressStat)	Switches (LCR)	Total Devices
Residential – SmartAC-only	Greater Bay Area	37,552	4,772	37,728	42,500
	Greater Fresno	14,153	2,395	13,506	15,901
	Humboldt[7]	712	48	703	751
	Kern	6,026	1,207	5,502	6,709
	Northern Coast	7,440	876	7,003	7,879
	Other	25,121	3,228	23,847	27,075
	Sierra	12,633	1,266	13,383	14,649
	Stockton	11,340	1,348	10,839	12,187
	Total	**114,977**	**15,140**	**112,511**	**127,651**
Residential – Dually Enrolled (SmartAC and SmartRate)	Greater Bay Area	13,981	1,676	14,125	15,801
	Greater Fresno	3,670	659	3,491	4,150
	Humboldt	204	24	190	214
	Kern	1,959	705	1,527	2,232
	Northern Coast	1,189	138	1,109	1,247
	Other	7,340	904	7,018	7,922
	Sierra	4,387	402	4,685	5,087

[6] All new SmartAC participants have switches installed at their premises. In prior years, the program also offered PCTs as a load control option and many of these are still operational throughout the territory.

[7] SmartAC™ customers in this area actually reside near Ukiah, which has a much hotter climate than Humboldt County.

Customer Class	Local Capacity Area	Enrolled Customers	PCTs (UtilityPro + ExpressStat)	Switches (LCR)	Total Devices
	Stockton	3,944	455	3,792	4,247
	Total	**36,674**	**4,963**	**35,937**	**40,900**
SMB	Greater Bay Area	1,542	2,634	206	2,840
	Greater Fresno	462	954	157	1,111
	Humboldt	37	44	6	50
	Kern	246	445	28	473
	Northern Coast	492	704	74	778
	Other	1,103	1,976	201	2,177
	Sierra	347	583	69	652
	Stockton	387	717	140	857
	Total	**4,616**	**8,057**	**881**	**8,938**
All	**Total**	**156,267**	**28,160**	**149,329**	**177,489**

The cycling algorithms currently in use depend on the control device and type of customer, as shown in Table 2-2. There are two basic kinds of cycling: simple and adaptive. With simple cycling, the AC compressor's duty cycle is capped at a chosen percentage value for each hour. For example, 50% simple cycling would mean that a unit's compressor could run for no more than half of a given hour. Under the simple cycling approach, if an AC's duty cycle was less than 50%, cycling would not result in any load reduction. In contrast, the adaptive cycling algorithm known as TrueCycle2 uses a baseline methodology to limit the compressor to run no more than the given percentage of what it would have been expected to run without switch activation. For example, 50% TrueCycle2 cycling constrains a compressor to run for no more than 50% of its duty cycle. All else equal, TrueCycle2 will produce larger load reductions than simple cycling.

Table 2-2: Control Strategies by Segment and Device Type

Segment	Control Device		
	LCR (Switch)	UtilityPro	ExpressStat
Residential	50% TrueCycle2	50% TrueCycle2	50% Simple Cycling
SMB	33% TrueCycle2	33% TrueCycle2	33% Simple Cycling

Eleven M&E test events were called during the 2015 event season[8] between June 25 and September 11. On August 17, PG&E called a series of one-hour test events spanning the hours from noon to 9 PM in which different test groups were called for each hour. This "cascading" event was designed to estimate impacts for hours outside the 1 to 6 PM resource adequacy

[8] The event season is aligned with the summer season for PG&E's rates, i.e. May 1 – October 31.

window. The other 10 test events were called between the hours of 1 and 8 PM and typically lasted for 2 to 3 hours. As in 2014, no emergency sub-LAP events were called in 2015.

It is important to distinguish between enrolled customers and enrolled devices since many customers (especially SMB customers) have multiple AC units and, therefore, multiple control devices. Some accounts may even have both kinds of control devices associated with separate AC units. Residential customer enrollment at the end of the summer consisted of approximately 152,000 unique residential accounts and 4,600 SMB accounts. Nearly 37,000 residential customers with approximately 41,000 devices were dually enrolled in SmartRate and SmartAC, leaving about 128,000 devices belonging to 115,000 customers in the SmartAC-only population.

The majority of SmartAC devices—96% of all devices, 98% of switches, and 82% of PCTs—are associated with residential households. Most residential devices (89%) are switches, while SMB customers primarily have PCTs. Forecasted residential enrollment is expected to remain relatively constant in future years. SMB accounts have roughly 1.9 devices per premise, whereas residential accounts average 1.1 devices per premise. The SMB segment of the program is currently closed to new enrollment and no events have been called since 2011.

3 Methods

This section provides a detailed discussion of the experimental design and methods used for the analysis of ex post and ex ante load impacts, device operability, and the customer experience during events. The core of the ex post methodology remains the randomized control trial (RCT) design, which has been used to estimate ex post impacts since 2011. The following sections focus on changes or updates to the methods used in previous years, including an updated ex ante methodology and the operability analysis that is included as part of the evaluation for the first time since 2012.

3.1 Experimental Design for Ex Post Estimation

As in the prior four SmartAC evaluations, the foundation for the estimation of ex post load impacts for 2015 was a randomized control trial (RCT). Because the RCT methodology is a tried and true approach that has been discussed extensively in past evaluations, this section provides only a brief summary of the approach for estimating load impacts on each test event day.[9]

Using the last digit of the serial number, each device in the SmartAC population was randomly assigned to 1 of 10 groups so that each group consisted of approximately 17,000 devices. During an event, the devices in one or more groups were controlled (treatment customers), while the devices in the remaining groups were not controlled (control customers). Within this experimental framework, estimating the load impacts for an event requires simply calculating the difference in loads between the treatment and control groups during the event period as well as in the hours following the event to capture any snapback effect. Proper randomization ensures that any differences in energy consumption that are observed during the event can be attributed to the load control. As a check to see if using the last digit of the serial number to determine a customer's group is indeed random, several comparisons between the groups are presented below.

Table 3-1 shows a comparison of the 10 M&E groups along 2 important dimensions: location (LCA) and mean daily usage. Figure 3-1 shows hourly loads for each group on a hot, non-event day (August 16). In both the table and the figure, differences between the 10 groups are very small, which provides strong evidence that the assignment of devices into the 10 different groups was indeed random.

[9] See "2011 Load Impact Evaluation for Pacific Gas & Electric's SmartAC Program" for additional discussion of the merits of the RCT methodology in the context of SmartAC™. Available at http://www.ercot.com/content/meetings/dswg/keydocs/2012/0920PM/2011_SmartAC_Evaluation_Final.pdf

Table 3-1: Average Loads for Randomized Groups on a Non-event Day (August 16, 2015)

Randomized Group	Usage (kW)								
	Greater Bay Area	Greater Fresno	Kern	Northern Coast	Other	Sierra	Stockton	Humboldt	All LCAs
0	1.51	1.89	2.05	1.49	1.57	1.47	1.70	1.30	1.62
1	1.50	1.86	2.08	1.42	1.55	1.46	1.67	1.22	1.60
2	1.52	1.88	2.03	1.45	1.54	1.48	1.65	1.30	1.61
3	1.53	1.89	2.05	1.39	1.54	1.46	1.62	1.16	1.58
4	1.54	1.94	2.08	1.38	1.57	1.43	1.64	1.33	1.61
5	1.52	1.87	2.08	1.42	1.57	1.47	1.66	1.41	1.63
6	1.53	1.91	2.05	1.52	1.58	1.43	1.66	1.38	1.63
7	1.52	1.87	2.04	1.42	1.52	1.49	1.65	1.33	1.61
8	1.51	1.89	2.04	1.42	1.57	1.46	1.69	1.28	1.61
9	1.53	1.90	2.05	1.45	1.57	1.48	1.63	1.25	1.61

Figure 3-1: Load Shapes for Randomized Groups on a Non-event Day (August 16, 2015)

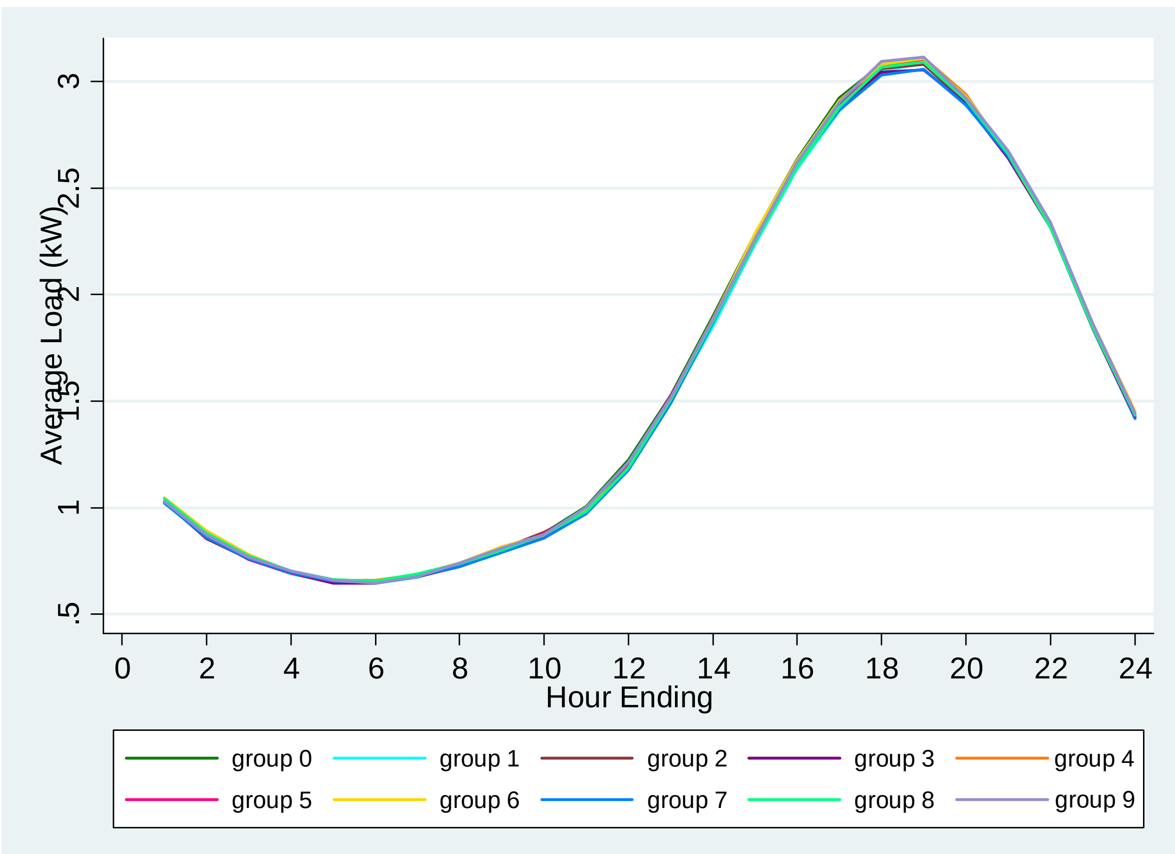
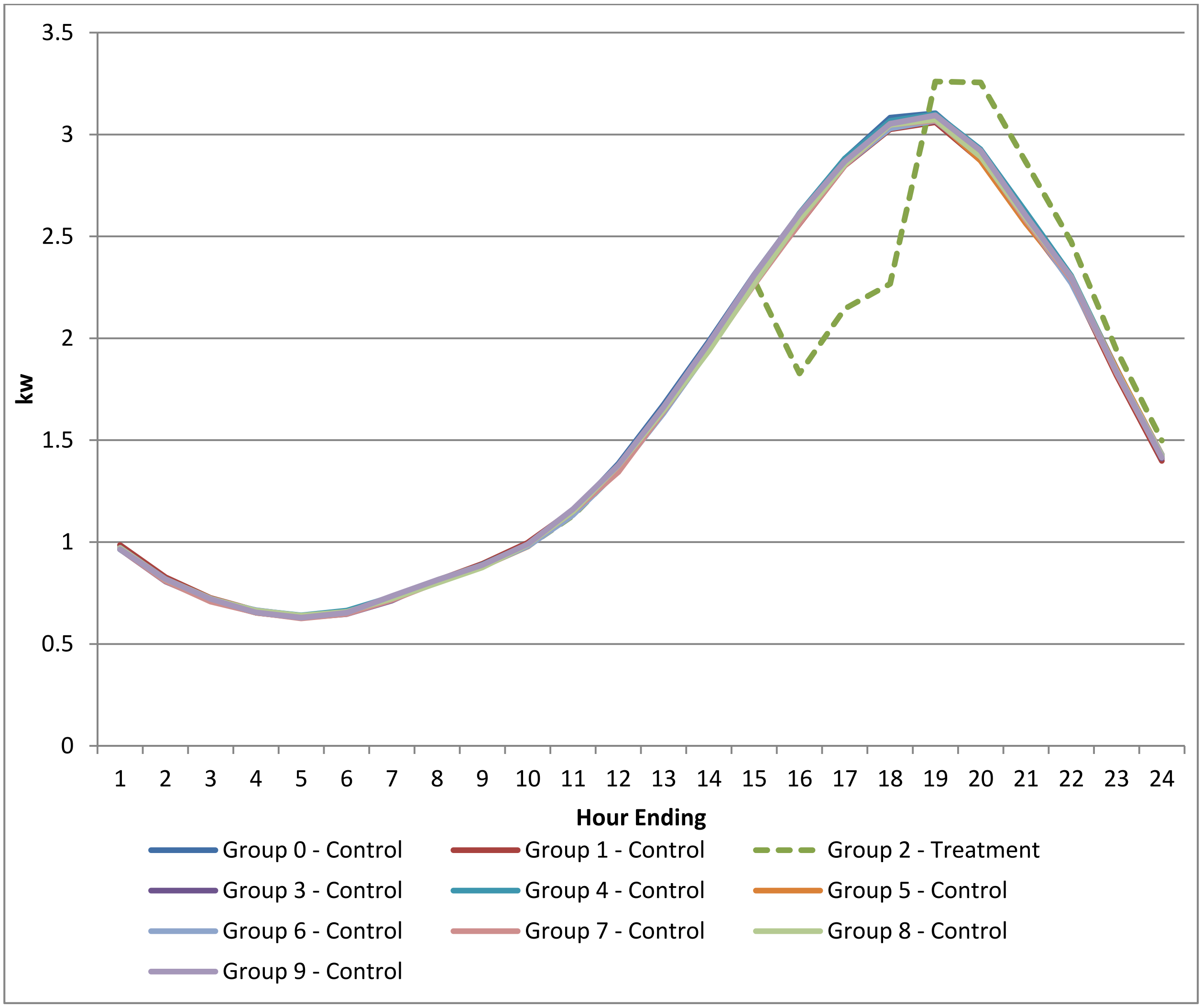


Figure 3-2 illustrates how load impacts are estimated in an RCT design. Because of the random assignment, the uncalled groups provide a valid counterfactual estimate of what usage would have been for treatment customers in the absence of an event. As a result, the estimated impact of an event is simply the difference in load between the group(s) that were called and those that were not.[10] As shown in the figure, for this particular event day, there was a clear reduction in loads between 4 and 6 PM, followed by a noticeable increase in loads for several hours after the event ended ("snapback").

Figure 3-2: Load Shapes for Randomized Groups for a Typical SmartAC Event



For most SmartAC test events, load control begins and ends at the same time for all treatment groups. On August 17, however, six groups were called starting at different hours between noon and 9 PM as part of a "cascading" event. Groups 0, 1, 5, and 7 were used as the control group

[10] In practice, the 10 groups can be divided between treatment and control in any way so long as all 10 groups are not assigned to the same one.

for all hours since they were not called at all throughout the course of the day.[11] June 25 can also be characterized as a cascading event, since Groups 3 and 8 were called at different times. Table 3-2 shows the individual event schedules for each of the 10 groups on the cascading event days. Devices were activated 30 minutes prior to each start time so that all devices were under control at the start of the hour.[12] Similar to non-cascading events, hourly impacts for cascading events were calculated as the difference between the average load for control group customers and the average load for the specific group of customers who were called during that hour.

Table 3-2: Individual Event Schedules for Cascading Events[13]

Date	Randomized Group	Event Start	Event Stop
June 25	0, 1, 2, 4, 5, 6, 7, 9	Not Called	Not Called
	3	3 PM	6 PM
	8	1 PM	3 PM
August 17	0, 1, 5, 7	Not Called	Not Called
	2	11 AM	1 PM
	3	2 PM	3 PM
	4	1 PM	2 PM
	6	3 PM	6 PM
	8	6 PM	7 PM
	9	7 PM	9 PM

In addition to average load impact estimates for the entire SmartAC population, there are several subpopulations for which load impacts are of interest to PG&E. Understanding differences in impacts between subpopulations provides valuable information for optimizing the performance of the program both now and in future years. These subpopulations will be described in Section 4 along with their corresponding results.

3.2 Ex Ante Estimation

Ex ante estimates are based on a model that predicts impacts as a function of weather using historical ex post load impacts from 2011 to 2015. The goal of the ex ante analysis is to produce forecasts of hourly load impacts for typical event days and monthly system peak load days in

[11] Including treatment customers as part of the control group during the hours before their event window and several hours after the end of the event window is also a valid approach, but sample sizes are large enough that we chose to simply estimate the impacts in each hour using only Group 0 and the group(s) called during that hour.

[12] A typical operation ramps device activation over a 30 minute period at the start and end of an event. This ramping is a pre-programmed feature of the control software that provides stability in grid operations for areas with higher concentrations of program participants. In order to capture the full effect of each test group for the full test hour, the ramping for these tests was started 30 minutes before the hour.

[13] Devices were activated 30 minutes prior to the “Event Start” time to accommodate the programmed randomized start (and stop) of devices. This ensures that all (or almost all) devices were in fact activated by the “Event Start” time.

each month under four distinct sets of system peaking weather conditions—PG&E 1-in-2, PG&E 1-in-10, CAISO 1-in-2 and CAISO 1-in-10.[14] Unlike previous evaluations that leaned heavily on the hour of 4 to 5 PM for ex ante estimation, this year's evaluation models the ex ante impacts for each hour separately using robust econometric methods and cross-validation techniques.

There are two key methodological issues that must be resolved in order to convert measured ex post impacts into ex ante forecasts. First, historical weather conditions differ from the weather used to represent ex ante conditions. Second, the hours for test events that occurred in the past often do not perfectly line up with the resource adequacy window of 1 to 6 PM for which ex ante impacts must be estimated.

The ex ante modeling process consisted of four fundamental steps:

1. Estimate the relationship between load impacts and weather conditions for each hour in the resource adequacy window and all subsequent hours (snapback) using historical ex post results;
2. Estimate relationship between usage and temperature on event days and hot, non-event days (to expand the number of observations) for control customers to predict reference loads under ex ante weather conditions;
3. Combine reference loads with impact estimates to infer load shapes for SmartAC participants; and
4. Scale up average customer impacts to aggregate impacts using forecasted enrollment provided by PG&E.

Step 1 is described in greater detail below, while the details of Step 2 are presented in Appendix A.

3.2.1 Estimating the Relationship between Impacts and Temperature

While the RCT design removes almost all modeling decisions for the ex post portion of the evaluation, such an experimental design cannot be entirely relied upon for ex ante estimation. Since 2011, the approach for ex ante has consisted of a complex sequence of steps involving the estimation of impacts for a single hour (4 to 5 PM) and ratios for translating the 4 to 5 PM impact into impacts for the remaining hours in the resource adequacy window. For purposes of discussion, this methodology will be referred to as the "ratio approach."[15]

The ratio approach existed for a very practical reason. At the time of its creation (2011), almost all SmartAC events were called only for two to three hours in the late afternoon. This allowed for robust ex ante estimates for those hours, but provided very little data that could be used to estimate impacts in the early portion of the resource adequacy window. Using the ratio approach allowed ex ante impacts for these hours to still be estimated in a way that produced results that intuitively aligned with the observed ex post impacts. Unfortunately, doing so

[14] "PG&E" and "CAISO" identify the system that is peaking, while 1-in-2 and 1-in-10 refer to the extremity of the weather conditions. 1-in-10 means that the modeled weather conditions are representative of those that would be seen once every 10 years, while 1-in-2 represents weather conditions that would be expected to occur every other year.

[15] See Appendix B for a detailed description of the ratio approach.

resulted in an approach that was not very transparent and somewhat difficult to explain. Furthermore, the ratio approach also made it very difficult to calculate standard errors that properly reflect the degree of uncertainty for each hourly impact estimate.

With each successive event season since 2011, the cumulative number of events containing each hour of the RA window has increased and steadily eroded the justification for using the ratio approach.[16] With 11 events called during the 2015 season, it was determined that enough data existed to simplify the ex ante estimation process by separately estimating the relationships between temperature and impact for each of the hours in the resource adequacy window.

For the modeling of 4 to 5 pm impacts in previous years, a simple model consisting of a single temperature variable was used to predict impact as a function of temperature. For this year, seven potential specifications (including last year's model) were evaluated on the basis of model fit.[17] Such model validation was last conducted for the 2012 evaluation and was performed this year to optimize model performance. The explanatory variables included in these specifications include several combinations of the following variables:

- Average temperature between midnight and 5 PM (mean17);
- Maximum daily temperature (maxtemp);
- Minimum daily temperature (mintemp); and
- Same hour temperature (temp).

Three different methods were used to assess model fit—10-fold cross validation (CV), leave one out CV and adjusted R-squared.[18] For the two CV methods, the outcome metric of interest is mean-squared error (MSE), which measures the error associated with a model's out of sample predictions. Lower MSE indicates better model fit. In contrast, adjusted R-squared is a goodness of fit metric based on model residuals that takes into account the number of explanatory variables included in the model. Higher values of adjusted R-squared indicate better model fit. Hour ending 17 (4 to 5 PM) was used for model validation since it is the hour for which the most historical data is available.

The results of the model validation analysis are shown in Table 3-3. For each specification tested, the table shows the metrics of interest for each method (either MSE or adjusted R-squared) and the rank among the different specifications according to each metric. The results show that adding other temperature variables to the model can improve performance. The best specification according to all three methods consists of mean17 and the same hour temperature (temp).

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[16] Cascading events have also allowed for impacts to be estimated across a wider range of hours.

[17] This analysis builds off of results from previous evaluations that identified mean17 as the best temperature variable for predicting impacts.

[18] For descriptions of 10-fold CV and leave one out CV, see James, G., et al. "An Introduction to Statistical Learning with Applications in R," available at https://web.stanford.edu/~hastie/local.ftp/Springer/ISLR_print1.pdf

Table 3-3: Cross-Validation Results for Ex Ante Model Selection (Hour 17)

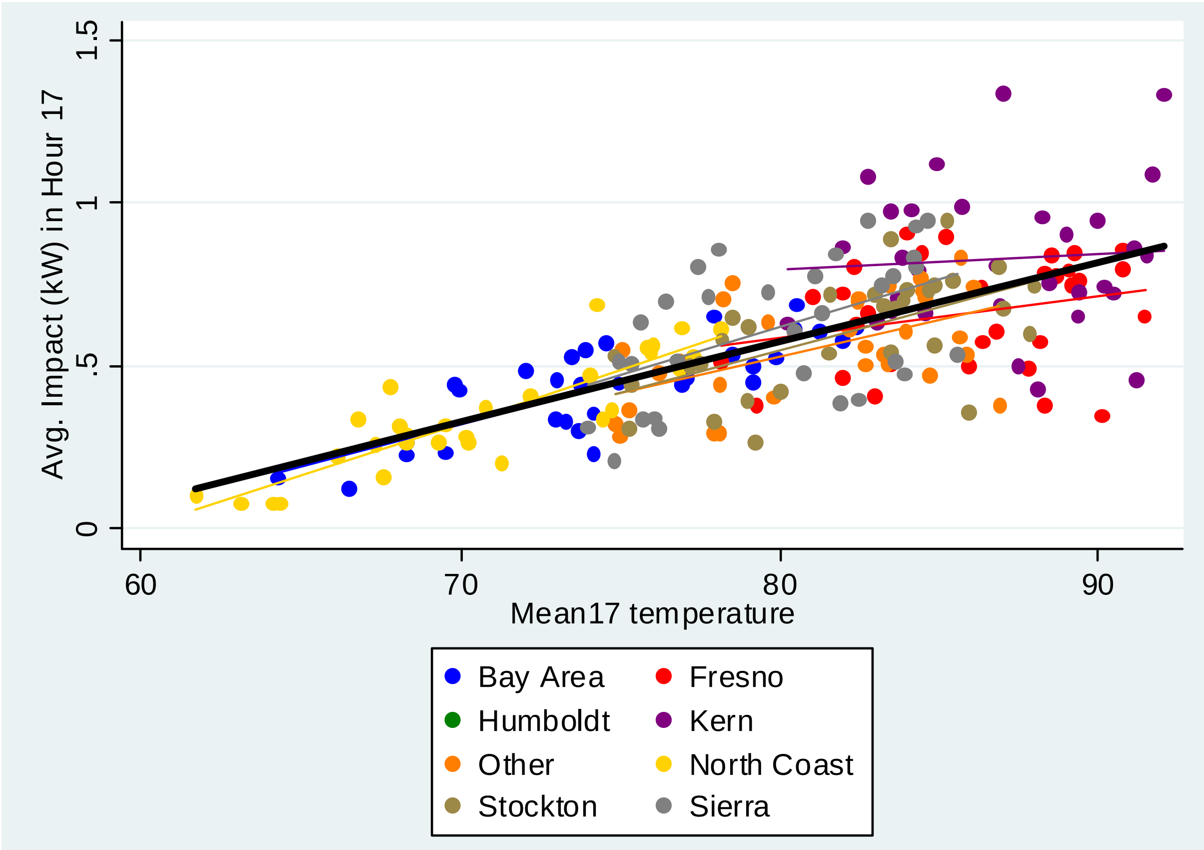
Explanatory Variables	10-fold CV		Leave One Out CV		Adjusted R-squared	
	MSE	Rank	MSE	Rank	Adj. R^2	Rank
mean17 temp	0.0235	1	0.0243	1	0.5404	1
mean17 maxtemp	0.0236	2	0.0244	2	0.5383	4
mean17 mintemp temp	0.0237	3	0.0244	3	0.5394	2
mean17 maxtemp temp	0.0242	4	0.0244	4	0.5388	3
mean17 mintemp	0.0243	5	0.0254	6	0.5191	6
mean17	0.0245	6	0.0258	7	0.5092	7
maxtemp mintemp temp	0.0248	7	0.0249	5	0.5312	5

The best-performing model specification is shown in Equation 1 and was estimated separately for each hour in the 1 to 6 PM resource adequacy window (the *h* subscript denotes hour ending) using a pooled sample of ex post impacts for the eight load capacity areas (LCAs). Pooling across LCAs increases the number of data points available for estimation as well as the range of observed temperatures. Pooling assumes that the relationship between weather variables and impacts is the same for each LCA.

$$\text{impact}_h = \alpha_h + \beta_{1h} * \text{meanh} + \beta_{2h} * \text{temp}_h + \varepsilon_h, \text{for all hours } h \in (14, 15, 16, 17, 18) \qquad (1)$$

Figure 3-3 demonstrates the ex ante modeling approach using hour ending 17 (4 to 5 PM) and provides a check on the assumption of a constant relationship between weather and impact for one of the temperature variables. Mean17 temperature is shown on the x-axis and average impact for hour 17 is on the y-axis. Each dot in the figure represents an estimated impact and its corresponding mean17 temperature for an individual LCA on an event day that occurred between 2011 and 2015. The eight LCAs are denoted by different colors with colored lines representing the linear relationship between impact and mean17 for each area. The thick black line represents the estimated relationship between impact and mean17 when all the LCAs are pooled together. The similarity in slopes between the pooled line and the colored lines for individual LCAs indicate that it is reasonable to assume that the pooled data can be used to accurately estimate the relationship between impact and temperature in each LCA.

Figure 3-3: Pooling LCAs to Estimate Hour 17 Impact vs. Temperature Relationship



Estimating Equation1 for each hour in the resource adequacy window results in five sets of parameter estimates that can predict the average load reduction that would be achieved during an event hour in each LCA under each set of hourly ex ante weather conditions. Because most historical load impact estimates exist only for SmartAC-only customers, impacts were adjusted to account for dually enrolled customers[19] prior to estimating Equation 1. Uncertainty for these predictions was based on the standard error of the regression for each hourly equation. For presentation purposes, 24-hour load shapes with and without load control were also estimated (see Appendix B). The predicted average impacts were scaled up to aggregate impacts (MW) by multiplying them by forecasted enrollment for each LCA provided by PG&E.

