Demand Side Analytics
DATA DRIVEN RESEARCH AND INSIGHTS

FINAL REPORT

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2019 Load Impact Evaluation for San Diego Gas and Electric's Residential Technology Deployment Program

Prepared for SD&GE
By Demand Side Analytics, LLC
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ABSTRACT

This study quantifies the demand impacts residential thermostats. The study focuses on two primary research questions: What were the 2019 demand reductions due to dispatch operations? What is the magnitude of dispatchable load reduction capability for 1-in-2 and 1-in-10 weather planning conditions?

AC Saver Day Ahead (ACSDA) participants receive event dispatch signals via either free ecobee thermostats or BYOT ecobee or Nest thermostats. The thermostats can also help reduce electricity consumption when a residence is unoccupied. The program began in 2018, with both a free thermostat and a BYOT option. Before the PY 2019 event season, SDG&E closed its free thermostat program to new enrollments and ramped up enrollment of BYOT thermostats, adding over three thousand thermostats to the program. In addition, before the beginning of the PY 2019 event season SDG&E closed its Peak Time Rebate program (another smart thermostat enabled program in existence since 2016) and transferred around four thousand participants to ACSDA, mostly of these transfers were from the free Programable Thermostat program. Events are most commonly dispatched on summer weekdays 6pm to 8pm. The average PY 2019 event during this dispatch window produced 1.20 MW of reduction for free thermostats and a reduction of 2.56 MW for BYOT thermostats.

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1 EXECUTIVE SUMMARY

The residential AC Saver Day Ahead (ACSDA) program is a smart thermostat enabled demand response program that has been in place since 2018. The participant population includes participants previously enrolled in the recently discontinued Reduce Your Use Peak Time Rebate program (RYU-PTR). Residential ACSDA participants receive event dispatch signals via ecobee or Nest thermostats which can also help reduce electricity consumption when a residence is unoccupied.

SDG&E's residential smart thermostat demand program was initially designed around an offer of a free ecobee thermostat[1]. In 2018, the program changed from a free thermostat to a rebate model and was broadened to include additional thermostat models. The impacts of the free and rebated Bring-Your-Own-Thermostat (BYOT) components were evaluated separately and are reported separately for this study.

During 2018, SDG&E began its Default TOU Pilot[2] which transitioned residential customers from rates that did not vary by time of day onto time varying pricing[3]. Prior to the PY 2019 demand response season, approximately 25% of residential ACSDA customers were on TOU rates, most of which were transitioned during 2018 as part of the first phase of the residential default TOU rollout. Over the course of the PY 2019 season, another 25% transitioned onto TOU rates. As of the final PY 2019 residential ACSDA event on October 22, 2019, about one-half of residential ACSDA participants had not yet transitioned onto TOU rates. The study segmentation included three TOU rate transition groups to isolate any differential effects across groups who did or did not experience the TOU transition.

The study analyzes two primary research questions:

- What were the 2019 demand reductions due to dispatch operations?
- What is the magnitude of dispatchable load reduction capability for 1-in-2 and 1-in-10 weather planning conditions?

Table 1 summarizes the estimated demand reductions for each of the interventions and distinguishes between free and BYOT resources. The two categories were dispatched identically on the same dates.

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[1] The RYU-PTR program provided participants with free ecobee thermostats from 2014 to 2017. After 2017, a BYOT option was offered.

[2] SDG&E's Residential Default TOU rate is being evaluated separately.

[3] SDG&E began to implement default Time-of-Use in March of 2018. This first phase targeted about 144,000 randomly selected customers. A control group of about 150,000 customers was withheld from the default rollout for evaluation purposes. The control group continued to stay on the residential tiered rate until the end of 2019. The second phase roll out began in 2019. Customers who were expected to benefit from the TOU rates were defaulted first, followed by customers whose rate impacts were expected to be neutral. Finally, the program was rolled out to customers with non-benefiting profiles. Because of the targeted deployment phase, populations from different rollout phases are not equivalent in their underlying energy usage patterns.

There are fewer sites in the free thermostats category, resulting in lower aggregate load and lower aggregate reduction. Notice, however, that the percent reductions are also lower for the free households.

Table 1: Summary of 2019 Demand Reductions

Technology Intervention	Sites	Load without DR (MW)	Load reduction (MW)	% Reduction
ACSDA Free devices (Avg 6-8 pm event)	6,916	8.98	1.20	13.3%
ACSDA BYOT devices (Avg 6-8 pm event)	10,281	12.55	2.56	20.4%
ACSDA All devices (Avg 6-8 pm event)	***17,187***	***21.54***	***3.76***	***17.4%***

Table 2 summarizes the residential thermostat dispatchable ex ante reductions under August monthly peaking conditions for a 1-in-2 weather year. The results are shown under both CAISO and SDG&E peaking conditions and reflect the reduction capability from 4-9 pm, which aligns with resource adequacy requirements. For both CAISO and SDG&E weather conditions, demand reductions are expected to initially increase as site enrollments increase. As enrollment forecasts flatten after 2022, reductions begin to decrease as thermostat connection rates are forecasted to decline.

In comparing the ex post and ex ante impacts for 2019 across both interventions, there are two key differences to consider. First, the ex ante estimate assumes a population of about 2,000 additional sites, the majority of which are BYOT devices which also produce greater reductions per device[4]. Second, in PY 2019 the average event was called on days with maximum daily temperatures more than 5 degrees below the 1-in-2 temperature conditions. Residential thermostat customers on ACSDA were called during events of varying duration and start times, though typically from 6 to 8 pm. Across the 20 ACSDA events dispatched in PY 2019 only seven were called on days with maximum temperatures above 88 degrees and some were called on days much cooler than that. Hourly temperatures during 11 events were below 75 degrees when there is far less cooling load available to be curtailed.

[4] Devices for about 2,000 sites were identified as needing classification updates to be dispatched effectively. The assumption is that the updated classification will be reflected going forward.

Table 2: Summary of Ex ante Dispatchable Demand Reductions

Year	Tech Deployment: Residential ACSDA Free and BYOT Devices		
	Sites[5]	MW (CAISO)	MW (SDG&E)
2019	18,892	6.19	5.92
2020	21,581	7.04	6.74
2021	24,271	7.81	7.47
2022	26,960	8.50	8.14
2023	26,960	7.76	7.43
2024	26,960	7.09	6.78
2025	26,960	6.46	6.18
2026	26,960	5.89	5.64
2027	26,960	5.36	5.13
2028	26,960	4.88	4.67
2029	26,960	4.44	4.25
2030	26,960	4.03	3.86

[5] Though SDG&E anticipates continuing the program beyond 2022, participants are held constant from 2023 onward.

2 INTRODUCTION

The residential AC Saver Day Ahead (ACSDA) program is a smart thermostat enabled demand response program in place since 2018. The participant population includes participants previously enrolled in the now discontinued Reduce Your Use Peak Time Rebate program (RYU-PTR). Residential ACSDA participants receive event dispatch signals via ecobee or Nest thermostats which can also help reduce electricity consumption when a residence is unoccupied. Smart thermostats allow for optimized energy use by shifting use towards off peak times. ACSDA customers participate in demand response events, where thermostat setpoints are adjusted slightly across a region to decrease aggregate AC runtime during peak times.

Two key transitions occurring in PY 2019 have the potential to produce differences in load impacts for residential ACSDA. First, the default transition of most residential customers onto TOU rates began in 2019 and was phased in progressively to over 600 thousand of SDG&E's roughly 1.3 million residential accounts[6]. The transition to time varying rates encourages customers to consider when they consume power in addition to how much they consume. Customers can save by modifying when they use energy and by reducing energy use. The rates also better align the prices customers face and with the cost of supplying power. Prior to and over the course of the transition, SDG&E implemented an outreach and education campaign designed to increase awareness and improve understanding of the new rate. The second key transition for ACSDA was to the participant and technology mix, as described below.

2.1 TECHNOLOGIES AND PROGRAMS EVALUATED

Smart thermostats are the delivery method through which the ACSDA program is dispatched. The program includes both ecobee and Nest thermostats. In addition to receiving event dispatch signals, the thermostats also can help reduce electricity consumption when a residence is unoccupied. ACSDA thermostats can be dispatched at any time between 12 pm to 9 pm (on-peak hours) for a maximum of 4 consecutive hours. ACSDA devices are curtailed by raising the thermostat temperature set point 4 degrees during the event window.

[6] Preceding the 2019 residential default time of use rollout was known as the Residential Default TOU Pilot. The first phase in 2018 targeted about 144,000 customers who were randomly selected to participate in the pilot along with a randomly selected control group. Once the pilot was over, SDG&E continued to roll out its default TOU rate to those customers who would benefit most from the TOU rates offered. The subsequent phase rolled out TOU rates to customers for which impacts were expected to be neutral, and finally to customers with non-benefiting profiles. A control group of about 150,000 customers is being withheld from the default rollout for evaluation purposes.

The residential ACSDA program began in 2018 and initially included both a free thermostat channel and a Bring Your Own Thermostat (BYOT) rebate channel. The BYOT channel allows customers to use their existing Nest or ecobee smart thermostats to receive the ACSDA program signals. Before the PY 2018 event season, SDG&E closed the free thermostat program to new enrollments and ramped up enrollment of BYOT thermostats, adding over three thousand thermostats to the program. In addition, before the beginning of the PY 2019 event season SDG&E closed the Peak Time Rebate program (another smart thermostat enabled program in existence since 2016) and transferred around four thousand participants to the ACSDA program. These factors substantially changed the participant mix. The Free and BYOT channels are evaluated in this report as two distinct programs and most of the transitioned PTR participants are included in the Free program population.

2.2 STUDY RESEARCH QUESTIONS

Table 3 summarizes the key research questions for each intervention. Thermostats are dispatchable resources that also can lead to daily changes in energy use.

Table 3: Key Research Questions

	Research Question
1	What were the demand reductions due to program operations and interventions in 2019 – for each event day and hour?
2	How does weather influence the magnitude of demand response?
3	How do load impacts differ for customers who were transitioned onto TOU rates during PY 2019?
4	How do load impacts vary for different thermostat segments-free vs BYOT?
5	What is the ex ante load reduction capability for 1-in-2 and 1-in-10 weather conditions? And how well does it align with ex post results?
6	What concrete steps or experimental tests can be undertaken to improve program performance?

