Demand Side Analytics
DATA DRIVEN RESEARCH AND INSIGHTS

FINAL REPORT

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2022 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 2022 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 2022 weekday 6pm to 8pm event produced 1.33 MW of reduction for free thermostats and a reduction of 7.32 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, 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 20% of participants are still not on TOU rates at the end of PY 2022. 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 2022 season or did not experience the TOU transition.

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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 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 2022 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 higher for the free households.

Table 1-1: Summary of Average 2022 Ex Post Demand Reductions[4]

Technology Intervention	Sites	Load without DR (MW)	Load reduction (MW)	% Reduction
ACSDA Free devices (Avg weekday 6-8 pm event)	2,732	5.02	1.33	26.6%
ACSDA BYOT devices (Avg weekday 6-8 pm event)	14,796	28.17	7.32	26.0%
ACSDA All devices (Avg weekday 6-8 pm event)	***17,528***	***33.18***	***8.65***	***26.1%***

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 2029, reductions begin to decrease as thermostat connection rates are forecasted to decline.

In comparing the ex post and ex ante impacts for 2022 across both interventions, there is one key difference to consider[5]: 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

[4] Five of nine weekday events were called from 6 to 8 pm. The two hottest events were called from 5 to 7 pm

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

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 2022 that is roughly half of the ex post estimate.

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[6]	MW (CAISO)	MW (SDG&E)
2022	18,049	4.01	4.01
2023	21,981	4.80	4.78
2024	27,769	5.96	5.91
2025	33,820	7.15	7.08
2026	40,342	8.43	8.34
2027	47,320	9.80	9.68
2028	54,742	11.25	11.10
2029	57,265	11.64	11.49
2030	57,265	11.49	11.34
2031	57,265	11.35	11.20
2032	57,265	11.21	11.06
2033	57,265	11.07	10.93

[6] Though SDG&E anticipates continuing the program beyond 2028, participants are held constant from 2029 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 that occurred 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[7]. 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 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.

[7] Preceding the 2019 residential default time of use rollout was a pilot 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[8] 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 2022 – 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 2022?
4	How do load impacts vary for different thermostat segments-free vs BYOT?

[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 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 difference-in-differences with a control site matched to each participant. Key modeling design components are as follows:

- **Matched control tournament:** In order to identify the control pool sites that best matched each participant's energy use patterns on event-like proxy days (similar in weather and system conditions to event days), several matching methods were tested. These methods included different matching algorithms (e.g. Euclidean and propensity matching) and different site characteristics to be used in the matching. Matching methods included different combinations of proxy day load characteristics such as load factor, load shape, and site weather sensitivity. Control candidates were also "hard-matched" on climate zone, net metering status, and Residential ELRP eligibility group.
- **Difference in-differences model with event and non-event days and participants and matched controls:** The data was structured with participant loads pre- and post-intervention and control loads pre- and post-intervention side by side. Per site load impacts were estimated with difference-in-differences to net out exogenous differences between treatment and control that existed prior to the intervention. This approach was used as the primary method for event impacts for critical peak events delivered by AC Saver Day Ahead thermostat participants.

Figure 2-1 summarizes the out of sample testing process used to select the matched controls 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 matching method 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.

