Demand Side Analytics
DATA DRIVEN RESEARCH AND INSIGHTS

FINAL REPORT

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2021 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 of residential thermostats. The study focuses on two primary research questions: What were the 2021 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 thermostats or BYOT thermostats. The thermostats can also help reduce electricity consumption when a residence is unoccupied. The program began in 2018 with a BYOT option and a Free option that was transitioned from the prior SCTD program. Prior to 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 program open to smart thermostats) and transferred around four thousand participants to ACSDA, mostly of these transfers were from the Free Programmable Thermostat program.

Events are most commonly dispatched on summer weekdays from 6pm to 8pm. The average PY 2021 event during this dispatch window produced 1.19 MW of reduction for free thermostats and a reduction of 4.83 MW for BYOT thermostats.

TABLE OF CONTENTS

Figures

Tables

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, though smart thermostat demand response has been available to residential customers since 2014. The current participant population also includes participants that received a free thermostat prior to 2018 and participants previously enrolled in the recently discontinued Reduce Your Use Peak Time Rebate program (RYU-PTR). Residential ACSDA participants receive event dispatch signals via smart 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] as part of the SCTD program (Small Customer Technology Deployment). In 2018, the program changed from a free thermostat model 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]. At the end of the PY 2019 demand response season, approximately 50% of residential ACSDA customers were on TOU rates, but nearly 23% of participants are still not on TOU rates at the end of PY 2021. However, the default TOU transition has largely concluded and the TOU population appears to have stabilized, with fewer than 1% of sites transitioning onto TOU rates during the study period. As such, the study segmentation has been simplified relative to prior years, with a non-TOU group and a TOU group including sites that were on a TOU at any time during the study period. In practice the latter group is largely comprised of the several thousand sites that were on a TOU rate for the duration of the study period plus the few dozen that moved onto a TOU rate at some time during the study period. Essentially, unlike in prior years the group that transitioned during the study period was too small for separate analysis and was therefore analyzed along with the TOU group. This segmentation structure still isolates any differential effects across groups who transitioned before or during the PY 2021 season or did not experience the TOU transition.

[1] The RYU-PTR program provided participants with free ecobee thermostats from 2014 to 2017. After 2017, a BYOT option was offered and the list of eligible models expanded.
[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.

The study analyzes two primary research questions:

- What were the 2021 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 1-1 summarizes the estimated ex post demand reductions for each of the interventions and distinguishes between free and BYOT resources. The two categories were dispatched identically on the same dates. 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 1-1: Summary of Average 2021 Ex Post Demand Reductions

Technology Intervention	Sites	Load without DR (MW)	Load reduction (MW)	% Reduction
ACSDA Free devices (Avg 6-8 pm event)	3,114	5.19	1.19	23.0%
ACSDA BYOT devices (Avg 6-8 pm event)	11,725	19.20	4.83	25.2%
ACSDA All devices (Avg 6-8 pm event)	***14,839***	***24.38***	***6.02***	***24.7%***

Table 1-2 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 increase with the increase in site enrollments. As enrollment forecasts flatten after 2028, reductions begin to decrease as thermostat connection rates are forecasted to decline.

In comparing the ex post and ex ante impacts for 2021 across both interventions, there is one key difference to consider[4]: enrollments ex post impacts are shown for the average 6pm to 8pm event while ex ante impacts are shown for the 5-hour resource adequacy window. However, the event reductions fade in each subsequent event hour leading to lower percent reductions over the longer event window. The result is an ex ante reduction estimate for PY 2021 that is roughly half the ex post estimate.

[4] Differences in enrollments, due to linear modeling of monthly enrollment ramps, are minor and do not result in meaningful differences

Table 1-2: Summary of Ex ante Dispatchable Demand Reductions, 1-in-2 Weather Conditions

Year	Tech Deployment: Residential ACSDA Free and BYOT Devices		
	Sites[5]	MW (CAISO)	MW (SDG&E)
2021	15,041	3.00	2.81
2022	17,463	3.78	3.53
2023	20,979	4.87	4.55
2024	24,617	5.96	5.57
2025	28,514	7.10	6.63
2026	32,660	8.28	7.74
2027	37,041	9.50	8.87
2028	38,527	9.64	9.00
2029	38,527	9.23	8.62
2030	38,527	8.84	8.25
2031	38,527	8.47	7.91
2032	38,527	8.11	7.57

[5] Though SDG&E anticipates continuing the program beyond 2027, participants are held constant from 2028 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 smart 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 ecobee, Nest, Honeywell Home, and Honeywell Total Connect 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 and for up to 20 events per season. 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.

SDG&E's residential smart thermostat demand program was initially designed around an offer of a free ecobee thermostat[7] as part of the SCTD program (Small Customer Technology Deployment). In 2018, the program changed from a free thermostat model to a rebate model and was broadened to include additional thermostat models. The current Bring Your Own Thermostat (BYOT) rebate model allows customers to use their existing 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 2-1 summarizes the key research questions for each intervention. Thermostats are dispatchable resources that also can lead to daily changes in energy use.

Table 2-1: Key Research Questions

	Research Question
1	What were the demand reductions due to program operations and interventions in 2021 – 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 2021?
4	How do load impacts vary for different thermostat segments-free vs BYOT?

[7] The RYU-PTR program provided participants with free ecobee thermostats from 2014 to 2017. After 2017, a BYOT option was offered and the list of eligible models expanded.

	Research Question
5	What are the ex ante load reduction capabilities 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 2-1 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 2-2 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. The model elements tested exhibit a directional improvement trend for additional proxy days and controls. However, this trend diminishes with each the marginal improvement. This trend is likely why the same model was selection as in the prior evaluation.