2.3 OVERVIEW OF METHODS

The primary challenge of impact evaluation is the need to accurately detect changes in energy consumption while systematically eliminating plausible alternative explanations for those changes, including random chance. Did the introduction of smart thermostats cause a change in critical peak period demand? Or can the differences be explained by other factors? To estimate energy savings, it is necessary to estimate what energy consumption would have been in the absence of the intervention—the counterfactual or reference load.

The change in energy use patterns was estimated using a panel regression with multiple control groups, each matched to a participant. Key modeling design components are as follows:

- **Multiple matched controls:** For each participant, five control sites were identified based on how closely their loads matched the participant on event-like proxy days (e.g. using Euclidian distance matching). A total of five matched control sites were selected for each participant site, ranked by their closeness of fit across all proxy days.
- **Panel regression model with event and non-event day and participants and matched controls:** The data was structured as a time series for each participant. The control loads, weather, and day characteristics were used to predict participant loads. The model coefficients for each control site essentially weight the various control sites based on their predictive power creating a more accurate prediction out of multiple controls. This approach was used as the primary method for event impacts for critical peak events delivered by AC Saver Day Ahead thermostat participants.
- **Event specific models:** Given the wide range of temperature conditions during events, five proxy days were selected for each event based on the how closely the proxy day conditions, measured by system load, matched the event days (e.g. using Euclidean distance matching). A separate model was estimated for each event including only loads for the event day and the proxy days selected for that event. The number of proxy days included was validated using the model validation process described below.
- **Pre and post event adjustment:** The impact regression also included pre and post event loads to adjust the model for differences. A two hour pre- and post-adjustment period with a two hour pre- and post-buffer was used. Inclusion of these parameters was validated using the model validation process described below.
- **Model validation:** The choice of the number of proxy days (ranging from two to five), of the number of matched control sites (ranging from one to five), and of the inclusion of pre and post event adjustment parameters was validated using a placebo effect approach: a subset of proxy days was used to predict load on the remaining proxy days for each event. In the absence of events, the difference between predicted and actual error should be zero and any deviation is a direct reflection of modeling error. In each case the approach with the least error and best fit was selected.

Figure 1 summarizes the out of sample testing process used to select the number of proxy days, controls, and adjustments to be used for modeling. Essentially, the out of sample process is an iterative approach whereby data is systematically left out of the matching model then used to assess model performance—a well performing model should produce matches for loads on days which were not used for the model. The final model is identified based on least bias (% Bias) and best fit (Relative RMSE) metrics. As an example, Figure 2 summarizes the model selection analysis for the residential ACSDA programs. Each row shows a different adjustment model and each cluster of bars shows results for a selected number of proxy days. Each individual bar in a cluster shows results for a selected number of control sites per participant site. Note that across the 60 models tested, the one with the best precision (lowest RMSE) is the one with a pre and post adjustment, using five proxy days and five control sites. This is the model that was selected for estimating counterfactual loads during events. Using multiple proxy days, matched controls, and adjustments systematically increased model precision.

Figure 1: Out of Sample Process for Model Selection

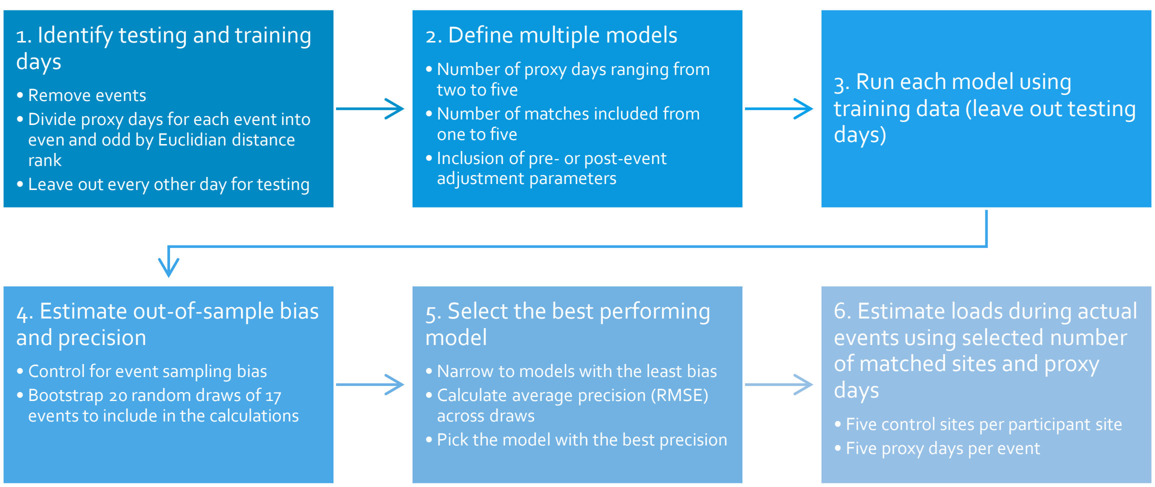


Figure 2: Model Selection Results

Table 4 summarizes the data sources, segmentation, and estimation methods used for each program. The segmentation was defined in advance of the analysis and is of particular importance because the evaluation used a bottom up approach to estimate impacts and to ensure that aggregate impacts across segments equaled the sum of the parts. Because impacts for each segment were added together, the segmentation was structured to be mutually exclusive and completely exhaustive. In other words, every customer was assigned to exactly one segment. By design, the segmentation differentiated customers who were expected to deliver greater demand reductions– such as customers in the inland climate zone where cooling loads are higher– from customers who were expected to deliver lower demand reductions. Importantly, the segmentation included three TOU rate transition groups to isolate any differential effects across groups who did or did not experience the TOU transition. It is notable that the second phase of the default TOU rollout has not been randomized, rather it has been deployed strategically after the first phase which was the default TOU pilot. The second phase targeted customers that were expected to benefit most from the new rates. As such the TOU segments for this study are not comparable populations and differ in their underlying usage patterns as well as in their rate status. Additional segments were analyzed, after the fact, as part of exploratory analysis, but the core results presented are based on the segmentation detailed below.

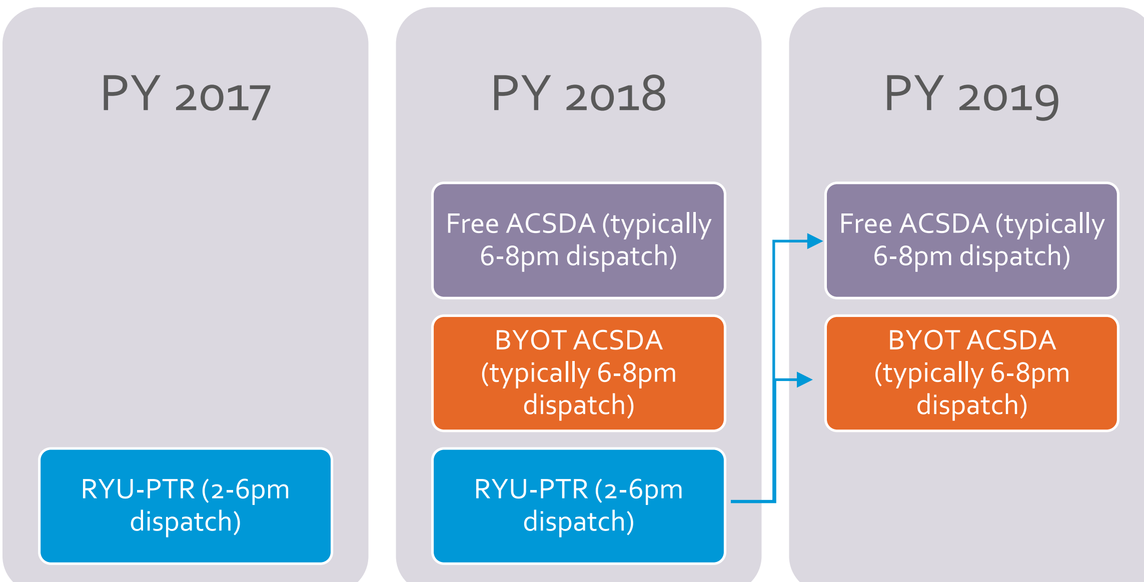
Table 4: Evaluation Methods

Evaluation Element	TD Programs
Data sources / samples	▪ Hottest 20 weekdays and weekends over the past summer (2019), plus any additional event days, for event day impacts. Prior years not used due to substantial shift in participant mix.
Segmentation	▪ Rate ✓ Not on TOU rate ✓ Transitioned to TOU rate during PY 2019 ✓ Transitioned to TOU rate prior to PY 2019 ▪ Climate zone (Coastal vs Inland) ▪ Thermostat type and program ✓ Free: ecobee ✓ BYOT: ecobee ✓ BYOT: Nest
Estimation method: Ex-post	▪ Panel regression with multiple matched control groups for each customer.
Estimation method: Ex-ante	▪ Weather normalized customer regressions by segment for reference loads ▪ Regression of historical event percent impacts versus weather for percent reductions ▪ ACSDA: Used 2019 impacts

3 RESIDENTIAL THERMOSTAT EVENT DAY IMPACTS

AC Saver Day Ahead (ACSDA) participants receive event dispatch signals via either free ecobee thermostats or BYOT ecobee or Nest thermostats. The thermostats can also help reduce electricity consumption when a residence is unoccupied. In 2018, the program changed from a free thermostat to a rebate model and was broadened to include additional thermostat models. Figure 3 summarizes the program development since 2017[7]. ACSDA events are typically called from 6 to 8 pm. ACSDA thermostats can be dispatched at any time between 12 pm to 9 pm (on-peak hours) for a maximum of 4 consecutive hours and most events in 2019 were called from 6-8pm. For both ACSDA programs, devices are curtailed by raising the thermostat temperature set point 4 degrees during the event window.

Figure 3: Summary of Residential Technology Deployment Program Taxonomy



There are over 20,000 devices installed at over 17,000 residential sites. Reductions for residential ACSDA sites were statistically significant on average and almost exclusively positive across events, with an average event savings of 13.3% to 20.4% for free and BYOT thermostats, respectively.

[7] The RYU-PTR program provided participants with free Ecobee thermostats from 2014 to 2017. After 2017, a BYOT option was offered.