Figure 2-1: Out of Sample Process for Control Group Selection

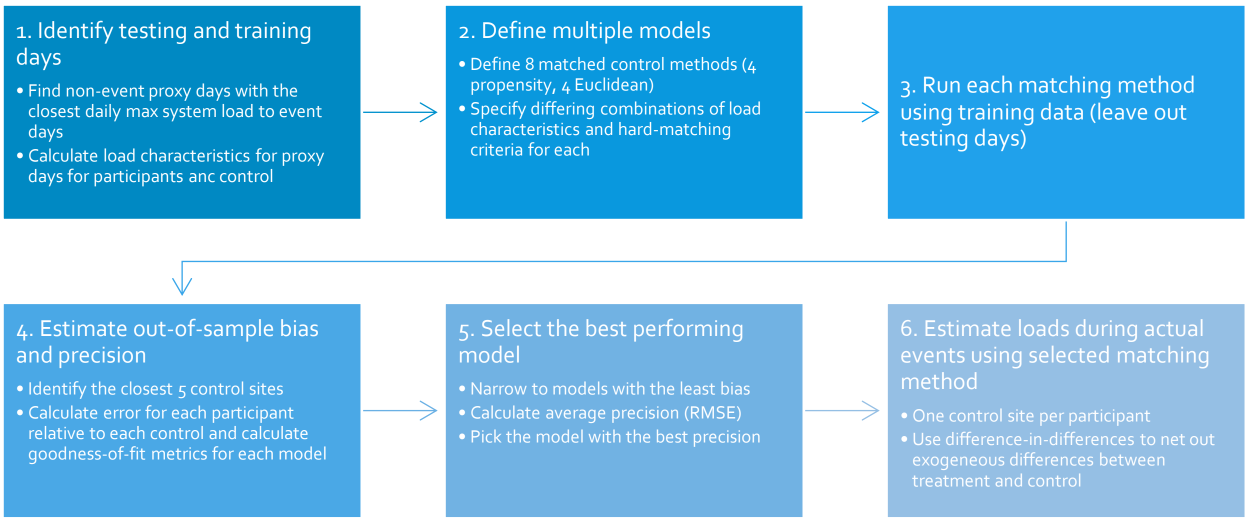


Figure 2-2 below demonstrates the mechanics of a difference in difference calculation. In the first panel, average observed loads on proxy days are shown for participants and for their matched controls. The difference between these two is the first "difference" and quantifies underlying differences between participants and their controls not attributable to event participation. Note that this first difference is very small, indicative of a high quality match and sufficient sample size to neutralize the noise inherent in individual customer loads. The second panel shows the average observed participant and matched control loads on event days. The gap between these two is the second difference which includes both the difference due to event participation as well as the underlying first difference observable on non-event days. The third panel shows the average event day loads after netting out the proxy day difference from the event day control load. The result is the difference in difference impact.

Figure 2-2: Difference-in-Differences Calculation Example

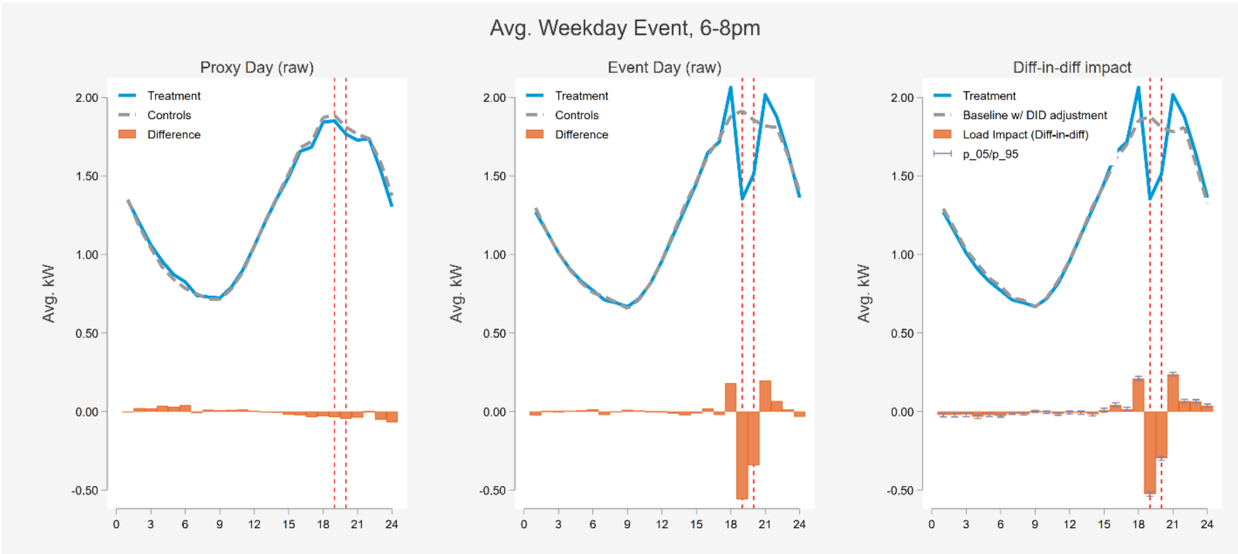


Table 2-2 summarizes the data sources, segmentation, and estimation methods used for each program. The segmentation was defined in advance of the analysis and is of particular importance because the evaluation used a bottom up approach to estimate impacts and to ensure that aggregate impacts across segments 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. This program year, segmentation by TOU status was simplified as the TOU transition has stabilized. As such, the TOU segments consist of those who were not on TOU at any point during the study period and those who transitioned onto TOU prior to or during the study period. Segmentation by solar/net metering status was also added for this program year. 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	▪ All event season data for the past program year for ~17k Residential ACSDA participants
Segmentation	▪ Rate ✓ Not on TOU rate ✓ Transitioned to TOU rate during or prior to PY2022 ▪ Climate zone (Coastal vs Inland)