3.2.2 Snapback

To complete ex ante estimation, it is also necessary to estimate the snapback that would occur after an event ends in addition to load impacts for event hours between 1 and 6 PM. For estimation purposes, snapback can be thought of simply as negative impacts. To model snapback, Equation 1 was estimated for all hours (separately) from 6 PM to midnight using a

[19] These adjustments involved scaling down each impact estimate by approximately 5% based on the ratio of impacts for all customers and SmartAC-only customers on the two non-SmartRate event days when dually enrolled customers are included in the analysis. Ratios were calculated based on results for individual LCAs to reflect geographic heterogeneity that exists in the population. For small LCAs where the results are clearly untrustworthy, the "All LCAs" results were used.

pooled dataset of historical LCA-level snapback estimates for events that ended at 6 PM. Similar to the impact estimates, using Equation 1 for snapback assumes that the relationship between weather and snapback is constant across LCAs. In addition, the magnitude of snapback was assumed to be unaffected by the duration of the event, i.e., for a given set of weather conditions, snapback during 7 to 8 PM would be the same for a one-hour event as it would for a three-hour event.

3.2.3 Ex Ante Analysis for SMB Customers

The SMB portion of SmartAC is closed to new enrollment and no M&E test events have been called for SMB customers since 2011. Because of this, no ex post impacts were estimated for 2015 and there is no new load impact information available to update the per-device ex ante estimates from 2011. As a result, ex ante estimation for SMB customers combine the ex post impacts from 2011 with the ex ante weather conditions and an updated enrollment file from PG&E.

3.3 Operability Analysis

A new component of this year's evaluation—not completed since 2012—was a robust operability analysis that used switch data collected from installed devices to identify the number of switches that are not functioning properly. There are four research questions of interest related to operability:

1. What is the overall switch failure rate in PG&E's territory?
2. What fraction of switch failures are caused by physical issues (disconnections, missing, etc.) vs. communications failures?
3. Do the failure rates differ regionally in PG&E's territory?
4. What is the relationship between failure rate and switch vintage for the current SmartAC population?

To answer these questions, a sampling plan was devised to test the operability of switches from two different geographic areas—the Greater Bay Area and the Central Valley. The sampling frame was limited to M&E groups that experienced three events in 2015 (Groups 3, 7, 8, and 9) in order to obtain the maximum number of sent signals for each device. Within each geographic area, a stratified sample across switch vintages was used to select an equal number of devices for each vintage. This design is shown in Table 3-4 with 50 customers in each cell so that the total targeted sample size was 900.

Table 3-4: Sample Design for Operability Analysis

Year of SmartAC Enrollment	Greater Bay Area	Central Valley	Total
2007	50	50	**100**
2008	50	50	**100**
2009	50	50	**100**
2010	50	50	**100**
2011	50	50	**100**
2012	50	50	**100**
2013	50	50	**100**
2014	50	50	**100**
2015	50	50	**100**
Total	**450**	**450**	**900**

Field technicians from GoodCents (SmartAC implementer) performed the fieldwork required for the operability analysis, including physical inspections of installed switches and downloading operating data from switches that are properly connected. Any switches determined to be non-functional during the physical inspection were recorded by the technician along with the cause of the malfunction (missing switch, broken switch, broken AC unit, etc.) prior to leaving the site.

Analysis consisted of estimating the rate of physically broken switches using data collected from technicians and the rate of communication failures using downloaded switch data on event days for each vintage in the two areas. Trends in each of these failure rates over switch vintage were also examined within each area and compared. Based on the experience of the operations team, PG&E hypothesized that failure rates would be higher for older switch vintages and trends in failure rates will be different in the Greater Bay Area vs. the Central Valley due to increased reliance on AC and more regular maintenance/upgrading in the Central Valley.

3.4 Post-event and Notification Surveys

Following the event on Wednesday, September 9, approximately 400 customers were surveyed via telephone. The survey was designed to evaluate any changes to thermal comfort, awareness of events, and overall satisfaction with SmartAC that occurred as a result of the event. Surveys were approximately evenly split between treatment and control customers to maximize the precision associated with any measured differences. A copy of the survey instrument is contained in Appendix A.

In addition to the post-event survey on September 9, PG&E also conducted surveys to assess the impacts of event notifications on customer satisfaction. PG&E identified a group of customers for whom there was an email address on file and randomly chose a subset of those customers to receive event alerts sent via email prior to SmartAC event days. The customers not selected to receive alerts were used as a control group. At the end of the event season,[20] approximately 700 total surveys were conducted via telephone asking customers about SmartAC communications, event awareness, and their overall satisfaction with the SmartAC program. Opt-out and de-enrollment rates for the notification and control groups were also compared as part of the analysis.

4 Ex Post Load Impacts

A total of 11 events were called during the 2015 event season, which represents a substantial increase compared to the 4 events that were called in 2014. The key details of each event are summarized in Table 4-1. Two of the events were called on days that were not SmartRate event days (August 15 and September 8) and for the first time, an event was called on a weekend (Saturday, August 15). In addition, there were several events that included hours outside the late afternoon period when events have traditionally been called. The beginning and ending times for all events are shown in Table 4-2.

Table 4-1: 2015 SmartAC Event Details

Event Date	Treatment Groups	SmartRate Day	Weekend Event	Includes Hours Before 1 pm	Includes Hours After 6 pm
June 25*	3, 8	Yes	No	No	No
June 30	7	Yes	No	No	Yes
July 1	9	Yes	No	No	Yes
July 28	0, 1, 5, 7	Yes	No	No	Yes
July 29	9	Yes	No	No	No
August 15	8	No	Yes	No	No
August 17*	2, 3, 4, 6, 8, 9	Yes	No	Yes	Yes
September 8	3	No	No	No	No
September 9	0, 1, 5, 7	Yes	No	No	Yes
September 10	8	Yes	No	No	Yes
September 11	2	Yes	No	No	No

* = Cascading Event

[20] The exact dates of the surveys were September 30, October 18, and October 21.

Table 4-2: Start and End Times for 2015 Events

Event Date	Treatment Groups	Start Time[21]	Stop Time
June 25	8	1:00 pm	3:00 pm
	3	3:00 pm	6:00 pm
June 30	7	7:00 pm	8:00 pm
July 1	9	4:00 pm	7:00 pm
July 28	0, 1, 5, 7	4:00 pm	7:00 pm
July 29	9	1:00 pm	5:00 pm
August 15[a]	8	4:00 pm	6:00 pm
August 17	2	12:00 pm	1:00 pm
	4	1:00 pm	2:00 pm
	3	2:00 pm	3:00 pm
	6	3:00 pm	6:00 pm
	8	6:00 pm	7:00 pm
	9	7:00 pm	9:00 pm
September 8[a,w]	3	1:00 pm	3:00 pm
September 9	0, 1, 5, 7	4:00 pm	7:00 pm
September 10	8	4:00 pm	7:00 pm
September 11	2	3:00 pm	6:00 pm

a = Non-SmartRate Day, w = Weekend Event

Table 4-3 presents hourly load impact estimates for each of the nine non-cascading event days. For these events, the average hourly impact per customer was equal to 0.45 kW, with a low value of 0.09 kW from 1 to 2 PM on September 8 and a high of 0.66 kW from 4 to 5 PM on July 29. The low impacts for September 8 are likely due to the event being called in the early afternoon on the first day of a heat wave that followed milder weather.[22]

[21] All events technically began half an hour before the stated start time to be sure that the devices received the cycling signals and that the maximum number of devices were functioning properly at the top of the hour.

[22] Reference loads for later in the day on September 8 are in line with reference loads for similar hours on September 9 through 11 after accounting for the differences in temperature.

Table 4-3: Ex Post Load Impact Estimates for Non-Cascading 2015 Events

Event Date[23]	Number of Customers Called[24]	Hour Ending	Ref Load (kW)	Avg. Impact (kW)	Std. Err. of Impact (kW)	% Impact	Agg. Impact (MW)[25]	Avg. Temp (°F)
6/30	12,497	20	3.29	0.55	0.02	17%	6.9	91.8
7/1	12,491	17	2.45	0.40	0.02	16%	5.0	94.5
		18	2.64	0.39	0.02	15%	4.9	92.8
		19	2.67	0.34	0.02	13%	4.3	90.0
7/28	48,157	17	2.42	0.49	0.01	20%	23.8	98.5
		18	2.75	0.54	0.01	20%	26.1	96.8
		19	2.91	0.53	0.01	18%	25.6	93.1
7/29	12,393	14	1.78	0.33	0.02	19%	4.1	99.2
		15	2.15	0.45	0.02	21%	5.6	100.3
		16	2.54	0.58	0.02	23%	7.2	100.7
		17	2.90	0.66	0.02	23%	8.1	99.3
8/15	16,764	17	2.20	0.39	0.02	18%	6.6	96.6
		18	2.41	0.40	0.01	17%	6.7	94.6
9/8	16,663	14	0.87	0.09	0.01	11%	1.6	96.3
		15	1.15	0.16	0.01	14%	2.6	97.7
9/9	48,601	17	2.57	0.50	0.01	19%	24.3	100.3
		18	2.86	0.56	0.01	20%	27.3	97.9
		19	2.95	0.52	0.01	18%	25.1	92.5
9/10	12,696	17	2.79	0.53	0.02	19%	6.8	99.2
		18	3.01	0.54	0.02	18%	6.8	95.5
		19	3.03	0.46	0.02	15%	5.8	90.5
9/11	12,410	16	2.19	0.41	0.02	19%	5.1	97.8
		17	2.52	0.45	0.02	18%	5.6	95.9
		18	2.69	0.42	0.02	16%	5.3	92.6
Avg.	**21,408**	**N/A**	**2.49**	**0.45**	**0.02**	**18%**	**10.5**	**96.0**

Load impacts for the cascading event days on June 25 and August 17 are presented in Table 4-4. Load impacts for this day ranged from a low of 0.24 kW in the first hour of the event (noon

23 All events except for August 15 and September 8 were SmartRate event days. August 15 was also a Saturday.

24 On SmartRate days, dually enrolled customers are not included in the customer count because load impacts due to SmartAC for those customers are estimated as part of the SmartRate evaluation. On non-SmartRate days (8/15 and 9/8), dually enrolled customers are included.

25 Aggregate loads are not directly comparable since each event had a different number of groups that were called.

to 1 PM) to a high of 0.67 kW between 5 and 6 PM. The maximum impact occurs several hours after the peak temperature and one hour before peak residential load for the day.

Table 4-4: Ex Post Loads, Impacts, and Temperatures for Cascading Events

Event Date	Treat Group	Number of Customers Called	Hour End	Ref Load (kW)	Avg. Impact (kW)	Std. Err. of Impact (kW)	% Impact	Aggregate Impact (MW)[26]	Avg. Temp (°F)
6/25	8	12,408	14	1.53	0.26	0.01	17%	3.3	97.0
			15	1.85	0.36	0.02	19%	4.4	98.1
	3	12,101	16	2.20	0.47	0.02	22%	5.7	97.9
			17	2.53	0.57	0.01	23%	7.0	97.3
			18	2.79	0.60	0.01	21%	7.2	95.6
8/17	2	11,010	13	1.40	0.24	0.01	17%	2.6	96.9
	4	11,185	14	1.76	0.33	0.01	19%	3.7	99.5
	3	11,147	15	2.12	0.46	0.01	22%	5.1	100.5
	6	11,135	16	2.51	0.56	0.01	22%	6.3	100.4
			17	2.85	0.63	0.01	22%	7.0	99.1
			18	3.09	0.67	0.01	22%	7.4	96.3
	8	11,299	19	3.15	0.57	0.01	18%	6.4	91.1
	9	11,303	20	2.92	0.44	0.01	15%	4.9	85.3
			21	2.61	0.28	0.01	11%	3.2	81.0
Avg.	**N/A**	**11,449**	**N/A**	**2.38**	**0.46**	**0.01**	**19%**	**5.3**	**95.4**

The average load impacts presented in Table 4-3 and Table 4-4 are useful for assessing the overall performance, but mask a significant amount of heterogeneity in impacts across different areas of PG&E's service territory. Table 4-5 shows the average impacts for single-device customers[27] in each of the eight LCAs during the July 28 event. These results show modest differences in per customer impacts, but larger differences in aggregate impacts that reflect differences in enrollment.[28] This explains why the Greater Bay Area has much larger aggregate impacts despite having per customer impacts that are in line with other areas.

26 Aggregate loads are not directly comparable since each event had a different number of groups that were called.

27 Impacts for multi-device customers were not estimated at the LCA level due to sample size constraints.

28 The 2015 evaluation is the first to estimate impacts for Humboldt as a separate LCA. In previous evaluations, Humboldt was included as part of the "Other" LCA.

Table 4-5: Event Impacts on July 28, 2015

Local Capacity Area	Per Customer Impact (kW)	% Impact	Aggregate Impact (MW)	Mean 17	Average Temperature during Event Window (°F)
Greater Bay Area	0.55	23%	7.1	79.2	92.7
Greater Fresno	0.59	20%	2.9	86.4	101.0
Humboldt	0.54	20%	0.1	76.9	96.3
Kern	0.70	23%	1.5	84.6	98.3
Northern Coast	0.49	23%	1.4	76.9	92.2
Other	0.53	20%	4.8	82.7	99.1
Sierra	0.57	21%	2.4	80.7	96.8
Stockton	0.58	20%	2.4	81.5	98.1
All	**0.56**	**21%**	**22.6**	**81.4**	**96.4**

Another important trend to analyze is how impacts have changed over time. Table 4-6 shows estimated impacts for SmartAC-only customers from 4 to 5 PM for all event days dating back to 2011.

Table 4-6: Load Impact per Device from 4–5 PM for All Events from 2011–2015

Date	Mean17 (°F)	Load Reduction from 4 to 5 PM (kW)
June 15, 2011	77.1	0.33
June 21, 2011	82.2	0.76
June 22, 2011	79.9	0.57
June 23, 2011	78.6	0.67
September 6, 2011	72.9	0.38
September 7, 2011	76.6	0.52
September 8, 2011	74.3	0.47
Average 2011	**77.4**	**0.53**
July 9, 2012	72.5	0.44
July 10, 2012	76.0	0.63
July 11, 2012	80.1	0.65
July 12, 2012	79.9	0.63
Aug 12, 2012	76.2	0.60
Aug 13, 2012	80.9	0.67
September 13, 2012	74.4	0.44
September 14, 2012	73.2	0.29
October 1, 2012	75.6	0.34

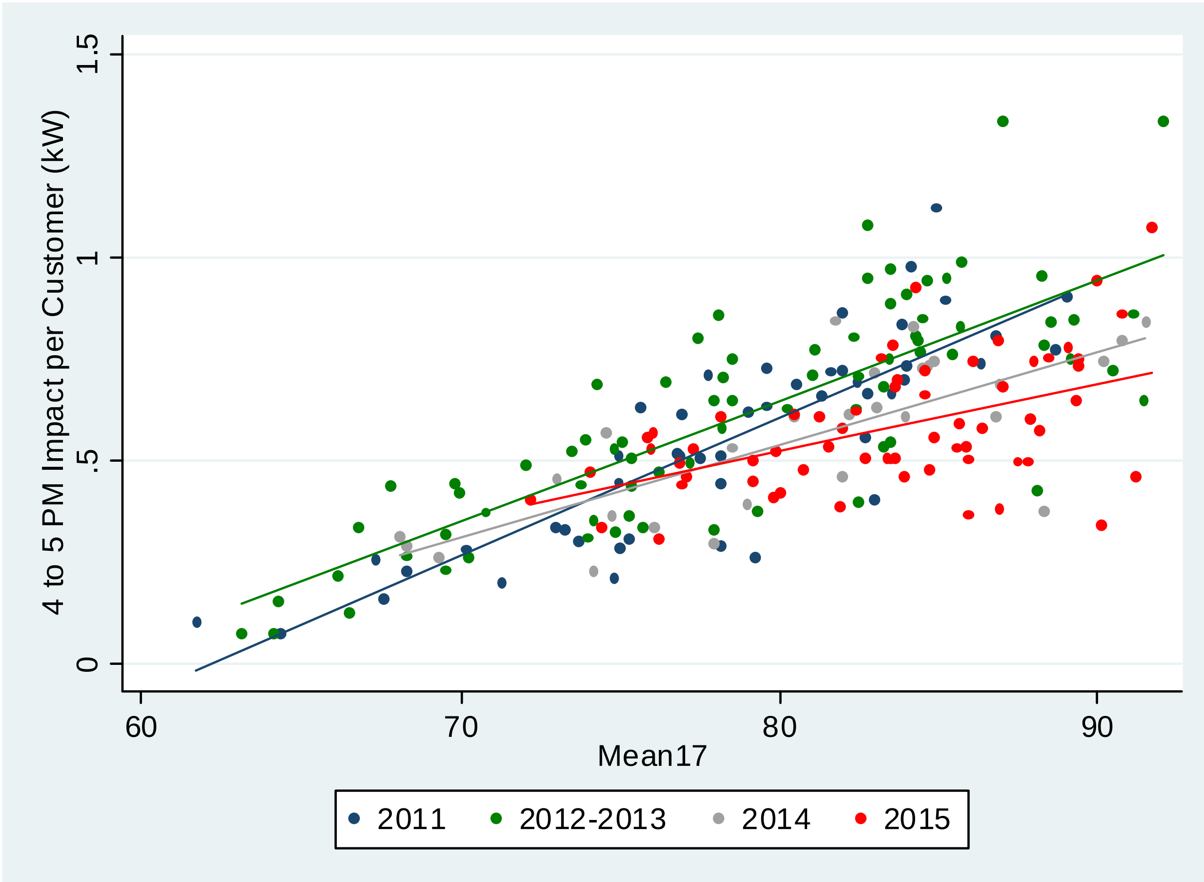
Date	Mean17 (°F)	Load Reduction from 4 to 5 PM (kW)
October 1[29], 2012	75.6	0.49
Average 2012	**76.5**	**0.52**
July 1, 2013	83.3	0.76
Average 2013	**83.3**	**0.76**
June 30, 2014	81.8	0.63
July 30, 2014	79.3	0.52
August 1, 2014	81.2	0.64
September 11, 2014	76.8	0.33
Average 2014	**79.8**	**0.53**
June 25, 2015	82.4	0.57
July 1, 2015	84.5	0.40
July 28, 2015	81.1	0.49
July 29, 2015	84.0	0.66
August 15, 2015	78.6	0.39
August 17, 2015	84.2	0.63
September 9, 2015	82.2	0.50
September 10, 2015	83.7	0.53
September 11, 2015	82.2	0.41
Average 2015	**82.5**	**0.51**

One of the key findings in the ex post evaluation is that despite hotter event temperatures for the 2015 events, average impacts are comparable to those observed in previous years. Given the positive relationship between impacts and temperature described in Section 3.2.1, the higher event temperatures in 2015 should have resulted in larger load reductions than were observed. This result is depicted in Figure 4-1, which plots historical impacts from 4 to 5 PM against the mean17 temperature at the LCA level for all events going back to 2011.[30] In each of the past two years, impacts at higher temperatures are noticeably lower than for the 2011–2013 events.

[29] Two test events were called on 10/1/2012. The first occurred from 2 to 5 PM and the second from 4 to 6 PM.

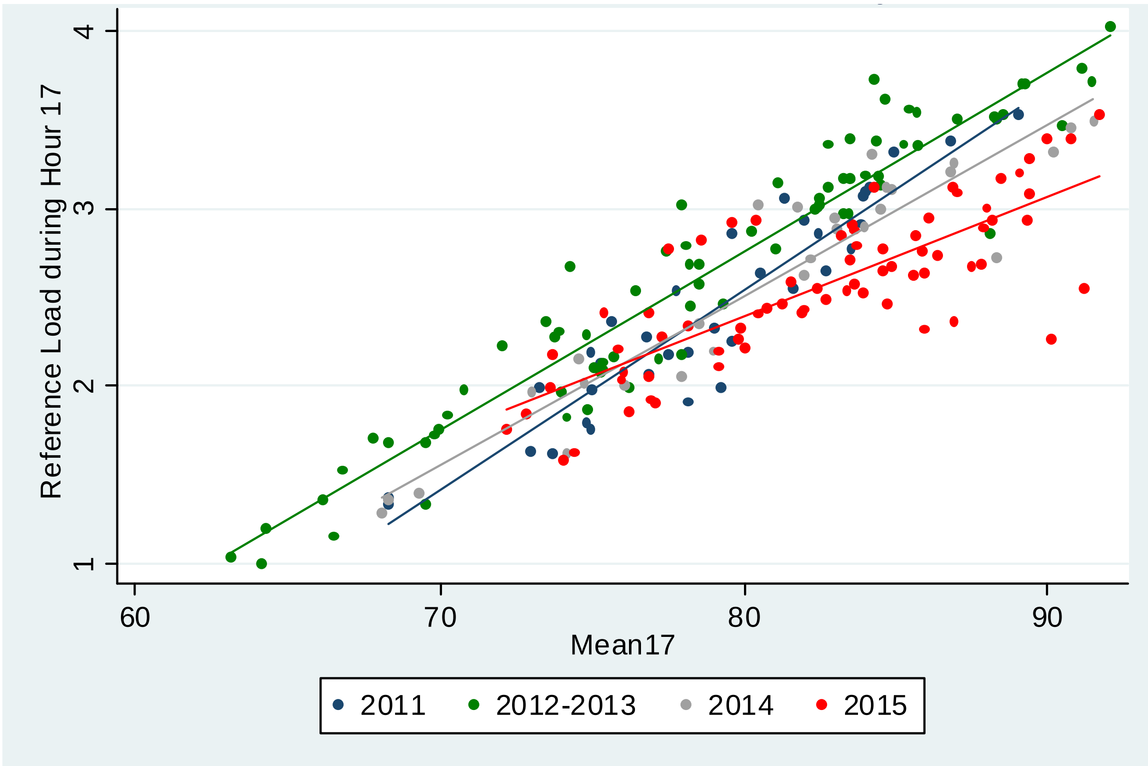
[30] Because 2013 only had 1 event that included 4-5 PM, it was combined with 2012 for the purposes of the graph.

Figure 4-1: Impact vs. Temperature for 4–5 PM Load Impacts during 2011–2015 Events



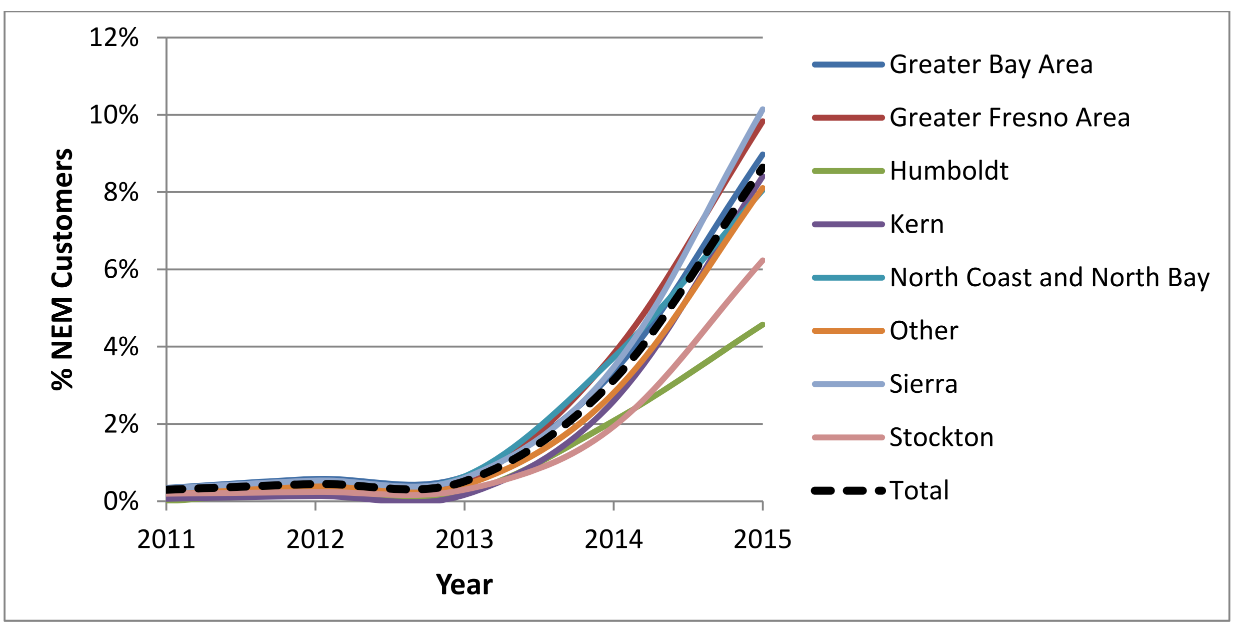
One potential cause of lower impacts in 2015 appears to be lower reference loads. Figure 4-2 shows the relationship between control group loads from 4 to 5 PM and mean17 temperature on event days spanning the past five years. After an upward shift from 2011–2013, reference loads have declined in the past two years after controlling for weather. Mirroring the trend in Figure 4-1, this pattern is represented by a downward shift of the lines in the figure and is particularly noticeable at hotter temperatures where impacts are expected to be the largest.

Figure 4-2: Reference Loads on Event Days for 2011–2015 Events



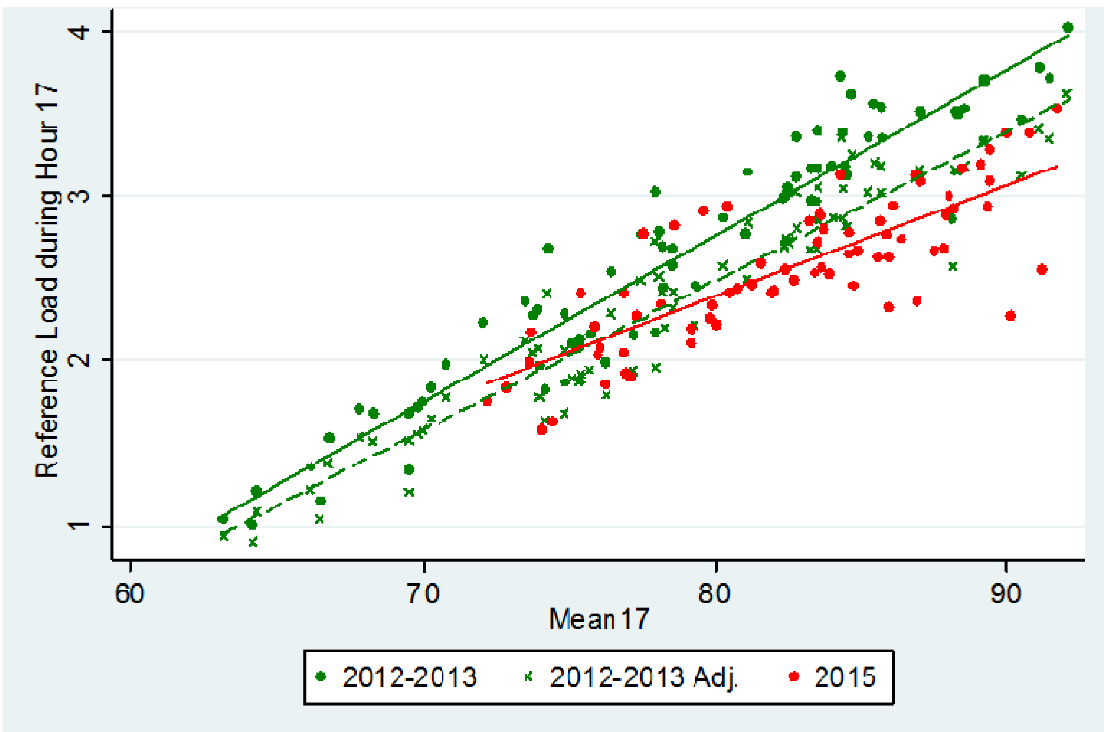
Increased adoption of solar PV by SmartAC customers appears to explain a large amount of the decline. Figure 4-3 shows the percentages of the SmartAC population with net energy metering (NEM) for 2014 and 2015 in each LCA. In nearly all LCAs, solar adoption has grown exponentially and NEM customers now make up nearly 10% of the SmartAC population.

Figure 4-3: Solar PV Adoption in SmartAC Population by LCA



SmartAC events are generally called during the late afternoon on very hot days when solar production is likely to be at or near its maximum. As a result, the net load for NEM customers during event hours will be much less than non-NEM customers and is likely to be negative in the early afternoon. To see the effect of this on reference loads, the 2012-2013 reference loads can be scaled down to account for NEM customers. Using a conservative assumption that the net load of solar customers is zero for 10% of the 2012-2013 SmartAC population allows for a more apples-to-apples comparison of reference loads on event days, which is shown in Figure 4-4. After controlling for NEM customers, there is less of a difference between 2015 reference loads and those in past years. Increased solar adoption appears to explain almost all of the difference on cooler days, but only about half of the difference during the hottest events.