For residential thermostats, connectivity rates are relatively high. Sixty-five percent of the installed free ecobees are connected and 99% of the BYOT devices are connected. Because only connected devices can receive signals and curtail AC load this lack of connectivity has direct implication for load impacts delivered by the Technology Deployment programs. Over time, connectivity rates tend to decrease. Because the residential program is relatively new, this will be a growing concern with each subsequent year. To pull from the non-residential study, the decline in connectivity appears to be substantial and continues to be relatively steady over time, ranging from 13% to 23% per year for most programs[8]. As the residential ACSDA program progresses, connectivity trends should be studied to see if declines continue. Future efforts to maintain and reconnect disconnected devices, particularly among programs or customer segments delivering greater reductions, is critical to maintaining an effective program.

3.1 TECHNOLOGY AND EVENT CHARACTERISTICS

The thermostats used as the enabling device receive a signal from SDG&E to curtail usage during events. For all PY19 events, thermostats were controlled by raising the setpoint temperature by 4 degrees. This approach is intended to reduce energy usage by air conditioning units. However, to receive the curtailment signals, the devices must be connected to the internet and registered in the SDG&E dispatch portal. This is initially set up during the device installation process, but connectivity can be affected by internet reliability. Once connected, the device can receive and execute curtailment signals, and it can also communicate event notifications to users before the beginning of an event. Participating, connected devices were sent event notifications 24 hours prior to an event.

Figure 4 shows cumulative thermostat installations over time (in blue) across three thermostat categories: the free ecobees and the BYOT thermostats-Nest and ecobee. The free ecobees have been installed for a longer period of time while the BYOT devices have been connected for at most two years. There are important caveats to consider assessing thermostat survival rates. First, the quality of the disconnect dates is key to estimating accurate survival rates. The data available to Nest devices is incomplete, providing only a single snapshot in time of number of thermostats connected but no data on disconnection dates. Second, survival data collected over longer periods of time is more complete than data collected over shorter periods over which there may not be enough time elapsed to draw robust conclusions. BYOT devices have been in the field for a year and a half or less, a time frame too short from which to draw conclusions about multi-year survival rates. As such the survival rates used to develop forecasts for future device connectivity were developed by assessing the full population of ecobee devices (free and BYOT).

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[8] With the exception of ACSDA quasi-residential sites where hundreds of sites managed by a single customer were disconnected around the same time in late 2017.

Figure 4: Residential Thermostat Cumulative Installations and Connectivity

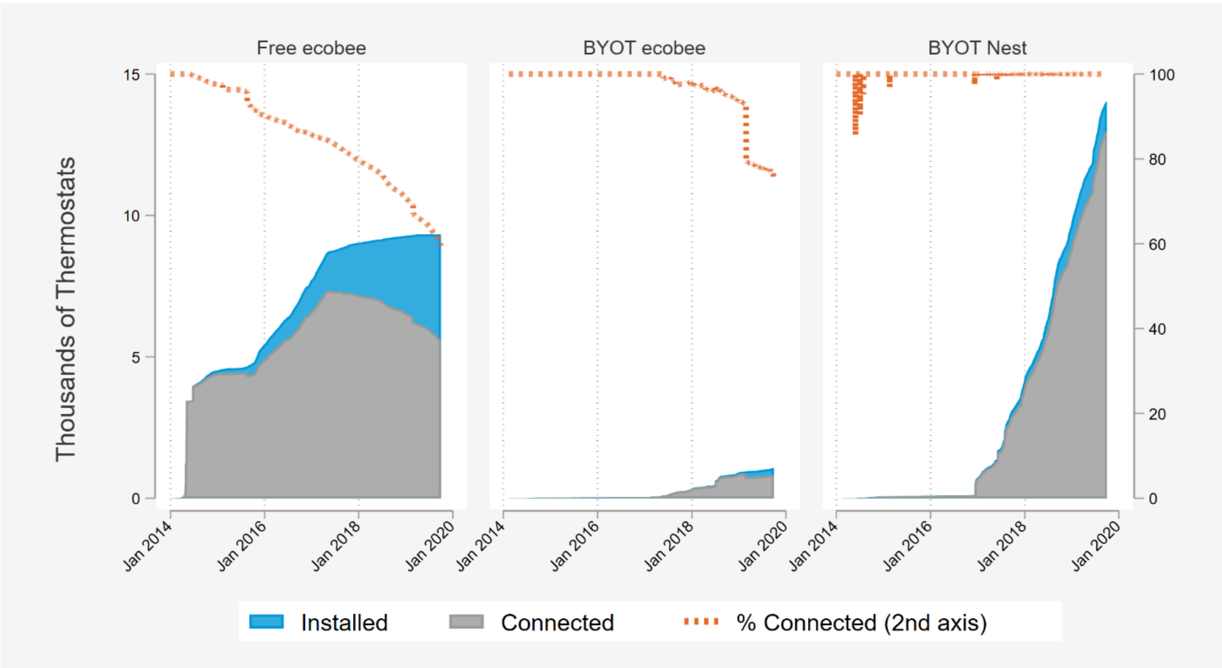


Figure 5 shows the proportion of ecobee devices still connected N years after installation. The survival curve and rate indicates a decay rate consistent with an unintentional loss of connectivity over time. Note that connectivity in the sixth or subsequent years after installation are not really known since the oldest thermostats were installed about five years ago. Given that load reductions are delivered by connected devices, this drop in connectivity has implications for load reductions that can be expected for TD programs. Consistent efforts to reconnect devices and enroll new devices will contribute to a prolonged program benefit and ensure continued ACSDA reductions. As is shown in Table 5, a failure rate of 8.16% is assumed for the residential ACSDA program, based on the connectivity data for all ecobee devices. This rate is incorporated into the enrollment forecasts to reflect the average yearly loss of thermostats through disconnection.

Figure 5: Thermostat Connectivity Survival Curves for CPP Programs

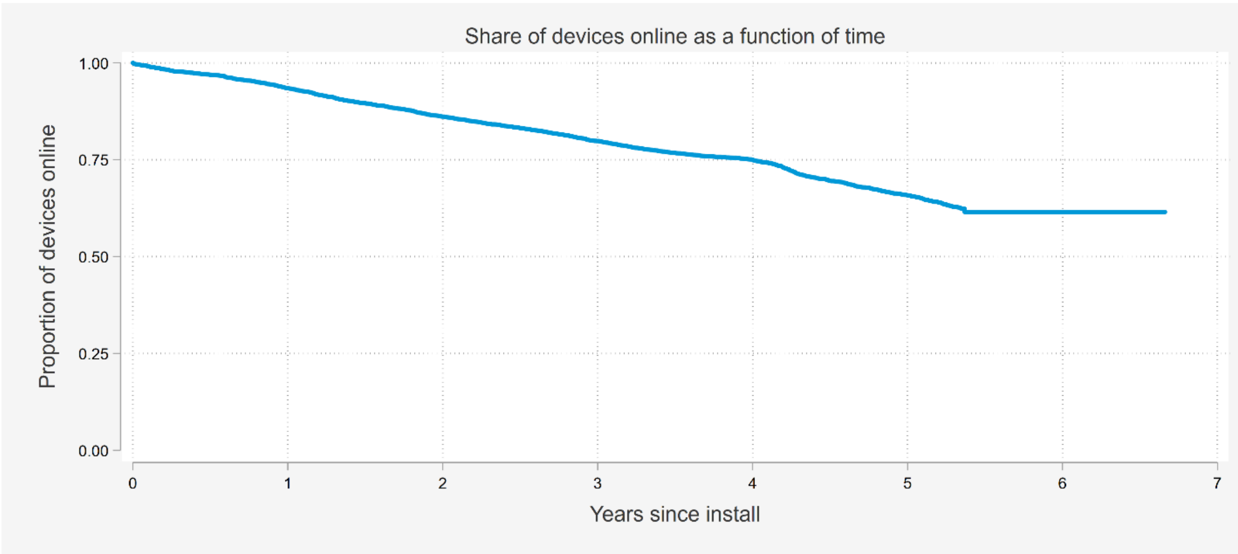


Table 5: Thermostat Connection Decay Rates for Residential ACSDA Programs

Program	Failure Rate	95% Confidence	
		Lower Bound	Upper Bound
Residential ACSDA[9]	8.16%	7.84%	8.49%

Table 6 shows program counts for enrolled sites, installed thermostats, and connected thermostats during the average PY 2019 event. Among all installed devices, 14% were no longer connected to the SDG&E dispatch portal during PY 2019 and therefore could not be curtailed during events. There are multiple reasons why a thermostat can become disconnected: a change in routers, a change in Wi-Fi passwords, deliberate disconnection (opt-outs), replacement of the thermostat, etc. When router or Wi-Fi passwords change, a thermostat may not be reconnected by the customers. Understanding the reason why thermostats become disconnected and how to effectively encourage customers to reconnect is critical to the long-term success of the program.

Residential thermostat event impacts were assessed by site (premise and service point combination). Sites were grouped together into segments to assess potential differences in impacts for various groups. The segmentation, summarized in Table 6, was developed based on thermostat category, brand, TOU status, climate zone, and net metering status which may influence impacts. The analysis

[9] Based on connectivity data for free and BYOT Ecobee devices

was performed at the segment level so these granular impacts could therefore be summed, yielding aggregate impacts in addition to the segment specific impacts.

The segmentation criteria were defined as follows:

- **Program:** was the thermostat provided by SDG&E or through the BYOT program?
- **Thermostat Type:** was the thermostat provider ecobee or Nest?
- **TOU Status:** was the site on a TOU rate at the start of the study period, did it get transitioned to TOU during the study period, or is it not yet on a TOU rate?
- **Climate zone:** in which SDG&E climate zone was the site located?
- **NEM status**: did the site have net metering?