Figure 2-1: Out of Sample Process for Model Selection

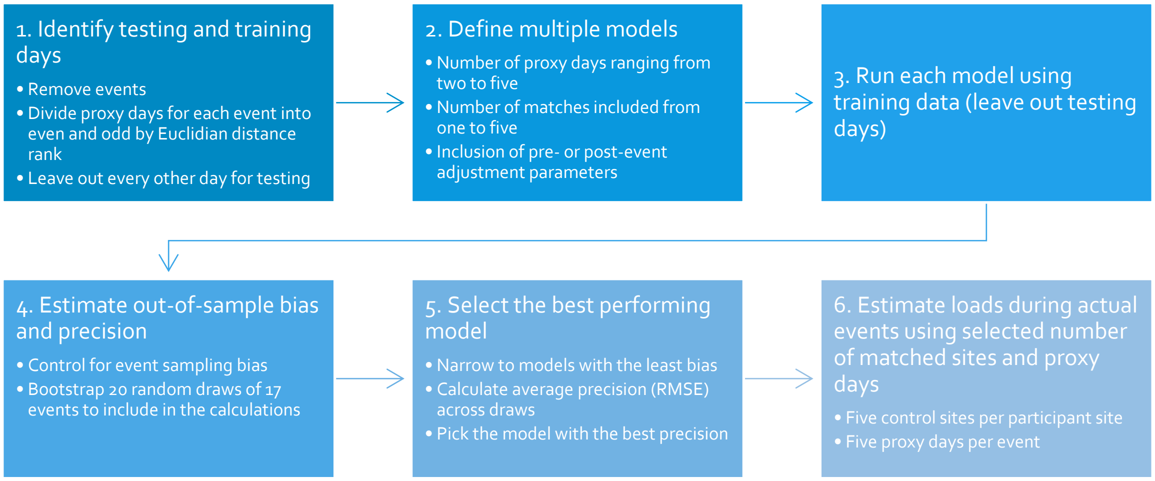


Figure 2-2: Model Selection Results

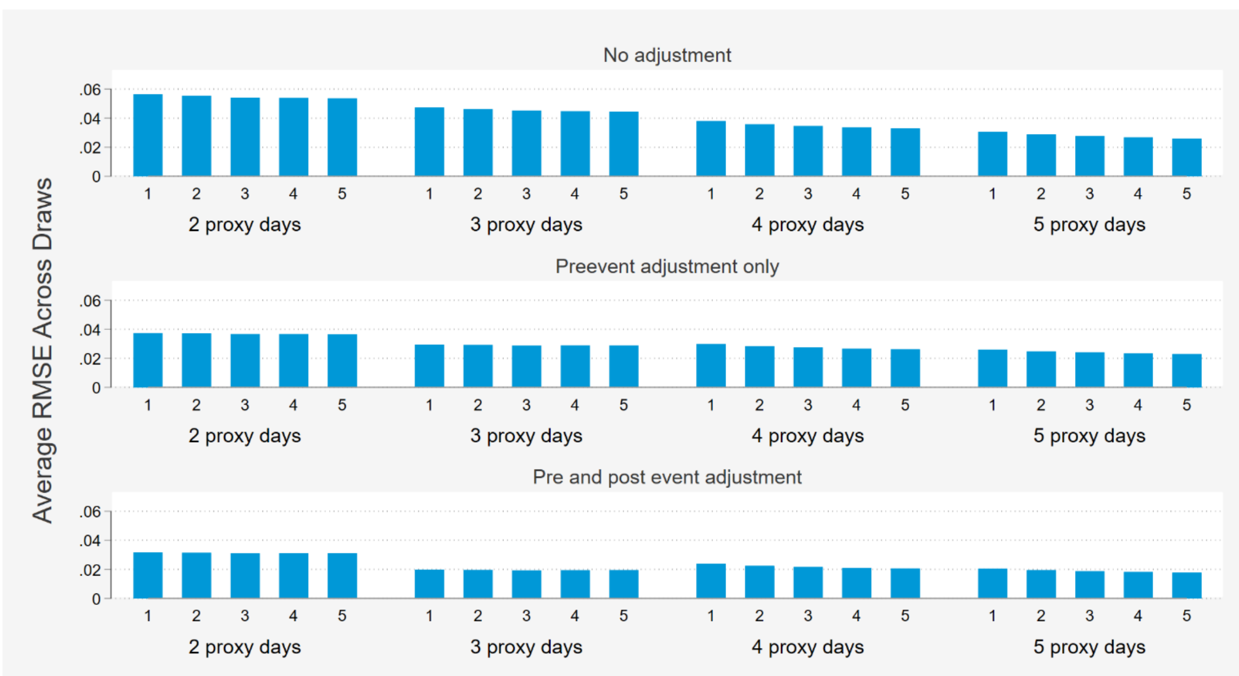


Table 2-2 summarizes the data sources, segmentation, and estimation methods used for each program. The segmentation was defined in advance of the analysis and is of particular importance because the evaluation used a bottom up approach to estimate impacts and to ensure that aggregate impacts across segments 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 2-2: Evaluation Methods

Evaluation Element	TD Programs
Data sources / samples	▪ Hottest 20 weekdays and weekends over the past summer (2021), 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 2021 ✓ Transitioned to TOU rate prior to PY 2021 ▪ Climate zone (Coastal vs Inland) ▪ Thermostat type and program ✓ Free: other ✓ BYOT: other ✓ 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 2021 impacts

3 RESIDENTIAL THERMOSTAT EVENT DAY IMPACTS

AC Saver Day Ahead (ACSDA) participants receive event dispatch signals via either free or BYOT 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 3-1 summarizes the program development since 2017[8]. 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 3-1: Summary of Residential Technology Deployment Program Taxonomy

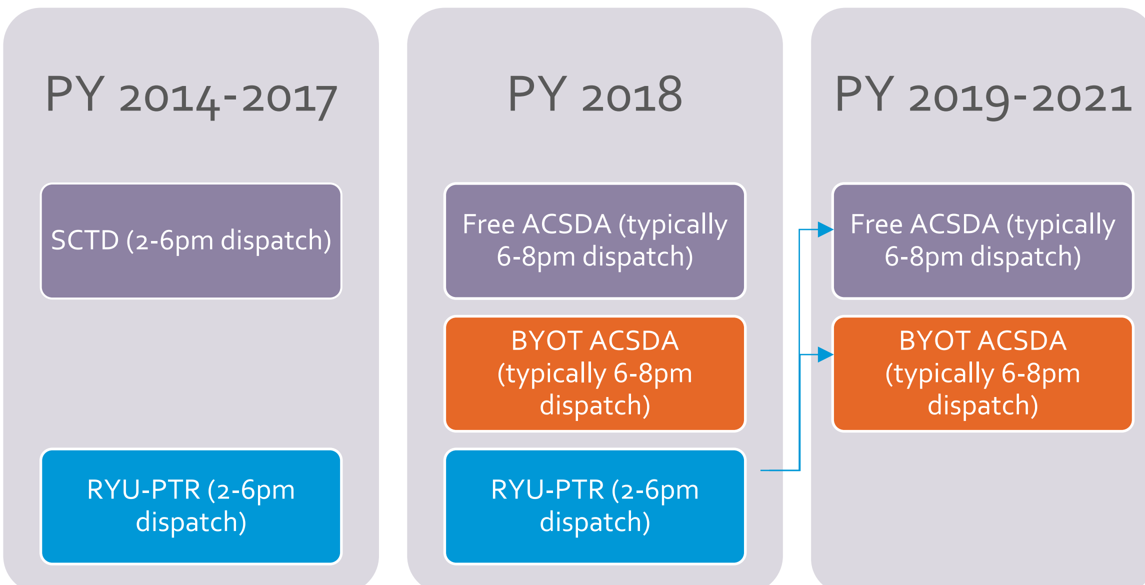


Table 3-1 shows the customer site counts and aggregate percent reduction for the previous four program years for each of the Residential TD programs.

Table 3-1: Historical Program Overview

	Count of Sites (Aggregate Percent Reduction)			
Program	2018	2019	2020	2021
ACSDA Free	10,007 (12.1 %)	6,916 (13.3%)	4,714 (13.5%)	3,114 (23.0%)
ACSDA BYOT		10,281 (20.4%)	10,423 (24.1%)	11,725 (25.2%)
RYU-PTR	80,798 (8.8%)	Migrated to ACSDA		

[8] The RYU-PTR program provided participants with free ecobee thermostats from 2014 to 2017. After 2017, a BYOT option was offered and the list of eligible thermostats was expanded.

There are over 16,000 devices installed at nearly 15,000 residential sites. Reductions for residential ACSDA sites were statistically significant on average and almost exclusively positive across events, with an average event savings of 23.0% to 25.2% for free and BYOT thermostats, respectively.

For residential thermostats, connectivity rates are relatively high. Ninety-one percent of the installed free thermostats are connected and 97% 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 decrease and 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 PY 2021 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.

The PY 2019 evaluation highlighted the issue of disconnected devices and the dampening effect this had on average "per-site" and "per-device" impacts. The failure rate described in the past incorporated two threads of failure-site attrition and thermostat failure. Site attrition occurs when a site, or customer, un-enrolls from a program or moves out of a service address. Thermostat failure occurs when a customer changes a setting that disconnects their thermostat from the internet. This could be caused by a change in the internet router, a new password, a new internet service provider or any other simple disconnection where the customer does not reconnect their device.

For PY 2021, as for PY 2020, site attrition and thermostat disconnections were disaggregated. In part, this helped distinguish between disenrollments, presumably largely due to move-outs, and device disconnections which may possibly be remedied through participant outreach. This was important for modeling enrollment going forward since historically customers moving into an enrolled site were automatically enrolled in the program, but in practice the device was no longer connected or receiving dispatch signals. Functionally this artificially lowered the observed thermostat survival rate because it was conflated with site move-outs. Just prior to the PY 2020 event season the practice of automatic enrollment at move-in was discontinued and roughly 2,000 previously enrolled due to this practice sites were unenrolled.

Table 3-2 shows the failure rates as a percentage of sites or devices that are no longer enrolled or connected. Figure 3-2 shows the reverse of the failure rate, the survival rates. The figure shows survival trends for enrolled sites and thermostat connectivity based on years since enrollment and years since installation, respectively. Note that thermostat survival only includes thermostats for enrolled sites. Essentially, the site survival reflects the rate at which sites remain enrolled over time while the thermostat survival shows the rate over time at which thermostats at enrolled sites remain connected.