Figure 4-4: Reference Loads After Controlling for NEM Customers



Lower reference loads—particularly at hotter temperatures—would plausibly lead to lower impacts because there is not as much air conditioning load available for control devices to interrupt. Other potential causes of the decline in 2015 impacts include declining performance for the ExpressStat PCTs and operability concerns related to the device paging network. These causes will be discussed in Sections 4.3 and 6, respectively.

4.1 Dually Enrolled Customers (SmartRate)

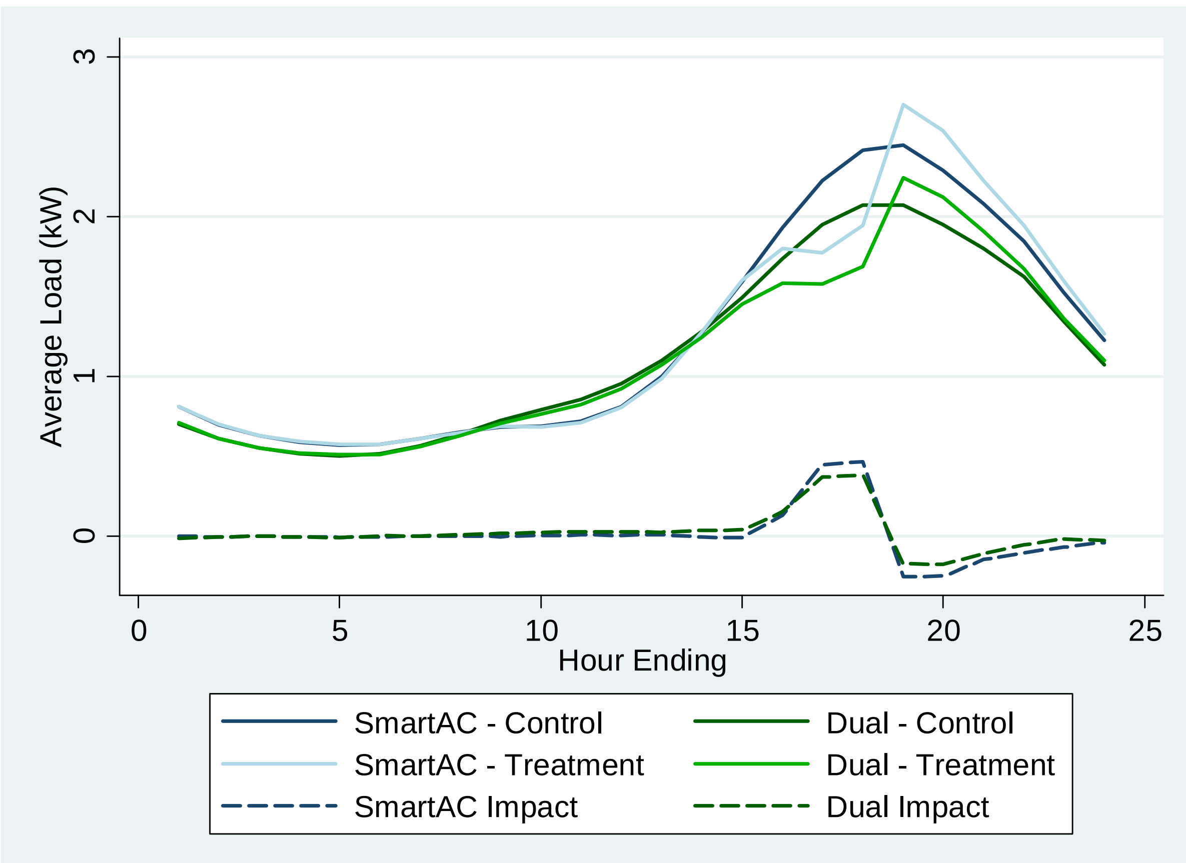
Out of the roughly 152,000 residential customers enrolled in the SmartAC program in 2015, approximately 37,000 were also enrolled in PG&E's SmartRate™ program.[31] These customers

[31] SmartRate is a critical peak pricing (CPP) program that uses price signals to encourage peak load reductions on system peak days.

have their AC units cycled on all SmartRate days,[32] which may or may not also be SmartAC event days. For days that are both SmartAC and SmartRate events, the impacts of SmartAC cannot be estimated for dually enrolled customers because they are confounded with the effect of SmartRate. On days when the SmartAC program is called and SmartRate is not, however, the impacts for dually enrolled customers can be estimated and compared to the impacts for SmartAC-only customers. Dually enrolled customers typically have lower impacts than SmartAC-only customers because they already use less energy on average. As such, even if the percent reductions for SmartAC-only and dually enrolled customers were the same, the absolute impacts for dually enrolled participants would be lower.

In 2015, there were two SmartAC test events on days when SmartRate was not called—August 15 and September 8. August 15 was also a Saturday, making it the first SmartAC event to ever be called on a weekend. Figure 4-5 shows the load shapes of treatment and control groups for dually enrolled customers compared to SmartAC-only customers on August 15. Usage for dually enrolled customers is lower than for SmartAC-only customers and absolute impacts are slightly lower as well.

Figure 4-5: Load Impacts for SmartAC-only and Dually Enrolled Customers on August 15



32 The ex post impacts for these days are estimated as part of the SmartRate evaluation.

Table 4-7 shows the absolute and relative impacts for single-device households on the two non-SmartRate days. Simple comparison of means tests show these differences in impacts to be significant at 95% on both days ($p<0.01$).

Table 4-7: 2015 Impacts for SmartAC-only and Dually Enrolled Customers

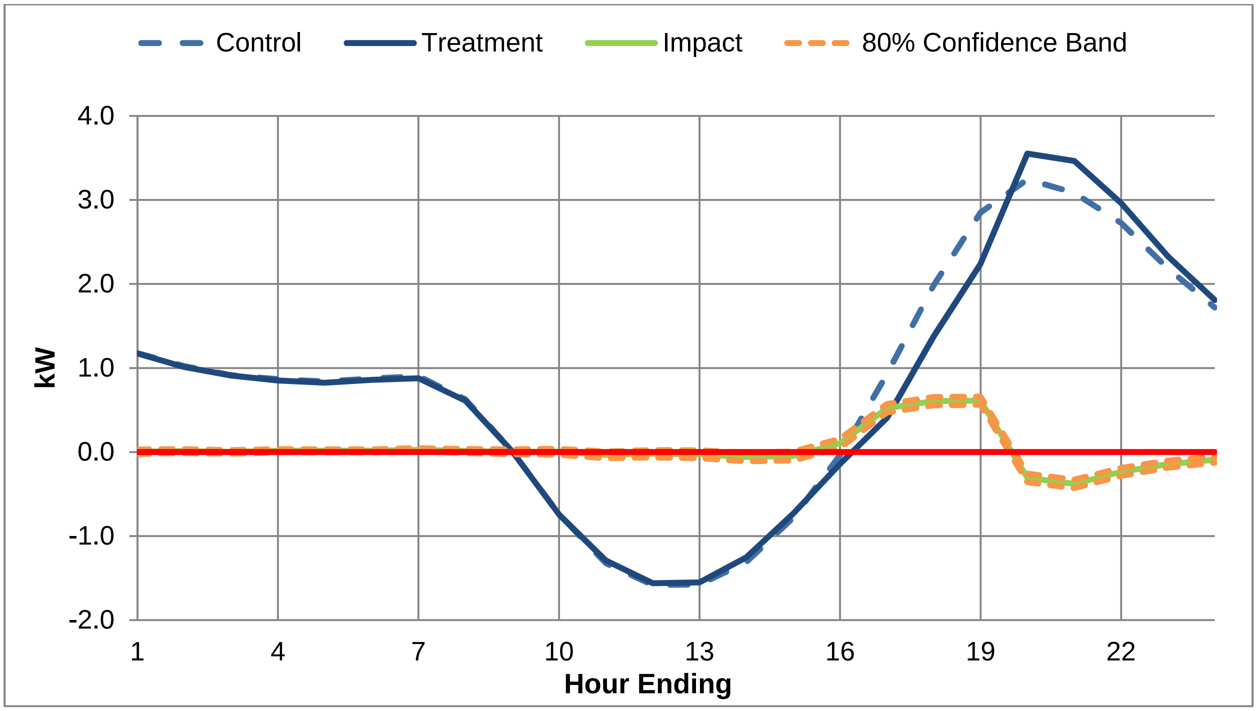
Date	Hour Ending	Impact (kW)		Impact (%)	
		SmartAC-only	Dually Enrolled	SmartAC-only	Dually Enrolled
August 15	17	0.45	0.37	20%	19%
	18	0.47	0.38	19%	18%
September 8	14	0.13	0.07	15%	7%
	15	0.20	0.09	17%	8%
Average	**NA**	**0.31**	**0.23**	**18%**	**13%**

4.2 Net Metered Customers

Another subpopulation of interest is customers who are net metered, indicating that they have a photovoltaic (PV) system installed at their residence. SmartAC has approximately 9,000 enrolled customers with PV systems. These customers have a very different load shape than non-net metered customers and it is common for net loads to become negative during the late morning and early afternoon hours when a PV system is producing more electricity than is being consumed by the home. On hot summer days, this can result in a rapid increase in net load from early afternoon to the peak hours in the early evening as solar production declines and usage in the home (particularly AC usage) increases. As the adoption of solar continues to accelerate in PG&E's service territory, this "duck curve" load shape poses a challenge to system operators due to the fast-ramping generation that is needed to meet the rapidly growing demand.

Figure 4-6 shows the load impacts for net metered customers during the July 28 event, which began at 4 PM and ended at 7 PM. The load reductions for customers with PV are on par with those for the SmartAC population as a whole (approx. 0.5 kW for July 28), but load control increased the rate of load growth from the early afternoon to the peak at 8 PM. For this particular event, snapback also increased peak usage for PV customers.

Figure 4-6: Load Shapes for PV Treatment and Control Groups on July 28

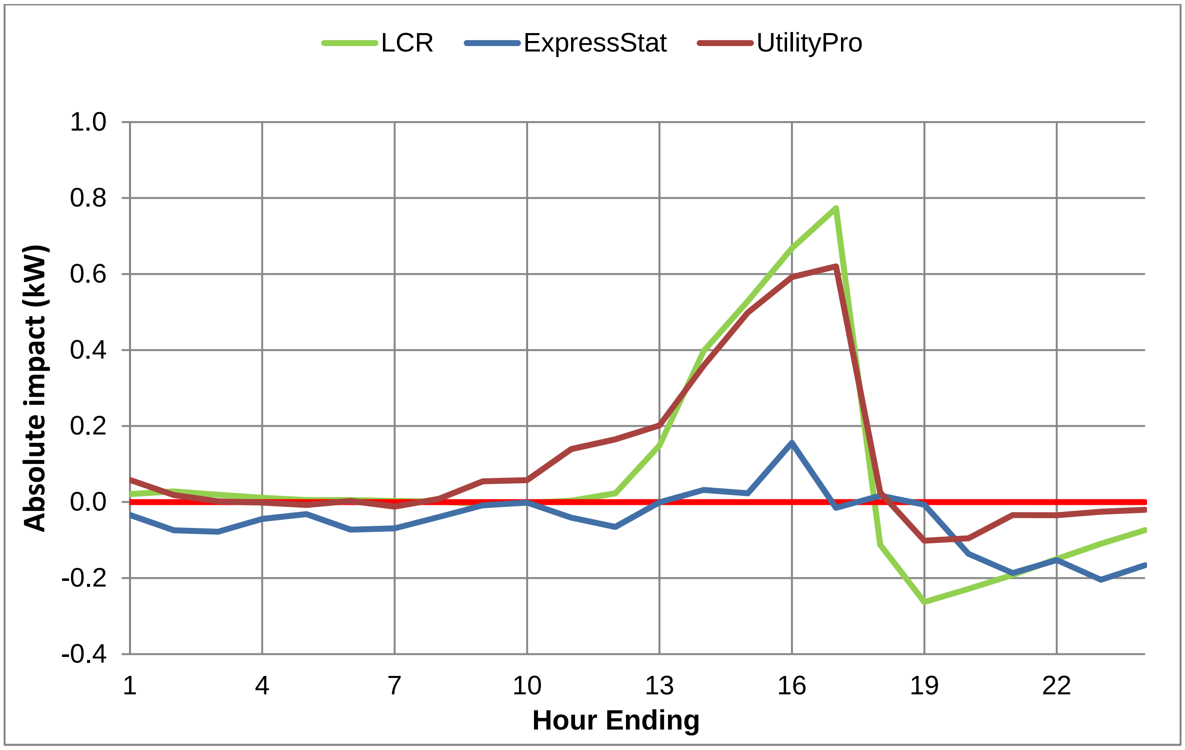


4.3 Device Type

As discussed in Section 2, there are two basic types of load control devices in use for SmartAC—LCR switches and PCTs. PCTs can be further classified as one of two models—UtilityPro or ExpressStat. All three technologies are designed to use cycling algorithms to reduce AC load during events, but evidence from past evaluations has suggested that the performance of ExpressStats has been declining.

This year, ExpressStat performance has eroded to the point where impacts are effectively zero. Figure 4-7 shows the load impacts for each technology as a function of time on a representative event day (July 29) when an event was called starting at 1 PM and ending at 5 PM. LCRs and UtilityPros performed similarly, while the ExpressStat impacts stayed close to zero throughout the event window. Mean comparison tests show that during the event window, differences between the ExpressStat and the other two devices are significant at the 95% confidence level.

Figure 4-7: Load Impacts by Device Type on a Representative 2015 Event Day (July 29)



There are approximately 5,000 SmartAC customers with ExpressStats enrolled in the program[33] and the absence of any load impacts for this group likely contributed to the decline in observed impacts in 2015 compared to previous years. Using the average hourly impact estimate of 0.45 kW from Table 4-3, the absence of ExpressStat impacts represents a loss of approximately 2.3 MW of demand response capacity.

4.4 Households with Multiple AC Units

At the end of the 2015 program year, there were close to 15,000 SmartAC residential customers (including dually enrolled customers) with more than one control device (just under 10% of the population). In past years, these houses were omitted from the ex post analysis because over 95% of customers with multiple AC units had control devices in different randomized groups. This often results in the same household being part of both the treatment and control groups during an event. In these situations, the whole-house load impact would not necessarily represent the true effect of a SmartAC event on that household, since during a non-test event when all customers were called, both units would be controlled.

In past evaluations, multi-device households have been handled in various ways as additional analyses have provided additional information about their impacts at the whole house level.[34]

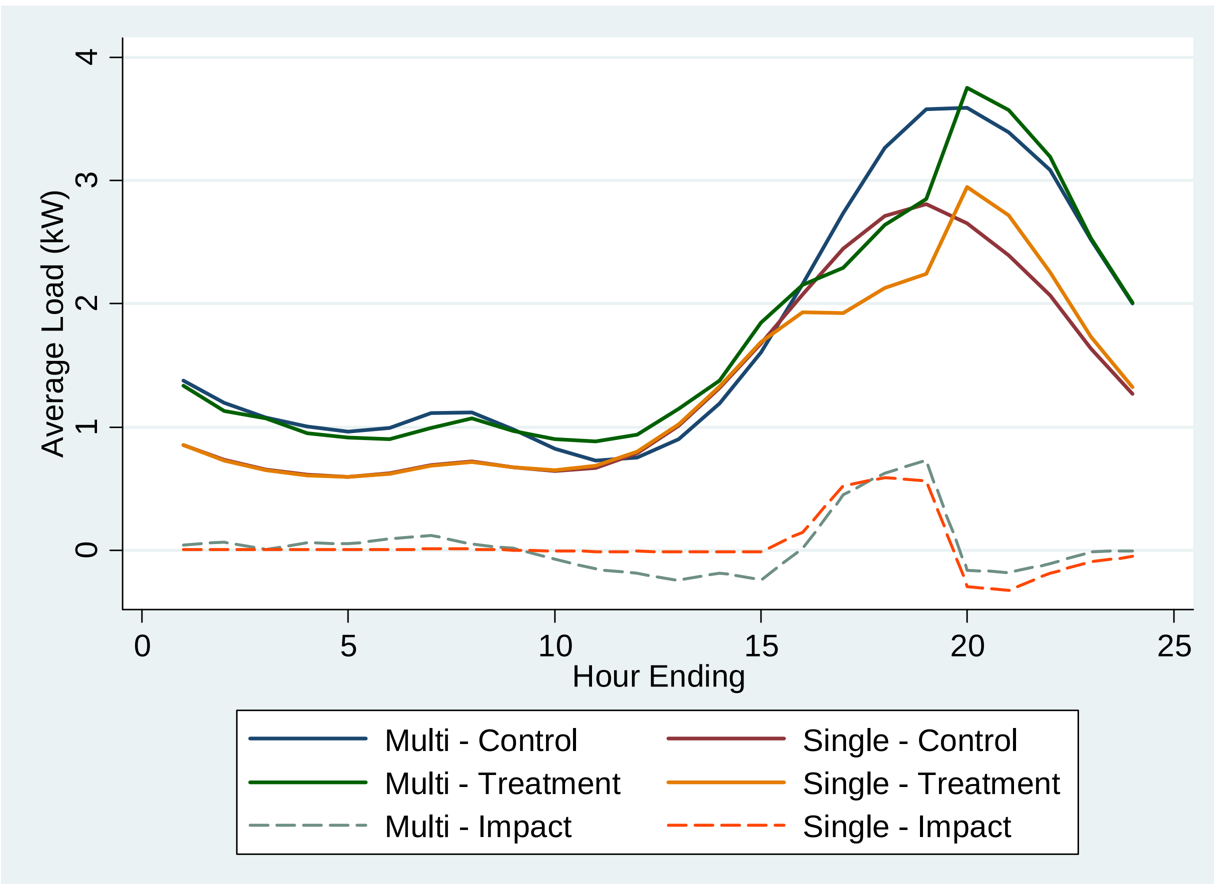
[33] Approximately 3,800 of these are SmartAC-only customers.

[34] Secondary analysis of multi-device premises in the 2012 evaluation showed that these premises do not provide higher impacts than single-device premises. In 2013, multi-device households were included in the primary ex post results, which lowered the average load impact per device, but increased the number of devices used to calculate the aggregate impact. In 2014, multi-device households were excluded from the calculation of per customer impacts, but included in the

This year's evaluation is similar to the 2014 analysis in that multi-device households were excluded from the calculation of per customer impacts, but included in the calculation of aggregate impacts under the assumption that multi-device customers provide the same load reductions as single-device customers on a per customer basis. Unlike 2014, however, this assumption was validated by estimating load impacts for multi-device customers independently and comparing them to single-device impacts.[35] For this analysis, only treatment customers who had all of their devices called and control customers who had none of their devices called were included and the analysis was limited to the July 28 and September 9 events in order to maximize the available sample size.[36]

Figure 4-8 displays the load shapes (treatment and control) for single and multi-device customers during the July 28 event (top part of graph) along with the estimated impacts for each group (bottom). Although customers with multiple SmartAC devices have larger loads throughout the day, impacts are similar to those for customers with only one device.

Figure 4-8: Load Curves for Single and Multi-device Customers on an Event Day (July 28)



calculation of aggregate impacts under the assumption that they provide the same load reductions as single-device customers.

35 This validation exercise was also completed as part of the 2012 SmartAC evaluation.

36 July 28 and September 9 had four groups called during the event window, while all other events only had one.

Table 4-8 shows the relative and absolute impacts for each group for the two events of interest. Differences between the average impacts on each day are modest and not statistically significant at the 95% confidence level (p>0.60). These results support the assumption that per customer impacts are the same for single and multi-device customers.

Table 4-8: Load Impacts for Multiple and Single Device SmartAC Customers on Event Days (4–7 PM)

Date	Hour Ending	Impact (kW)		Impact (%)		Enrolled Customers	
		Multiple-Device	Single-Device	Multiple-Device	Single-Device	Multiple-Device	Single-Device
July 28	17	0.35	0.52	13.5%	21.8%	14,487	133,816
	18	0.50	0.58	15.9%	21.5%		
	19	0.70	0.58	19.9%	20.5%		
	Average	**0.51**	**0.56**	**16.8%**	**21.2%**		
Sept. 9	17	0.55	0.53	19.0%	21.1%	14,665	135,965
	18	0.75	0.59	22.2%	21.6%		
	19	0.76	0.55	20.7%	19.7%		
	Average	**0.69**	**0.56**	**20.7%**	**20.8%**		

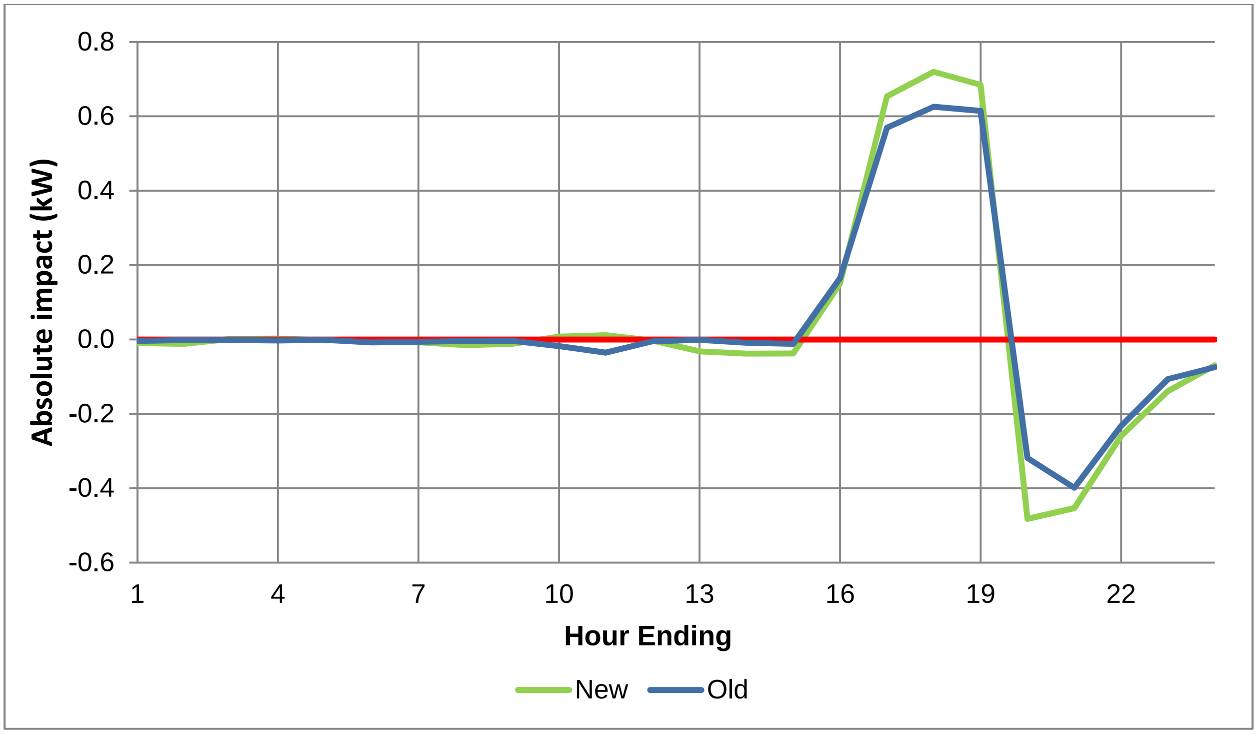
4.5 Targeted Marketing Strategy

In 2014, PG&E began using a new marketing strategy for targeting customers for SmartAC that combined estimates of enrollment probability with an estimate of AC load for customers throughout the service territory. By incorporating usage in addition to the likelihood of enrollment, PG&E aimed to maximize the new DR capacity it obtained from every marketing dollar spent.

The new marketing strategy was used on a trial basis early in 2014, but became the primary marketing strategy by September 1 and was used for all of 2015. To test the effectiveness of the new strategy, the impacts for customers who enrolled on or after September 1, 2014 were compared to the impacts of customers recruited from January 1, 2012 through August 31, 2014.[37] The results of this comparison for July 29 are shown in Figure 4-9. In the figure, impacts for customers recruited using the new method do appear to be larger on both an absolute and relative basis.

[37] January 1, 2012 was used as a cutoff to mitigate the potential for confounding causes of any differences in impacts between customers recruited at different times. Limiting the sample of "old marketing" customers to post-2011 reduces concerns about differences in device performance that arise due to the age of the device as well as the specific geographic targeting of marketing efforts that took place in the early years of SmartAC™ (2007 and 2008).

Figure 4-9: Impact Estimates for Customers Recruited Using New vs. the Old Marketing Strategy (July 28)



As a more formal test of whether or not larger impacts are associated with the new targeting strategy, comparison of means tests were computed for individual hours on the July 28 and September 9 events.[38] These tests show that the differences in impacts between customers enrolled using the new and old targeting strategies are significant at the 95% confidence level.[39]

4.6 Multi-family and CARE Customers

The final segments of interest in the ex post analysis were two segments of the PG&E population that have not been examined in previous SmartAC evaluations—multi-family customers and CARE customers. There are approximately 5,000 multi-family customers[40] and 39,000 CARE customers currently enrolled in SmartAC.[41] Similar to the other segments analyzed in this section, impacts were calculated separately for single vs. multi-family and CARE vs. Non-CARE customers to determine if any differences exist.

A comparison of impacts for single vs. multi-family customers on July 28 is presented in Figure 4-10 and the estimated impacts for each group on July 28 and September 9 are presented in

[38] Similar to the single vs. multi—device comparison, these events were chosen to maximize the number of treatment customers and therefore the precision of the estimated impacts.

[39] For hour ending 18 on July 28, p=.029 and for hour ending 18 on September 9, p<0.01.

[40] PG&E does not track whether a customer lives in a single-family or multi-family residence. For the purposes of this analysis, multi-family customers were defined as those having a service address containing any of the following: APT, STE, SPC, UNIT, BLDG, BUILDING, #, LOT or LT.

[41] Approximately 80% of CARE customers are SmartAC-only customers who are not dually enrolled in SmartRate.

Table 4-9. These results indicate that single-family customers produced significantly greater absolute impacts than multi-family premises and this result is statistically significant at the 95% confidence level (p<0.01). Single family households also had larger percentage impacts compared with multi-family households, but this difference is not as great as the difference in absolute impacts.

Figure 4-10: Load Impacts for Single-family vs. Multi-family Premises (July 28)

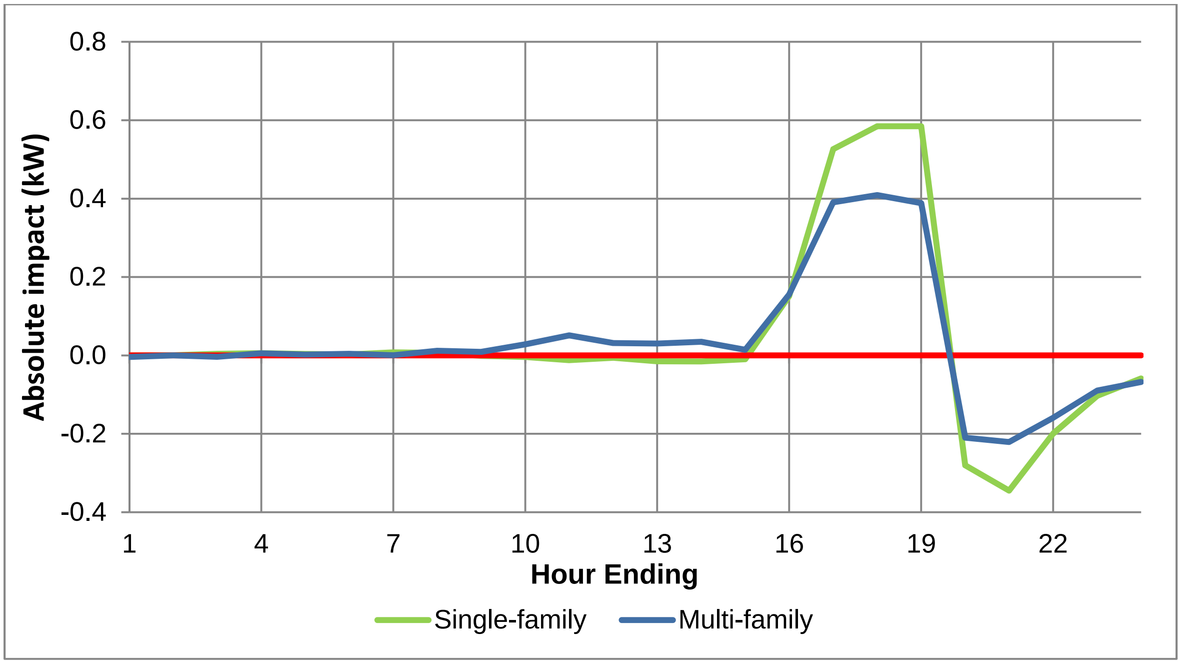


Table 4-9: Load Impacts for Multiple and Single Family SmartAC Customers on Event Days (4–7 PM)

Date	Hour Ending	Impact (kW)		Impact (%)		Enrolled Customers	
		Multi-family	Single-Family	Multi-family	Single-Family	Multi-family	Single-Family
July 28	17	0.39	0.53	19.9%	21.8%	6,505	142,810
	18	0.41	0.58	19.5%	21.6%		
	19	0.39	0.58	18.8%	20.6%		
	Average	**0.40**	**0.57**	**19.4%**	**21.3%**		
Sept. 9	17	0.34	0.54	17.4%	21.2%	6,729	144,922
	18	0.36	0.61	17.7%	21.7%		
	19	0.31	0.57	15.3%	19.8%		
	Average	**0.34**	**0.57**	**16.8%**	**20.9%**		

Load impact estimates for CARE and Non-CARE customers are shown in Table 4-10. Due to the relatively large number of Non-CARE customers, all events are included in the comparison. Impacts for CARE and Non-CARE customers are very similar both in absolute and relative terms. The largest differences observed in Table 4-10 (e.g., July 29 and September 8) are statistically significant at the 95% confidence level, but on many event days there is either no discernable difference or the difference is not statistically significant. Given the mixed results, it is difficult to make a definitive statement on whether or not a true difference between CARE and Non-CARE impacts exists.