Evaluation Element	TD Programs
	▪ Thermostat type and program ✓ Free ✓ BYOT ▪ Solar/NEM status
Estimation method: Ex-post	▪ Difference-in-differences with matched control sites
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 2022 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[9]. 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

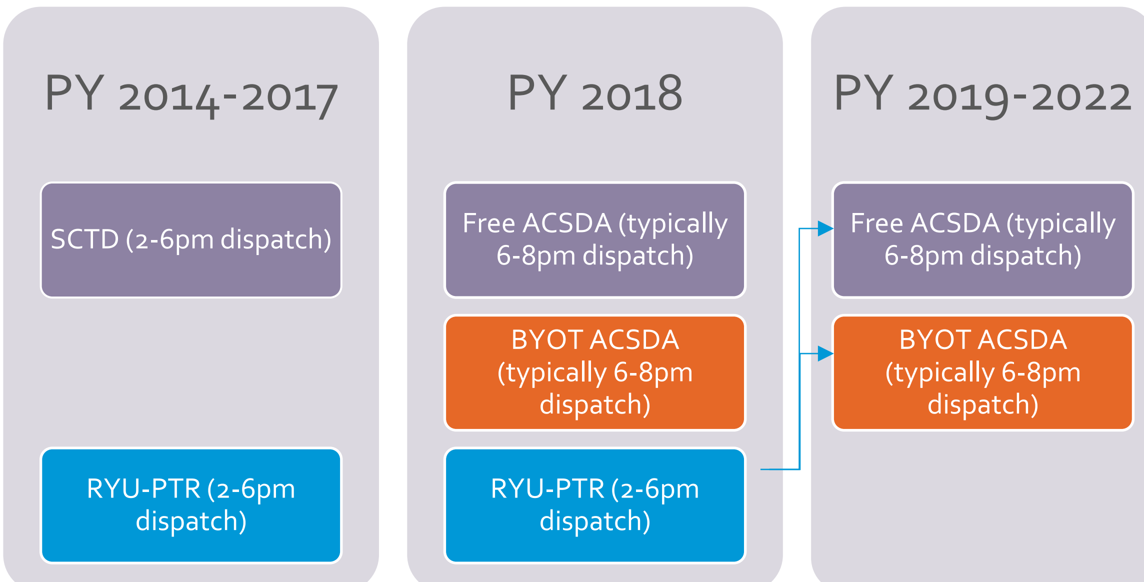


Table 3-1 shows the customer site counts and aggregate percent reduction for the previous four program years for each of the Residential TD programs.

Table 3-1: Historical Program Overview

Program	Count of Sites (Aggregate Percent Reductions) 2019	2020	2021	2022
ACSDA Free	6,916 (13.3%)	4,714 (13.5%)	3,114 (23.0%)	2,732 (26.6%)
ACSDA BYOT	10,281 (20.4%)	10,423 (24.1%)	11,725 (25.2%)	14,796 (26.0%)

[9] 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 19,000 devices enrolled at over 17,000 residential sites. Reductions for residential ACSDA sites were statistically significant on average and almost exclusively positive across events, with average weekday 6-8pm event savings of 26.6% and 26.0% for free and BYOT thermostats, respectively.

For residential thermostats, connectivity rates are relatively high. Ninety-six percent of the enrolled 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 2022 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 2022, as for PY 2021, 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. New program management in PY 2022 elected to begin a regular manual disenrollment of thermostats that had not been connected in more than 365 days, which boosted connectivity rates. The drop in enrollment after 7 years is a reflection of bulk unenrollment in the summer of PY 2022 of a large portion of the cohort of sites which enrolled in 2015 and 2016.

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. The drop in enrollment after 7 years is a reflection of bulk unenrollment in the summer of PY 2022 of a large portion of the cohort of sites which enrolled in 2015 and 2016.