Table 3-2: Failure Rates by Cause

Program	Site Attrition			Tstat Disconnection		
	Expected	Lower bound	Upper bound	Expected	Lower bound	Upper bound
Res ACSDA	4.8%	4.5%	5.2%	4.2%	3.9%	4.5%

Figure 3-2: Survival Trends Over Time

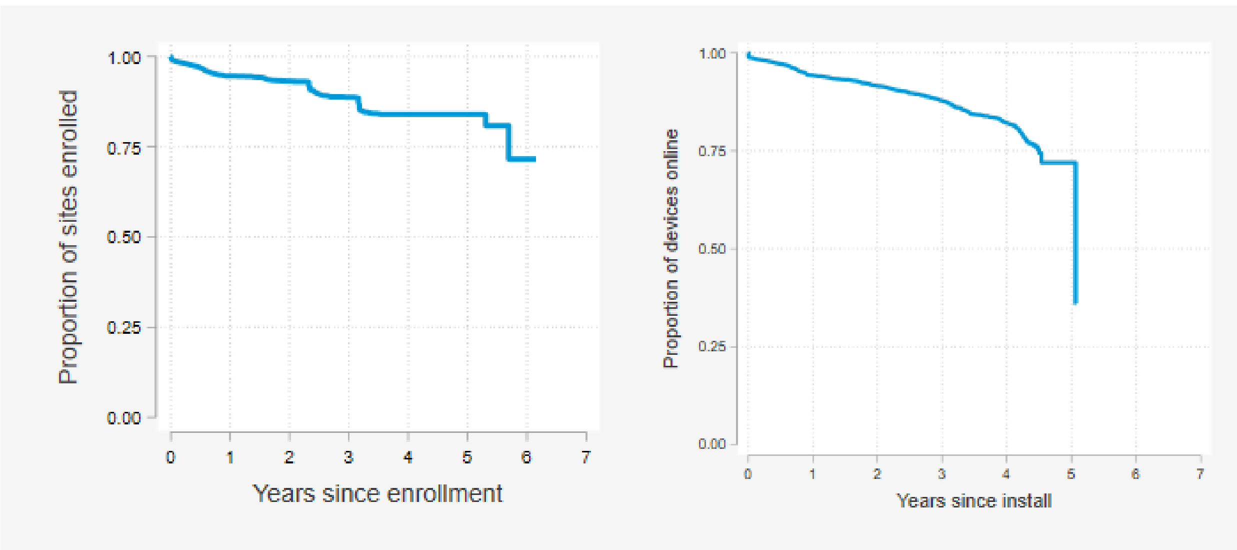


Table 3-3 shows program counts for enrolled sites, installed thermostats, and connected thermostats during the average PY 2021 event. Among all installed devices, nearly 5% were no longer connected to the SDG&E dispatch portal during PY 2021 and therefore could not be curtailed during events.[9] There 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

[9] Connectivity data was not made available for Nest devices so these devices are assumed to be connected. For all other devices, connectivity was defined as being connected within the last month of the analysis period, which ended on October 8, 2021. Therefore any device online on or after September 8, 2021 was considered to be online. This buffer is important in distinguishing between short term connectivity issues and prolonged disconnection.

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 3-3, was developed based on thermostat category, brand, TOU status, climate zone, and net metering status which may influence impacts. The analysis 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 for free by SDG&E or through the BYOT program?
- **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 3-3: Thermostat Programs and Populations

Program Rate	TOU Status	Climate zone	NEM	Total sites	Sites in event analysis	Total installed devices	Total connected devices
ACSDARES (Free)	Non-TOU -	Coastal	No	343	343	392	363
		Inland	No	656	656	731	666
			Yes	1	1	1	1
	TOU -	Coastal	No	818	818	997	920
			Yes	90	90	112	103
		Inland	No	1,007	1,007	1,155	1,056
			Yes	199	199	243	213
ACSDARES (BYOT)	Non-TOU -	Coastal	No	1,099	1,097	1,145	1,103
		Inland	No	1,222	1,221	1,277	1,234
			Yes	29	29	34	30
	TOU -	Coastal	No	4,851	4,850	5,190	5,008
			Yes	501	501	636	601
		Inland	No	3,414	3,413	3,597	3,509
			Yes	586	585	689	658
TOTAL				**14,816**	**14,810**	**16,199**	**15,465**

Table 3-3 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 slightly more of Nest thermostats. The majority of BYOT sites (55%) 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 (40%) are in the coastal zone. About 1,406 sites (9% 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 3-4: shows the five PY 2021 Residential ACSDA event days. The ACSDA season started in June and extended to September. All events occurred on weekdays. Daily maximum temperatures ranged from 78.1 to 86.6 F.

Table 3-4: Residential Thermostat ACSDA Events in 2021

Event day	Day of week	Event start	Event end	Max daily temp (F)	SDG&E system load (MW)
6/17/2021	Thursday	6:00 PM	9:00 PM	78.2	2,892
7/12/2021	Monday	6:00 PM	8:00 PM	78.1	2,912
7/29/2021	Thursday	6:00 PM	9:00 PM	81.0	3,301
9/9/2021	Thursday	6:00 PM	8:00 PM	86.6	3,812
9/10/2021	Friday	5:00 PM	8:00 PM	85.0	3,672

3.2 DATA SOURCES AND ANALYSIS METHOD

Table 3-5 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 3-5: Residential Thermostat Event Impact Evaluation Data Sources

Source	Comments
Hourly interval data	▪ Summer 2021 ▪ All analysis done by site (premise id-service point id pair)

[10] The cleaning algorithm ensured that complete data was available for the study period. Loads and impacts were scaled to address the 829 sites not in the analysis.

Source	Comments
Outage information	▪ PSPS and emergency outage data details which customers and what timeframes were impacted by outages
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 2021 ▪ 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 nearly 15,000 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 model selection process and results are covered more in depth in section 2.3. 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 SCTD program was rebranded as ACSDA in 2018 and transitioned from a free thermostat channel and a Bring Your Own Thermostat (BYOT) rebate channel. The BYOT channel allows customers to use their existing smart thermostats, or those newly purchased and qualified for a rebate, to receive the ACSDA program signals. The program is only open to specific smart thermostat models and brands including Nest, ecobee, Honeywell Home. 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 and prior years. In addition, before the beginning of the PY 2019 event season SDG&E closed the Peak Time Rebate program (another program open to smart thermostats in existence since 2012) 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.

In PY 2021, Nest thermostats were not dispatched during the first three events, because participants were still in the process of accepting the updated terms and conditions. About two thirds of the 2020 participants ultimately accepted the terms and were dispatched for the last two events in September. Therefore, the average weekday impacts refer to the 6-8pm impacts for the September 9 event only since that is the sole 6-8pm weekday event where the full population was dispatched, including the Nest thermostats.

There were five residential events called during PY 2021. The Residential ACSDA events were typically called from 6 to 8 pm, though three weekday events were called during slightly different windows. It is useful to consider that events have diminishing impacts with each subsequent hour, so comparing average impacts between events of different durations is not apples-to-apples. We separate the 6 to 8pm events for straightforward comparisons and to show clearly which events are used to create the average weekday event. The 6 to 8pm weekday events are used to create the Average Event impacts. Load reductions were significant for all events. The average weekday event window was also significant with an average aggregate reduction of 6.02 MW.

Load reductions are a function of the reference load. When there is lower load, specifically lower cooling load, demand response programs have less opportunity for reduction. However, there are limitations to the differences that can be identified by comparing ex post loads across years given multiple changing variables such as weather and participant population. Most notably, the population of customers and thermostats changed meaningfully during the past three seasons due to the removal of disconnected sites and thermostats. Controlling for these external factors such as population variability and weather helps isolate the effect of demand response programs on loads.

Table 3-6 and Table 3-7 summarize the load reductions for Residential ACSDA sites for the five events and 6 pm to 8 pm reductions for the average weekday event, e.g. September 9. The full event hours for the non-standard event days are provided below the average event impacts. Note that all events occurred on a weekday.

The impacts for the free thermostats are detailed in Table 3-6 for weekday events. The average aggregate load reduction for weekday events from 6 to 8 pm was 1.19 MW across all 3,114 enrolled sites and the average reduction per site was 0.38 kW. Though 3,631 devices were installed at enrolled sites, only 3,322 devices on average were connected during the PY 2021 event season. Because only connected devices can be dispatched, all reductions are delivered by these connected devices. The average reduction per connected device was 0.36 kW. Impacts tended to be larger for events where the average event temperature was higher.