Table 4-10: Load Impacts of CARE and Non-CARE Customers

Date	Event Window	Avg. Impact in Event Window (kW)		Avg. Percent Impact in Event Window (%)		p-value for Comparison of Means Test
		CARE	Non-CARE	CARE	Non-CARE	
June 25	1-3 PM	0.38	0.31	19.4%	21.1%	0.06
	3-6 PM	0.50	0.56	24.7%	24.4%	0.11
June 30	7-8 PM	0.65	0.58	20.8%	19.1%	0.03
July 1	4-7 PM	0.47	0.41	18.3%	17.0%	0.06
July 28	4-7 PM	0.62	0.53	22.0%	20.9%	0.01
July 29	1-5 PM	0.64	0.53	23.8%	24.7%	< 0.01
August 15	4-6 PM	0.46	0.43	18.6%	20.0%	0.34
August 17	12-1 PM	0.32	0.22	17.8%	18.1%	0.02
	1-2 PM	0.40	0.31	18.3%	19.7%	0.03
	2-3 PM	0.58	0.46	22.9%	23.4%	< 0.01
	3-6 PM	0.75	0.63	24.6%	23.8%	< 0.01
	6-7 PM	0.57	0.62	18.0%	20.3%	0.20
	7-9 PM	0.41	0.35	15.1%	13.4%	0.11
September 8	1-3 PM	0.20	0.12	14.8%	13.7%	0.01
September 9	4-7 PM	0.56	0.56	20.6%	20.8%	0.96
September 10	4-7 PM	0.53	0.57	18.5%	20.5%	0.21
September 11	3-6 PM	0.49	0.46	19.6%	19.9%	0.35
Average	**N/A**	**0.51**	**0.45**	**19.9%**	**20.0%**	**N/A**

5 Ex Ante Load Impact Forecasts

One of the primary purposes of the SmartAC evaluation is to predict the load impacts that would occur under a pre-chosen set of temperature profiles that are representative of system peaking conditions. These temperature profiles are created for monthly system (PG&E and CAISO) peak days that would be expected to occur every other year (1-in-2) and every tenth year (1-in-10). This section presents the ex ante impact estimates for residential and SMB customers. Aggregate estimates of load impacts combine estimates of per customer load impacts developed in this report with estimates of program enrollment developed in a separate effort by PG&E.

5.1 Residential

Enrollment projections for residential customers by local capacity area for August of each year from 2016–2026 are presented in Table 5-1. These estimates were developed by PG&E and reflect slight declines from the current enrollment of approximately 152,000 customers. Due to the new targeted marketing approach, however, customers coming into the program will provide larger impacts than the customers they are replacing.

Table 5-1: Forecasted Residential Enrollment for August of Each Year

LCA	2016	2017 to 2026
Greater Bay Area	50,086	49,320
Greater Fresno	17,729	17,719
Humboldt	8,351	8,432
Kern	8,629	8,483
Northern Coast	33,067	32,805
Other	16,907	16,834
Sierra	15,492	15,511
Stockton	925	920
Total	**151,186**	**150,024**

Ex ante load impact estimates for 2016 are shown for residential customers in Table 5-2, including those who are dually enrolled in SmartRate. The first column shows the average hourly ex ante load impact estimates per customer over the event period from 1 to 6 PM and the second column shows the maximum per customer hourly impact. Columns 3 and 4 show the corresponding estimated aggregate load impacts. The top half of the table corresponds to PG&E system peaking conditions; the bottom half shows results for CAISO system peaking conditions. For the 1-in-2 weather year based on PG&E peaking conditions, the highest estimated impact occurs on the July peak day, with an average impact of 79 MW and a peak hourly impact of 100 MW. The mean hourly impact for the typical event day under 1-in-2 year weather conditions is approximately 74 MW. Under 1-in-10 year weather conditions, the highest estimated impacts also occur in July, with a peak day impact of 94 MW and a peak hourly impact of 114 MW. The mean hourly impact on the typical event day under 1-in-10 year conditions is 85 MW.

Table 5-2: 2015 Residential SmartAC Ex Ante Load Impact Estimates by Weather Year and Day Type (Event Period 1–6 PM)

Weather Year	Day Type	Mean Hourly Per Customer Impact (kW)	Max. Hourly Per Customer Impact (kW)	Aggregate Mean Hourly Impact (MW)	Aggregate Max Hourly Impact (MW)
1-in-2 PG&E	Typical Event Day	0.49	0.61	73.8	92.3
	May Peak Day	0.29	0.39	43.8	60.0
	June Peak Day	0.49	0.61	74.6	93.2
	July Peak Day	0.52	0.66	78.8	100.0
	August Peak Day	0.48	0.61	73.2	92.2
	September Peak Day	0.45	0.57	68.5	86.3
	October Peak Day	0.18	0.27	26.4	40.8
1-in-10 PG&E	Typical Event Day	0.56	0.69	85.0	105.0
	May Peak Day	0.49	0.61	74.1	92.1
	June Peak Day	0.57	0.71	86.0	107.7
	July Peak Day	0.62	0.76	93.9	114.4
	August Peak Day	0.58	0.71	87.7	107.6
	September Peak Day	0.48	0.60	72.7	91.4
	October Peak Day	0.39	0.50	58.6	75.7
1-in-2 CAISO	Typical Event Day	0.39	0.51	59.7	77.4
	May Peak Day	0.25	0.35	37.5	53.5
	June Peak Day	0.48	0.60	72.4	90.8
	July Peak Day	0.42	0.54	63.8	81.9
	August Peak Day	0.36	0.48	54.7	72.1
	September Peak Day	0.32	0.43	47.8	65.0
	October Peak Day	0.21	0.31	31.5	46.6
1-in-10 CAISO	Typical Event Day	0.49	0.62	74.4	93.1
	May Peak Day	0.37	0.49	56.8	74.2
	June Peak Day	0.45	0.57	68.4	86.9
	July Peak Day	0.58	0.72	87.9	108.6
	August Peak Day	0.53	0.65	79.4	98.6
	September Peak Day	0.41	0.53	61.8	79.3
	October Peak Day	0.31	0.41	46.2	62.4

Under CAISO system peaking weather conditions, forecasted impacts from SmartAC decline by approximately 10–15%. This drop results from the fact that PG&E and CAISO peaks are not perfectly correlated with one another[42] so that during CAISO system peaks, demand on the PG&E system is not at its maximum.

5.2 Small and Medium Businesses (SMB)

SmartAC operations for the SMB segment have not changed since 2011, while ex ante weather conditions were updated in 2014 to include both PG&E and CAISO. The only source of change in ex ante load impact estimates for SMB customers in 2015 stems from a new enrollment forecast that was provided by PG&E. Enrollment projections for SMB customers by local capacity area as of August for the period 2016–2026 are presented in Table 5-3, which shows a continued decline in SMB enrollment for each LCA.

Table 5-3: Projected SMB Enrollment for August of Each Year

LCA	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Greater Bay Area	1,391	1,309	1,231	1,157	1,089	1,024	963	906	852	801	753
Greater Fresno	413	388	365	344	323	304	286	269	253	238	224
Humboldt	34	32	30	28	26	25	23	22	21	19	18
Kern	225	197	199	187	176	165	156	146	138	129	122
Northern Coast	450	394	398	374	352	331	311	293	275	259	243
Other	919	864	812	764	719	676	636	598	562	529	497
Sierra	317	299	281	264	248	234	220	207	194	183	172
Stockton	351	330	311	292	275	258	243	229	215	202	190
Total	**4,100**	**3,856**	**3,626**	**3,410**	**3,207**	**3,017**	**2,837**	**2,668**	**2,509**	**2,360**	**2,220**

Table 5-4 shows the per-customer and aggregate ex ante impact estimates for the SMB population under both PG&E and CAISO peaking conditions. For the 1-in-2 weather year based on PG&E peaking conditions, the highest average hourly aggregate impact occurs on June peak days, with an impact of 2.6 MW. The maximum hourly impact during a 1-in-2 year for June equals 3.0 MW. The July peak day shows the highest impacts for the PG&E 1-in-10 weather year, with a mean aggregate impact during the five hour event of 3.0 MW and a maximum hourly impact of 3.6 MW.

[42] The CAISO peak is often driven by peak demands in Southern California, which often do not line up with PG&E's system peaks.

Table 5-4: 2015 SMB SmartAC Ex Ante Load Impact Estimates by Weather Year and Day Type (Event Period 1–6 PM)

Weather Year	Day Type	Mean Hourly Per Customer Impact (kW)	Max. Hourly Per Customer Impact (kW)	Aggregate Mean Hourly Impact (MW)	Aggregate Max Hourly Impact (MW)
1-in-2 PG&E	Typical Event Day	0.61	0.72	2.5	3.0
	May Peak Day	0.39	0.46	1.6	1.9
	June Peak Day	0.62	0.73	2.6	3.0
	July Peak Day	0.62	0.73	2.6	3.0
	August Peak Day	0.61	0.71	2.5	2.9
	September Peak Day	0.53	0.63	2.2	2.6
	October Peak Day	0.30	0.36	1.2	1.5
1-in-10 PG&E	Typical Event Day	0.70	0.82	2.9	3.4
	May Peak Day	0.66	0.78	2.8	3.3
	June Peak Day	0.71	0.83	2.9	3.4
	July Peak Day	0.74	0.87	3.1	3.6
	August Peak Day	0.72	0.84	3.0	3.5
	September Peak Day	0.58	0.69	2.4	2.8
	October Peak Day	0.47	0.55	1.9	2.2
1-in-2 CAISO	Typical Event Day	0.49	0.59	2.0	2.4
	May Peak Day	0.38	0.45	1.6	1.9
	June Peak Day	0.58	0.68	2.4	2.8
	July Peak Day	0.57	0.67	2.3	2.8
	August Peak Day	0.45	0.53	1.8	2.2
	September Peak Day	0.43	0.51	1.7	2.1
	October Peak Day	0.30	0.36	1.2	1.5
1-in-10 CAISO	Typical Event Day	0.65	0.77	2.7	3.2
	May Peak Day	0.48	0.57	2.0	2.4
	June Peak Day	0.56	0.66	2.3	2.7
	July Peak Day	0.72	0.84	3.0	3.5
	August Peak Day	0.68	0.79	2.8	3.2
	September Peak Day	0.51	0.60	2.1	2.5
	October Peak Day	0.42	0.50	1.7	2.0

5.3 Relationship between Ex Post and Ex Ante Aggregate Impacts

Ex post and ex ante aggregate load impacts may differ for a variety of reasons, including differences in weather conditions, differences in the number of customers dispatched, differences in the event window, etc. Table 5-5 lists all of the possible factors that might cause differences and indicates the expected magnitude of the influence for each factor. The biggest reason why ex post and ex ante aggregate impacts differ so much is that typically only 10% of the program is called during a test event, whereas the ex ante analysis assumes that all customers in the program would be called. Including dually enrolled customers in the ex ante aggregate estimates is another important differentiating factor. Differences in weather and the length and timing of the event window can also be influential, while differences in methodology should have a relatively small impact since the ex ante model uses ex post impacts as an input.

Table 5-5: Summary of Factors Underlying Differences Between Ex Post and Ex Ante Aggregate Impacts for the Residential SmartAC Program

Factor	Ex Post	Ex Ante	Magnitude of Expected Impact
% of resource dispatched	10-20% of the program is typically dispatched for each event, with the other 80-90% acting as the control group for the evaluation	Assumes 100% dispatch	Biggest impact of all factors
Event window	This varies significantly from event to event with the shortest events lasting only one hour and the longest lasting upwards of 9 hours (cascading event)	Uniform ex ante event window is 5 hours, from 1 to 6 PM	Could have significant impact since most ex post events occurred during the highest load hours and a longer event window will include lower load hours
Weather	78.2 < mean17 < 84.6 (event day) Average event day mean17 = 82.3	Mean17 for the 1-in-2 typical event day (PG&E/CAISO) = 81.0/77.8 Mean17 for the 1-in-10 typical event day (PG&E/CAISO) = 84.0/81.4 CAISO peaking weather conditions significantly different from PG&E peaking weather conditions	PG&E 1-in-2 year typical event day impact will be slightly higher than the average ex post event due to differences in weather PG&E and CAISO 1-in-10 year typical event day impacts will be significantly higher due to weather
Enrollment	The number of dually enrolled customers has increased from a very small fraction in 2011 to approximately 24% in 2015. As discussed in Section 3, ex post impacts	Includes dually enrolled customers and assumes their share of total program enrollment does not change from the end of summer 2015	Average impacts are lower for dually enrolled customers than for SmartAC-only customers. However, incorporating dually enrolled customers into

Factor	Ex Post	Ex Ante	Magnitude of Expected Impact
	typically can only be estimated for SmartAC-only customers[43]		the aggregate program estimate increases the value significantly compared with the ex post estimates that do not include this customer segment
Methodology	Impacts based on RCT with large sized treatment and control groups	Regression of ex post impacts against weather variables for common hours using five years of ex post impacts	Small

Table 5-6 and Figure 5-1 show how aggregate load impacts change as a result of differences in the factors underlying ex post and ex ante estimates. Table 5-6 covers the 2015 events, while the figure plots the average values shown at the bottom of the table. For the cascading event on August 17, only the impacts from 3 to 6 PM are shown to allow for an easier comparison to other events.

As seen in column C in Table 5-6, mean17 varied by roughly 7% across ex post event days, from a low of 78.8 on August 15 to a high of 84.5 on September 10. Because mean17 is an average temperature across 17 hours, the high end of this range can represent a much hotter day than the lower end, which can result in significant differences in loads and load impacts. The percent of the resource dispatched (Column D) was 10% for all events except July 28 and September 9, when 4 of the 10 groups were called. Column E shows the aggregate impacts for the percent of the program dispatched—excluding dually enrolled customers—whereas Column F represents what the load reduction would have been under the event conditions if all SmartAC-only customers had been dispatched. Column G scales the aggregate impacts up further to include dually enrolled customers and estimates the impact that would have been achieved under the observed ex post weather and event window conditions if the whole program had been called and SmartRate was not called at the same time.

Columns H through L incorporate the influence of ex ante assumptions about weather, event window, and forecasted enrollment, and also capture differences between the ex post and ex ante methodologies. Column H uses the ex ante model to predict what the impacts would have been under ex post weather conditions and event duration and timing. This reflects the influence of the change in methodology from the RCT based ex post estimates to the regression based ex ante estimates. The regression model over predicts the ex post values by about 12% (82.5 MW vs. 76.8 MW) because the model is estimated using data from 2011–2015 and the observed impacts in 2015 are lower than in past years (see Section 4).

43 The exceptions to this are event days that were not also SmartRate Days, which allows for dually enrolled customers to be included in the analysis.

Table 5-6: Differences in Ex Post and Ex Ante Impacts Due to Key Factors

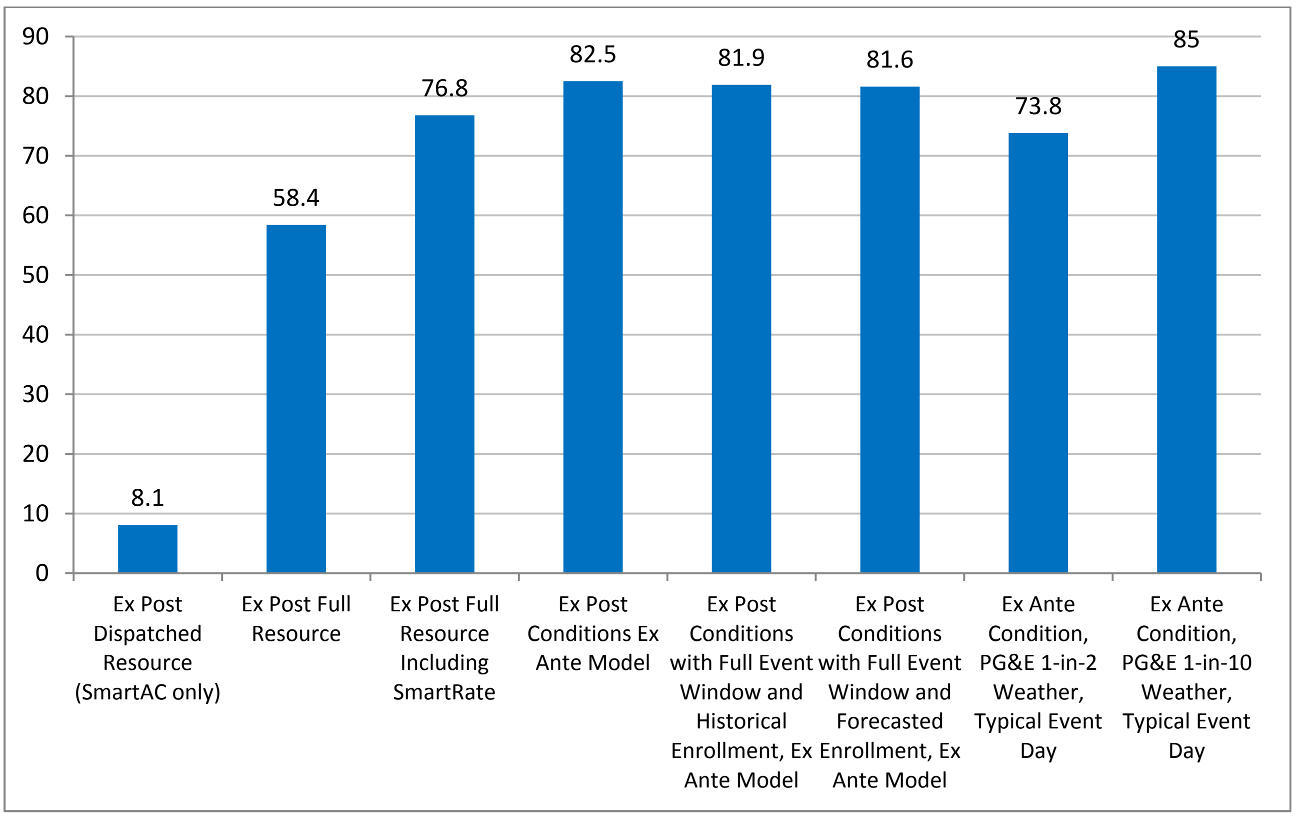
<table>
<tr><th rowspan="3">(A)
Date</th><th colspan="6">2014 Ex Post Aggregate Estimates</th><th colspan="5">Aggregate Estimates Based on Ex Ante Model</th></tr>
<tr><th rowspan="2">(B)
Event Window</th><th rowspan="2">(C)
Mean17</th><th rowspan="2">(D)
% of Resources Dispatched</th><th rowspan="2">(E)
Aggregate Reduction of SmartAC-only (MW)[44]</th><th rowspan="2">(F)
Scaled to Entire SmartAC-only Population</th><th rowspan="2">(G)
Scaled Up to include Dually Enrolled</th><th rowspan="2">(H)
Historical Window, Weather & Enrollment</th><th colspan="4">Standardized Event Window</th></tr>
<tr><th>(I)
Historical Weather & Enrollment</th><th>(J)
Historical Weather, Forecast Enrollment</th><th>(K)
1-in-2 Year Weather, Forecast Enrollment</th><th>(L)
1-in-10 Year Weather, Forecast Enrollment</th></tr>
<tr><td>June 25</td><td>1-6 PM</td><td>81.8</td><td>10%</td><td>5.0</td><td>66.0</td><td>86.8</td><td>86.4</td><td>78.7</td><td>78.5</td><td rowspan="12">73.8 (PG&E)
59.7 (CAISO)</td><td rowspan="12">85.0 (PG&E)
74.4 (CAISO)</td></tr>
<tr><td>June 30</td><td>7-8 PM</td><td>84.1</td><td>10%</td><td>6.1</td><td>69.0</td><td>90.8</td><td>80.0</td><td>91.7</td><td>91.4</td></tr>
<tr><td>July 1</td><td>4-7 PM</td><td>84.1</td><td>10%</td><td>4.3</td><td>47.0</td><td>61.8</td><td>82.6</td><td>77.5</td><td>77.2</td></tr>
<tr><td>July 28</td><td>4-7 PM</td><td>81.3</td><td>40%</td><td>22.6</td><td>62.8</td><td>82.6</td><td>87.6</td><td>79.7</td><td>79.5</td></tr>
<tr><td>July 29</td><td>1-5 PM</td><td>84.0</td><td>10%</td><td>5.7</td><td>63.0</td><td>82.9</td><td>78.9</td><td>87.6</td><td>87.3</td></tr>
<tr><td>August 15</td><td>4-6 PM</td><td>78.8</td><td>10%</td><td>4.8</td><td>66.0</td><td>86.8</td><td>82.0</td><td>70.2</td><td>70.0</td></tr>
<tr><td>August 17</td><td>12AM -9 PM</td><td>84.3</td><td>10%</td><td>5.0</td><td>69.0</td><td>90.8</td><td>95.1</td><td>87.7</td><td>87.4</td></tr>
<tr><td>September 8</td><td>1-3 PM</td><td>79.2</td><td>10%</td><td>1.7</td><td>17.0</td><td>22.4</td><td>48.4</td><td>73.5</td><td>73.2</td></tr>
<tr><td>September 9</td><td>4-7 PM</td><td>83.1</td><td>40%</td><td>22.9</td><td>64.0</td><td>84.2</td><td>91.9</td><td>87.3</td><td>87.1</td></tr>
<tr><td>September 10</td><td>4-7 PM</td><td>84.5</td><td>10%</td><td>5.8</td><td>65.0</td><td>85.5</td><td>89.9</td><td>88.7</td><td>88.4</td></tr>
<tr><td>September 11</td><td>3-6 PM</td><td>83.0</td><td>10%</td><td>4.8</td><td>53.0</td><td>69.7</td><td>84.2</td><td>78.1</td><td>77.9</td></tr>
<tr><td>Average</td><td>N/A</td><td>82.6</td><td>15.5%</td><td>8.1</td><td>58.4</td><td>76.8</td><td>82.5</td><td>81.9</td><td>81.6</td></tr>
</table>

[44] Column E accounts for only single-device customers. Multi-device customers are incorporated in Column F.

Another potential influential factor underlying the difference between ex post and ex ante impacts is the change in the event window from the typically short ex post window covering the hottest hours of the day to the longer resource adequacy window that includes lower load hours in the early afternoon. As seen in column I, shifting from the ex post to the ex ante event window has only a minor effect on the predicted impact (less than 1%). Column J shows the influence of the very slight decrease in projected enrollment between the end of the summer in 2015 and the projected enrollment in 2016, which is very small.

The last two columns (K and L) show the impact of changing from ex post weather conditions to 1-in-2 and 1-in-10 year weather conditions (PG&E system peaking conditions). Shifting from ex post to ex ante 1-in-2 year weather reduced impacts by roughly 10%, whereas using 1-in-10 year weather conditions results in impacts that differ from the observed ex post conditions by only 4%. This suggests that 2015 events were called on particularly hot days that are more representative of the extreme 1-in-10 conditions than the more mild (and common) 1-in-2 conditions.

Figure 5-1: Differences in Ex Post and Ex Ante Impacts Due to Key Factors



6 Operability Analysis

Two primary datasets were used to conduct the operability analysis, both of which were collected by PG&E's implementer for SmartAC (GoodCents). All information was collected through site visits to individual customers' homes in the Greater Bay Area and Central Valley according to the sample design described in Section 3.3.

The first analysis dataset contains information recorded by GoodCents technicians during a physical inspection of 835 load control devices[45] that also included a test of the device's ability to receive load control signals. Table 6-1 shows the actions performed by GoodCents' technicians on site, including whether a switch was removed or replaced.[46] Nearly all of the site visits (98%) consisted of inspections only.

Table 6-1: Inspections, Removals, and Replacements Conducted by GoodCents

Device Action	Switch Vintage									
	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Inspection Only	84	79	88	95	93	99	96	92	89	**815**
Removed Switch	1	3	0	3	2	0	1	1	0	**11**
Replaced Switch	1	1	2	1	0	0	1	2	1	**9**
Total	**86**	**83**	**90**	**99**	**95**	**99**	**98**	**95**	**90**	**835**

Table 6-2 shows the device statuses that were recorded for the 815 sites where an inspection was performed and provides more information on the physical condition of the switches. In both the Greater Bay Area and Central Valley, most switches were present and appeared to be connected properly, while only a handful were missing, connected incorrectly, or dysfunctional because of other issues with the air conditioning unit.

Table 6-2: Status of Inspected Devices

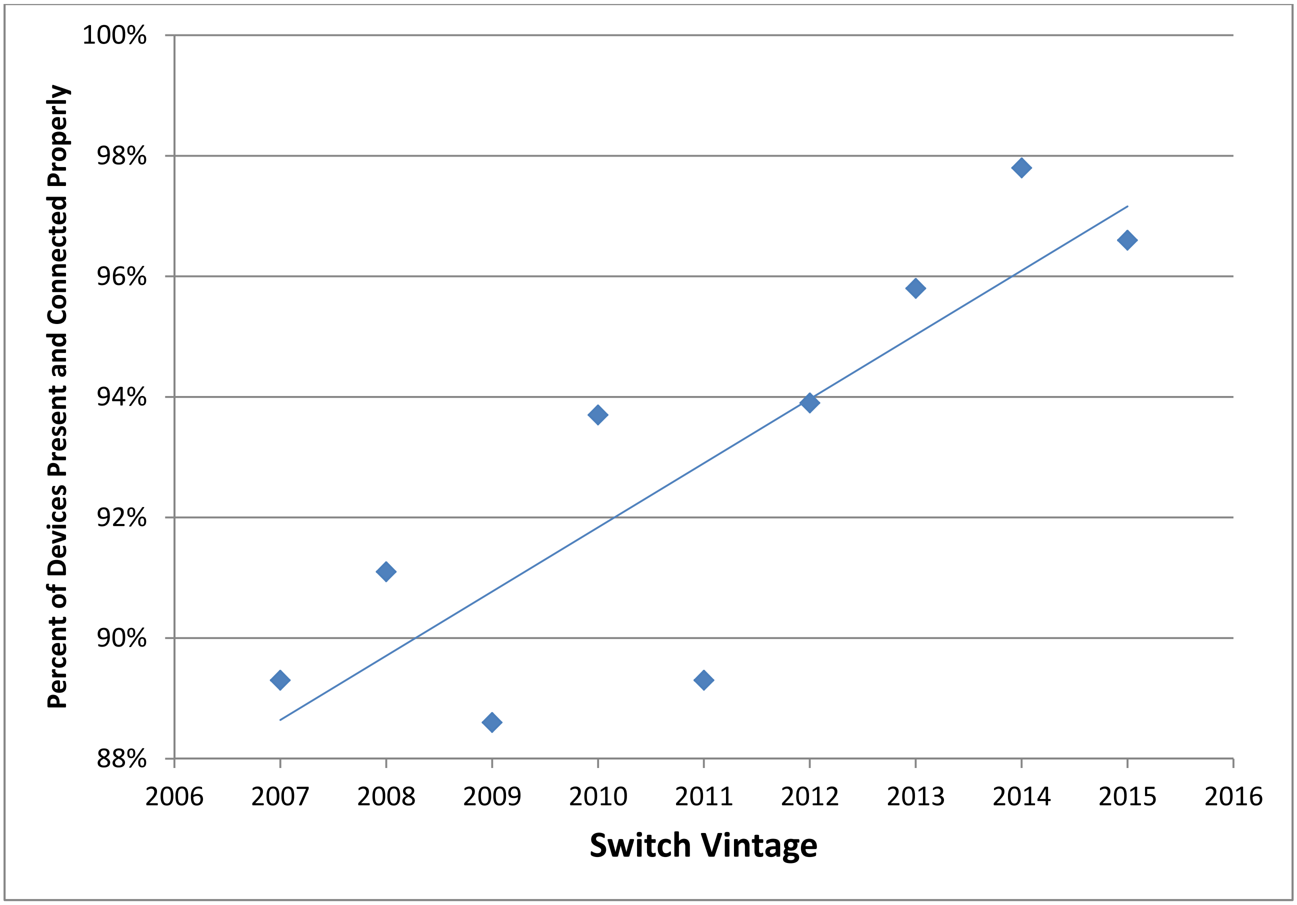
Device Status	Bay Area (n=395)	Central Valley (n=420)
Device Present and Connected Properly	94%	92%
Device Present but Not Connected	3%	3%
Device Not Present	<1%	1%
HVAC Company Tampering	2%	1%
New AC Installed	<1%	1%
Device Malfunctioning – Internal Errors	0%	<1%
AC Not Working	0%	<1%
Device Malfunctioning - Communications	0%	<1%

45 Only LCR switches were included in the operability analysis sample due to the difficulty in getting access to PCTs inside customers' homes and the poor performance of the ExpressStat devices.