Table 3-2: Failure Rates by Cause

Program	Site Attrition			Tstat Disconnection		
	Expected	Lower bound	Upper bound	Expected	Lower bound	Upper bound
Res ACSDA	2.8%	2.7%	3.0%	1.2%	1.1%	1.4%

Figure 3-2: Survival Trends Over Time

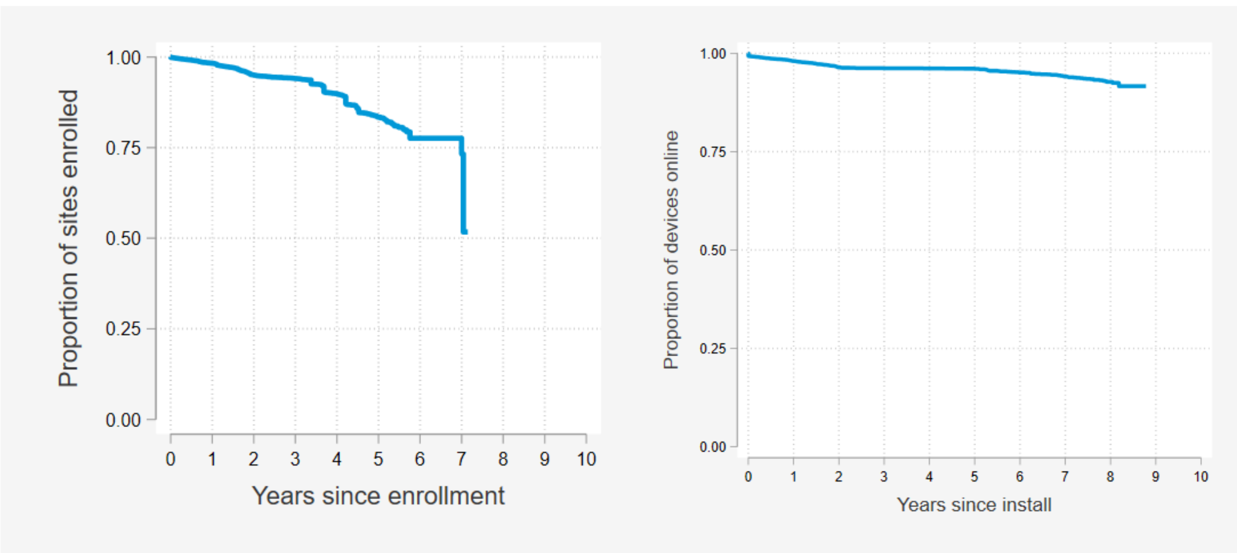


Table 3-3 shows program counts for enrolled sites, enrolled thermostats, and connected thermostats during the average PY 2022 weekday 6-8pm event. Among all enrolled devices, about 3% were no longer connected to the SDG&E dispatch portal during PY 2022 and therefore could not be curtailed during events. 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 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 any time 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 enrolled devices	Total connected devices
ACSDARES (Free)	Non-TOU -	Coastal	No	275	260	313	296
		Inland	No	512	481	566	549
	TOU -	Coastal	No	683	632	825	783
			Yes	151	144	184	176
		Inland	No	798	733	916	879
			Yes	302	284	368	353
ACSDARES (BYOT)	Non-TOU -	Coastal	No	993	927	1,030	999
			Yes	72	66	72	72
		Inland	No	1,055	969	1,092	1,065
			Yes	271	250	316	307
	TOU -	Coastal	No	5,012	4,648	5,334	5,170
			Yes	1,815	1,689	2,137	2,061
		Inland	No	3,420	3,148	3,589	3,471
			Yes	2,018	1,894	2,359	2,297
TOTAL				**17,528**	**16,256**	**19,293**	**18,662**

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. BYOT makes up the majority of sites and thermostats. The majority of BYOT sites (54%) 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 (41%) are in the coastal zone. About 4,628 sites (27% 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 12 PY 2022 Residential ACSDA event days. The ACSDA season started in August and ended in September. Nine events occurred on weekdays and three occurred on weekends or holidays. Daily maximum temperatures ranged from 82.7 to 95.5 F. On August 17, program implementers were unable to dispatch all enrolled thermostats. This led to significantly diminished demand reductions and as such August 17 is not included in the 6-8 pm weekday average event definition.