Aggregate reductions for significant events range from 0.38 MW (June 17) to 1.19 MW (September 9). The September 9 event, shown in Table 3-6 exhibited the highest average reductions with a maximum reduction of 0.38 kW per site and 0.36 kW per connected thermostat. In the tables, the orange bars show a visual comparison of the reductions that are numerically labeled on the left of the bars.

Table 3-6: ACSDA Residential Program Weekday 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)		
7/12/2021	6 to 8 pm	68.3	3,179	3,705	3,431	0.51	0.16	0.15	20.48	Yes
9/9/2021	6 to 8 pm	73.7	3,114	3,631	3,322	1.19	0.38	0.36	32.82	Yes
Avg Weekday Event	**6 to 8 pm**	**73.7**	**3,114**	**3,631**	**3,322**	**1.19**	**0.38**	**0.36**	**32.82**	**Yes**
6/17/2021	6 to 9 pm	65.9	3,199	3,729	3,467	0.38	0.12	0.11	22.65	Yes
7/29/2021	6 to 9 pm	70.7	3,179	3,709	3,413	0.81	0.25	0.24	35.16	Yes
9/10/2021	5 to 8 pm	72.0	3,114	3,631	3,322	1.02	0.33	0.31	34.54	Yes

The impacts for the BYOT thermostats are detailed in Table 3-7 for weekday events. The average aggregate load reduction for weekday events from 6 to 8 pm was 4.83 MW across all 11,725 enrolled sites and the average reduction per site was 0.41 kW. Almost all 12,598 installed devices were still enrolled throughout the PY 2021 event season, with 12,171 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 0.40 kW. Aggregate impacts are about four times as large for the BYOT devices. There are over three times as many connected devices in the BYOT program and impacts per connected thermostat are slightly larger for the BYOT program with 0.40 kW compared to the 0.36 kW savings per free connected device.

BYOT aggregate reductions for significant events range from 0.83 MW (June 17) to 4.83 MW (September 9). These dates, respectively, also exhibited the lowest and highest average site reductions and average connected thermostat reductions of the BYOT thermostats.

Table 3-7: ACSDA Residential Program Weekday 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)		
7/12/2021	6 to 8 pm	68.6	5,047	5,772	5,447	1.18	0.23	0.22	34.00	Yes
9/9/2021	6 to 8 pm	73.6	11,725	12,598	12,171	4.83	0.41	0.40	68.18	Yes
Avg Weekday Event	**6 to 8 pm**	**73.6**	**11,725**	**12,598**	**12,171**	**4.83**	**0.41**	**0.40**	**68.18**	**Yes**
6/17/2021	6 to 9 pm	65.9	4,822	5,516	5,236	0.83	0.17	0.16	36.17	Yes
7/29/2021	6 to 9 pm	70.7	5,047	5,773	5,413	1.38	0.27	0.25	46.13	Yes
9/10/2021	5 to 8 pm	72.2	11,725	12,598	12,165	4.43	0.38	0.36	76.71	Yes

Reductions were also analyzed by TOU status for residential customers in the ACSDA program. In order to tease out any differential impacts by TOU status, customers were classified as not being on TOU rates throughout the entire PY 2021 demand response season or being on TOU rates by September 7. There is no separate classification for customers who transitioned onto TOU rates during the PY 2021 demand response season because only a few customers did[11]. Table 3-8 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 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, 23.0% of whole building load was curtailed during the average event, while 44% of cooling load was curtailed per connected device.

In aggregate, 42% of connected devices were in the coastal zone and these devices delivered 0.35 MW of the 1.19 MW—30%—of reductions for the ACSDA Residential Free program. However, as expected, the load reduction (kW) per device is higher among participants in the inland climate zone.

Almost one-third of the sites and devices are Non-TOU, and more than two-thirds are TOU. Less than 1% of sites transitioned during PY 2021 and these are included in the TOU group. Average connected

[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.

thermostat percent reductions are 44% of cooling load for all customers. TOU sites exhibit larger reductions than the Non-TOU sites do in aggregate. Differences are not meaningful on average but can be observed by comparing sub-segments. For non-NEM customers, inland TOU customers showed percent reductions of 51% of cooling load compared to 46% for coastal. For participants not on TOU rates, non-NEM average percent impacts were 43% of cooling load.

In Table 3-8, the Non-TOU, Inland, NEM category has only one customer and a percent load increase (negative reduction) of 23%. Given the small sample, this result need not draw inferences to larger populations. However, NEM sites do appear to deliver smaller percent reductions per connected device than non-NEM when comparing within the same across rate and climate zone categories. Load (kW) reductions per connected device are also mostly somewhat small for NEM sites.

Table 3-8: ACSDA Residential Program Average Event Reductions by Segment (FREE)

TOU Status	Climate Zone	NEM	Event Window	Avg Event Temp (F)	Sites Enrolled	Installed Devices	Connect-ed Devices	Aggregate (MW)			Average connected tstat (kW)			
								Ref load (whole bldg)	Reduc-tion	% Reduc-tion	Ref load (cooling)	Reduc-tion	% Reduc-tion	t-stat
Non-TOU	Coastal	No	6 to 8 pm	72.6	343	392	363	0.46	0.09	19.8%	0.59	0.25	43%	9.54
	Inland	No	6 to 8 pm	74.9	656	731	666	1.30	0.30	23.5%	1.14	0.46	40%	17.03
		Yes	6 to 8 pm	80.5	1	1	1	0.00	0.00	-37.9%	3.95	-0.93	-23%	-10.84
TOU	Coastal	No	6 to 8 pm	72.6	818	997	920	1.13	0.23	20.7%	0.55	0.25	46%	13.87
		Yes	6 to 8 pm	72.1	90	112	103	0.16	0.03	17.3%	0.71	0.26	37%	3.84
	Inland	No	6 to 8 pm	74.2	1,007	1,155	1,056	1.73	0.46	26.8%	0.87	0.44	51%	22.22
		Yes	6 to 8 pm	74.1	199	243	213	0.40	0.07	17.6%	1.03	0.33	32%	5.96
			6 to 8 pm	73.7	3,114	3,631	3,322	5.19	1.19	23.0%	0.81	0.36	44%	32.82

Table 3-9 shows the same results for the two BYOT categories-Nest and other thermostats. Overall, aggregate reductions were 4.83 MW which is 23.0% of whole building load. As with the Free thermostats, inland thermostats deliver greater load reductions (kW) per thermostat and the majority of sites have transitioned to TOU rates. Also similarly to the Free devices, NEM sites appear to deliver smaller per connected device, on a kW and percent basis, than non-NEM when comparing within the same across rate and climate zone categories.

Table 3-9:ACSDA Residential Program Average Event Reductions by Segment (BYOT)

TOU Status	Climate Zone	NEM	Event Window	Avg Event Temp (F)	Sites Enrolled	Installed Devices	Connect-ed Devices	Aggregate (MW)			Average connected tstat (kW)			t-stat
								Ref load (whole	Reduc-tion	% Reduc-tion	Ref load (cooling)	Reduc-tion	% Reduc-tion	
Non-TOU	Coastal	No	6 to 8 pm	72.9	1,099	1,145	1,103	1.67	0.47	28.4%	0.68	0.43	63%	25.33
	Inland	No	6 to 8 pm	74.8	1,222	1,277	1,234	2.34	0.64	27.5%	1.16	0.52	45%	25.49
		Yes	6 to 8 pm	74.4	29	34	30	0.07	0.01	14.6%	1.39	0.36	26%	2.17
TOU	Coastal	No	6 to 8 pm	72.9	4,851	5,190	5,008	7.05	1.66	23.6%	0.57	0.33	58%	37.98
		Yes	6 to 8 pm	72.6	501	636	601	0.92	0.17	18.6%	0.88	0.28	32%	9.89
	Inland	No	6 to 8 pm	74.4	3,414	3,597	3,509	5.87	1.56	26.6%	0.97	0.45	46%	40.91
		Yes	6 to 8 pm	74.4	586	689	658	1.23	0.29	23.7%	1.12	0.44	40%	15.87
			6 to 8 pm	73.6	11,725	12,598	12,171	19.20	4.83	25.2%	0.86	0.40	46%	68.18

The average event day load shape is summarized in greater detail in Figure 3-3 for Free thermostats and Figure 3-4 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 3-3 exhibit a clear impact during the event window, followed by a one-hour snapback in hour ending 21. There is a 23.0% reduction across all Free residential thermostats on the average weekday 2021 event.