46 Switches are sometimes removed or replaced by technicians performing AC maintenance or replacing an old AC unit.

Plotting the percentage of devices properly connected by switch vintage shows a clear pattern between the age of the switch and its functionality. As shown in Figure 6-1, the likelihood of a switch being broken or disconnected increases the older the switch becomes.

Figure 6-1: Connectivity of Installed Switches by Vintage



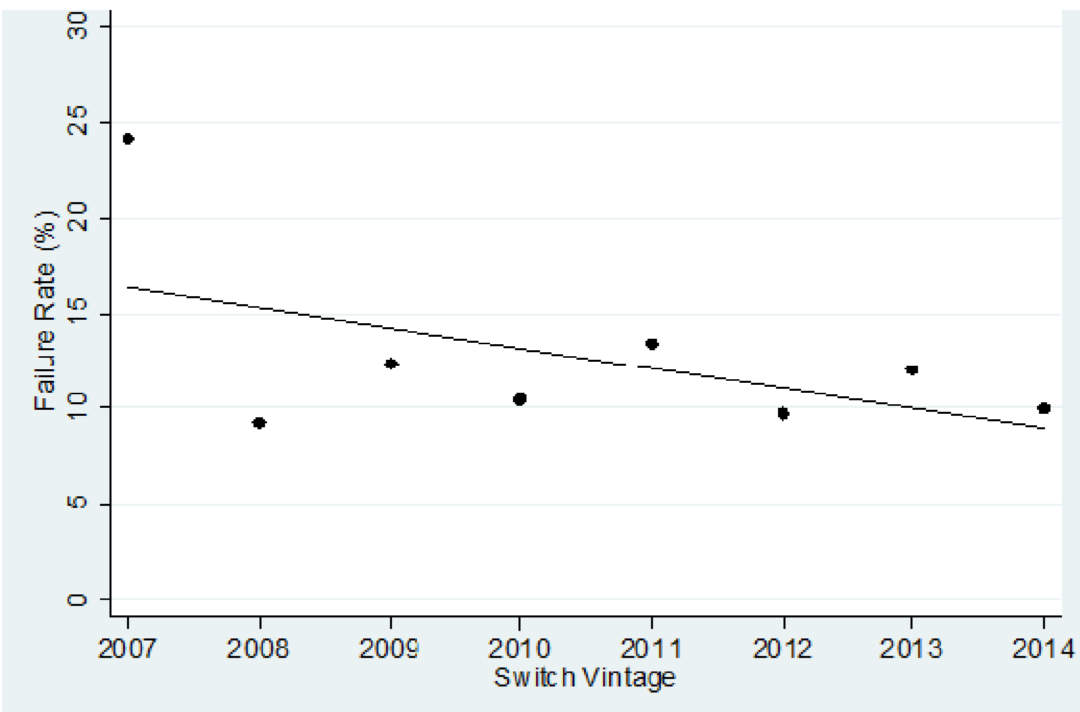
The second dataset used for the operability analysis contained runtime data from the switches that was downloaded by GoodCents' technicians during site visits. Due to a compatibility issue between the newer generation of load control devices and the equipment used to complete the download, data was downloaded for only about 700 of the 821 devices for which inspections were completed. The downloaded data contained hourly information on the runtime of the AC unit as well as the number of minutes of load control, which were both used to assess the performance of switches during events. The primary outcome variable for analysis was the rate at which switches did not provide load control during event hours when AC units were running. Data cleaning and limiting the sample to only the event hours where a AC unit was running whittled the sample size down to a little over 1,200 individual event hours for about 400 individual devices spread across the 18 sample cells (Table 6-3). Devices installed between 2007 and 2013 are well represented in the sample, but the number of 2014 switches is considerably smaller.

Table 6-3: Analysis Dataset Used for Estimation of Switch Failure Rates

Metric	Region	Switch Vintage								Total
		2007	2008	2009	2010	2011	2012	2013	2014	
Devices	Central Valley	23	26	26	32	30	34	30	13	214
	Bay Area	25	22	25	28	32	27	28	6	193
	Total Devices	**48**	**48**	**51**	**60**	**62**	**61**	**58**	**19**	**407**
Event Hours	Central Valley	58	74	77	96	94	118	120	40	677
	Bay Area	77	49	68	78	85	101	87	14	559
	Total Event Hours	**135**	**123**	**145**	**174**	**179**	**219**	**207**	**54**	**1,236**

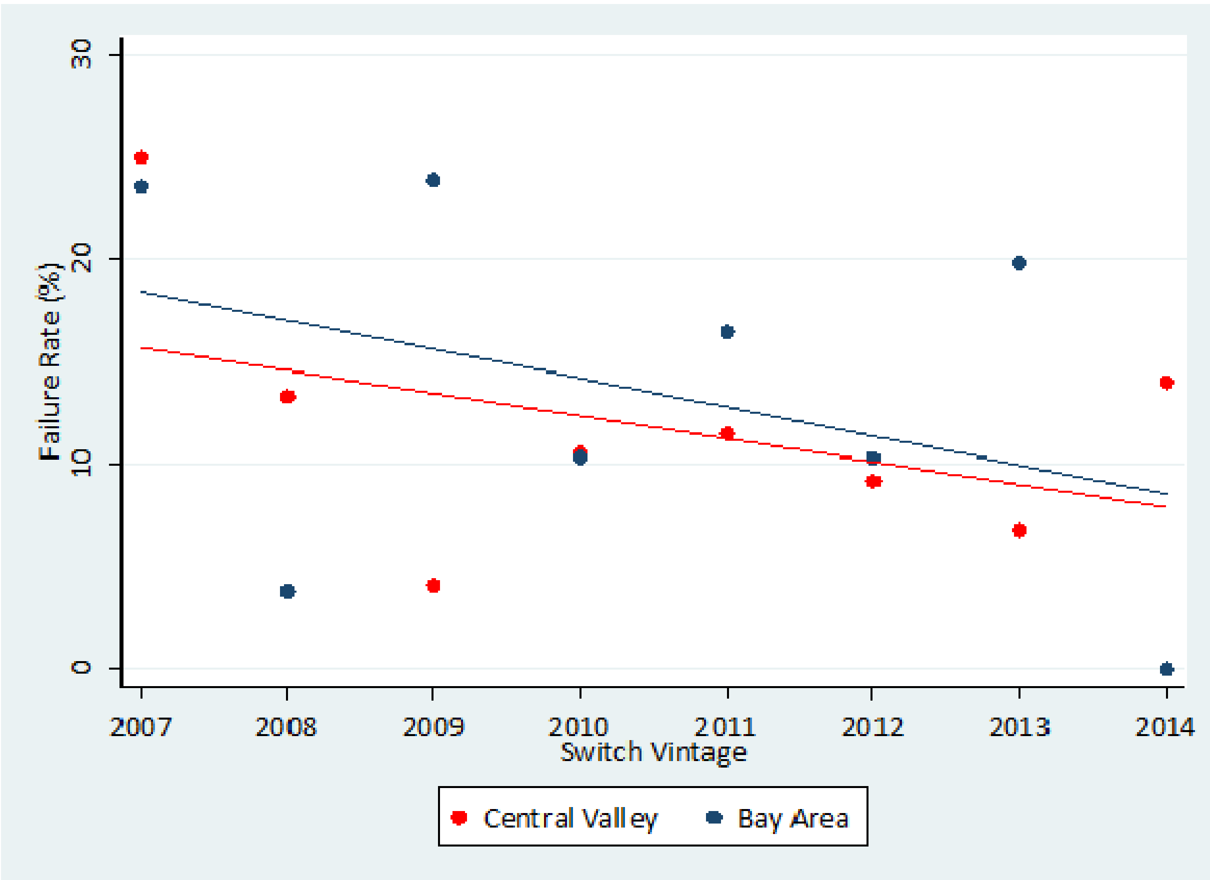
Using event hours as the denominator and the number of event hours when a AC unit was running, but no load control occurred, yields an estimate of the switch failure rate. Plotting the failure rate against switch vintage—shown in Figure 6-2—reveals a similar pattern of older switches having higher failure rates. Because there is no data from physically damaged switches in the runtime dataset, these failures can be attributed to communications failures associated with the pager network.

Figure 6-2: Estimated Communication Failure Rates for SmartAC Switch Vintages



Communication failure rates range from a high of about 25% for devices installed in 2007 to lows slightly below 10%. When the two regions are pooled together, the 2007 switches clearly stick out as the worst performers. When 2007 switches are excluded, failure rates stabilize between 10–15% and the trend between failure rate and vintage becomes much more difficult to discern. When comparing the Bay Area to the Central Valley—as shown in Figure 6-3—the overall trends are similar even though there are some large differences for individual vintages. The 2007 switches remain the worst performers in both areas, but patterns become harder to discern.

Figure 6-3: Communication Failure Rates by Vintage and Region



Combining the communication failure estimates with the physical connectivity failures gives a sense of the overall failure rates for switches of different vintages. For 2007 devices, the overall failure rate could potentially be as high as 34%, while failure rates for 2009 and 2011 are also potentially above 20%.

Table 6-4: SmartAC Switch Failure Rates by Vintage

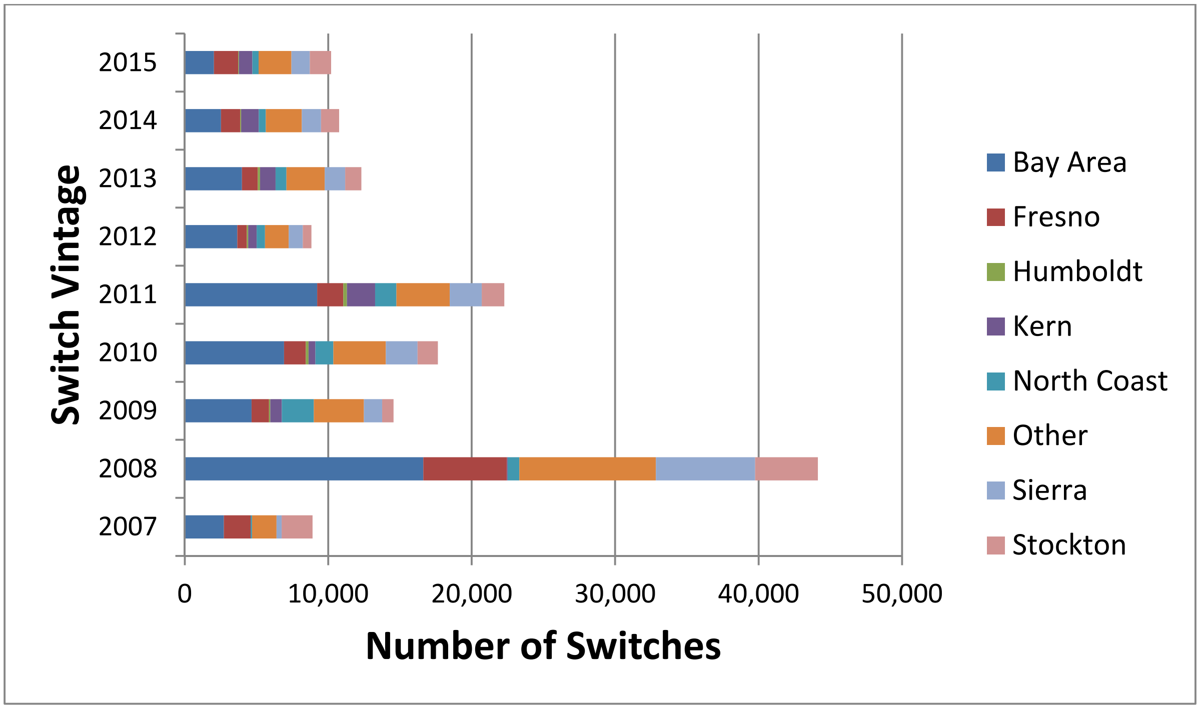
Switch Vintage	# of Switches in SmartAC Population	% of Total Switches	Physical Failure Rate	Communications Failure Rate	Overall Failure Rate[47]
2007	8,912	6%	11%	25%	33%
2008	44,132	30%	9%	10%	18%
2009	14,549	10%	11%	12%	22%
2010	17,643	12%	6%	10%	15%
2011	22,275	15%	11%	13%	23%
2012	8,827	6%	6%	10%	15%
2013	12,307	8%	4%	12%	16%
2014	10,765	7%	2%	10%	12%
2015	10,204	7%	3%	10%	13%
All	**149,615**	**100%**	**8%**	**12%**	**19%**

A weighted average of the failure rates using the data in Table 6-4 yields an overall failure rate of approximately 19% for the population.[48] When thinking about how the failure rates affect the amount of DR resource SmartAC is capable of providing, it is important to consider that the distribution of each switch vintage across space is not the same. Figure 6-4 shows where the devices in each switch vintage are installed. Although the number of 2007 switches is smaller than other vintages, about 65% of these switches are located in Fresno, Stockton, and “Other” LCAs that experience very hot temperatures during events and have high load reduction potential. This means that while 2007 switches make up only 6% of the population, the failure of those switches is likely to have an outsized effect on overall program performance.

[47] To calculate the overall failure rate, it was assumed that the percentage of devices that are not connected correctly would be equally likely to experience communication failure as the population of properly connected devices (i.e., the two causes of failure are independent). To avoid double counting, the overlap of the two types of failure was subtracted from the sum of the individual causes.

[48] For the purposes of the overall failure rate, 2015 switches were assumed to experience the same failure rate as 2014 switches.

Figure 6-4: Distribution of LCAs for Each Switch Vintage



7 Survey Results

This section contains an analysis of the post-event survey that was conducted after the event on Wednesday, September 9 as well as the notification surveys conducted at the end of the 2015 event season. In total, 410 post-event surveys and 700 notification surveys were completed, with half of the responses coming from treatment customers who experienced load control and the other half coming from customers not called during the event (control).[49] The focus of both surveys was customer thermal comfort, awareness of events, and any actions that customers took in reaction to perceiving that an event occurred. The complete post-event survey instrument is provided in Appendix A.1, with supplemental survey analysis provided in Appendix A.2. Key results from the notification surveys are provided in Appendix D.

7.1 Thermal Comfort

Survey participants were asked questions about whether or not the temperature in their homes was uncomfortable in recent days. Responses to Question 4—as shown in Figure 7-1—show that customers who had their SmartAC devices activated during the event were equally likely to report uncomfortable temperatures in their homes around the time of the event as control customers (about 40%). Similarly, when customers who reported being uncomfortable were asked whether or not the uncomfortable temperature at home was a regular occurrence—as shown in Figure 7-2—responses for treatment and control customers were again very similar, with around 25% of customers stating that uncomfortable temperatures happened often. Two sample tests of proportions show that neither of the above differences is statistically significant,[50] which is evidence that the event on September 9 did not have a meaningful impact on the thermal comfort of customers who experienced load control.

[49] All surveys were fully completed so that there are no missing responses for any of the questions. No surveys were terminated due to customers having a household affiliation with PG&E.

[50] p=0.84 for Q4 and p=0.81 for Q6.

Figure 7-1: "Was home temperature uncomfortable recently?" (Q4)

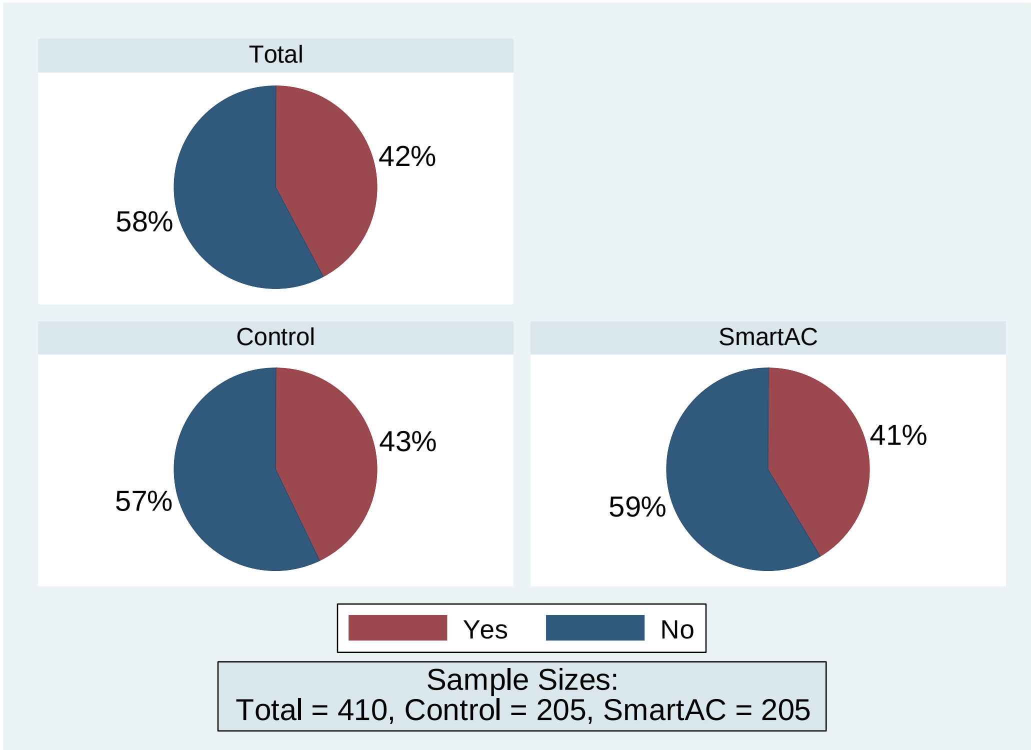
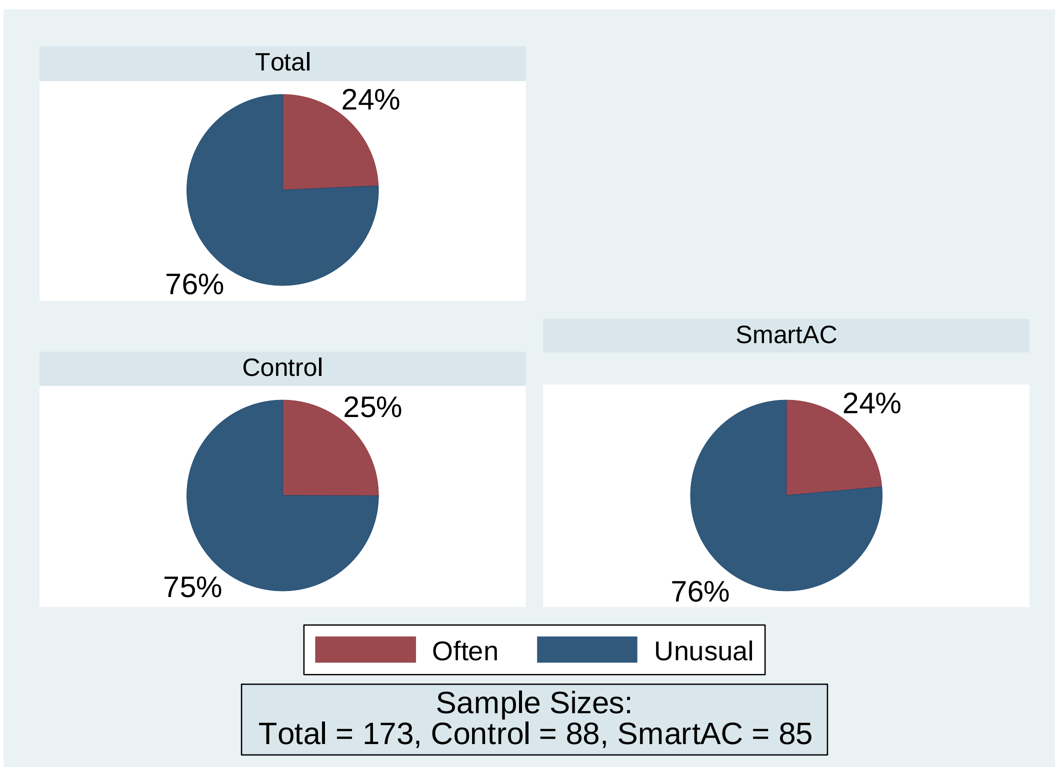


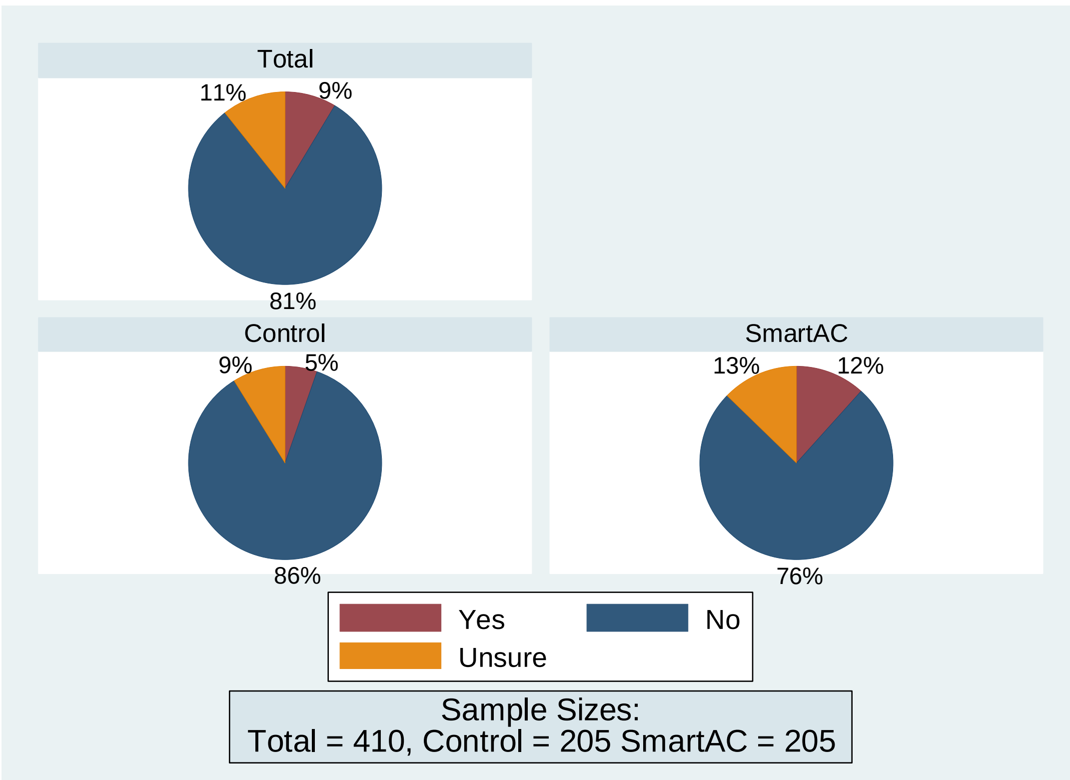
Figure 7-2: "Is home temperature uncomfortable often or is this an unusual day?" (Q6)



7.2 Event Awareness

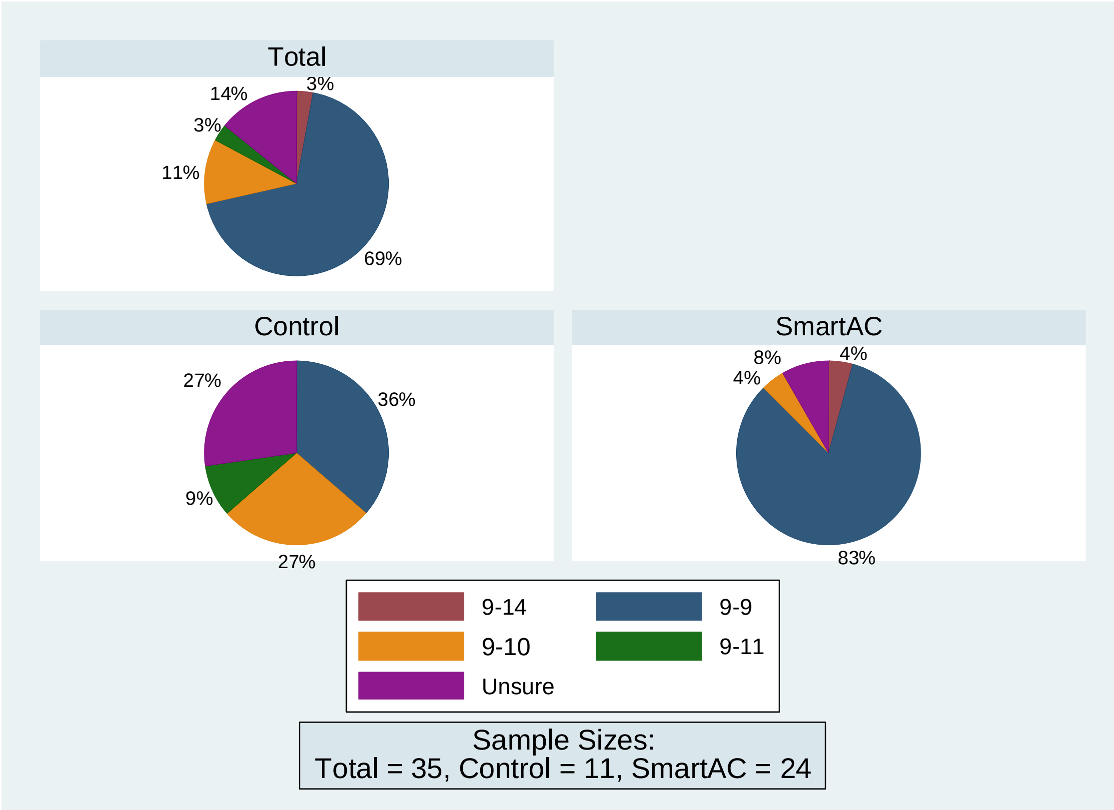
Other survey questions asked customers about their awareness of the event. In Question 11, customers were asked if their SmartAC device was activated recently—see Figure 7-3. Only 20% of all customers answered “Yes” or “Unsure;” however, treatment customers were more likely to suspect that their device was activated than control customers[51] (12% vs. 5%). Question 12 asked customers who answered “Yes” to Question 11—which day they thought their device was activated. Of the 24 treatment customers who said that their device was activated, 20 (83%) were able to correctly identify the event day (September 9). Responses for control customers who mistakenly believed that their devices were activated lack any discernable pattern.

Figure 7-3: “Did you notice that your SmartAC device was activated in the last few days?” (Q11)



[51]Chi-square goodness of fit test produces a p-value < 0.01.