Table 3-4: Residential Thermostat ACSDA Events in 2022

Event day	Day of week	Event start	Event end	Max daily temp (F)	SDG&E system load (MW)
8/16/2022	Tuesday	6:00 PM	8:00 PM	83.4	3,753
8/17/2022[10]	Wednesday	6:00 PM	8:00 PM	84.2	3,738
8/30/2022	Tuesday	6:00 PM	8:00 PM	83.4	3,790
8/31/2022	Wednesday	6:00 PM	8:00 PM	88.9	4,158
9/1/2022	Thursday	6:00 PM	8:00 PM	91.0	4,483
9/3/2022	Saturday	6:00 PM	8:00 PM	95.5	4,406
9/4/2022	Sunday	6:00 PM	8:00 PM	90.0	4,168
9/5/2022	Monday	5:00 PM	9:00 PM	90.1	4,201
9/7/2022	Wednesday	5:00 PM	9:00 PM	92.9	4,633
9/8/2022	Thursday	5:00 PM	9:00 PM	92.5	4,291
9/9/2022	Friday	5:00 PM	7:00 PM	86.0	3,898
9/26/2022	Monday	5:00 PM	7:00 PM	82.7	3,694

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 2022 ▪ All analysis done by site (premise id-service point id pair)

[10] Program implementers experienced a dispatch issue during the August 17th event that greatly diminished demand reductions for this event. As such, August 17 is not included in the 6-8pm average weekday impacts.

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 (except for Residential ELRP defaults) ▪ Residential ELRP eligibility group, NEM status, climate zones used in matched control selection
Thermostat installation data	▪ Installation and last connected dates
SDG&E hourly system loads	▪ Summer 2022 ▪ 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 modeling

The primary analysis method was difference-in-differences with matched controls. The distance matching approach selected one matched control site for each of the more than 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 (except for Residential ELRP defaults) 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, Residential ELRP eligibility group, and size (annual usage for non-NEM and system capacity for NEM sites). Once the matches were selected for each participant, the difference-in-differences model was used to assess impacts and standard errors for each event and each study segment.

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 2022, program management encountered an issue dispatching thermostats for the August 17 6-8pm event. This failed dispatch had a visible effect on load impacts, causing event impacts for that day to be not statistically significant or directionally accurate. Therefore, the average weekday 6-8pm impacts refer to the averaged impacts of all 6-8pm weekday events besides August 17 (August 16, August 30, August 31, September 1). Due to the large number of events this season with varying start and end times, impacts will also be reported for the average 5-9pm weekday event and the average 6-8pm weekend event.

There were 12 residential events called during PY 2022. The Residential ACSDA events were typically called from 6 to 8 pm, though four weekday events and one weekend event in September were called during slightly different windows. Because events have diminishing impacts with each subsequent hour, comparing average impacts between events of different durations is not comparable. Though there were only two weekday events dispatched using a 5 to 9pm event window, the average event for this window was reported because these were the two hottest events of PY 2022. Load reductions were significant for all events with the exception of the August 17th event due to a dispatch error. The average weekday 6-8pm event window and average event 5-9pm window were significant with an average aggregate reduction of 8.65 MW and 5.95 MW, respectively. The average weekend 6-8pm window was also significant with an average aggregate reduction of 12.66 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, Table 3-7, and Table 3-8 summarize the load reductions for Residential ACSDA sites for the 12 events and the three average event windows: the average 6-8 pm weekday event (excluding the 8/17 event), the average 5-9 pm weekday event, and the average 6-8 pm weekend event. The full event hours for the non-standard event days are provided below the average event impacts.

The combined impacts for the BYOT and 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 8.65 MW across all 17,528 enrolled sites and the average reduction per site was 0.49 kW. Though 19,293 devices were enrolled at enrolled sites, only 18,662 devices on average were connected during the PY 2022 event season. Because only connected devices can be dispatched, all reductions are delivered by these connected devices. The average reduction per connected device was 0.46 kW. Impacts tended to be larger for events where the average event temperature was higher.

Aggregate reductions for significant events range from 3.45 MW (August 17) to 10.73 MW (September 1). The September 1 event, shown in Table 3-7 exhibited the highest average reductions with a maximum reduction of 0.60 kW per site and 0.56 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. Note that when the BYOT and Free program impacts are pooled, reductions for the August 17th event that experienced dispatch issues do surpass the threshold for statistical significance. However, impacts for this event date are uncharacteristically low and when analyzed for the Free customers only are not statistically significant.