Table 6: Residential Thermostat Programs and Populations

Program Rate	Tstat Type	TOU Status	Climate zone	NEM	Total sites	Sites in event analysis	Total installed devices	Total connected devices
ACSDARES (Free)	Free ecobee	Non-TOU -	Coastal	No	1,341	1,332	1,647	1,091
				Yes	17	17	24	19
			Inland	No	2,020	2,005	2,366	1,543
				Yes	30	30	43	27
		TOU -	Coastal	No	637	632	816	525
				Yes	59	59	78	55
			Inland	No	912	906	1,110	747
				Yes	122	121	159	110
		TOU Trans -	Coastal	No	600	596	728	462
				Yes	49	49	61	38
			Inland	No	1,017	1,009	1,170	730
				Yes	112	111	142	98
ACSDARES (BYOT)	BYOT Nest	Non-TOU -	Coastal	No	2,752	2,694	3,161	3,162
				Yes	28	28	40	40
			Inland	No	2,054	2,011	2,262	2,262
				Yes	28	28	37	37
		TOU -	Coastal	No	1,164	1,139	1,525	1,525
				Yes	67	66	95	95
			Inland	No	775	759	932	932
				Yes	85	84	102	102
		TOU Trans -	Coastal	No	1,291	1,264	1,987	1,988
				Yes	76	75	102	102
			Inland	No	1,218	1,193	1,604	1,605
				Yes	106	104	137	137
	BYOT ecobee	Non-TOU -	Coastal	No	170	167	183	153
				Yes	2	2	3	3
			Inland	No	158	154	167	134
				Yes	3	3	3	2
		TOU -	Coastal	No	58	57	60	53
				Yes	15	15	16	15
			Inland	No	50	49	50	32
				Yes	7	7	9	8
		TOU Trans -	Coastal	No	78	76	79	67
				Yes	8	8	9	4
			Inland	No	80	79	81	57
				Yes	6	6	6	5
TOTAL					17,197	16,933	20,995	17,964

Table 6 also summarizes the total number of sites in each segment and the final number of sites used for the ex post event analysis once data cleaning was completed[10]. BYOT makes up the majority of sites and thermostats, comprised mostly of Nest thermostats. The majority of BYOT sites (56%) are in the coastal climate zone where cooling loads and therefore impacts per thermostat are expected to be lower. In contrast, a smaller portion of free sites (39%) are in the coastal zone. About 820 sites (5% of all sites) across both programs were net-metered, but it was important to estimate impacts separately for this segment given the difference in underlying load shapes typical of solar customers.

Table 7 shows the 20 PY 2019 ACSDA event days. The ACSDA season started in April and extended to October. Most events occurred on weekdays, with the exception of August 4, which was a Sunday. Daily maximum temperatures ranged from 75.1 to 93.5 F.

Table 7: Residential Thermostat ACSDA Events in 2019

Event day	Day of week	Event start	Event end	Max daily temp (F)	SDG&E system load (MW)
4/24/2019	Wednesday	7:00 PM	9:00 PM	75.1	2,599
7/22/2019	Monday	6:00 PM	9:00 PM	82.1	3,130
7/23/2019	Tuesday	6:00 PM	8:00 PM	87.0	3,500
7/24/2019	Wednesday	6:00 PM	8:00 PM	89.8	3,654
7/29/2019	Monday	6:00 PM	8:00 PM	81.6	3,146
8/4/2019	Sunday	6:00 PM	8:00 PM	83.2	3,040
8/5/2019	Monday	6:00 PM	8:00 PM	82.9	3,310
8/6/2019	Tuesday	6:00 PM	8:00 PM	81.3	3,205
8/14/2019	Wednesday	6:00 PM	8:00 PM	83.2	3,320
8/15/2019	Thursday	6:00 PM	8:00 PM	82.7	3,209
8/26/2019	Monday	6:00 PM	8:00 PM	88.6	3,666
8/27/2019	Tuesday	6:00 PM	8:00 PM	83.6	3,438
9/4/2019	Wednesday	4:00 PM	7:00 PM	89.9	4,148
9/5/2019	Thursday	5:00 PM	8:00 PM	89.3	4,034
9/6/2019	Friday	6:00 PM	8:00 PM	89.1	3,958
9/23/2019	Monday	1:00 PM	4:00 PM	80.0	3,032
9/24/2019	Tuesday	6:00 PM	8:00 PM	83.3	3,222
9/25/2019	Wednesday	6:00 PM	8:00 PM	78.2	3,104
10/21/2019	Monday	6:00 PM	8:00 PM	89.7	3,067
10/22/2019	Tuesday	5:00 PM	8:00 PM	93.5	3,260

[10] The cleaning algorithm ensured that complete data was available for the study period. Loads and impacts were scaled to address the 264 sites not in the analysis.

3.2 DATA SOURCES AND ANALYSIS METHOD

Table 8 summarizes the five data sources used to conduct the residential thermostat event impact analysis. The analysis was done by site on hourly load data. Various data sources were used to classify sites into the study segments. While different segments were developed for the various analyses in this report, the characteristic definitions used to build segments were consistent across analyses.

Table 8: Residential Thermostat Event Impact Evaluation Data Sources

Source	Comments
Hourly interval data	▪ Summer 2019 ▪ All analysis done by site (premise id-service point id pair)
Customer characteristics	▪ Treatment: All residential thermostat participants ▪ Control: All residential sites not in other DR programs ▪ TOU transition date, NEM status, climate zones used in matched control selection
Thermostat installation data	▪ Installation and last connected dates
SDG&E hourly system loads	▪ Summer 2019 ▪ Used to identify non-event high system load days
Ex post weather data by weather station	▪ Used to derive cooling degree hours for impact evaluation panel model

The primary analysis method was a panel regression with multiple matched control groups. The distance matching approach used selected five matched control sites for each of the roughly 17,000 residential thermostat sites among a control candidate pool of roughly 10,000 sampled residential sites who were not enrolled in CPP or other DR programs which might influence energy use. Non-typical, or very large customers tend to be more difficult to match because there are fewer other customers with similar load patterns. To ensure there would be sufficient control candidates for every type of participant, the control pool was constructed within bins by TOU status, NEM status, and size (annual usage for non-NEM and system capacity for NEM sites). Once the matches were selected for each participant, the panel regression model was used to assess impacts and standard errors for each event and each study segment.

To identify which model best predicted customer loads absent demand reductions, an out of sample approach was still used to select the model specification. The model selection relied on testing how well each model estimated loads for hot non-event days out-of-sample. Because there was, in fact, no event, it was possible to assess how close model estimates were to the correct answer and the most accurate model. A total of 60 models were tested to select the number of proxy days, number of matched controls, and structure of same day adjustments to use. The regression model structure is detailed in the Appendix.

3.3 EX POST LOAD IMPACTS

3.3.1 AC Saver Day Ahead: Residential with Technology

The residential ACSDA program began in 2018 and initially included both a free thermostat channel and a Bring Your Own Thermostat (BYOT) rebate channel. The BYOT channel allows customers to use their existing Nest or ecobee smart thermostats to receive the ACSDA program signals. Before the PY 2019 event season, SDG&E closed the free thermostat program to new enrollments and substantially ramped up enrollment of BYOT thermostats, adding over three thousand thermostats to the program and also substantially changing the participant mix compared to PY 2018. In addition, before the beginning of the PY 2019 event season SDG&E closed the Peak Time Rebate program (another smart thermostat enabled program in existence since 2016) and transferred around four thousand participants to the ACSDA program, substantially changing the participant mix. The Free and BYOT channels are evaluated in this report as two distinct programs and most of the transitioned PTR participants are included in the Free program population.

There were 20 residential events called during PY 2019. These ACSDA events were typically called from 6 to 8 pm, though six events were called during slightly different windows and another event was called on a weekend. The remaining events are used to create the Average Event impacts. Load reductions were significant for all events. The average event window was also significant with an average aggregate reduction of 1.20 MW.

Table 9 and Table 10 summarize the load reductions for Residential ACSDA sites for the 20 events and 6 pm to 8 pm reductions for the average event. The full event hours for the seven non-standard event days are provided at the bottom of the tables. None of these are included in the calculations for the average event.

The impacts for the free thermostats are detailed in Table 9. The average aggregate load reduction for all event days from 6 to 8 pm was 1.20 MW across all 6,916 enrolled sites and the average reduction per site was 0.17 kW. Though 8,344 devices were installed at enrolled sites, only 5,445 devices on average were connected during the PY 2019 event season. Because only connected devices can be dispatched, all reductions are delivered by these connected devices. The average reduction per connected device was 0.22 kW. Impacts tended to be larger for events where the average event temperature was higher.

Aggregate reductions for significant events range from 0.03 MW (April 24) to 3.28 MW (September 4). These dates, respectively, also exhibited the highest and lowest average site reductions and average connected thermostat reductions of the free thermostats.

Table 9: ACSDA Residential Program Event Reductions (FREE)

Event Date	Event Window	Avg Event Temp (F)	Sites Enrolled	Installed Devices	Connect-ed Devices	Reduction			t-stat	Significant (90% CI)
						Aggregate (MW)	Average Site (kw)	Average Connected Tstat (kw)		
7/23/2019	6 to 8 pm	79.5	6,918	8,348	5,553	2.12	0.31	0.38	34.37	Yes
7/24/2019	6 to 8 pm	77.9	6,919	8,349	5,543	2.20	0.32	0.40	40.88	Yes
7/29/2019	6 to 8 pm	73.0	6,918	8,348	5,517	0.89	0.13	0.16	20.61	Yes
8/5/2019	6 to 8 pm	73.4	6,915	8,342	5,481	1.05	0.15	0.19	23.71	Yes
8/6/2019	6 to 8 pm	70.8	6,916	8,344	5,482	1.19	0.17	0.22	26.53	Yes
8/14/2019	6 to 8 pm	73.9	6,917	8,345	5,473	0.87	0.13	0.16	19.50	Yes
8/15/2019	6 to 8 pm	71.6	6,916	8,343	5,467	0.82	0.12	0.15	19.17	Yes
8/26/2019	6 to 8 pm	76.5	6,917	8,346	5,449	1.34	0.19	0.25	25.46	Yes
8/27/2019	6 to 8 pm	73.2	6,917	8,346	5,443	1.19	0.17	0.22	25.35	Yes
9/6/2019	6 to 8 pm	78.4	6,915	8,344	5,406	2.07	0.30	0.38	34.15	Yes
9/24/2019	6 to 8 pm	73.0	6,916	8,345	5,353	0.79	0.11	0.15	20.90	Yes
9/25/2019	6 to 8 pm	71.4	6,915	8,344	5,351	0.79	0.11	0.15	21.20	Yes
10/21/2019	6 to 8 pm	76.3	6,907	8,332	5,266	0.23	0.03	0.04	9.16	Yes
Avg Event	**6 to 8 pm**	**74.5**	**6,916**	**8,344**	**5,445**	**1.20**	**0.17**	**0.22**	**81.52**	**Yes**
4/24/2019	7 to 9 pm	62.4	6,920	8,351	5,760	0.03	0.00	0.01	1.64	Yes
7/22/2019	6 to 9 pm	73.1	6,917	8,347	5,555	1.16	0.17	0.21	37.02	Yes
8/4/2019	6 to 8 pm	72.5	6,918	8,348	5,488	1.17	0.17	0.21	22.51	Yes
9/4/2019	4 to 7 pm	83.9	6,914	8,343	5,418	3.28	0.47	0.61	68.02	Yes
9/5/2019	5 to 8 pm	80.7	6,914	8,343	5,414	1.65	0.24	0.31	34.08	Yes
9/23/2019	1 to 4 pm	80.0	6,916	8,345	5,358	0.71	0.10	0.13	25.87	Yes
10/22/2019	5 to 8 pm	77.7	6,907	8,332	5,262	0.69	0.10	0.13	24.78	Yes

The impacts for the BYOT thermostats are detailed in Table 10. The average aggregate load reduction for all event days from 6 to 8 pm was 2.56 MW across all 10,281 enrolled sites and the average reduction per site was 0.24 kW. Almost all 12,651 installed devices still enrolled throughout the PY 2019 event season, with 12,519 connected devices on average. Because only connected devices can be dispatched, all reductions are delivered by these connected devices. The average reduction per connected device was 0.20 kW. Aggregate impacts are about twice as large for the BYOT devices. There are over twice as many connected devices, but impacts per connected thermostat are slightly smaller for the BYOT program with 0.20 kW compared to the 0.22 kW savings per free connected device.