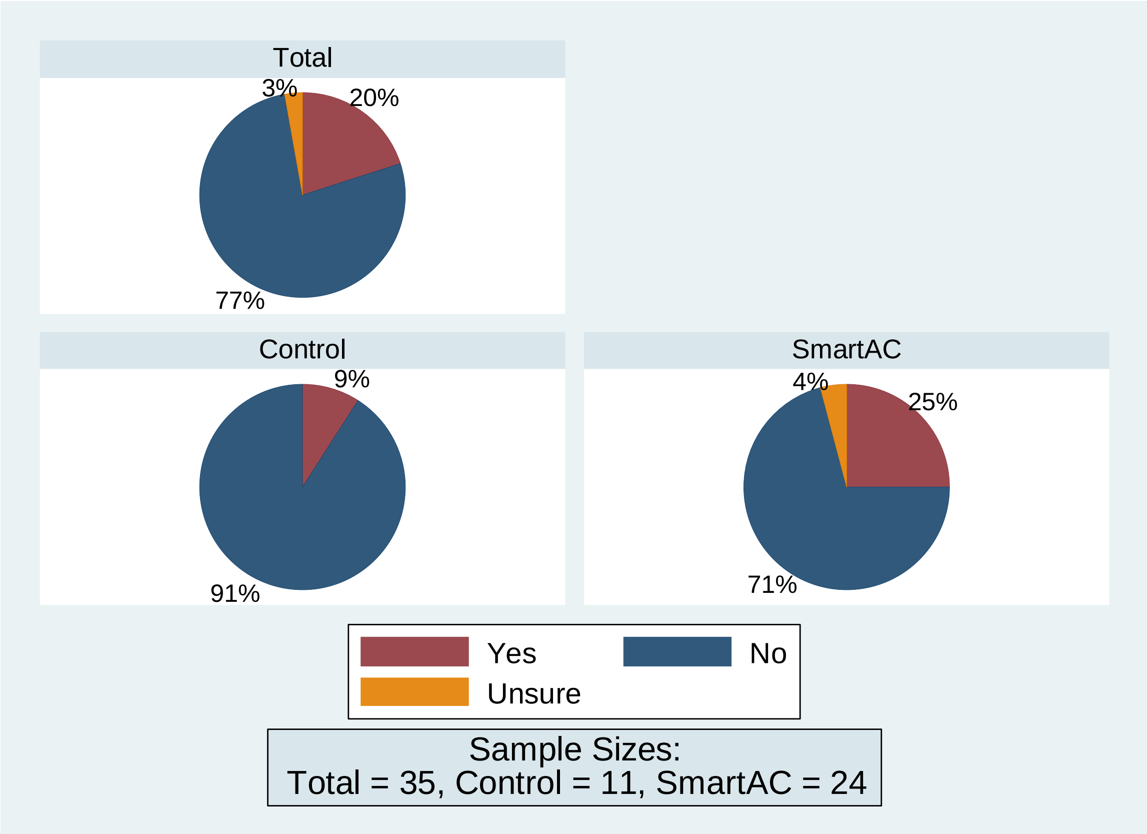
Figure 7-4: “Which day was the device activated?” (Q12)



7.3 Actions Taken in Response to Event

Of the 35 survey respondents who believed that an event recently took place, only seven—six treatment, one control—stated that they did anything differently on the event day or took “any action” in response, as shown in Figure 7-5. When asked what types of actions were taken, one treatment customer reported contacting PG&E, while the remaining six said that they took “other actions.”

Figure 7-5: "Did you take any action or do anything differently because of this event?" (Q15)



Overall, the results of the September 9 post-event survey show that most customers who experienced load control did not notice that their devices were activated. The small number of customers who did notice the event were generally able to correctly identify the date and time that it occurred. The survey results do not provide any evidence that customers who had their SmartAC devices activated were negatively impacted in terms of their thermal comfort or that a significant number of customers took any kind of direct actions in response to the event.

7.4 Event Notifications

Surveys for the group of customers who received event notifications and the corresponding control group showed that sending notifications increased awareness of SmartAC events and improved several key measures of customer satisfaction. Twice as many customers in the test group reported being aware of SmartAC events (46% vs. 23%) and most customers who were aware that events characterized them as "easy." Customer satisfaction benefits included higher satisfaction with load control devices, increased trust in PG&E, and higher overall satisfaction with the SmartAC program. Notifying customers of events also did not result in any statistically significant increases in either opt-out rates or de-enrollment.

8 Conclusions and Recommendations

The 2015 SmartAC test events produced a number of useful insights into the program's operation and load curtailment capability. The 11 events covered a wide range of hours and also included 2 days that did not coincide with SmartRate event days. Furthermore, the 2015 ex post event day on which multiple events were called for different groups across the hours from noon through 9 PM produced very useful data on the magnitude of the demand response resource in the early afternoon and early evening hours. Test events provided evidence that PG&E's new targeted marketing approach is succeeding in attracting customers with larger AC loads and that single family customers provide larger load reductions than customers in multi-family dwellings. Results from the ex post analysis did not show any significant differences in impacts for CARE vs. Non-CARE customers or single vs. multi-device households when impacts were estimated at the whole-house level.

Results from the ex post analysis also revealed a downward trend in average impacts after controlling for the hours when the events were called and event day temperatures. Several factors likely contributed to these lower impacts. Reference loads on event days in 2015 were lower than reference loads at comparable temperatures for previous years, suggesting that there may not be as much load available for curtailment as in past years. A second contributing factor is that approximately 5,000 ExpressStat PCTs provided no measureable load reductions during event days. Finally, an analysis of the operability of switches estimated a switch failure rate of nearly 20% for the current SmartAC population and 34% for switches installed during the first year of SmartAC enrollment (2007). Failure rates were higher for older switches and were caused both by physical connection issues (missing/broken switches) and communication issues that prevent signals from being received through the pager network.

As a result of the declining load impacts revealed in the ex post analysis, aggregate ex ante impacts have also declined compared to previous years. Under 1-in-2 weather conditions for PG&E peaking conditions, SmartAC is expected to produce an average load impact of 73.8 MW on a typical event day, with a maximum reduction of 92.3 MW. For CAISO, the forecasted 1-in-2 impacts on a typical event day are 59.7 MW (average) and 77.4 MW (maximum). The two factors causing reduced impacts that can be most easily addressed by PG&E are the failure of the ExpressStat PCTs and the decline in the operability of older switches. We recommend replacing ExpressStat PCTs and non-communicating older switches with new LCR switches[52] to improve performance in a cost-effective manner. We also recommend conducting additional analysis in the spring and early summer to better understand the declining reference loads and assess PG&E's options for addressing it.

The large number of events called by PG&E during the 2015 season facilitated a shift in the ex ante methodology to a more streamlined model that is more transparent than previous versions and requires fewer assumptions. Robust cross-validation techniques were used to test the ex ante model specification for the first time since 2012 and showed that adding same-hour temperature as a predictor reduced model prediction error by 4 to 6%. More granular

[52] PG&E is in the process of field testing new two-way communicating switches that leverage the AMI network, so these switches should be used if possible.

adjustments for dually enrolled customers were also incorporated into the analysis based on ex post results from non-SmartRate days. For the ex ante analysis, we continue to recommend calling a large number of test events in future years to generate more useful data and to further increase the robustness of the estimates.

Similar to past years, the post-event survey conducted after the September 9 event showed that customers who experience load control during events are not significantly more uncomfortable than customers who do not experience load control. Events are not generally noticed when they occur and in the rare cases where they are noticed, customers do not often adjust their behavior at all in response. Sending event notifications to customers on the day prior to an event via email resulted in small improvements in customer satisfaction. Going forward, we recommend revisiting the post-event survey design to identify new research questions of interest to the SmartAC program team that could be answered by the survey in 2016.

Appendix A: 2015 SmartAC Post-Event Survey (Sept. 9, 2015)

A.1 Survey Instrument

INTRODUCTION

Hello, my name is (______) and I am calling on behalf of PG&E to ask you a few questions about how your household uses electricity and your satisfaction with our service. This will take only a few minutes and will help us to better understand your service needs and what we can do to improve our service.

For this survey, I need to speak to an adult member of the household. Are you an adult member of the household?

No – ask for adult
Yes – Go to next question

This will just take a few minutes, can we do it now?

No – reschedule
Yes – Proceed with interview

SCREENER

1. Are you or is anyone in your household employed by PG&E?
    1. [Yes] THANK AND TERM
    2. [No] CONTINUE
    3. [Don't Know] THANK AND TERM

QUESTIONS

First, I would like to ask you some questions about your air conditioning system and the way you use it.

2. Could you tell me how often you or someone else in your household uses your air conditioning on <u>summer weekday afternoons</u> between 12 PM and 6 PM?
    1. Almost never
    2. Once or twice a week
    3. Three or four times a week
    4. Five days a week

2a. Could you tell me how often you or someone else in your household uses your air conditioning on <u>summer weekend afternoons</u> between 12 PM and 6 PM?
    1. Almost never
    2. One day
    3. Both days

3. Could you tell me how often you or someone else in your household uses your air conditioning on <u>summer weekday evenings</u> between 6 PM and midnight?
    1. Almost never
    2. Once or twice a week
    3. Three or four times a week
    4. Five days a week

3a. Could you tell me how often you or someone else in your household uses your air conditioning on summer weekend evenings between 6 PM and midnight?
  1. Almost never
  2. One day
  3. Both days

4. Was there any time earlier [today/ yesterday/on Thursday] when the temperature in your home was uncomfortable?
   1. Yes
   2. No – Go to Q8

4a. Can you rate how uncomfortable you were? Please use a discomfort scale of 1 to 5 where 1 means "Very Uncomfortable" and 5 means "Not at all Uncomfortable".
  1 Very Uncomfortable
  2
  3
  4
  5 Not at all Uncomfortable

5. During what hours were you uncomfortable?
   1. Uncomfortable start _____
   2. Uncomfortable end ____

6. Is the temperature in your home often uncomfortable during those hours or was [today/yesterday/Thursday] an unusual day?
   1. Often uncomfortable during those hours
   2. It was an unusual day

7. What do you think caused the temperature in your home to be uncomfortable?
   1. Air conditioner unit was not on
   2. Air conditioner doesn't work properly
   3. PG&E was controlling air conditioner
   4. It was a very hot day
   5. Other (specify) ____

Now I'd like to ask you some questions regarding PG&E's SmartAC Program.

8. According to our records, your home is enrolled in PG&E's SmartAC™ program. Are you familiar with this program?
   1. [Yes]
   2. [No]
   3. [Don't know/Not sure]

9. **[**IF Q8=a**]** Based on all of your experiences with the SmartAC™ program so far, how satisfied have you been with the program overall? Please use a satisfaction scale of 1 to 10 where 10 means “Very Satisfied,” 5 means neither satisfied nor dissatisfied, and 1 means “Very Dissatisfied.”
    1 Very Dissatisfied
    2
    3
    4
    5 Neither Satisfied nor Dissatisfied
    6
    7
    8
    9
    10 Very Satisfied
    98 [Don’t know/Not sure]

10. [IF Q9<98] Why did you give that rating? OPEN END

11. PG&E recently tested the SmartAC™ system and activated some customers’ SmartAC™ devices. Did you notice if your device was activated in the past few days?
    1. Yes – I did notice the activation
    2. No – I did not notice the activation (skip to 20)
    8. I am unsure

12. [IF Q11=1] On which day was your device activated?
    1. Tuesday, September 9th
    2. Wednesday, September 10th
    3. Thursday, September 11th
    4. Friday, September 12th
    5. Saturday, September 13th
    6. Sunday, September 14th
    7. Monday, September 15th
    8. I am unsure

13. [IF Q11=1] How did you notice this event? *(Check all that apply.)*
    1. [It was a hot day – I knew from the temperature outside]
    2. [It got warmer inside – the inside temperature went up]
    3. [Saw a message on the thermostat]
    4. [Saw a red light on the switch]
    5. [Did not hear the air conditioner running like I knew it should]
    6. [Heard about it on the news]
    7. [Heard about it from someone I know]
    8. [Some other way: ________________________]
    9. [Don’t know/Not sure]

14. [IF Q11=1] About what time did you first notice this event?
    1. Before noon
    2. Noon to 2:59pm
    3. 3:00pm to 4:59pm
    4. 5:00pm to 6:59pm
    5. 7:00pm or later
    6. Next day
    8. [Don't know/Not sure]

15. [IF Q11=1] Did you take any action or do anything differently because of this event?
    1. [Yes]
    2. [No]
    8. [Don't know/Not sure]

16. [IF Q15=1] What action did you take? *(Check all that apply.)*
    1. [Contacted PG&E]
    2. [Left home/work to go somewhere else to keep cool]
    3. [Changed activities, for example, decided to do something less strenuous]
    4. [Turned off lights and other energy using devices]
    5. [Declined to participate in the event (e.g., opted out) for the day]
    6. [Something else: _____________]
    8. [Don't know/Not sure]

17. [IF Q11=1] How did you feel about this activation event?

    ____

    ____

18. [IF Q11=1] Would you say this activation experience was …
    1. [Very easy]
    2. [Somewhat Easy]
    3. [Neither easy nor difficult]
    4. [Somewhat difficult]
    5. [Very difficult]
    8. [Don't know/Not sure]

19. Did you know that you can contact PG&E to decline to participate in a SmartAC event that day, meaning your air conditioner won't be cycled for that day?
    1. [Yes]
    2. [No]
    8. [Don't know/Not sure]

The next few questions are about how you typically use your central air conditioning (AC) on weekdays (Monday through Friday) and weekends (Saturday and Sunday) during the summer.

23. What type of thermostat(s) do you have – manual or programmable? Manual is one that has a dial or lever you move to turn it on and programmable has digital numbers.
    1. [Programmable]
    2. [Manual]
    3. [Both]
    8. [Don't know/Not sure]

24. Which of the following best describes how you operate your central AC system(s) during the summer? Do you … [READ]
    1. [Keep it set at a constant temperature so it runs whenever the temperature goes above this]
    2. [Manually turn the AC on and off when needed]
    3. [Manually adjust the temperature setting at different times such as when you leave your home or go to bed at night]
    4. [IF Q23=1 or 3][Allow the program to automatically change the temperature at different times]
    5. [Never use it]
    8. [Don't know/Not sure]

25. [IF Q24<5] How often does your central AC run in your home during summer weekday afternoons? Would you say it is … [READ]
    1. [Always on]
    2. [On most of time but sometimes cycles on and off]
    3. [On occasionally]
    4. [On rarely]
    5. [Never on]
    8. [Don't know/Not sure]

25a. [IF Q24<5] How often does your central AC run in your home during summer weekend afternoons? Would you say it is … [READ]
    1. [Always on]
    2. [On most of time but sometimes cycles on and off]
    3. [On occasionally]
    4. [On rarely]
    5. [Never on]
    8. [Don't know/Not sure]

26. Is someone who might control or adjust your AC temperature typically at home during summer weekday afternoons between 2 and 7pm?
    1. [Yes – Someone is usually at your home this entire time]
    2. [Yes – Someone is usually at your home for part of this time]
    3. [No]
    8. [Don't know/Not sure]

26a. Is someone who might control or adjust your AC temperature typically at home during summer weekend afternoons between 2 and 7pm?
    1. [Yes – Someone is usually at your home this entire time]
    2. [Yes – Someone is usually at your home for part of this time]
    3. [No]
    8. [Don't know/Not sure]

29. How would you compare your AC use on weekdays (Monday through Friday) vs. weekends (Saturday and Sunday)?
    1. [Use AC all of the time, regardless of time of week]
    2. [Use AC more on weekdays]
    3. [Use AC equally on weekdays and weekends]
    4. [Use AC more on weekends]
    5. [Varies every week]
    6. [Never Use AC]

The remaining questions will help us ensure that we are reaching all customers. Again, your individual identity will remain confidential and all of your answers will be summarized with responses from others.

D1. Do you own or rent your home?

1. [Own]
2. [Rent/lease]
3. [Other]
8. [Don't know/Not sure/Prefer not to answer]

D2. Which of the following best describes the type of home you live in? [READ LIST]

1. [Single family, detached (e.g., freestanding house)]
2. [Single family attached such as town house or row house]
3. [Apartment or condo in multi-unit structure of 2–4 units]
4. [Apartment or condo in multi-unit structure of 5 or more units]
5. [Mobile home]
8. [Don't know/Not sure/Prefer not to answer]

D3. Including yourself, how many people live in your home at least six months of the year?

1. 1
2. 2
3. 3
4. 4
5. 5
6. 6 or more
8. [Prefer not to answer]

D4. What is *your* age?

1. Under 25
2. 25 to 34
3. 35 to 44
4. 45 to 54
5. 55 to 64
6. 65 to 74
7. 75 or older
8. [Prefer not to answer]

D5. Which of the following is the highest level of education you completed?

1. [8th grade]
2. [High school]
3. [Associates degree, vocational or technical school, or some college]
4. [Four year college degree/Undergraduate bachelor's degree]
5. [Graduate or professional degree (Master's, PhD, JD, MD]
8. [Prefer not to answer]

D6. What is your household's total annual income before taxes?

1. [Less than $15,000]
2. [$15,000 to less than $20,000]
3. [$20,000 to less than $30,000]
4. [$30,000 to less than $40,000]
5. [$40,000 to less than $50,000]
6. [$50,000 to less than $75,000]
7. [$75,000 to less than $100,000]
8. [$100,000 to less than $125,000]
9. [$125,000 to less than $175,000]
10. [$175,000 or more]
88. [Don't know/Not sure/Prefer not to answer]

CONCLUSION

Thank you for completing this survey. Your input is very valuable to us, and we appreciate your time and feedback. We use customer input to continually improve our programs.

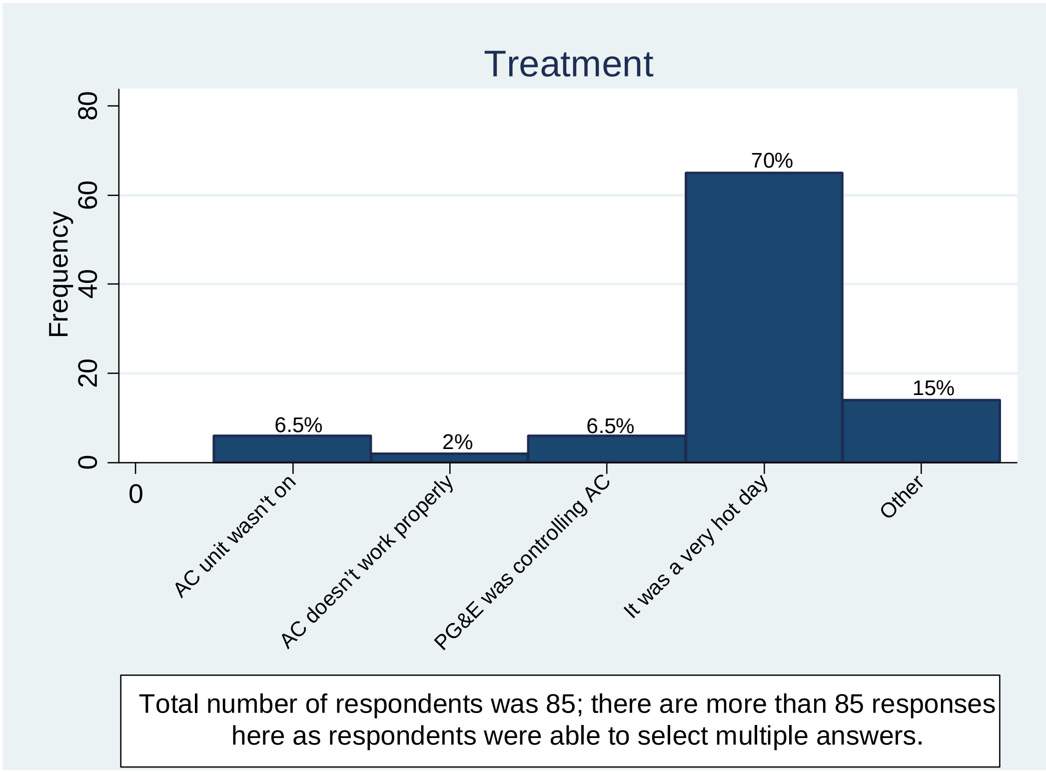
TERMINATION MESSAGE

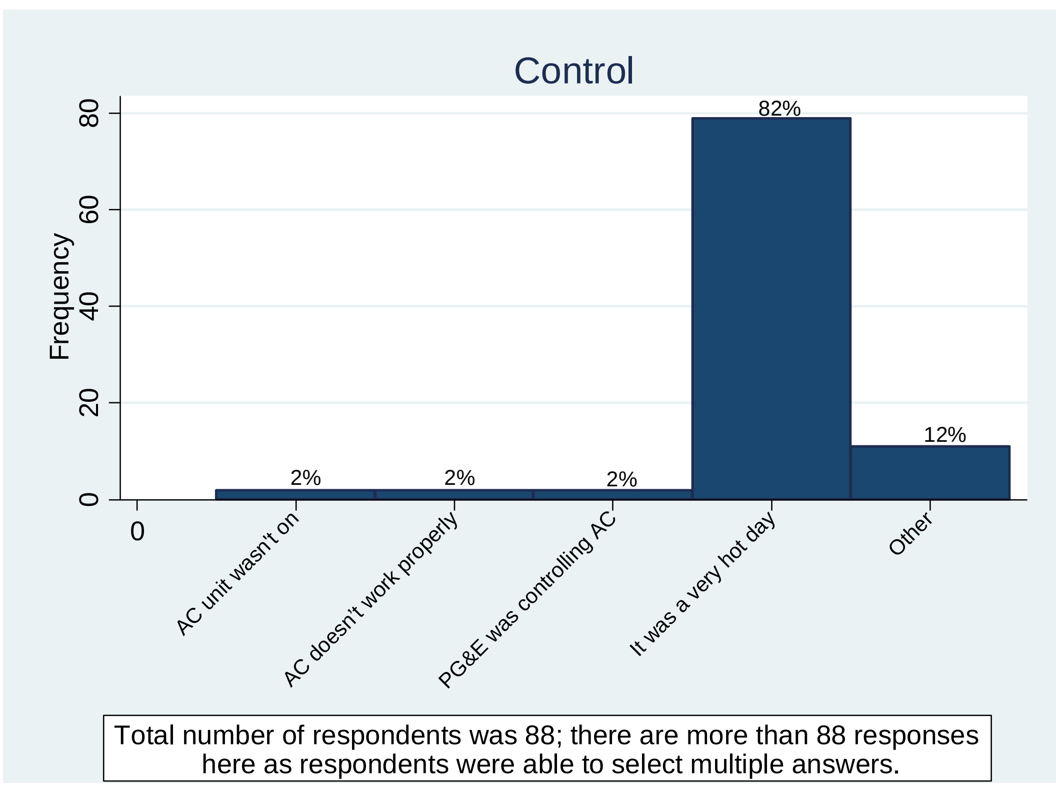
Thank you for agreeing to participate. Unfortunately, since a member of your household is employed by PG&E, we cannot include your answers in the results of this study.

A.2 Supplemental Survey Analysis

Responses to Question 7 (Figure A-1) from customers who said that they experienced uncomfortable temperatures (Figure A-1) show that on the days leading up to the survey, both treatment and control customers reported that "a very hot day" was most likely what caused the temperatures in their homes to be uncomfortable (70% for treatment, 82% for control). Customers who experienced load control were only slightly more likely than control customers to say that "the air conditioner unit was not on" (6.5% vs. 2%) or "PG&E was controlling the air conditioner" (6.5% vs. 2%) were important factors.

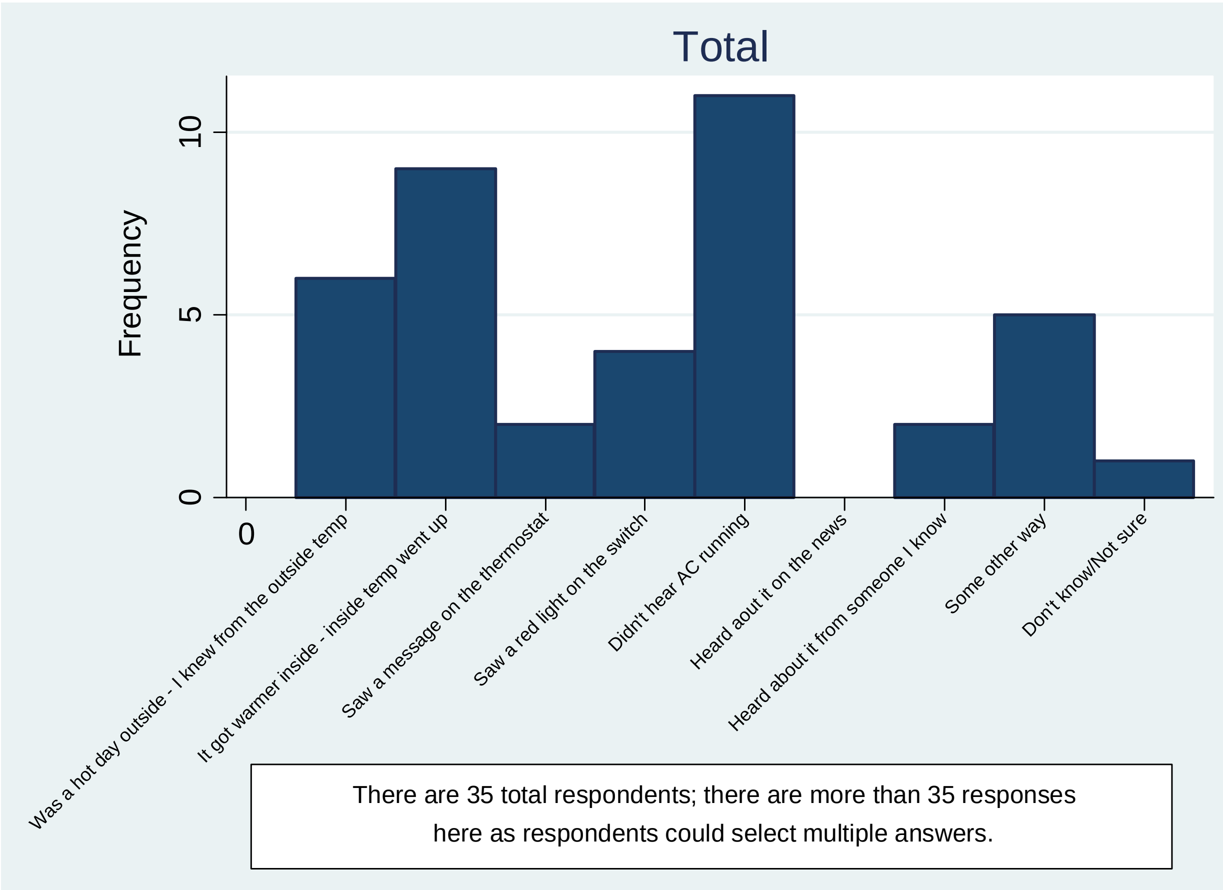
Figure A-1: "What do you think caused the temperature in your home to be uncomfortable?" (Q7)





Question 13 (Figure A-2), which asked how survey participants noticed the event,[53] allowed respondents to select more than one answer and produced a wide range of responses. The response with the highest frequency was that participants "did not hear the air conditioner running like they knew it should." Other common responses include, "it got warmer inside" and "it was a hot day outside."

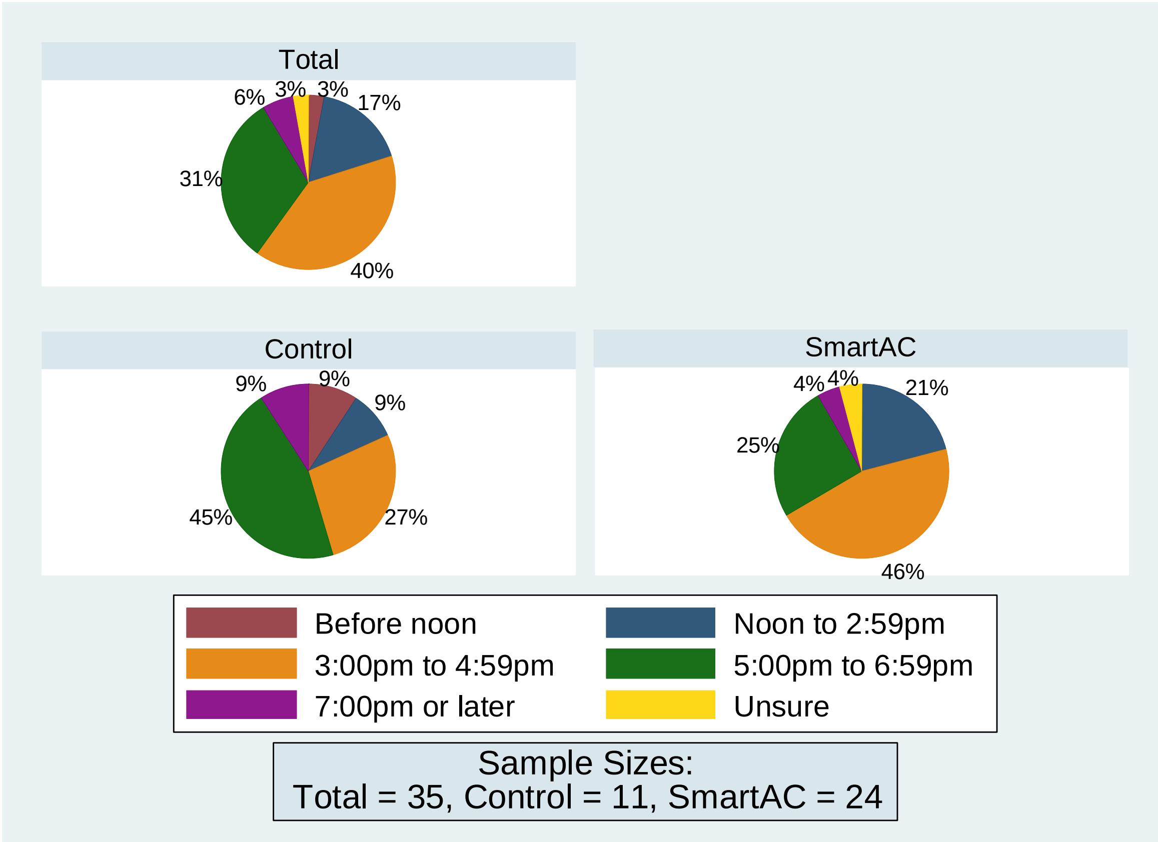
Figure A-2: "How did you notice this event?"