Table 3-6: ACSDA Residential Program Weekday Event Reductions (BYOT + Free)

Event Date	Event Window	Avg Event Temp (F)	Sites Enrolled	Enrolled Devices	Connect-ed Devices	Reduction			t-stat	Significant (90% CI)
						Aggregate (MW)	Average Site (kw)	Average Connected Tstat (kw)		
8/16/2022	6 to 8 pm	71.9	17,374	19,132	18,481	6.77	0.39	0.37	29.27	Yes
8/17/2022	6 to 8 pm	72.9	17,375	19,134	18,483	3.45	0.20	0.19	14.76	Yes
8/30/2022	6 to 8 pm	74.6	17,376	19,131	18,444	7.47	0.43	0.41	31.40	Yes
8/31/2022	6 to 8 pm	78.6	17,374	19,129	18,439	9.95	0.57	0.54	34.62	Yes
9/1/2022	6 to 8 pm	77.9	17,988	19,780	19,283	10.73	0.60	0.56	39.16	Yes
Avg Weekday Event	**6 to 8 pm**	**75.7**	**17,528**	**19,293**	**18,662**	**8.65**	**0.49**	**0.46**	**57.15**	**Yes**
9/7/2022	5 to 9 pm	79.1	17,985	19,778	18,701	7.73	0.43	0.41	35.85	Yes
9/8/2022	5 to 9 pm	84.4	17,985	19,781	18,703	6.39	0.36	0.34	26.86	Yes
Avg Weekday Event	**5 to 9 pm**	**78.5**	**17,985**	**19,780**	**18,702**	**5.95**	**0.33**	**0.32**	**38.03**	**Yes**
9/9/2022	5 to 7 pm	71.3	17,985	19,781	18,702	4.42	0.25	0.24	17.85	Yes
9/26/2022	5 to 7 pm	72.4	17,980	19,775	18,657	4.29	0.24	0.23	20.36	Yes

The impacts for the free thermostats are detailed in Table 3-7 for weekday events. The average aggregate load reduction for weekday events from 6 to 8 pm was 1.33 MW across all 2,732 enrolled sites and the average reduction per site was 0.49 kW. Though 3,186 devices were enrolled at enrolled sites, only 3,050 devices on average were connected during the PY 2022 event season. Because only connected devices can be dispatched, all reductions are delivered by these connected devices. The average reduction per connected device was 0.44 kW. Impacts tended to be larger for events where the average event temperature was higher.

Aggregate reductions for significant events range from 0.29 MW (September 9) to 1.70 MW (September 1). The September 1 event, shown in Table 3-7 exhibited the highest average reductions with a maximum reduction of 0.63 kW per site and 0.56 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. Note that the impacts for the August 17 event that experienced dispatch issues were not significant.

Table 3-7: ACSDA Residential Program Weekday Event Reductions (FREE)

Event Date	Event Window	Avg Event Temp (F)	Sites Enrolled	Enrolled Devices	Connect-ed Devices	Reduction: Aggregate (MW)	Reduction: Average Site (kw)	Reduction: Average Connected Tstat (kw)	t-stat	Significant (90% CI)
8/16/2022	6 to 8 pm	71.8	2,738	3,193	3,059	0.92	0.34	0.30	10.51	Yes
8/17/2022	6 to 8 pm	72.8	2,738	3,193	3,059	-0.08	-0.03	-0.03	-0.96	No
8/30/2022	6 to 8 pm	74.7	2,739	3,194	3,048	1.18	0.43	0.39	13.36	Yes
8/31/2022	6 to 8 pm	78.7	2,740	3,195	3,047	1.57	0.57	0.51	14.57	Yes
9/1/2022	6 to 8 pm	78.1	2,710	3,161	3,045	1.70	0.63	0.56	16.29	Yes
Avg Weekday Event	**6 to 8 pm**	**75.7**	**2,732**	**3,186**	**3,050**	**1.33**	**0.49**	**0.44**	**23.58**	**Yes**
9/7/2022	5 to 9 pm	79.2	2,709	3,160	2,870	1.26	0.47	0.44	15.73	Yes
9/8/2022	5 to 9 pm	84.3	2,709	3,160	2,870	1.04	0.38	0.36	11.58	Yes
Avg Weekday Event	**5 to 9 pm**	**78.6**	**2,709**	**3,160**	**2,870**	**0.89**	**0.33**	**0.31**	**15.30**	**Yes**
9/9/2022	5 to 7 pm	71.1	2,709	3,160	2,869	0.29	0.11	0.10	3.19	Yes
9/26/2022	5 to 7 pm	72.5	2,711	3,162	2,861	0.40	0.15	0.14	5.22	Yes

The impacts for the BYOT thermostats are detailed in Table 3-8 for weekday events. The average aggregate load reduction for weekday events from 6 to 8 pm was 7.32 MW across all 14,796 enrolled sites and the average reduction per site was 0.49 kW. Almost all 16,107 enrolled devices were still connected throughout the PY 2022 event season, with 15,612 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 0.47 kW. Aggregate impacts are about five times as large for the BYOT devices. There are nearly five times as many connected devices in the BYOT program and impacts per connected thermostat are slightly larger for the BYOT program with 0.47 kW compared to the 0.44 kW savings per free connected device.