BYOT aggregate reductions for significant events range from 0.04 MW (October 21) to 5.16 MW (September 4). These dates, respectively, also exhibited the highest and lowest average site reductions and average connected thermostat reductions of the BYOT thermostats.

Table 10: ACSDA Residential Program Event Reductions (BYOT)

Event Date	Event Window	Avg Event Temp (F)	Sites Enrolled	Installed Devices	Connect-ed Devices	Reduction			t-stat	Significant (90% CI)
						Aggregate (MW)	Average Site (kw)	Average Connected Tstat (kw)		
7/23/2019	6 to 8 pm	78.5	9,875	12,198	12,070	3.43	0.32	0.28	41.85	Yes
7/24/2019	6 to 8 pm	77.2	9,900	12,228	12,099	4.04	0.38	0.33	56.42	Yes
7/29/2019	6 to 8 pm	72.2	10,036	12,385	12,256	2.10	0.20	0.17	37.16	Yes
8/5/2019	6 to 8 pm	72.7	10,158	12,520	12,392	2.32	0.22	0.19	39.30	Yes
8/6/2019	6 to 8 pm	70.3	10,171	12,534	12,405	2.54	0.24	0.20	43.21	Yes
8/14/2019	6 to 8 pm	73.0	10,268	12,639	12,510	2.34	0.22	0.19	40.42	Yes
8/15/2019	6 to 8 pm	70.8	10,284	12,656	12,527	2.17	0.20	0.17	41.23	Yes
8/26/2019	6 to 8 pm	75.7	10,388	12,771	12,640	3.16	0.30	0.25	49.02	Yes
8/27/2019	6 to 8 pm	72.7	10,399	12,780	12,649	2.82	0.27	0.22	46.95	Yes
9/6/2019	6 to 8 pm	78.1	10,484	12,872	12,738	4.40	0.41	0.35	60.44	Yes
9/24/2019	6 to 8 pm	72.7	10,564	12,961	12,823	1.95	0.18	0.15	39.83	Yes
9/25/2019	6 to 8 pm	71.4	10,562	12,959	12,820	1.96	0.18	0.15	42.17	Yes
10/21/2019	6 to 8 pm	76.4	10,563	12,961	12,816	0.04	0.00	0.00	0.51	Yes
Avg Event	**6 to 8 pm**	**74.0**	**10,281**	**12,651**	**12,519**	**2.56**	**0.24**	**0.20**	**136.15**	**Yes**
4/24/2019	7 to 9 pm	62.0	8,608	10,789	10,677	0.21	0.02	0.02	5.43	Yes
7/22/2019	6 to 9 pm	72.5	9,847	12,171	12,044	2.19	0.21	0.18	50.35	Yes
8/4/2019	6 to 8 pm	71.9	10,144	12,505	12,377	2.61	0.25	0.21	39.48	Yes
9/4/2019	4 to 7 pm	83.3	10,468	12,855	12,721	5.16	0.49	0.41	93.19	Yes
9/5/2019	5 to 8 pm	80.1	10,474	12,861	12,727	3.73	0.35	0.29	66.21	Yes
9/23/2019	1 to 4 pm	78.7	10,564	12,961	12,823	1.59	0.15	0.12	45.36	Yes
10/22/2019	5 to 8 pm	77.9	10,562	12,960	12,814	0.15	0.01	0.01	6.95	Yes

Reductions were also analyzed by TOU status for residential customers in the ACSDA program. During PY 2019, many customers were transitioned onto TOU rates. In order to tease out any differential impacts by TOU status, customers were classified as not having TOU, having TOU for the entire demand response season, and the customers who transitioned onto TOU rates during the PY 2019 demand response season (i.e. customers who were not TOU as of April 24, but were on TOU rates by October 21)[11]. Table 11 details the reference loads and load reductions overall and by TOU category for the average 6 pm to 8 pm event window. In addition to aggregate reductions, average reductions per

[11] It is notable that the second phase of SDG&E's default TOU rollout has not been randomized, rather it has been deployed strategically targeting customers expected to benefit most from the new rates. As such the TOU segments for this study are not comparable populations and differ in their underlying usage patterns as well as in their rate status.

connected thermostat are also shown. Note that the reference load for aggregate impacts includes the whole building load across all enrolled sites as recorded at the meter; the reference load for the average connected thermostat is the cooling load per connected thermostat, estimated by isolating the weather sensitive portion of whole building load. In aggregate, 13.3% of whole building load was curtailed during the average event, while 48% of cooling load was curtailed per connected device.

In aggregate, 40% of connected devices were in the coastal zone and these devices delivered 0.40 MW of the 1.20 MW—one third—of reductions for the ACSDA Residential program. However, as expected the load reduction (kW) per device is higher among participants in the inland climate zone.

Approximately half of the sites and devices are Non-TOU, and the remaining are split evenly between the TOU and TOU transition groups. Average connected thermostat percent reductions are 48% for all customers. Reductions as a percent of cooling load were not meaningfully different for participants on TOU rates or for those who were transitioned onto TOU rates during PY 2019. For non-NEM customers, both groups showed inland percent reductions of 48% and the coastal percent reductions range from 52% to 49% for TOU and TOU transition customers, respectively. For participants not on TOU at all, these non-NEM percent impacts were slightly lower than TOU sites in the inland zone (43%) and slightly higher than TOU sites in the coastal zone (57%).

Table 11: ACSDA Residential Program Average Event Reductions by Segment (FREE)

Tstat Type	TOU Status	Climate Zone	NEM	Event Window	Avg Event Temp (F)	Sites Enrolled	Installed Devices	Connect-ed Devices	Aggregate (MW): Ref load (whole bldg)	Aggregate (MW): Reduc-tion	Aggregate (MW): % Reduc-tion	Average connected tstat (kW): Ref load (cooling)	Average connected tstat (kW): Reduc-tion	Average connected tstat (kW): % Reduc-tion	t-stat
Free ecobee	Non-TOU	Coastal	No	6 to 8 pm	73.4	1,341	1,647	1,091	1.66	0.25	15.1%	0.40	0.23	57%	39.31
			Yes	6 to 8 pm	72.1	17	24	19	0.03	0.00	13.6%	0.25	0.18	71%	4.61
		Inland	No	6 to 8 pm	75.3	2,020	2,366	1,543	3.03	0.43	14.1%	0.64	0.28	43%	48.96
			Yes	6 to 8 pm	75.5	30	43	27	0.05	0.00	4.3%	0.60	0.09	14%	1.98
	TOU	Coastal	No	6 to 8 pm	73.3	637	816	525	0.66	0.07	10.5%	0.25	0.13	52%	17.99
			Yes	6 to 8 pm	73.2	59	78	55	0.08	0.01	12.5%	0.47	0.18	39%	6.53
		Inland	No	6 to 8 pm	75.1	912	1,110	747	1.11	0.15	13.2%	0.41	0.20	48%	28.18
			Yes	6 to 8 pm	75.7	122	159	110	0.23	0.03	12.9%	0.91	0.27	30%	12.14
	TOU Trans	Coastal	No	6 to 8 pm	73.6	600	728	462	0.61	0.06	10.0%	0.27	0.13	49%	16.37
			Yes	6 to 8 pm	73.1	49	61	38	0.06	0.01	8.6%	0.44	0.14	32%	3.83
		Inland	No	6 to 8 pm	75.0	1,017	1,170	730	1.26	0.16	12.7%	0.46	0.22	48%	29.01
			Yes	6 to 8 pm	75.9	112	142	98	0.20	0.03	16.1%	0.67	0.33	48%	13.80
All	**All**			**6 to 8 pm**	**74.5**	**6,916**	**8,344**	**5,445**	**8.98**	**1.20**	**13.3%**	**0.46**	**0.22**	**48%**	**81.52**

Table 12 shows the same results for the two BYOT categories-Nest and ecobee thermostats. Overall, aggregate reductions were 2.56 MW which is 20.4% of whole building load. As with the free thermostats, inland thermostats deliver greater load reductions (kW) per thermostat. Also similarly to the free thermostats, approximately half of the enrolled sites have not yet been transitioned to TOU rates. For the Nest BYOT thermostats, impacts are not meaningfully different by TOU status. There are nominal differences by TOU status among ecobee. However, there are too few devices (dozens) within each category and t-statistics are too low to draw robust conclusions between subgroups. This stands in contrast to Nest subgroups, most of which include over a thousand participant sites and have highly robust t-statistics (in the double digits).