Responses to Question 14 (Figure A-3) identify the times during which respondents first noticed the event. The actual event lasted from 3:30 to 7:00 PM. The majority of treatment correctly identified the true time period, with 46% saying they first noticed the event from 3:00 to 4:59 PM and 25% choosing 5:00 to 6:59 PM. A similar proportion of control customers also selected one of these two times (27% for 3:00 to 4:59 PM and 45% for 5:00 to 6:59 PM) despite the fact that these customers did not experience load control.

[53] Questions 13 and 14 were asked only to customers who believed that an event occurred in the days leading up to the survey, i.e. answered "Yes" to Question 11.

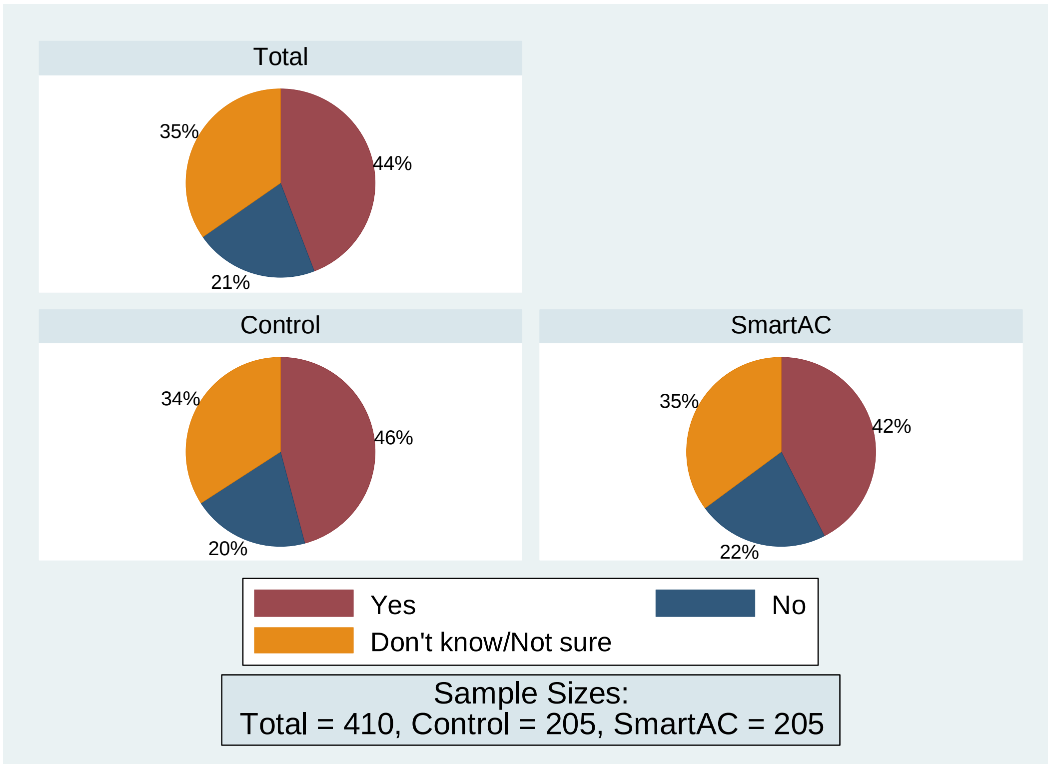
Figure A-3: "About what time did you first notice this event?"



A.2.1 Customer Satisfaction with SmartAC

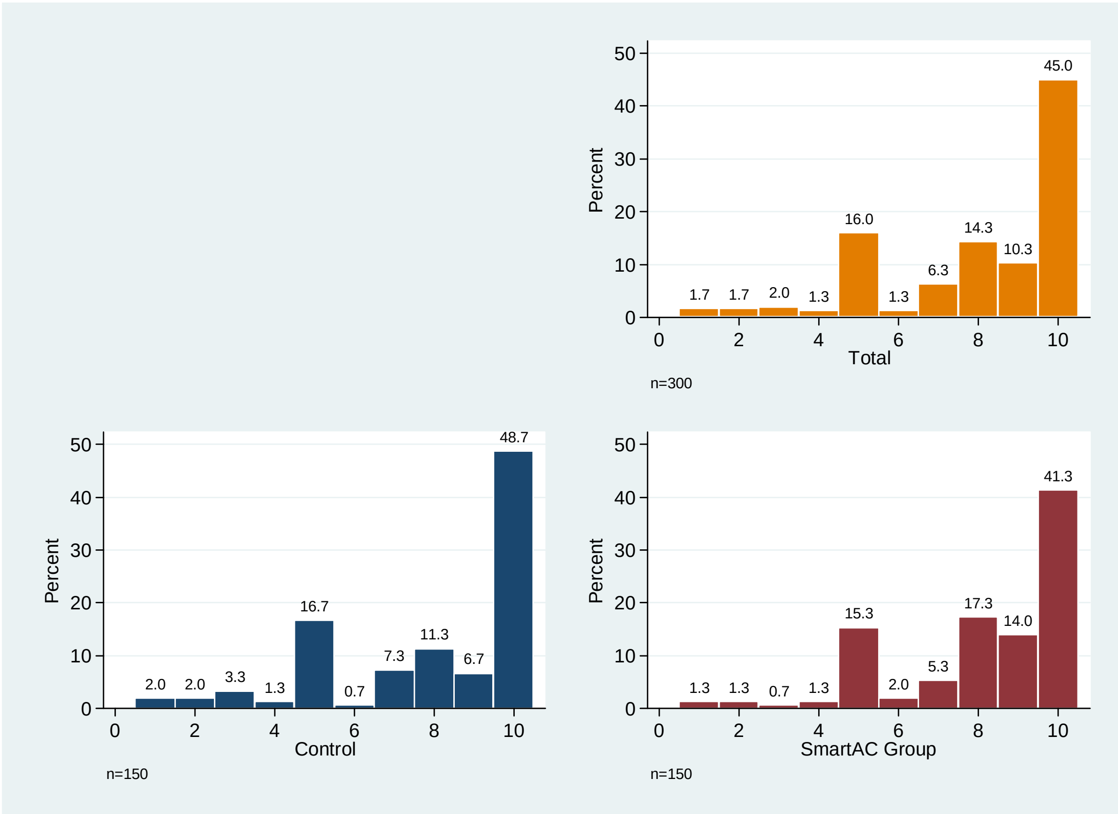
The survey also asked participants to evaluate their familiarity and overall satisfaction with the SmartAC program. Question 8 (Figure A-4) assesses customer familiarity with the program, and the results show that the distribution of responses between the two groups is relatively similar.

Figure A-4: "According to our records, your home is enrolled in PG&E's SmartAC™ program. Are you familiar with this program?"



Question 9 (Figure A-5) asked survey participants who are familiar with the SmartAC program about their satisfaction with the program. The responses indicate that customers called for the September 9 event are slightly less likely to have a satisfaction level of "10" compared to the Control group. Overall, most customers (~77%) reported their satisfaction with SmartAC as at least a 6 out of 10 and there is no statistically significant difference in satisfaction across the three groups.

Figure A-5[54]: "Based on all of your experiences with the SmartAC program so far, how satisfied have you been with the program overall?"

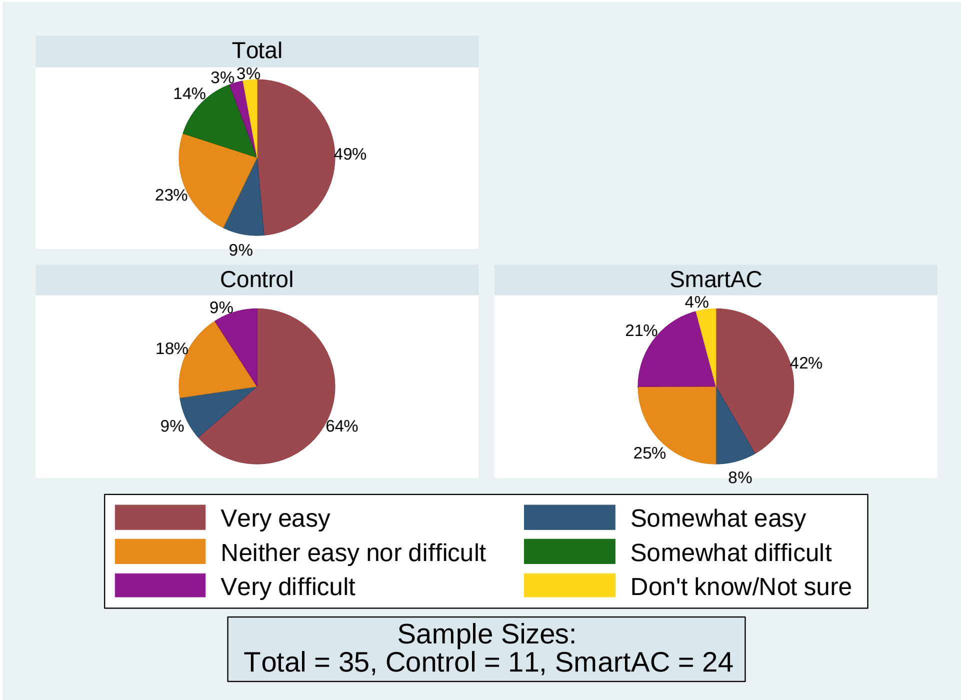


Question 10 asked survey participants for an open-ended explanation of their satisfaction rating. Customers with high satisfaction typically report something to the effect of the program being unnoticeable or "having no problems with it." Customers with middling ratings almost always have a similar response, claiming to "see no difference" or "haven't noticed anything" and giving a rating of 5 despite having no complaints. Popular responses for low ratings include not receiving the desired savings on the bill and not being able to control the AC when internal temperatures become uncomfortably hot.

In addition, participants who noticed their device was activated during the event (those who responded "Yes" to Question 11) were asked how they felt about the activation event in Question 17 (Figure A-6). The results produced a range of responses including, "It was fine," "Don't know," "No problem whatsoever," and something to the effect of the participant being uncomfortable to some degree. These customers were also asked to rate the activation experience in Question 18. Of the 35 participants who responded, SmartAC treatment customers were more likely to report being uncomfortable during the activation experience. 64% of Control customers described the experience as "Very easy" compared to 42% of SmartAC customers, and 9% of Control customers described the experience as "Very difficult" compared to 21% of SmartAC customers.

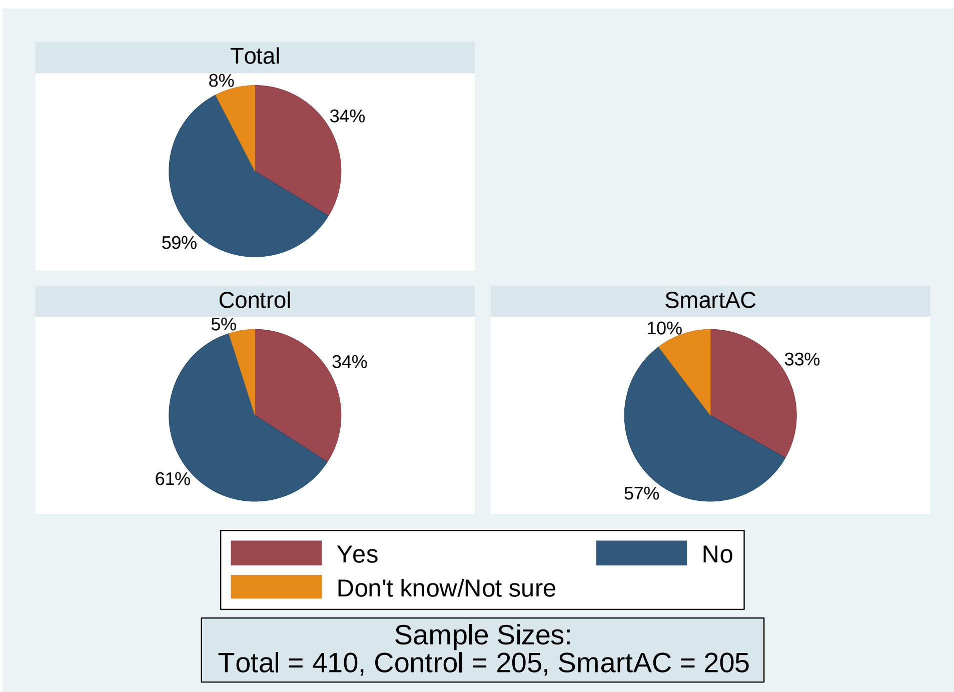
54 Doesn't include 19 responses of "Don't know / Not sure"

Figure A-6: "Would you say this activation experience was …"



Question 19 (Figure A-7) evaluated customer awareness regarding the ability to opt out of events. The distribution of responses shows no statistical significance between groups.

Figure A-7: "Did you know that you can contact PG&E to decline to participate in a SmartAC event that day, meaning your air conditioner won't be cycled for that day?"

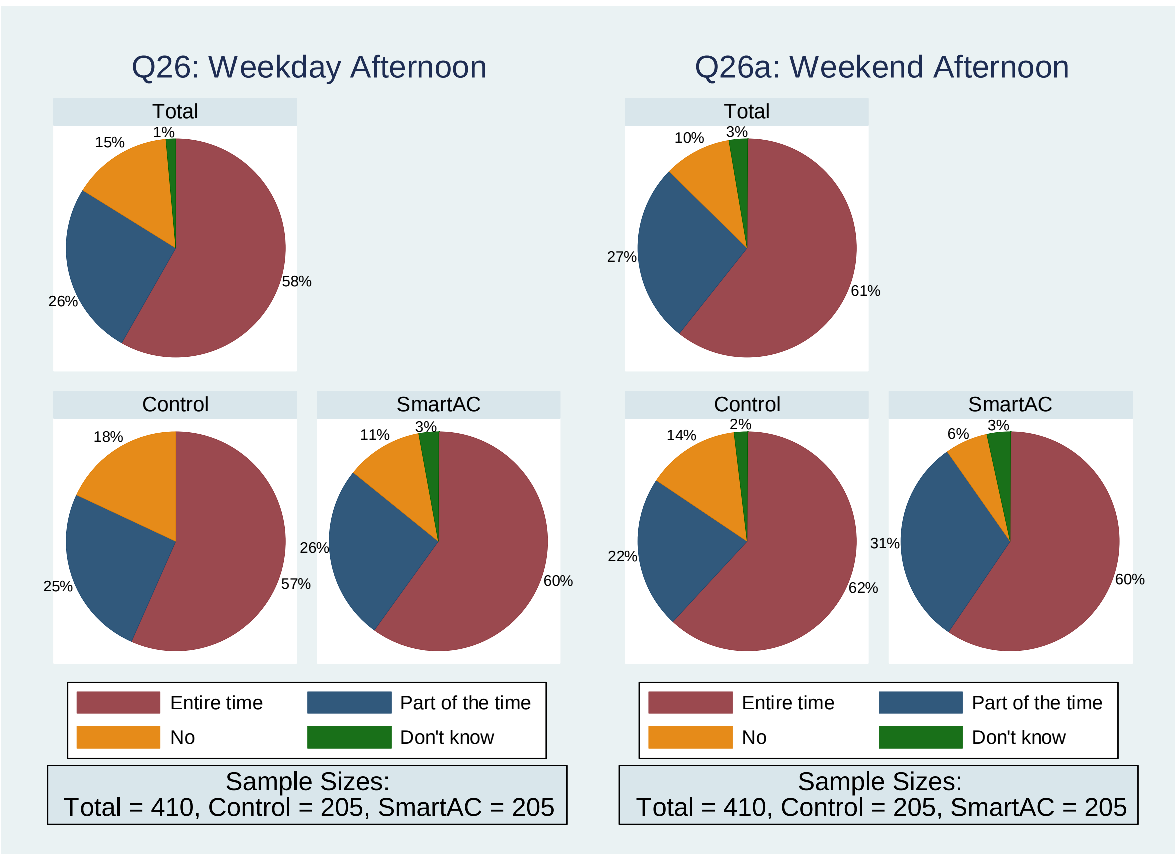


A.2.2 Other Differences in Survey Responses

In addition to thermal comfort, event awareness and actions taken in response to the event, Nexant examined the rest of the survey in search of any questions where customer responses were significantly different between the control group and treatment groups.

One area of apparent difference between treatment and control customers is regarding the AC user's presence at home during summer afternoons. Question 26 and 26a (Figure A-8) ask customers about this topic directly and the responses are shown below. SmartAC customers are less likely to report "No" for both summer weekday and weekend afternoons. Additionally, about 31% of SmartAC treatment customers report "Part of the time" on summer weekend afternoons compared to 22% of Control customers.

Figure A-8: "Is someone who might control or adjust your AC temperature typically at home during summer weekday/weekend afternoons between 2 and 7pm?"



Other than these differences, however, the distribution of responses between the two groups regarding usage patterns was relatively similar and any differences were not statistically significant. In addition to Questions 26 and 26a, the survey contained six questions about usage patterns, which are shown as Figures A-9 through A-14 below.

Figure A-9: "Could you tell me how often you or someone else in your household uses your air conditioning on summer weekday/weekend afternoons between 12 PM and 6 PM?"

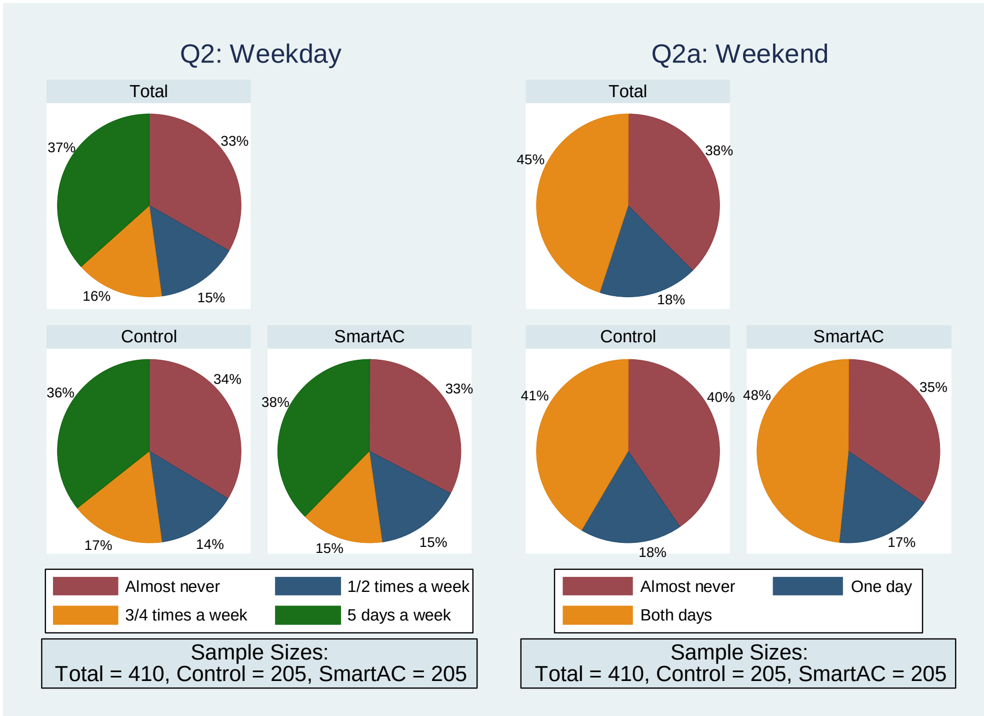


Figure A-10: "Could you tell me how often you or someone else in your household uses your air conditioning on summer weekday/weekend evenings between 6 PM and midnight?"

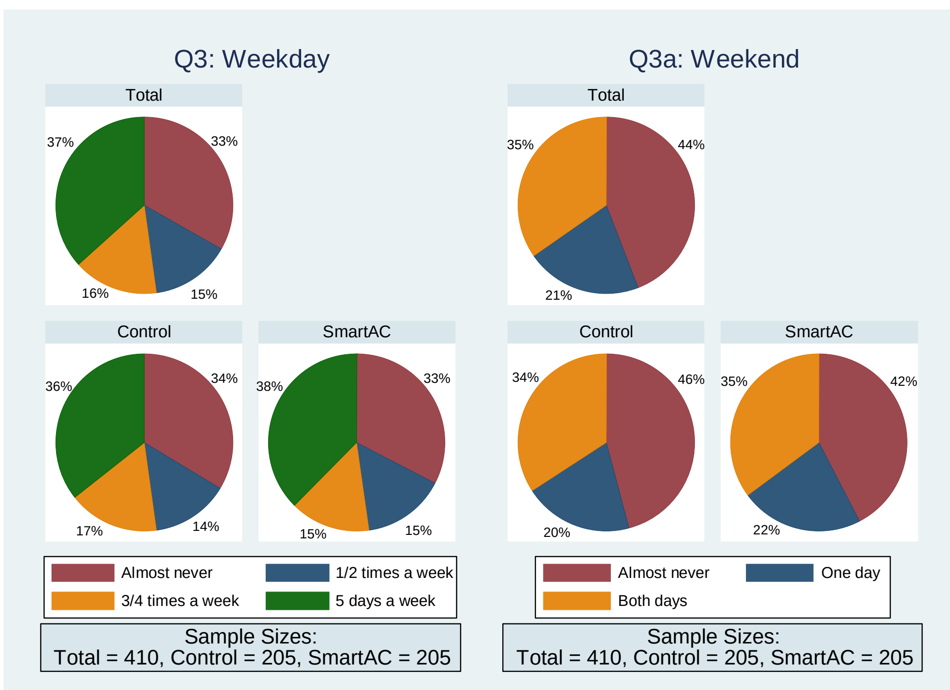


Figure A-11: "What type of thermostat(s) do you have?"

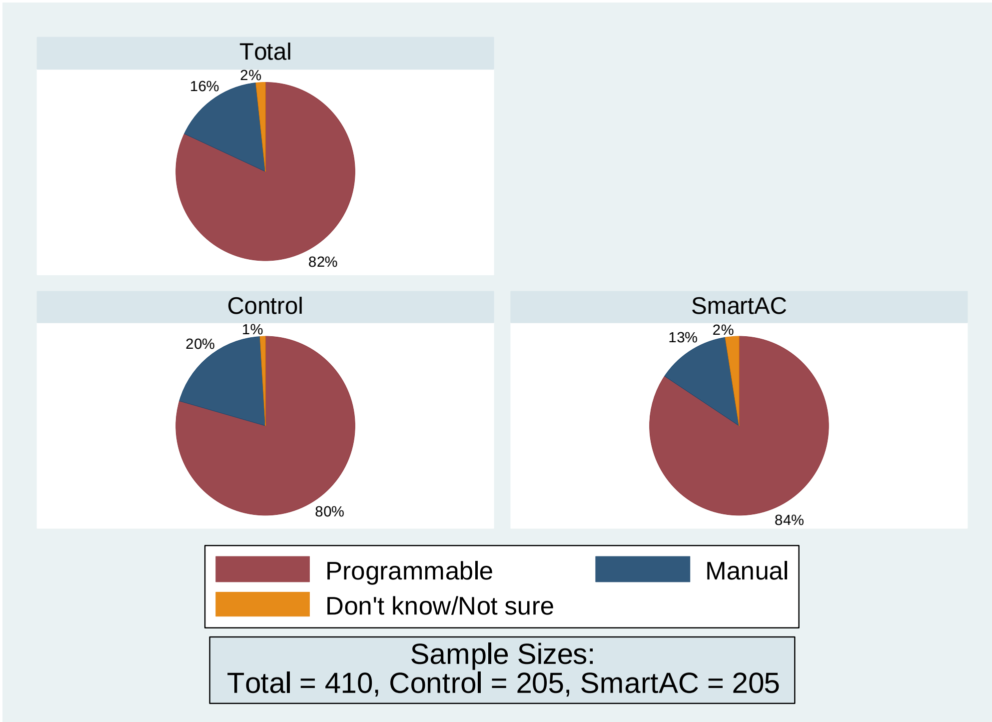
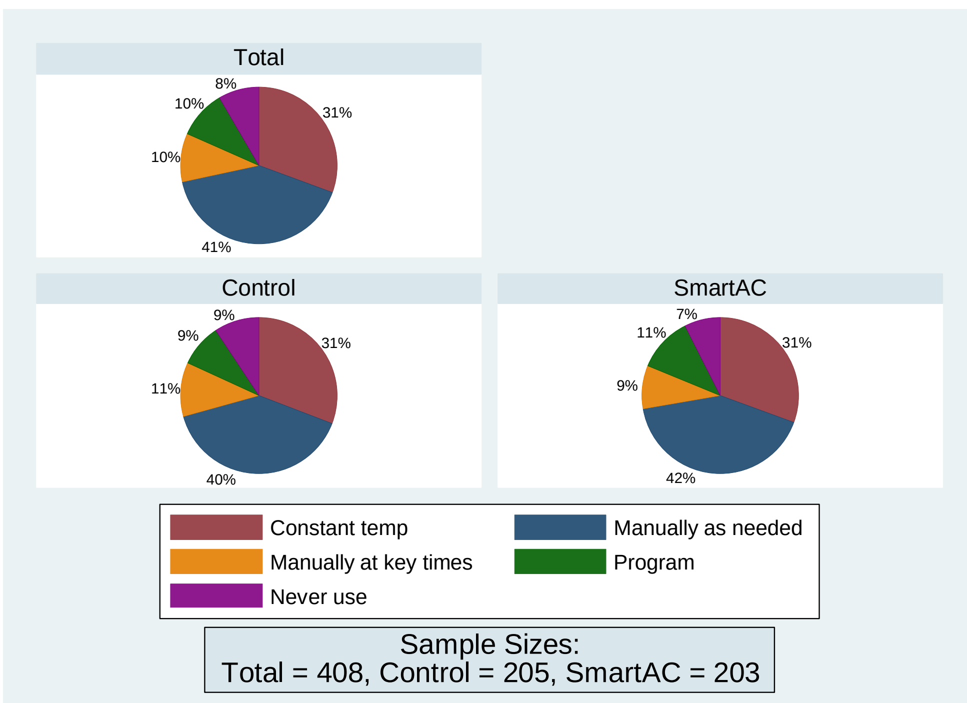


Figure A-12[55]: "Which of the following best describes how you operate your central A/C system(s) during the summer?"



55 Doesn't include 2 responses of "Don't know / Not sure"

Figure A-13[56]: "How often does your central A/C run in your home during summer weekday/weekend afternoons?"