BYOT aggregate reductions for significant events range from 3.54 MW (August 17) to 9.03 MW (September 1). These dates, respectively, also exhibited the lowest and highest average site reductions and average connected thermostat reductions of the BYOT thermostats.

Table 3-8: ACSDA Residential Program Weekday Event Reductions (BYOT)

Event Date	Event Window	Avg Event Temp (F)	Sites Enrolled	Enrolled Devices	Connect-ed Devices	Reduction			t-stat	Significant (90% CI)
						Aggregate (MW)	Average Site (kw)	Average Connected Tstat (kw)		
8/16/2022	6 to 8 pm	71.9	14,636	15,939	15,422	5.85	0.40	0.38	27.33	Yes
8/17/2022	6 to 8 pm	72.9	14,637	15,941	15,424	3.54	0.24	0.23	16.33	Yes
8/30/2022	6 to 8 pm	74.6	14,637	15,937	15,396	6.29	0.43	0.41	28.47	Yes
8/31/2022	6 to 8 pm	78.5	14,634	15,934	15,392	8.38	0.57	0.54	31.45	Yes
9/1/2022	6 to 8 pm	77.9	15,278	16,619	16,238	9.03	0.59	0.56	35.65	Yes
Avg Weekday Event	**6 to 8 pm**	**75.7**	**14,796**	**16,107**	**15,612**	**7.32**	**0.49**	**0.47**	**52.15**	**Yes**
9/7/2022	5 to 9 pm	79.1	15,276	16,618	15,831	6.46	0.42	0.41	32.33	Yes
9/8/2022	5 to 9 pm	84.4	15,276	16,621	15,833	5.35	0.35	0.34	24.30	Yes
Avg Weekday Event	**5 to 9 pm**	**78.4**	**15,276**	**16,620**	**15,832**	**5.06**	**0.33**	**0.32**	**34.86**	**Yes**
9/9/2022	5 to 7 pm	71.3	15,276	16,621	15,833	4.13	0.27	0.26	17.91	Yes
9/26/2022	5 to 7 pm	72.4	15,269	16,613	15,796	3.88	0.25	0.25	19.81	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 2022 demand response season or being on TOU rates at any point during the season. There is no separate classification for customers who transitioned onto TOU rates during the PY 2022 demand response season because only a few customers did[11]. Table 3-9 details the reference loads and load reductions overall and by TOU category for the average 6 pm to 8 pm weekday 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, 26.6% of whole building load was curtailed during the average event, while 45% of cooling load was curtailed per connected device.

In aggregate, 41% of connected devices were in the coastal zone and these devices delivered 0.41 MW of the 1.33 MW—31%—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.

[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.

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 2022 and these are included in the TOU group. Average connected thermostat percent reductions are 45% 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 45% of cooling load compared to 46% for coastal. For participants not on TOU rates, non-NEM average percent impacts were 39% of cooling load.

NEM sites appear to deliver larger 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 substantially larger for NEM sites.

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

TOU Status	Climate Zone	NEM	Event Window	Avg Event Temp (F)	Sites Enrolled	Enrolled 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
Non-TOU	Coastal	No	6 to 8 pm	74.7	275	313	296	0.42	0.10	24.9%	0.90	0.35	39%	6.67
	Inland	No	6 to 8 pm	76.8	512	566	549	1.09	0.30	27.2%	1.32	0.54	41%	12.35
TOU	Coastal	No	6 to 8 pm	74.8	683	825	783	1.02	0.23	22.5%	0.65	0.29	46%	8.53
		Yes	6 to 8 pm	74.3	151	184	176	0.31	0.08	26.1%	0.59	0.46	77%	5.56
	Inland	No	6 to 8 pm	76.3	798	916	879	1.42	0.38	26.9%	0.96	0.44	45%	12.31
		Yes	6 to 8 pm	76.0	302	368	353	0.73	0.24	32.3%	1.14	0.67	59%	11.35
			6 to 8 pm	75.7	2,732	3,186	3,050	5.02	1.33	26.6%	0.98	0.44	45%	23.58

Table 3-10 shows the same results for the two BYOT categories-Nest and other thermostats. Overall, aggregate reductions were 7.32 MW which is 26.0% 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 larger reductions per connected device, on a kW and percent basis, than non-NEM when comparing within the same across rate and climate zone categories.