Table 12: ACSDA Residential Program Average Event Reductions by Segment (BYOT)

Tstat Type	TOU Status	Climate Zone	NEM	Event Window	Avg Event Temp (F)	Sites Enrolled	Installed Devices	Connect-ed Devices	Aggregate (MW) Ref load (whole bldg)	Aggregate (MW) Reduc-tion	Aggregate (MW) % Reduc-tion	Average connected tstat (kW) Ref load (cooling)	Average connected tstat (kW) Reduc-tion	Average connected tstat (kW) % Reduc-tion	t-stat
BYOT Nest	Non-TOU	Coastal	No	6 to 8 pm	73.1	2,752	3,161	3,162	3.33	0.72	21.7%	0.45	0.23	51%	75.44
			Yes	6 to 8 pm	73.4	28	40	40	0.05	0.01	15.4%	0.56	0.19	34%	6.30
		Inland	No	6 to 8 pm	75.1	2,054	2,262	2,262	2.94	0.68	23.1%	0.67	0.30	45%	74.29
			Yes	6 to 8 pm	74.9	28	37	37	0.06	0.02	24.5%	0.95	0.41	43%	9.98
	TOU	Coastal	No	6 to 8 pm	73.1	1,164	1,525	1,525	1.26	0.22	17.2%	0.28	0.14	51%	36.56
			Yes	6 to 8 pm	73.0	67	95	95	0.11	0.02	20.9%	0.46	0.23	51%	10.68
		Inland	No	6 to 8 pm	74.8	775	932	932	0.91	0.17	19.0%	0.41	0.19	45%	34.28
			Yes	6 to 8 pm	75.5	85	102	102	0.15	0.04	24.5%	0.76	0.35	47%	16.43
	TOU Trans	Coastal	No	6 to 8 pm	73.3	1,291	1,987	1,988	1.26	0.21	16.5%	0.20	0.10	52%	34.41
			Yes	6 to 8 pm	73.1	76	102	102	0.14	0.02	17.6%	0.64	0.24	38%	11.24
		Inland	No	6 to 8 pm	74.9	1,218	1,604	1,605	1.40	0.27	19.6%	0.35	0.17	49%	43.36
			Yes	6 to 8 pm	75.0	106	137	137	0.18	0.05	26.5%	0.66	0.36	54%	19.95
BYOT ecobee	Non-TOU	Coastal	No	6 to 8 pm	73.2	170	183	153	0.21	0.03	14.2%	0.50	0.20	39%	12.57
			Yes	6 to 8 pm	71.9	2	3	3	0.01	0.00	-10.9%	1.27	-0.21	-16%	-2.37
		Inland	No	6 to 8 pm	75.1	158	167	134	0.22	0.05	21.7%	0.64	0.35	55%	19.33
			Yes	6 to 8 pm	73.7	3	3	2	0.01	0.00	2.1%	1.50	0.07	5%	0.29
	TOU	Coastal	No	6 to 8 pm	72.4	58	60	53	0.05	0.00	9.0%	0.23	0.08	36%	4.12
			Yes	6 to 8 pm	73.5	15	16	15	0.02	0.00	18.4%	0.58	0.27	47%	4.73
		Inland	No	6 to 8 pm	74.6	50	50	32	0.04	0.01	18.0%	0.33	0.23	70%	8.79
			Yes	6 to 8 pm	75.1	7	9	8	0.01	0.00	19.3%	0.83	0.27	32%	2.83
	TOU Trans	Coastal	No	6 to 8 pm	73.9	78	79	67	0.08	0.02	21.8%	0.42	0.27	63%	13.96
			Yes	6 to 8 pm	72.6	8	9	4	0.01	0.00	4.9%	0.20	0.12	63%	0.75
		Inland	No	6 to 8 pm	74.9	80	81	57	0.10	0.02	18.0%	0.55	0.31	57%	11.14
			Yes	6 to 8 pm	74.5	6	6	5	0.01	0.00	17.7%	0.70	0.25	36%	3.09
All	All			6 to 8 pm	74.0	10,281	12,651	12,519	12.55	2.56	20.4%	0.44	0.20	46%	136.15

The average event day load shape is summarized in greater detail in Figure 6 for Free thermostats and Figure 7 for BYOT thermostats. Note that the figures, extracted from the Ex Post Load Impact Table, are for the ACSDA residential participant population for the average event day. The average event day reflects weekday events where event hours matched the 6 to 8 pm window. The left panel shows the aggregate hourly loads (actual and counterfactual) for these sites. The right panel shows impacts per connected thermostat. The tables accompanying each figure show aggregate impacts for the 6 pm to 8 pm event window.

The load shapes in Figure 6 exhibit a clear impact during the event window, followed by a one-hour snapback in hour ending 21. There is a 13.3% reduction across all connected Free residential thermostats on the average weekday 2019 event.

Figure 7 also has clearly visible event impacts , and provides the load shapes for the BYOT thermostats. Unlike the free thermostats, there is a pre-cooling effect in hour ending 18, where households are increasing their cooling prior to the event window. There is a similar snapback effect in hour ending 21 as is seen in Figure 6 for the free thermostats. In contrast, there is also a clear load increase just prior to the event start, typically indicative of pre-cooling. Upon further investigation this appeared to be unique to the BYOT Nest thermostats. Overall savings are 20.4% load reductions for average connected thermostats and on aggregate for the BYOT category.

Figure 6: ACSDA Residential Summary for Average Event (FREE)

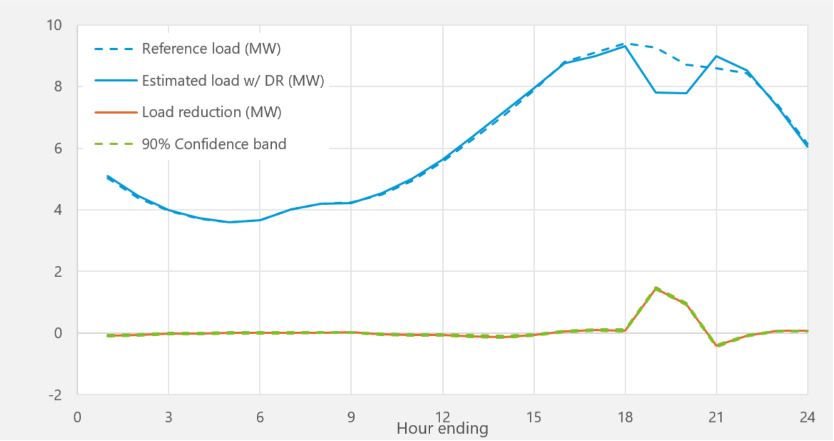
Update menus

Table 1: Menu options

Program	ACSDARES (Free)
Type of result	Aggregate
Type of site	All
Category	All
Subcategory	All study segments
Event date	Avg. Weekday Event 2019

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total sites	6,916
Total installed thermostats	8,344
Total connected thermostats	5,445
Percent of thermostats connected	65%
Avg load reduction 6PM-8PM	1.20
% Load reduction 6PM-8PM	13.3%



Update menus

Table 1: Menu options

Program	ACSDARES (Free)
Type of result	Average Customer
Type of site	All
Category	All
Subcategory	All study segments
Event date	Avg. Weekday Event 2019

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total sites	6,916
Total installed thermostats	8,344
Total connected thermostats	5,445
Percent of thermostats connected	65%
Avg load reduction 6PM-8PM	0.17
% Load reduction 6PM-8PM	13.3%

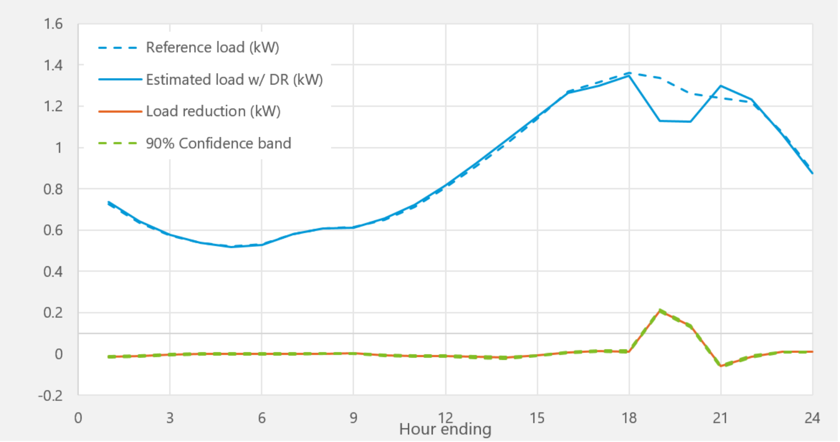


Figure 7: ACSDA Residential Summary for Average Event (BYOT)

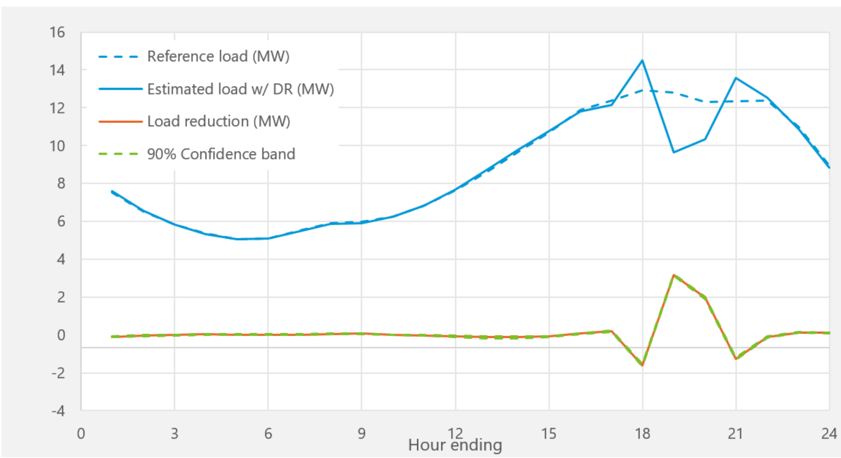
Update menus

Table 1: Menu options

Program	ACSDARES (BYOT)
Type of result	Aggregate
Type of site	All
Category	All
Subcategory	All study segments
Event date	Avg. Weekday Event 2019

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total sites	10,281
Total installed thermostats	12,651
Total connected thermostats	12,519
Percent of thermostats connected	99%
Avg load reduction 6PM-8PM	2.56
% Load reduction 6PM-8PM	20.4%