Figure 3-4 also has clearly visible event impacts, and provides the load shapes for the BYOT thermostats. There is a similar snapback effect in hour ending 21 as is seen in Figure 3-3 for the free thermostats. In contrast, there is also a clear load increase just prior to the event start, typically indicative of pre-cooling. Overall savings are 25.2% load reductions for average connected thermostats and on aggregate for the BYOT category.

Figure 3-3: ACSDA Residential Summary for Average Event (FREE)

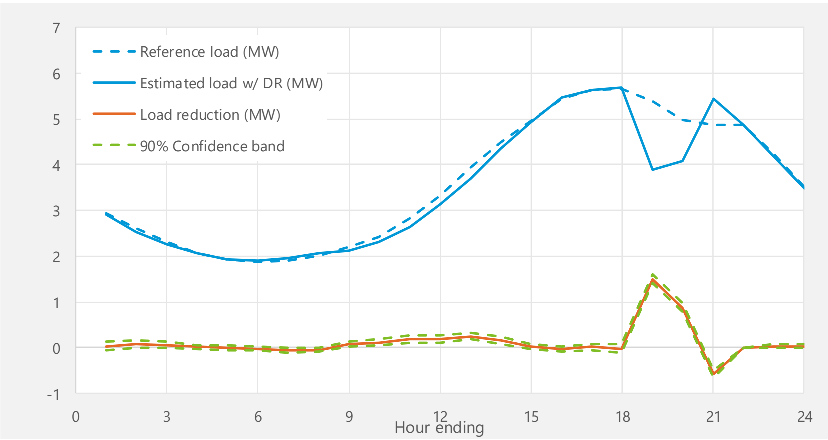
Aggregate (MW)

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 2021

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total sites	3,114
Total installed thermostats	3,631
Total connected thermostats	3,322
Percent of thermostats connected	91%
Avg load reduction 6PM-8PM	1.19
% Load reduction 6PM-8PM	23.0%



Average Customer (kW)

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 2021

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total sites	3,114
Total installed thermostats	3,631
Total connected thermostats	3,322
Percent of thermostats connected	91%
Avg load reduction 6PM-8PM	0.38
% Load reduction 6PM-8PM	23.0%

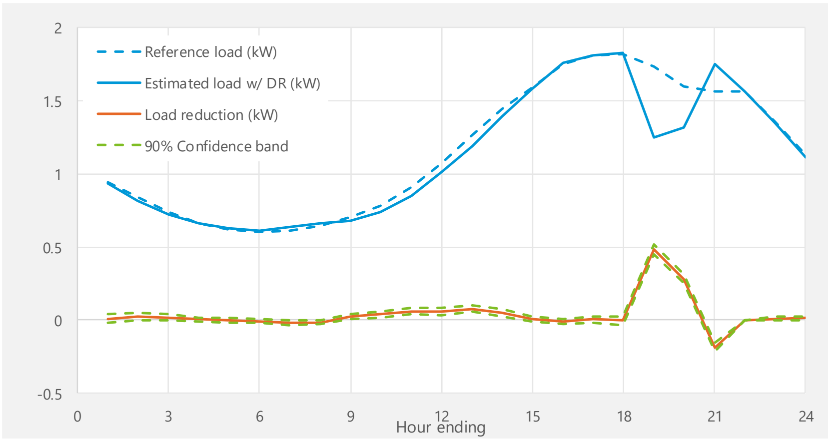


Figure 3-4: ACSDA Residential Summary for Average Event (BYOT)

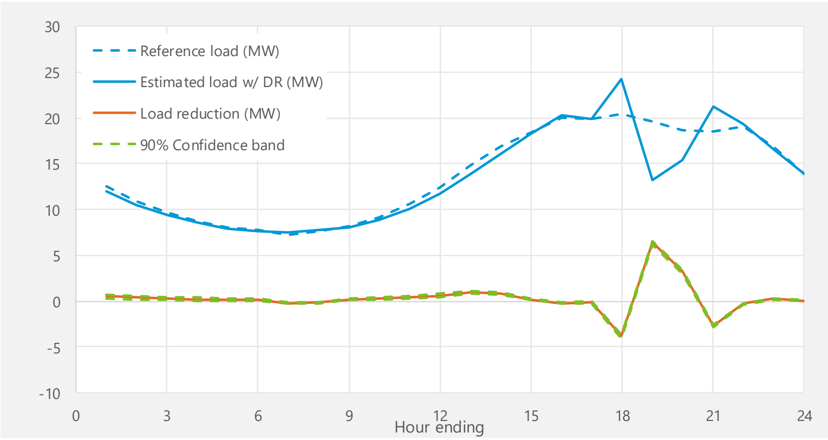
Aggregate (MW)

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 2021

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total sites	11,725
Total installed thermostats	12,598
Total connected thermostats	12,171
Percent of thermostats connected	97%
Avg load reduction 6PM-8PM	4.83
% Load reduction 6PM-8PM	25.2%



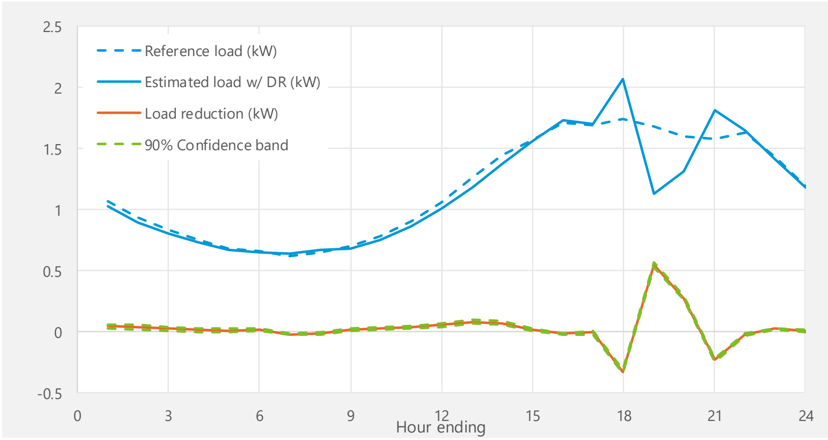
Average Customer (kW)

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 2021

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total sites	11,725
Total installed thermostats	12,598
Total connected thermostats	12,171
Percent of thermostats connected	97%
Avg load reduction 6PM-8PM	0.41
% Load reduction 6PM-8PM	25.2%



3.4 EX ANTE LOAD IMPACTS

A key objective of the 2021 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 3-5 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 (blue line in left panel). Net cooling loads (right panel) are total loads for each weather bin minus the baseload.

On days with 93 to 96 max daily temperature, average cooling load per thermostat for residential ACSDA devices is about 0.6 to 0.8 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 noon 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 3-5: Weather Sensitivity of ACSDA Residential Program Participant Loads