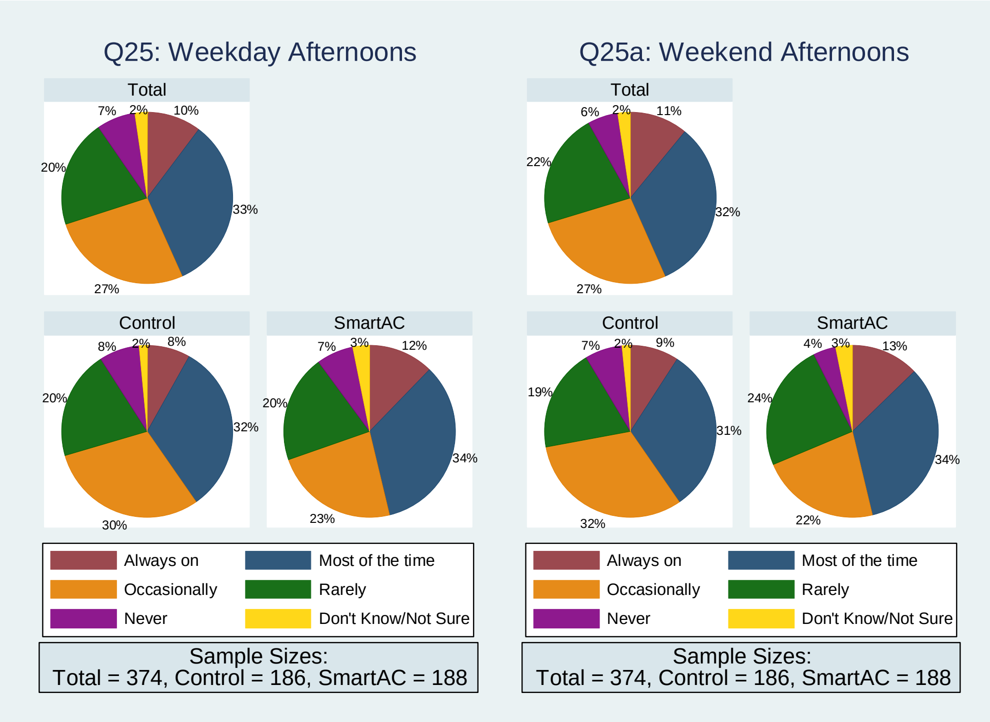
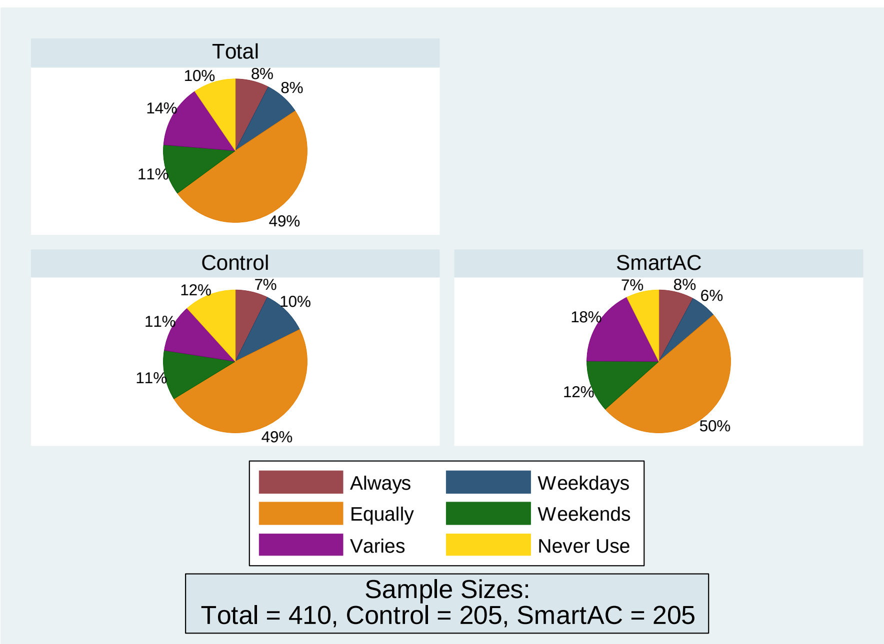


Figure A-14: "How would you compare your AC use on weekdays (Monday through Friday) vs weekends (Saturday and Sunday)?"

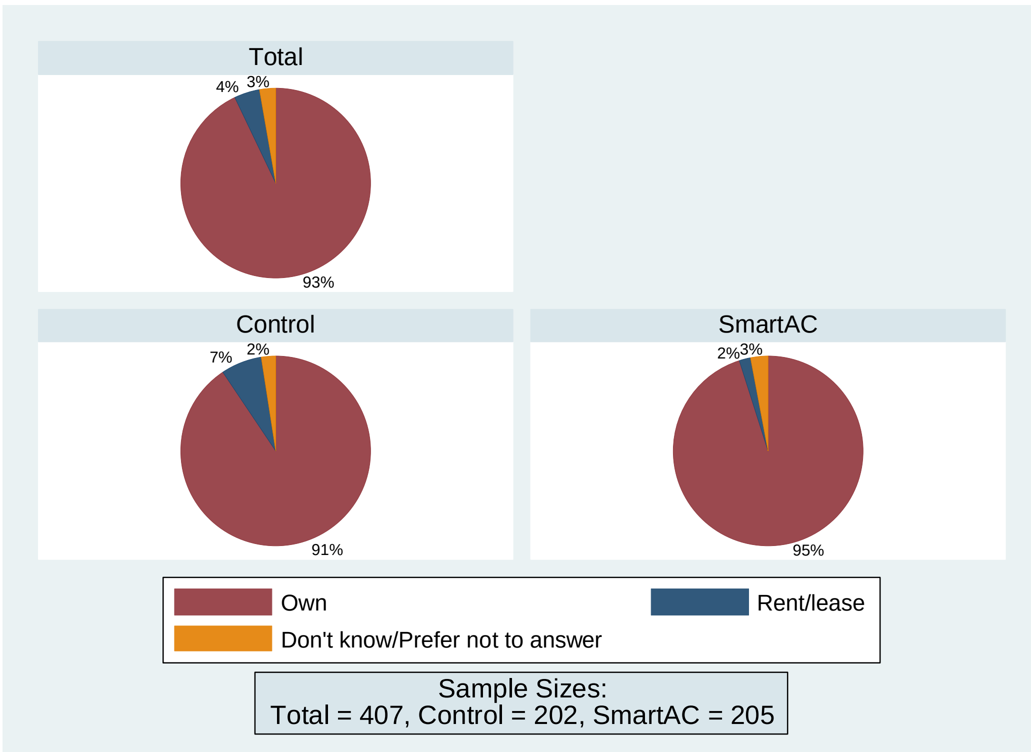


56 The sample rate is less than 100% for this set of questions because people who claimed in (Q24) either that they do not use central A/C in the summer or that they were unsure of their summer central A/C usage were screened out.

A.2.3 Demographics

The survey concluded with several questions on customer demographics. Figure A-15 shows that SmartAC survey participants were significantly more likely to report owning a home and less likely to report renting/leasing a home as compared with Control participants.

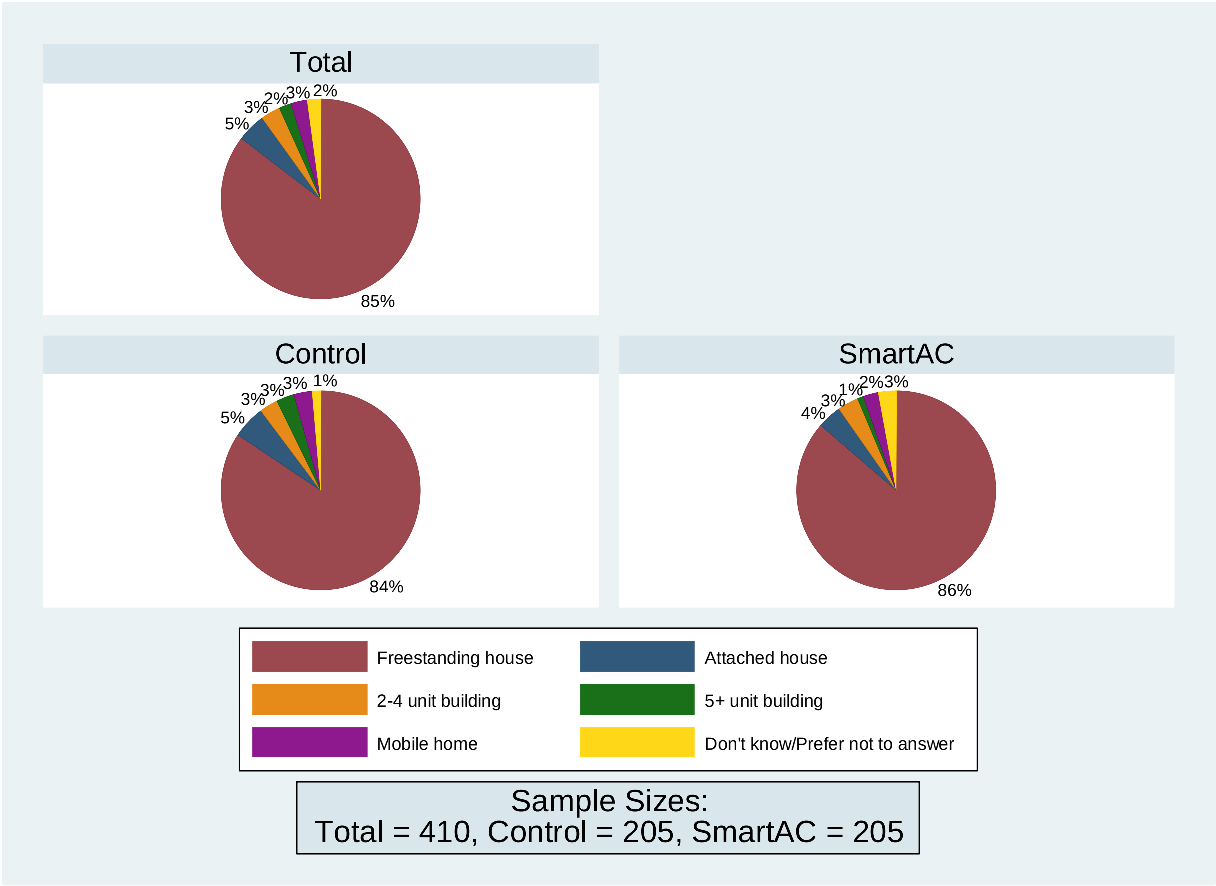
Figure A-15-[57]: "Do you own or rent your home?"



The SmartAC group described their type of home differently from the Control group (Figure A-16). Compared to the Control group, the SmartAC group was more likely to report living in a freestanding house, and less likely to report living in an attached house, mobile home, or 5+ unit building. However, the distribution of responses between groups was not significant.

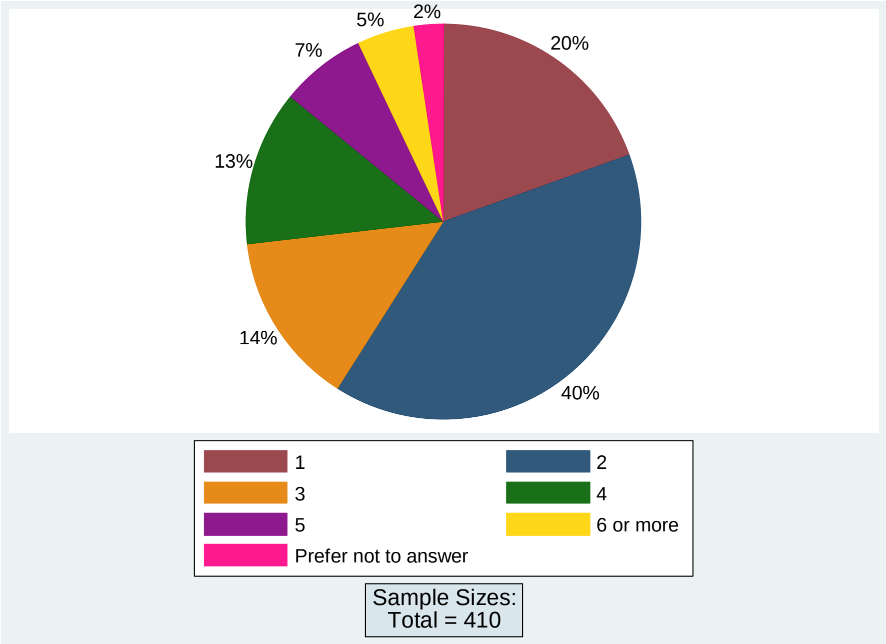
57 Does not include three participants who responded "Other."

Figure A-16: "Which of the following best describes the type of home you live in?"



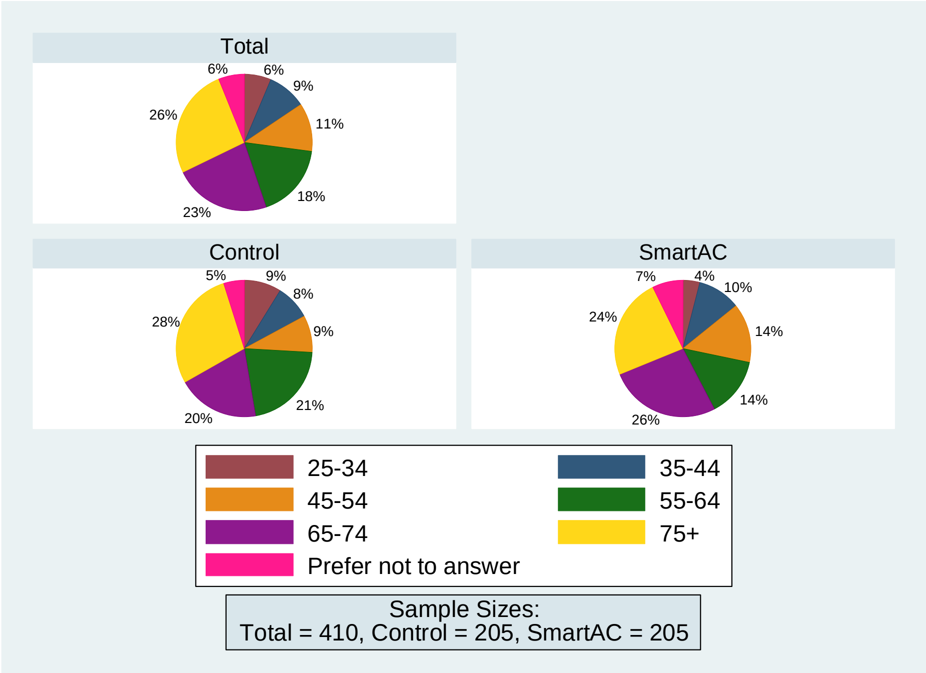
Question D3 (Figure A-17) asked how many people live at the survey participant's residence for at least six months of the year. There were no significant differences between groups. Ignoring the 2% who preferred not to answer and counting the 6+ category as 6, the average number of residents was 2.61.

Figure A-17: "Including yourself, how many people live in your home at least six months of the year?"



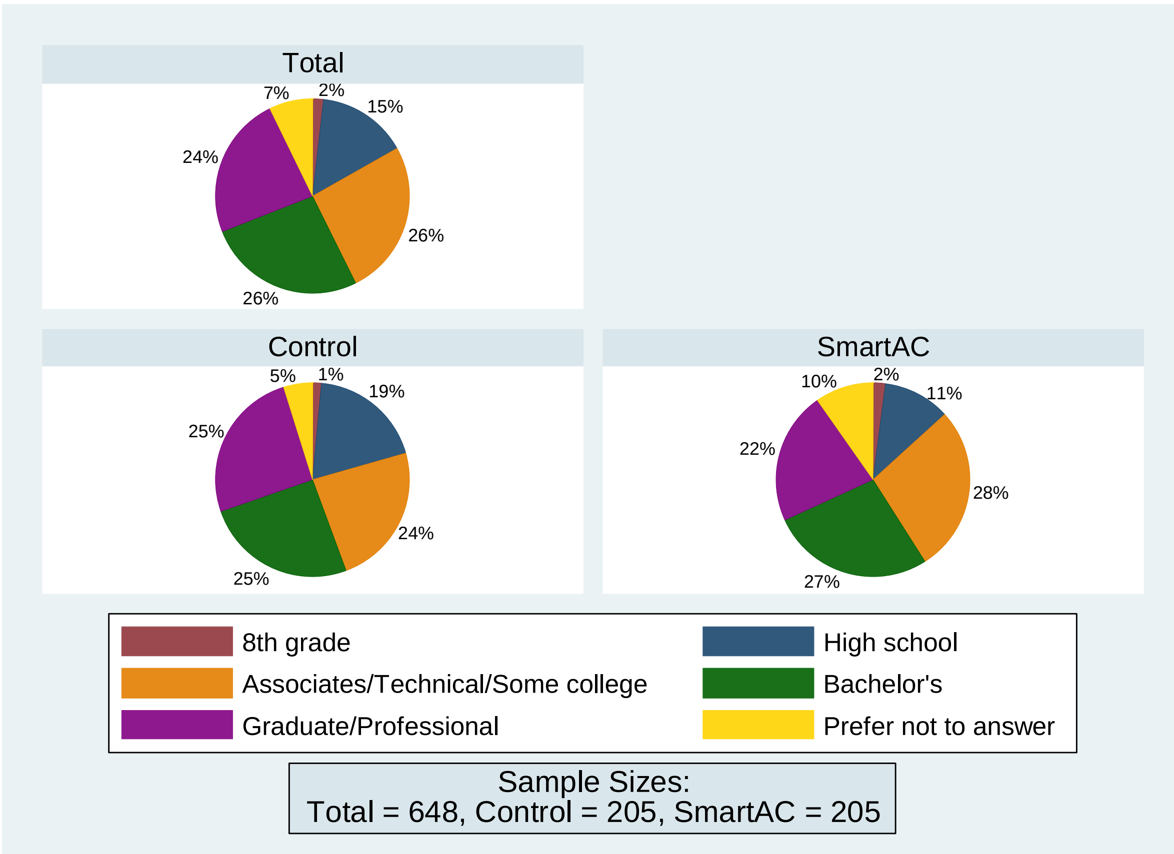
Question D4 (Figure A-18) asked for the survey participants' age. There was a significant difference between the SmartAC treatment customers and Control customers, as the SmartAC treatment group contains less 25–34, 55–64, and 75+ year olds, and more 45–54 and 65–74 year olds than the Control group.

Figure A-18: "What is your age?"



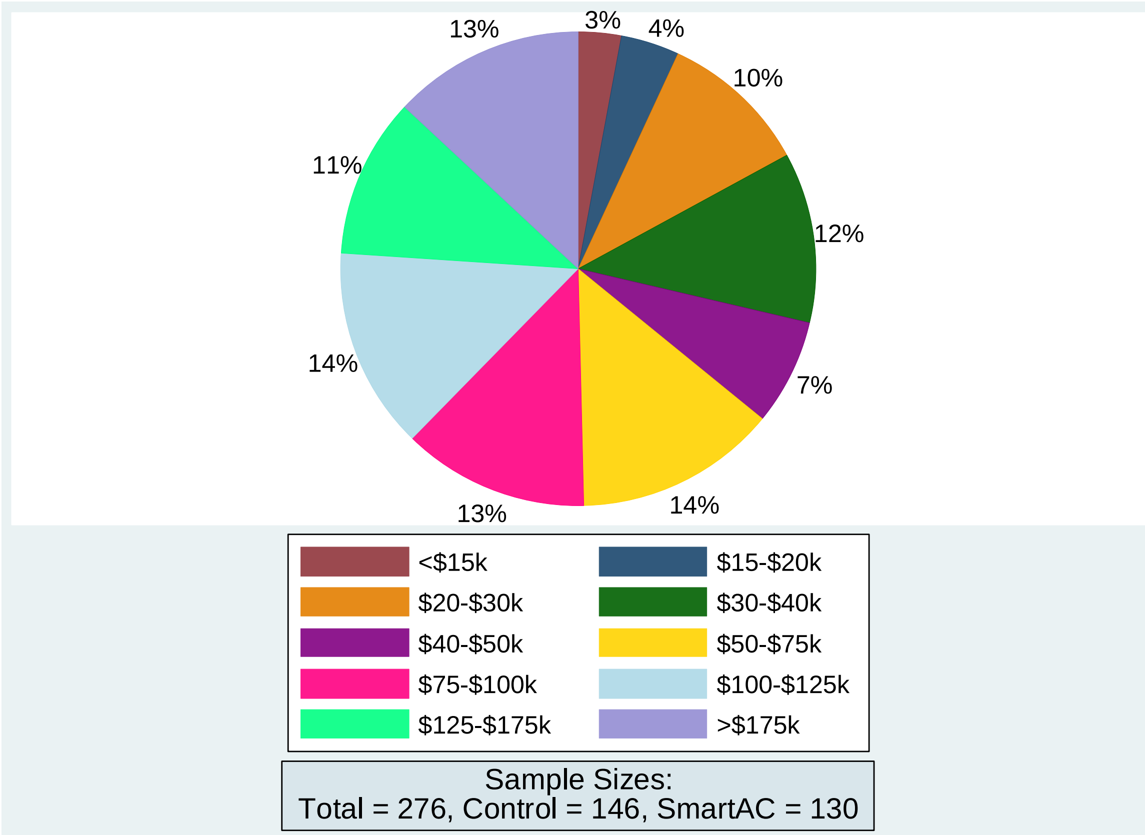
Question D5 (Figure A-19) asked about educational attainment. The Control group was more likely to respond that their highest level of education is high school, while the SmartAC group was more likely to prefer not to answer. However, the distribution of responses between the two groups is relatively similar and lacks statistical significance.

Figure A-19: “Which of the following is the highest level of education you completed?”



Question D6 (Figure A-20) asked about total household pre-tax income. There were no significant differences between groups. 134 participants responded as unsure or preferred not to answer, and were excluded from Figure A-20.

Figure A-20: "What is your household's total annual income before taxes?"



Appendix B: Ex Ante Reference Load Estimation

Estimating reference loads for the ex ante analysis has no bearing on aggregate impact estimates, but is useful for visualization purposes. This year's evaluation built upon the methods developed in previous years to produce reference loads for all combinations of LCA, weather years (1-in-2, 1-in-10), and peaking conditions (PG&E, CAISO). The methodology is summarized by the following seven steps:

1. Use Non-SmartRate event days from 2015 to calculate the ratio between control group usage for All customers and SmartAC-only customers in each hour;
2. Use average control group loads on 2015 event days (scaled to account for duals using the results from Step 1) to estimate load shapes for each LCA (store as ratio between each hour's kwh and hour17 kwh);
3. Calculate ratios of Humboldt & All relative to Other in each hour since historical impacts do not exist for these LCAs (historical impacts are at the individual LCA level);
4. Model hour 17 reference loads (adjusted for dually enrolled customers using results from Step 1) as a function of weather on historical event days for each LCA for which there is historical event data (2011–2015);
5. Use regression coefficients from Step 4 to predict hour17 reference loads under ex ante weather conditions;

6. Use 2015 load shapes from Step 2 to create 24 hour load shapes from predicted hour17 usage; and
7. Use ratios from Step 3 to estimate reference loads for Humboldt and All based on the reference loads for the “Other” LCA.

Appendix C: Detailed Description of Ratio Approach for Ex Ante

The ratio approach can be summarized by the following steps:

1. Directly estimate the relationship between impact and mean17 temperature for a single hour (4 to 5 pm) using a regression model;
2. Predict the impact that would occur under ex ante weather conditions using the estimated parameters from Step 1;
3. For all other hours in the resource adequacy window other than 4 to 5 PM, calculate the ratio of the impact in that hour to the impact from 4 to 5 PM for each event;
4. Estimate the relationship between the ratio calculated in Step 3 and mean17 temperature;
5. Predict the ratios of impacts in other hours to impact from 4 to 5 PM under ex ante weather conditions using the estimated parameters from Step 4; and
6. Apply the predicted ratios from Step 5 to the predicted impact from Step 2 to obtain ex ante impact estimates for the resource adequacy window hours other than 4 to 5 PM.

Appendix D: Event Notification Survey Results

Select results of the notification surveys are shown in the figures below.

Figure D-1: Effect of Notification on Event Awareness

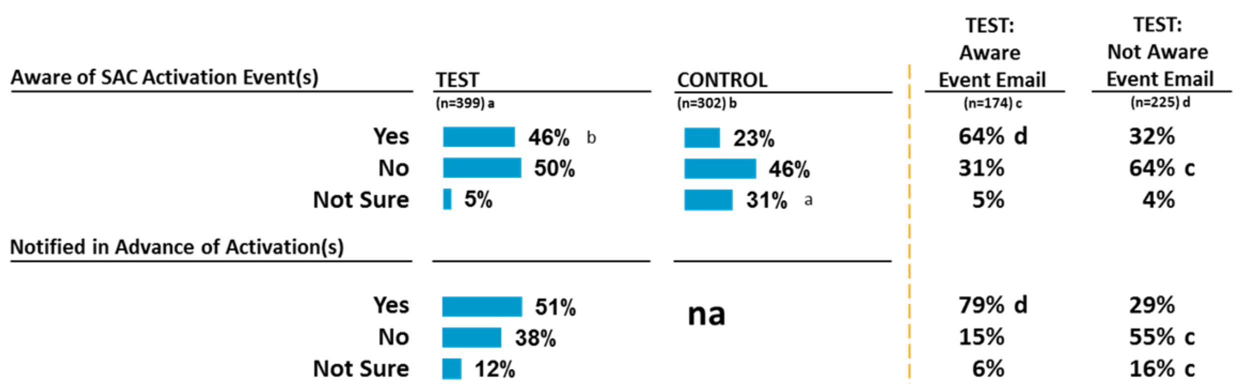


Figure D-2: Experiences of Customers who Received Notifications

Activation Easy or Difficult	TEST (n=182) a	CONTROL (n=69) b	TEST: Aware Event Email (n=111) c	TEST: Not Aware Event Email (n=71) d
Easy	86% b	67%	87%	83%
Difficult	9%	25% a	5%	15% c
Not Sure	5%	9%	8% d	1%
Noticed an Increase in Temperature				
Yes		na	54%	52%
No			44%	42%
Not Sure			2%	6%

Figure D-3: Overall Satisfaction with SmartAC Program

Satisfaction with the SmartAC Program	TEST (n=384) a	CONTROL (n=275) b	TEST: Aware Event Email (n=167) c	TEST: Not Aware Event Email (n=217) d
8-10	75%	70%	78%	73%
4-7	23%	23%	20%	25%
1-3	2%	7% a	2%	2%
Mean	8.4 b	8.0	8.5	8.3

Figure D-4: Trust in PG&E as a Company

A Company You Can Trust	TEST (n=393) a	CONTROL (n=289) b	TEST: Aware Event Email (n=172) c	TEST: Not Aware Event Email (n=221) d
8-10	63%	60%	70% d	58%
4-7	32%	30%	26%	36% c
1-3	5%	10% a	4%	6%
Mean	7.8 b	7.4	8.1 d	7.6

Figure D-5: Event Opt-Outs for Notified Customers and Control Group

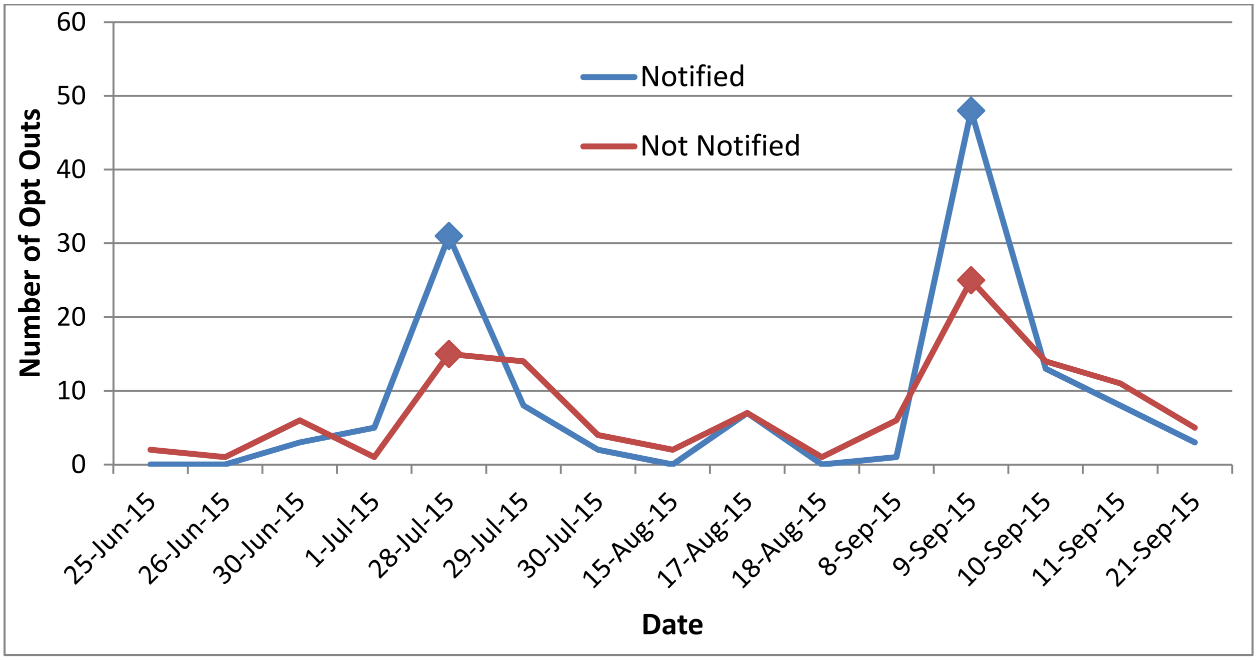


Table D-1: De-Enrollments for Notified Customers and Control Group

Date	Number of Notified Customers Leaving	Number of Non-Notified Customers leaving
16-Oct-15	2	2
17-Oct-15	1	0
18-Oct-15	2	0
20-Oct-15	2	5
21-Oct-15	1	2
22-Oct-15	0	2
23-Oct-15	0	1
25-Oct-15	0	1
27-Oct-15	1	1
29-Oct-15	0	3
30-Oct-15	3	1
31-Oct-15	0	2
Total	12	20