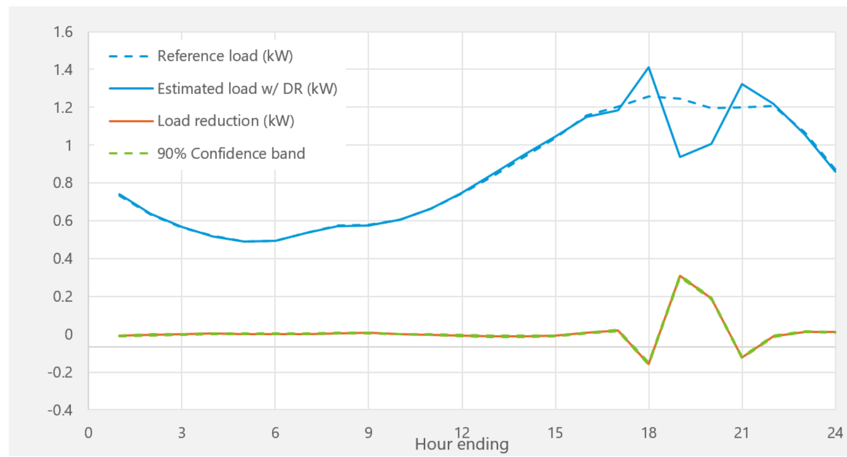
Update menus

Table 1: Menu options

Program	ACSDARES (BYOT)
Type of result	Average Customer
Type of site	All
Category	All
Subcategory	All study segments
Event date	Avg. Weekday Event 2019

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total sites	10,281
Total installed thermostats	12,651
Total connected thermostats	12,519
Percent of thermostats connected	99%
Avg load reduction 6PM-8PM	0.25
% Load reduction 6PM-8PM	20.4%



3.4 EX ANTE LOAD IMPACTS

A key objective of the 2019 evaluation is to quantify the relationship between demand reductions, temperature, and hour of day. Ex ante impacts are estimated load reductions as a function of weather conditions, time of day, and forecasted changes in enrollment. By design, they reflect planning conditions defined by normal (1-in-2) and extreme (1-in-10) peak demand weather conditions. The historical load patterns and performance during actual events are used as the reductions for a standardized set of weather conditions.

At a fundamental level, the process of estimating ex ante impacts included five main steps:

1. Estimate the relationship between cooling load per thermostat (absent DR) and weather by hour of day
2. Estimate the relationship between cooling load percent reduction, temperature, and hours into an event using historical event data
3. Predict cooling loads and percent reductions for 1-in-2 and 1-in-10 weather year conditions
4. Combine the loads and percent reductions to estimate impacts per connected thermostat
5. Incorporate the enrollment/device forecast and device connectivity forecast

3.4.1 RELATIONSHIP OF CUSTOMER LOADS AND PERCENT REDUCTIONS TO WEATHER

Figure 8 summarizes the relationship between weather and customer load for residential ACSDA customers. Only days when the smart thermostat resources were not dispatched are included. Overall, energy demand and discretionary load increases with hotter weather.

These figures also provide an estimate for typical cooling loads for residential thermostat sites by assessing how whole building loads per thermostat vary with temperature (left panel). The baseload is estimated by the load on cooling neutral days (max daily temperatures around 65 degrees, e.g. blue line in left panel). Net cooling loads (right panel) are total loads for each weather bin minus the baseload.

On days with 90-93 max daily temperature, average cooling load per thermostat for residential ACSDA devices is about 2.6 kW during the 4 pm to 9 pm period that counts towards resource adequacy requirements—ACSDA events are typically called late in the day but can be called anytime from 11 am to 9 pm.

Because impacts are directly driven by connected thermostats controlling cooling loads, ex ante impacts were estimated as a function of cooling loads on a per thermostat basis.

Figure 8: Weather Sensitivity of ACSDA Residential Program Participant Loads

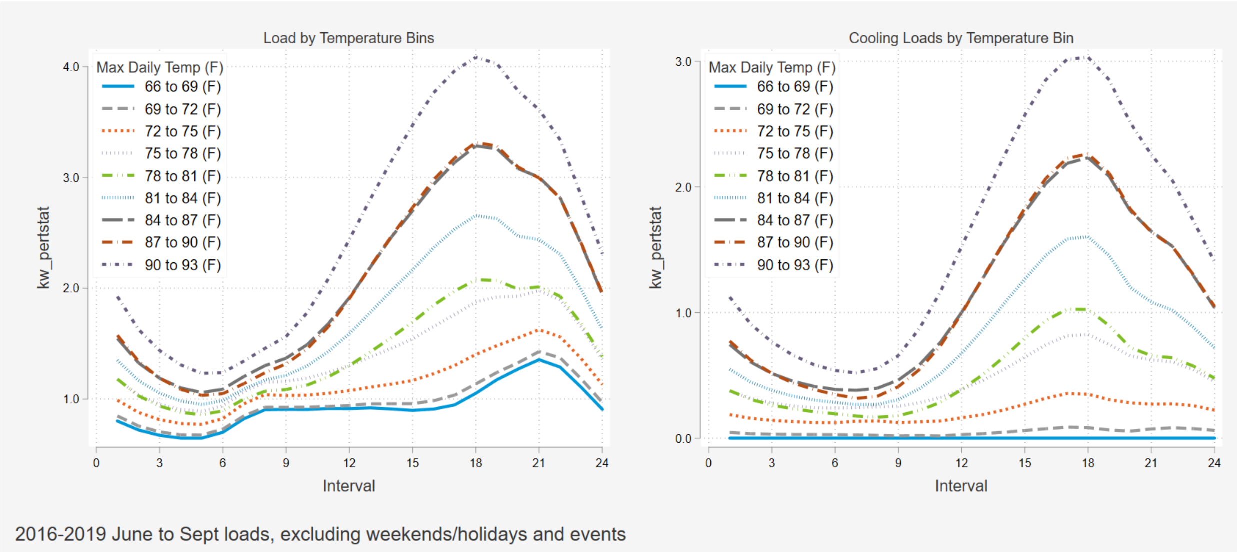
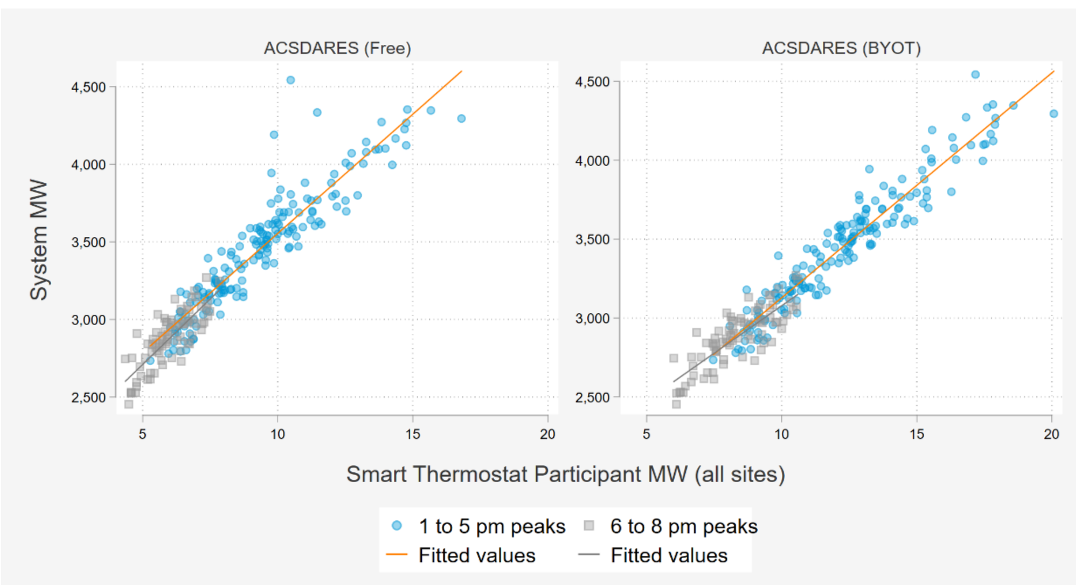


Figure 9 shows the relationship between aggregate loads for ACSDA sites and SDG&E daily peak loads. Daily system peaks that occurred before 5pm (typically at 4 or 5pm) are shown in blue and those that occurred later are shown in grey. The patterns are very similar for ACSDA sites with free thermostats and BYOT thermostats. The differences in MW of participant load versus system load are largely proportional to the different number of devices in each program. Recall there are about 50% more installed thermostats in the BYOT category, so we expect higher aggregate load compared to the free thermostat participant load.

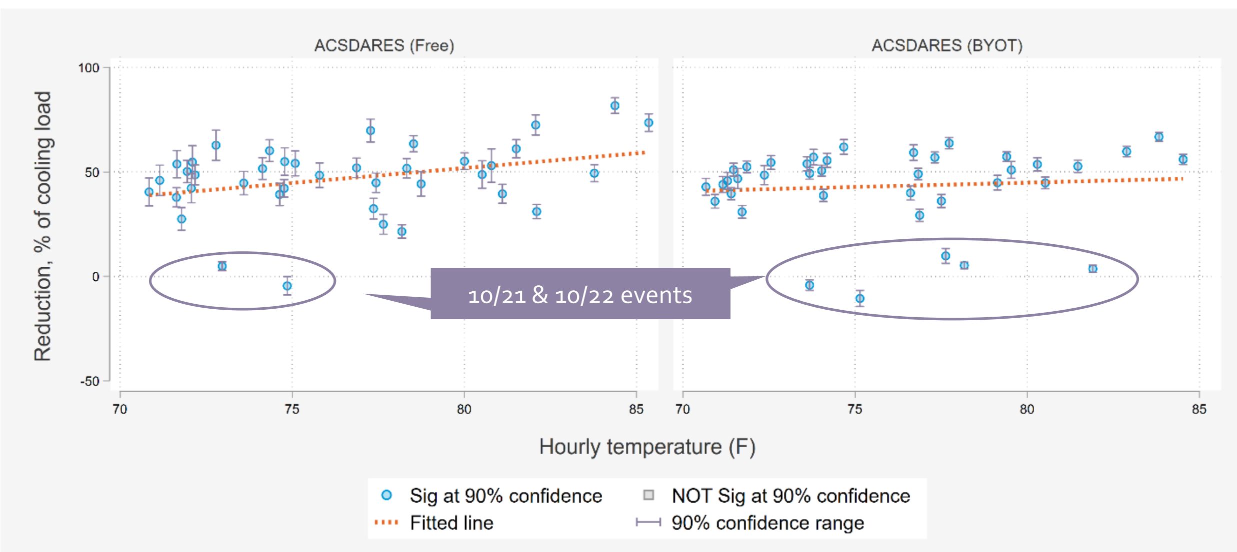
Figure 9: Residential Thermostat Customer Loads During System Daily Peaks



Because ACSDA thermostats are dispatched automatically for events, the main driver of differences in ex ante impacts are differences in loads. PY 2019 was the first season with residential ACSDA events. These event impacts are utilized to build the ex ante model.