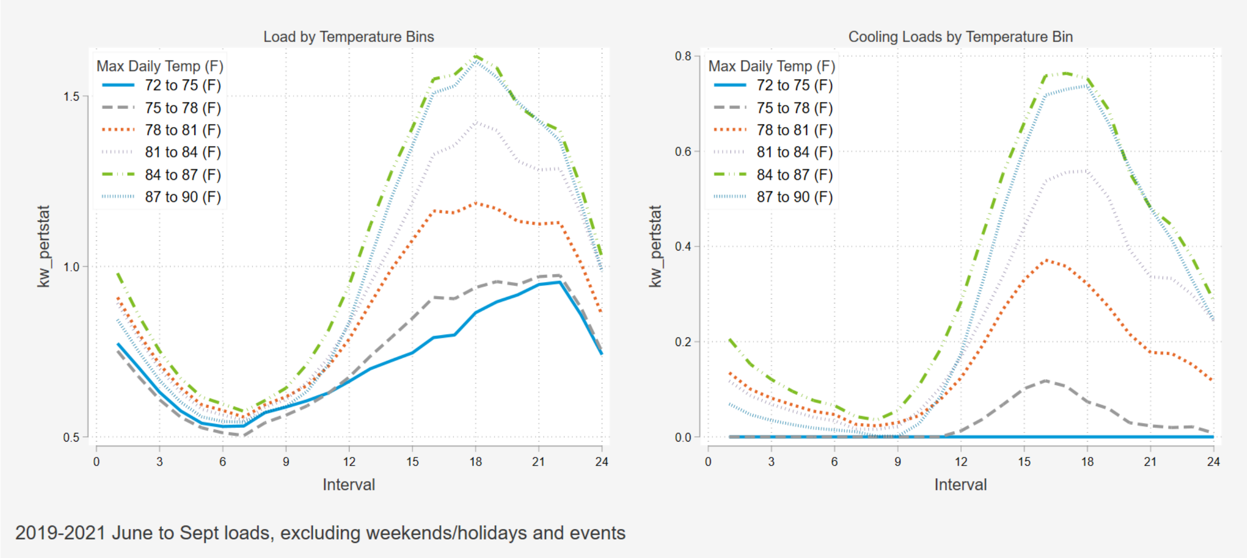
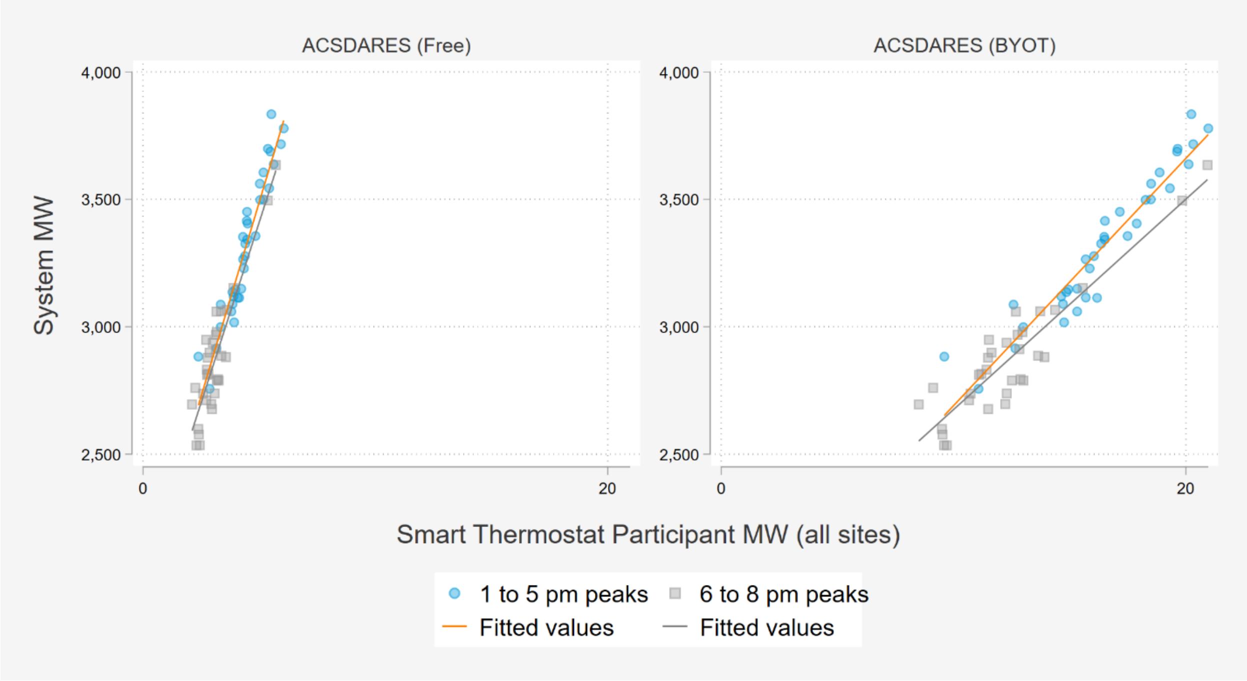


Figure 3-6 shows the relationship between aggregate loads for ACSDA sites and SDG&E daily peak loads. Daily system peaks that occurred before 5pm (typically at 4 or 5pm) are shown in blue and those that occurred later are shown in grey. The patterns are similar for ACSDA sites with free thermostats and 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 more than three times as many installed thermostats in the BYOT category, so we expect higher aggregate load compared to the free thermostat participant load.

Figure 3-6: Residential Thermostat Customer Loads During System Load Daily Peaks



Because ACSDA thermostats are dispatched automatically for events, the main driver of differences in ex ante impacts are differences in loads. PY 2021 event impacts are utilized to build the ex ante model. However, given the small number of PY 2021 events, PY 2020 ex post percent impacts are used to supplement the PY 2021 model. When developing the ex ante impact model, historical events were weighted based on the number of PY 2021 participants enrolled for that event. This served to account for any substantial participant population differences from one year or event to the next. Among other things there was notable shift in population including a reduction in the number of existing customers due to changes made by manufacturers and the addition of a substantial number of new devices.

Figure 3-7 shows hourly event percent reductions for historical weekday events as a function of hourly temperatures for sites for the free and BYOT programs. The left panel shows the PY 2020 observations while the right panel shows an overlay of both PY 2020 and PY 2021 events. Reductions are all positive in magnitude, indicating an increase in load. All event hours are significant. Both programs have positive trends, but the free program has slightly lower percent reductions overall.

Figure 3-7: 2021 ACSDA Hourly Reductions and Temperatures[12]

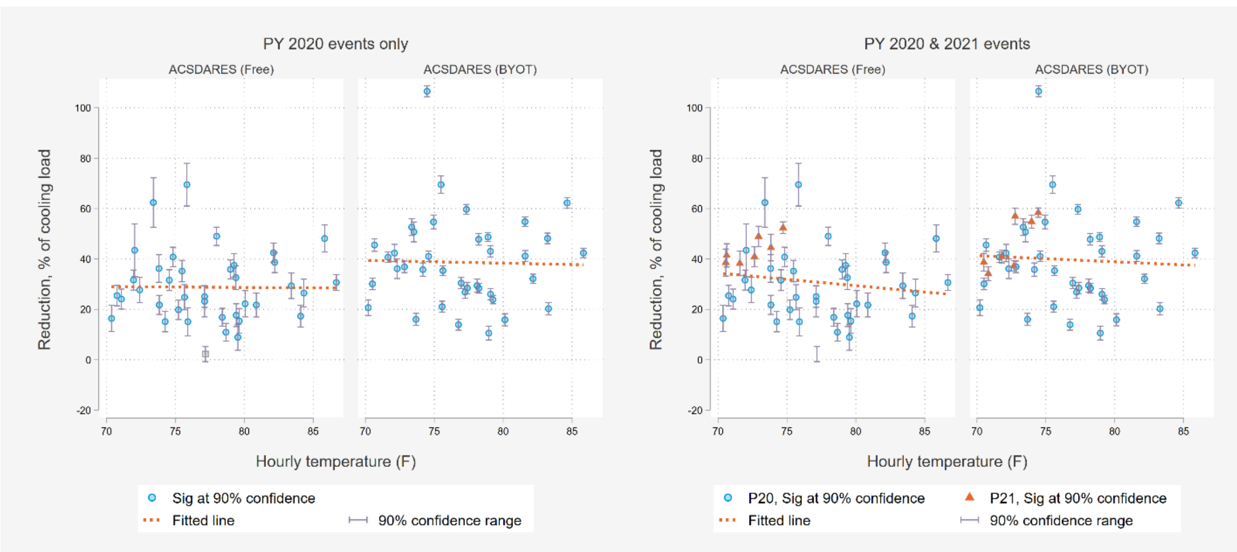


Figure 3-8 shows the same percent reduction points as in Figure 3-7 but is formatted to highlight the trends for the first, second, and third event hour. There is a notable decline in load reductions for each event hour, especially for the BYOT program. This comparison is more robust. The implication of this declining trend is that as reductions are estimated for the five-hour ex ante resource adequacy window,

[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.

modeled impacts follow the observed trend and diminish substantially by the third, fourth, and fifth hour.

Figure 3-8: 2021 ACSDA Hourly Reductions and Temperatures with Event Hour Trend[13]

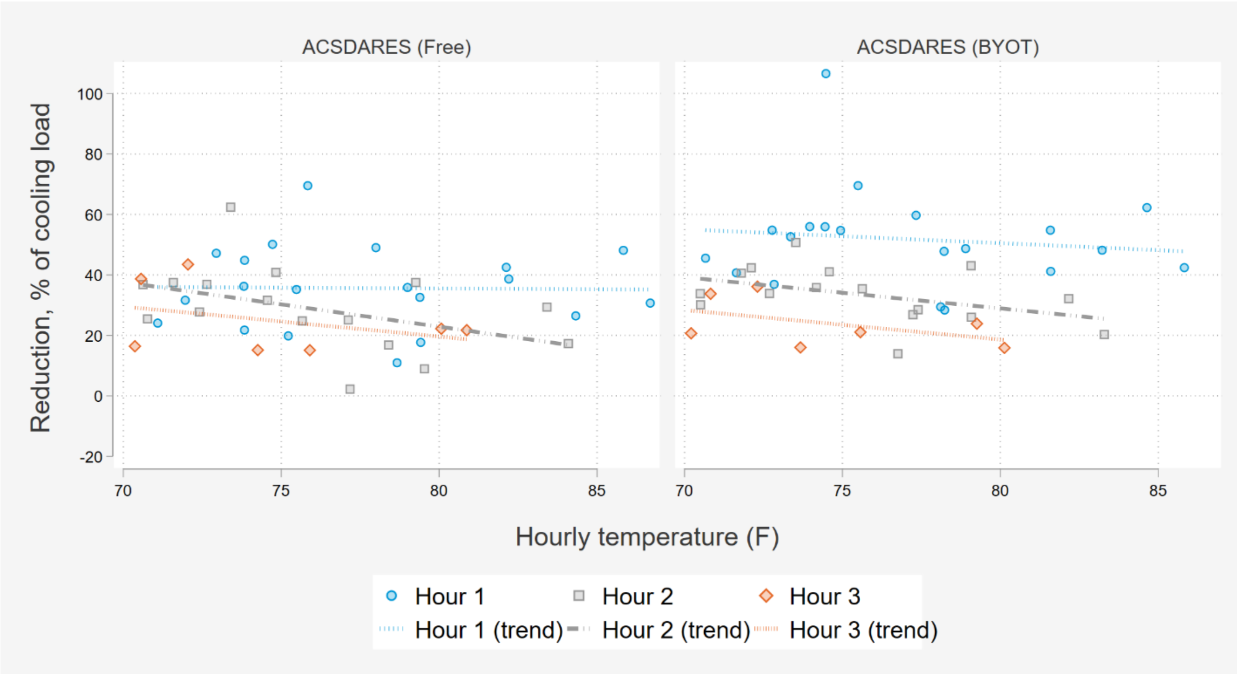


Table 3-10 shows the same data points averaged by event hour with the addition of data points for hour 4 which are too few to establish a trend but still echo the general pattern. Hourly reductions, as a percentage of cooling load, decrease with each subsequent event hour. This trend is typical for load control programs but the steepness of the decline can be modulated by adapting the control strategy. For example, progressive setback dispatch strategies which add a degree in each subsequent event hour tend to maintain consistent load shed, but fixed setbacks and precooling tend to produce the greatest impacts in the first event hour and diminish in the following hours. Though there is some variation across vendors, most ACSDA devices are dispatched using a four degree setback with pre cooling, so the decreasing reductions are to be expected.

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[13] 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.

Table 3-10: Average Hourly Reduction as Percentage of Cooling Load

		Event Hour			
		1	2	3	4
Free	Percent Impact (%)	35.7%	28.8%	24.7%	19.3%
	Temperature (F)	77.7	76.0	74.9	78.4
	Number of Event Hours	20	16	7	2
BYOT	Percent Impact (%)	51.8%	33.4%	23.9%	20.5%
	Temperature (F)	77.1	75.7	74.6	78.0
	Number of Event Hours	20	16	7	2

3.4.2 COVID-19 Load Considerations

Beginning in March 2020, shutdowns began across the United States as a response to the COVID-19 pandemic. As commercial businesses closed, many workers either lost their jobs or began working from home. The shutdown impacted sectors at different levels of intensity and during different time periods, but all PY 2020 ACSDA Residential events are assumed to have occurred under COVID-19 conditions. As such, PY 2020 reference loads were modeled under COVID-19 conditions.

During PY 2021, DSA and SDG&E analysis showed that COVID-19 effects have largely subsided and any remaining effects are small. For instance, many workers have returned in-person to their commercial businesses, although there are some who still work remotely or have left the workforce. Therefore, we assume loads are a "new normal" going forward.

3.4.3 Ex Ante Enrollment Forecast

To derive the aggregate forecast and reference and loads percent impacts per connected thermostat and are scaled to the site and connected device population expected to be enrolled in each planning year. The enrollment forecast for both residential TD programs was developed by the evaluator and incorporates:

- Expected new site enrollments per year
- Expected site retention
- Expected number of thermostats per site
- Expected retention of thermostat connectivity per year

Figure 9 summarizes the enrollment model architecture.

Figure 9: ACSDA Enrollment Model Architecture

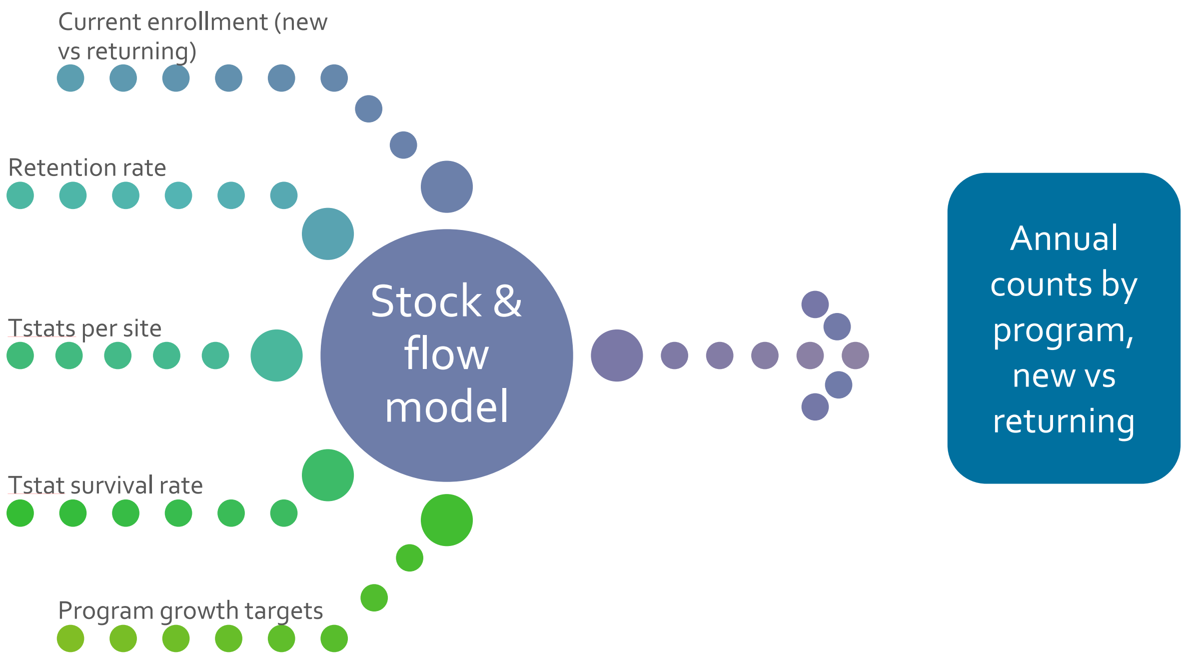

Table 11 summarizes retention, connectivity, thermostats per site, and annual new site enrollments used to derive the enrollment forecasts for PY 2021 using the enrollment model described above. Note that site attrition and device connectivity rates are the same figures described in section 3.1

Table 11: Residential TD Program Enrollment Forecast Assumptions

Program	Program Type	Site retention rate	Tstat failure rate	Tstats per site (current)[14]	Tstats per site (capped)[15]	Projected New Enrollment
ACSDARES (Free)	ACSDARES	95.2%	4.2%	1.2	1.2	0
ACSDARES (BYOT)	ACSDARES	95.2%	4.2%	1.1	1.1	6,408

Table 12 below summarizes key assumptions incorporated into the forecast used.