Figure 10 shows hourly event percent reductions for historical weekday events as a function of hourly temperatures for sites for the free and BYOT programs. Reductions are largely positive in magnitude, a handful are near zero and few are negative, indicating an increase in load. Due to large sample size, confidence intervals are tight, and all event hours are significant. Both programs have fairly flat trends, but the free program has a slightly increasing trend with higher hourly temperatures resulting in larger percent reductions. The seven event hours nearest zero-two in the free category and 5 in the BYOT category-are from events on October 21 and October 22. Further exploration revealed that a meaningfully portion of thermostats were no longer set to "Cooling" mode at this late point in the season. Although these events were called on days with warm temperatures they followed several days of cooler weather. Functionally this means that there would be less thermal heat accumulation than on similarly warm days in the summer. The intervening cooler days may also have been enough to trigger the thermostats to pass out of "Cooling" mode into "Heating". For all these reasons impacts for these two late season events were considered atypical and excluded from the inputs to the ex ante analysis.

Figure 10: 2016-2019 ACSDA Hourly Reductions and Temperatures[12]



[12] Participant weighted temperature in each event hour. Hourly event temperatures shown are largely lower than daily maximum temperatures since event hours mostly occur between 6 pm and 8 pm when temperatures are cooler.

3.4.2 Ex Ante Load Impacts

Table 13 summarizes the ex ante demand reduction capability by forecast year for 1-in-2 SDG&E weather planning conditions across all four Technology Deployment programs. The tables reflect demand reductions available from 4 pm to 9 pm on August monthly peaking conditions. They align with the planning conditions used for resource adequacy attribution. They incorporate an enrollment forecast developed by SDG&E reflecting substantial growth in enrollment for BYOT sites. The Free program is no longer enrolling sites, and sites are forecast to decline. The enrollment forecast also incorporates declines in device connectivity in line with the historical average discussed at the beginning of this chapter. Ultimately, forecasted ex ante load reductions reflect load reductions delivered by connected devices among enrolled sites. Reductions are a function of the number of enrolled sites, the connectivity rate over time for installed devices, and the estimated load reduction per connected device.

Table 13: Residential Smart Thermostat Portfolio Impacts for 1-in-2 August Monthly Peak Day

Year	ACSDA - Residential		Total
	Free	BYOT	
2019	1.47	4.45	5.92
2020	1.17	5.57	6.74
2021	0.88	6.59	7.47
2022	0.60	7.53	8.14
2023	0.51	6.92	7.43
2024	0.43	6.35	6.78
2025	0.35	5.84	6.18
2026	0.28	5.36	5.64
2027	0.21	4.92	5.13
2028	0.15	4.52	4.67
2029	0.09	4.15	4.25
2030	0.04	3.81	3.86

Table 14 summarizes the ex ante demand reduction capability by forecast year for different planning conditions. The tables reflect dispatchable demand reductions available from 4 pm to 9 pm on August monthly peaking conditions for 1-in-2 and 1-in-10 weather conditions. They align with the planning conditions used for resource adequacy attribution. The enrollment forecast for the number of enrolled sites was developed by SDG&E, was also applied to the counts of installed thermostats, and shows moderate increases in the number of thermostats over time. The number of thermostats connected reflects the decline in connectivity observed historically and overlays this decline on the total population of installed thermostats. Impacts are a function of connected thermostats and therefore also decline over time.

Table 14: ACSDA Portfolio Impacts for August Monthly Peak Day

Year	Sites	Tstats installed	Tstats connected	CAISO		SDG&E	
				1-in-2	1-in-10	1-in-2	1-in-10
2019	18,892	23,046	19,763	6.19	6.05	5.92	6.88
2020	21,581	26,692	22,042	7.04	6.89	6.74	7.83
2021	24,271	30,338	24,077	7.81	7.64	7.47	8.68
2022	26,960	33,983	25,887	8.50	8.31	8.14	9.44
2023	26,960	33,983	23,601	7.76	7.59	7.43	8.62
2024	26,960	33,983	21,502	7.09	6.93	6.78	7.87
2025	26,960	33,983	19,573	6.46	6.32	6.18	7.17
2026	26,960	33,983	17,802	5.89	5.76	5.64	6.54
2027	26,960	33,983	16,176	5.36	5.24	5.13	5.95
2028	26,960	33,983	14,682	4.88	4.77	4.67	5.42
2029	26,960	33,983	13,310	4.44	4.34	4.25	4.92
2030	26,960	33,983	12,049	4.03	3.94	3.86	4.47

3.4.3 Comparison of Ex Post And Ex Ante Load Impacts

Table 15 compares the demand reductions from 2019 events to the PY 2019 reductions expected for the 1-in-2 weather conditions used for planning. Results are shown for the 4 to 9 pm resource adequacy window. An important difference is that ex post impacts are shown on average only across events with average temperature surpassing 70 F. Excluding the cooler events makes for a more meaningful comparison with ex ante results. In 2019, residential ACSDA customers delivered 3.76 MW during the typical dispatch period of 6 pm to 8 pm. However, because thermostat resources were largely only dispatched for two hours during the five-hour window, ex post reductions during the 4 to 9 pm resource adequacy window were lower (0.92 MW). In contrast, ex ante reference loads and impacts are greater for the 4 to 9 pm window, mostly because they assume five hours of dispatch. In addition, temperatures were about five degrees higher for 1-in-2 planning conditions than for the PY 2019 events. Percent reductions for the event period were 17.4%, over the full resource adequacy window, this value dropped to 4.3%. Ex ante predictions show a 22 to 23% reduction over the 4 to 9 pm window. Further, it is important to note that ex post results also reflect a changing mix of connected devices over the course of the summer and the unique hourly temperature profiles of each event, whereas ex ante impacts assume a fixed number of connected devices and weather for a single peak day.

Table 15: ACSDA Comparison of Ex Post and Ex Ante Load Impacts for 2019

Result Type	Day Type and Period	Sites	Tstats connected	Load without DR (MW)	Load Reduction (MW)	% Reduction	Daily Max Temp (F)
Ex Post Avg. Weekday**	Event Period (6pm to 8pm)	17,187	17,957	21.54	3.76	17.4%	84.6
	Resource Adequacy Period (4 to 9pm)	17,187	17,957	21.60	0.92	4.3%	84.6
Ex ante SDG&E	1-in-2 Weather August Peak (4 to 9pm)	18,892	19,763	26.44	5.92	22.4%	90.0
Ex ante CAISO	1-in-2 Weather August Peak (4 to 9pm)	18,892	19,763	26.81	6.19	23.1%	89.7

*Table shows portfolio impacts. To avoid double counting, it excludes customers dually enrolled in other DR programs.
**For comparability to ex ante, only includes events with average event temperature above 70F

4 CONCLUSIONS AND RECOMMENDATIONS

The residential ACSDA program delivered statistically significant demand reduction and energy savings, but there is room for improvement. The recommendations below may not be currently funded, and costs need to be considered alongside other research and program priorities.

4.1 TECHNOLOGY DEPLOYMENT RECOMMENDATIONS

- **If possible, avoid bidding sites that lack connected thermostats into the CAISO markets.** Sites with loads that cannot be controlled or dispatched do not deliver any detectable demand reduction. They simply dilute the demand reductions and make them harder to detect.

- **Test different ways to nudge customers with disconnected thermostats to reconnect them.** Only connected thermostats deliver reductions and roughly 14% of installed thermostats are now disconnected. Without an intervention, a larger share of those devices will become disconnected as more time elapses. Specifically, we recommend randomized control trial with four different groups:

    - Control (n = 100)
    - Postcard or letter reminder (n = 100)
    - Postcard or letter reminder + follow up phone call (n = 100)
    - Postcard or letter reminder + incentive (n =100)
    - Postcard or letter reminder + follow up phone call + incentive (n=100)

  This will allow SDG&E to quantify how well different methods work at getting customers to reconnect and assess their cost-effectiveness.

APPENDIX

A. PANEL REGRESSION MODELS WITH MULTIPLE CONTROLS

Panel regressions with multiple control groups were used as the primary method for estimating load impacts for PY 2019 impacts for ACSDA. The approach is implemented on a time series of individual customer loads. It relies on multiple non-equivalent control sites that did not experience the intervention, plus weather and day characteristics, to estimate the counterfactual. The panel model estimates a counterfactual load using weather and loads for the matched control sites. A separate model is estimated for each hour of day. Reductions are the difference between the participant and counterfactual loads with a panel model, one should observe:

- Very similar energy use patterns for participant and counterfactual loads when the intervention is not in place.
- A change in demand patterns for customers who are dispatched or subject to time varying prices, but no similar change for the counterfactual load.
- The timing of the change should coincide with the introduction of intervention.

The use of a panel model allows for incorporation of multiple control sites and does not rely on finding a single ideal match. The equation for the model is presented below. A separate model was estimated for each intervention and hour of the day for each of the analysis segments identified as part of the evaluation plan. Pre and post event terms (single hour with two-hour buffer) were added to the Technology Deployment models to implement the same calibration for these load control programs.

$$kW_{i,t} = \mathrm{a} + \mathrm{b} \cdot kW_1 - kW_{5_i} + \sum_{n=1}^{max} \mathrm{c}_n \cdot Event_n + \mathrm{d} \cdot CDH_{i,t} + \delta_t + \varepsilon_{i,t}$$

Where:

$\mathrm{kW}_{i,t}$	Is the usage by for each individual customer and time period
a	Is the model intercept
b	Loads for the five most closely matched control sites based on Euclidean distance matching. They did not experience the treatment and are weighted based on their predictive power.
c	Controls for differences between event and non-event days
d	Is the parameter for weather sensitivity of loads
Event	Is a binary variable indicating if day is an event. Separate variables are used for each event so impacts are estimated for each event. It has a value of zero on event-like proxy days. The five closest non-event days were included as proxy days for each event. Separate proxy days were selected for each event using Euclidean distance matching.
δ_t	Represents time effects for each time period. This accounts for observed and unobserved factors that vary by time but affect all customers equally.
$\varepsilon_{i,t}$	Represents the error term for each individual customer and time period.