[14] Reflects average thermostat counts for existing participants. This is the figure applied to current enrollments
[15] Reflects average thermostat counts for existing participants if total thermostats per participant is capped at 4. This is the figure applied to future enrollments

Table 12: Key Forecast Assumptions TD Program Enrollment Model

Assumption	Description
Residential BYOT NEM	Given rule change which open eligibility to NEM, assume incremental 1000/yr in new enrollments
New participant forecast for residential BYOT ACSDA	Assumed to be 5,408, based on average new enrollments from 2017 through 2020, derated by 8%.
New participant forecast	Assumed to be zero for ACSDA and very modest for PSW (40) and CPP-D (10).
Long term flattening out of enrollments	Assume enrollments stabilize starting in 2028 (no new enrollments, no attrition, only change to connected thermostats is from connectivity)
Ramping of enrollments to mirror expected smart thermostat uptake	Thermostat market share of smart thermostats assumed to grow by 10% a year from 2023 through 2026, conservative application of market forecast projecting 18% annual growth[16]. Enrollment growth is ramped to mirror this market share growth.
Thermostats enrolled per site	Also assume future enrollments reflect historical average, but cap historical figures at 4 thermostats per site before taking the average. This assumption was applied to both residential and non-residential forecasts but had minimal impact of the residential forecast.
Monthly ramp of enrollments	Annual forecast changes spread linearly across months

3.4.4 Ex Ante Load Impacts

Table 3-13 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 in alignment with the planning conditions used for resource adequacy attribution. They incorporate an enrollment forecast for sites and devices described above.

[16] https://www.freedoniagroup.com/industry-study/smart-and-connected-thermostats-3659.htm

Table 3-13 summarizes expected August peak day 1-in-2 reductions for the two residential TD programs. 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 (which increase over time until 2028), the connectivity rate over time for installed devices (which decreases over time), and the estimated load reduction per connected device (which stays constant over time on a percentage basis). The estimated load reductions are also influenced by reference loads. Impacts are assumed to first increase substantially as BYOT enrollment grows through 2028 then slowly decrease over time as thermostats become disconnected.

Table 3-13: Portfolio Impacts for SDG&E 1-in-2 Weather Conditions, August Monthly Peak Day

Year	ACSDA - Residential		Total
	Free	BYOT	
2021	0.33	2.48	2.81
2022	0.31	3.22	3.53
2023	0.28	4.27	4.55
2024	0.26	5.31	5.57
2025	0.24	6.40	6.63
2026	0.21	7.52	7.74
2027	0.20	8.68	8.87
2028	0.18	8.81	9.00
2029	0.18	8.44	8.62
2030	0.17	8.09	8.25
2031	0.16	7.75	7.91
2032	0.16	7.42	7.57

Table 3-14 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 DSA in conjunction with assumptions supplied by SDG&E. The forecast was also applied to the counts of installed thermostats and shows moderate increases in the number of thermostats over time until it plateaus in 2028. The number of thermostats connected reflects the decline in connectivity observed historically and overlays this decline on the total population of installed thermostats.

Table 3-14: Portfolio Impacts for August Monthly Peak Day

Year	Sites	Tstats installed	Tstats connected	Average Reference Load	CAISO		SDG&E	
					1-in-2	1-in-10	1-in-2	1-in-10
2021	15,041	16,489	13,037	1.61	3.00	2.85	2.81	3.20
2022	18,829	20,561	16,149	1.61	3.78	3.59	3.53	4.04
2023	24,329	26,473	20,543	1.61	4.87	4.63	4.55	5.22
2024	29,990	32,559	24,937	1.61	5.96	5.66	5.57	6.40
2025	36,019	39,042	29,525	1.61	7.10	6.74	6.63	7.63
2026	42,397	45,903	34,290	1.61	8.28	7.87	7.74	8.90
2027	49,109	53,123	39,216	1.61	9.50	9.02	8.87	10.21
2028	51,383	55,569	39,729	1.61	9.64	9.15	9.00	10.36
2029	51,383	55,569	38,057	1.61	9.23	8.76	8.62	9.92
2030	51,383	55,569	36,456	1.61	8.84	8.39	8.25	9.50
2031	51,383	55,569	34,922	1.61	8.47	8.04	7.91	9.10
2032	51,383	55,569	33,453	1.61	8.11	7.70	7.57	8.72

3.4.5 Comparison of Ex Post And Ex Ante Load Impacts

Table 3-15 compares the demand reductions from 2021 events to the PY 2021 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.

A critical consideration for demand response events which use a 4-degree setback is that there are diminishing returns with each subsequent event hour. The first hour of an event will have the largest impact, and as additional hours are added to an event, the "average event impact" will decrease. Consider two events with the same impacts in hour 1. If one event is a single hour, the average event impact will be equal to the savings in the largest hour, hour 1. The second event may be 4 hours, and with the impacts diminishing each hour, the "average event impact" will be lower than the single hour event. While the total value provided by the longer event will produce more savings in aggregate, the average event savings will differ greatly.

In 2021, residential ACSDA customers delivered 6.02 MW during the typical dispatch period of 6 pm to 8 pm. However, ex post reductions during the 4 to 9 pm resource adequacy window were lower (0.98 MW) because thermostat resources were largely only dispatched for two hours during the five-hour window. The two hours of ex post load reductions are essentially spread across a five-hour window. The hour preceding the 6pm ex post start window also exhibits snap back, further diminishing the average ex post impact observed for the 4 to 9 pm window. 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 degrees higher for 1-in-2 planning conditions than for the PY 2021 events. Percent reductions for the event period were 24.7%[17], over the full resource adequacy window, this value dropped to 4.0%. Ex ante predictions show an 11.1% to 11.2% 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 3-15: Residential ACSDA Comparison of Ex Post and Ex Ante Load Impacts for 2021

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)	14,839	15,493	24.38	6.02	24.7%	86.6
	Resource Adequacy Period (4 to 9pm)	14,839	15,493	24.77	0.98	4.0%	86.6
Ex ante SDG&E	1-in-2 Weather August Peak (4 to 9pm)	15,041	13,037	25.45	2.81	11.1%	89.9
Ex ante CAISO	1-in-2 Weather August Peak (4 to 9pm)	15,041	13,037	26.72	3.00	11.2%	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
***Ex post includes sites enrolled through beginning of October, but ex-ante site counts also include sites who enrolled through November

[17] For purposes of comparing the ex post events and ex ante predictions, the ex post average weekday shown in Table 3 14 only includes events with event temperatures greater than 70 degrees (F).

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. SDG&E should continue efforts to remove thermostats disconnected for prolonged periods[18] from the dispatch portal.

- **Continue to monitor loads and assumptions about the effect of COVID-19 on loads.** Analyze load data and public health data to evaluate the appropriateness of the "new normal" assumption going forward.

- **Review dispatch strategy to optimize load reductions.** While there are a few methods of demand response dispatch, the 4-degree setback is an algorithm with diminishing returns. PY 2020 was the first year with several events lasting 3 to 5 hours, demonstrating that impacts may be high in the first hour or two of an event drop notably in the third and fourth hour of an event. Dispatch strategies can be designed to maintain more consistent impacts across multiple event hours and potentially produce higher average impacts across event hours by producing greater impacts in later event hours, e.g. in hour 3 or 4. For example, setbacks can be stepped such that the setback is 2-degrees in hour 1, 3-degrees in hour 2, and 4- degrees in hour 3. Setback strategies can also be used to minimize customer discomfort while maximizing average impact. As an example, a stepped dispatch may be less noticeable and less uncomfortable for residential occupants, which is all the more important as residential weekday occupancy has increased in the face of COVID-19. Another area for consideration is a more gradual pre-cooling strategy. BYOT thermostats exhibit a clear, substantial pre-cooling notch in the hour before events. Stepped pre-cooling, similar to stepped event hour setbacks, can be used to dampen the pre-cooling notch while improving participant comfort.

[18] Currently devices disconnected for more than two years are periodically removed and unenrolled

APPENDIX

A. PANEL REGRESSION MODELS WITH MULTIPLE CONTROLS: TD PROGRAMS

Panel regressions with multiple control groups were used as the primary method for estimating load impacts for PY 2021 impacts for Technology Deployment Programs. 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 in Equation A 0-1 and Table A 0-1. 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.

Equation A 0-1: Ex Post Regression Model for TD Programs

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

Where:

Table A 0-1: Ex Post Regression Elements for TD Programs

$\mathrm{kW}_{\mathrm{i,t}}$	Is the usage by for each individual customer and time period
$Control_{\,i,t,n}$	The hourly used for five control sites, with each match
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.
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
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.