Table 3-10: ACSDA Residential Program Average Event Reductions by Segment (BYOT)

TOU Status	Climate Zone	NEM	Event Window	Avg Event Temp (F)	Sites Enrolled	Enrolled 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
Non-TOU	Coastal	No	6 to 8 pm	74.9	993	1,030	999	1.65	0.36	21.7%	0.96	0.36	37%	10.65
		Yes	6 to 8 pm	75.3	72	72	72	0.16	0.04	26.2%	1.46	0.57	39%	3.52
	Inland	No	6 to 8 pm	76.9	1,055	1,092	1,065	2.14	0.59	27.4%	1.41	0.55	39%	16.75
		Yes	6 to 8 pm	76.7	271	316	307	0.83	0.24	29.2%	1.83	0.79	43%	9.51
TOU	Coastal	No	6 to 8 pm	75.1	5,012	5,334	5,170	7.93	1.85	23.3%	0.86	0.36	42%	24.84
		Yes	6 to 8 pm	74.8	1,815	2,137	2,061	3.96	1.05	26.5%	1.11	0.51	46%	18.35
	Inland	No	6 to 8 pm	76.6	3,420	3,589	3,471	6.12	1.61	26.4%	1.12	0.46	42%	26.49
		Yes	6 to 8 pm	76.7	2,018	2,359	2,297	4.96	1.46	29.5%	1.36	0.64	47%	25.11
			6 to 8 pm	75.7	14,796	16,107	15,612	28.17	7.32	26.0%	1.08	0.47	43%	52.15

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[12]. The left panel shows the aggregate hourly loads (actual and counterfactual) for these sites. The right panel shows impacts per customer. The tables accompanying each figure show aggregate impacts for the 6 pm to 8 pm weekday 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 26.6% reduction across all Free residential customers on the average weekday 6-8 pm 2022 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 26.0% load reductions for the average customer and on aggregate for the BYOT category.

[12] August 17 was excluded from the 6-8 pm weekday event definition in this program year due to dispatch issues.

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

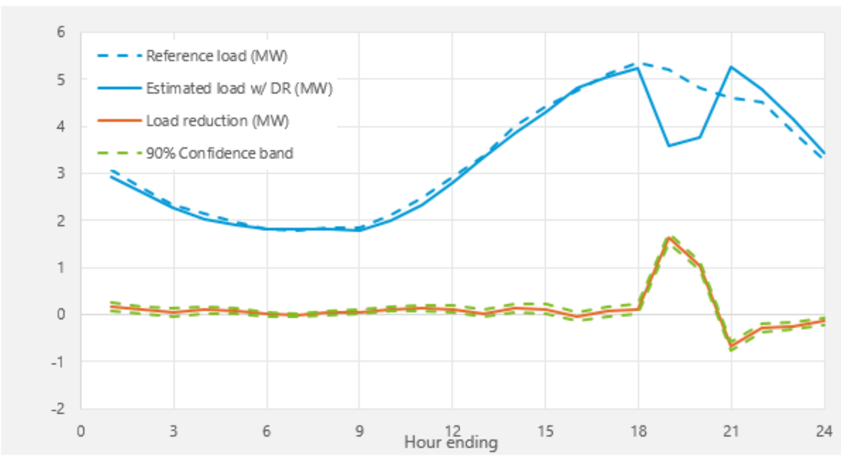
Aggregate (MW)

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, 6-8pm

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total sites	2,732
Total enrolled thermostats	3,186
Total connected thermostats	3,050
Percent of thermostats connected	96%
Avg load reduction 6PM-8PM	1.33
% Load reduction 6PM-8PM	26.6%



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, 6-8pm

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total sites	2,732
Total enrolled thermostats	3,186
Total connected thermostats	3,050
Percent of thermostats connected	96%
Avg load reduction 6PM-8PM	0.49
% Load reduction 6PM-8PM	26.6%

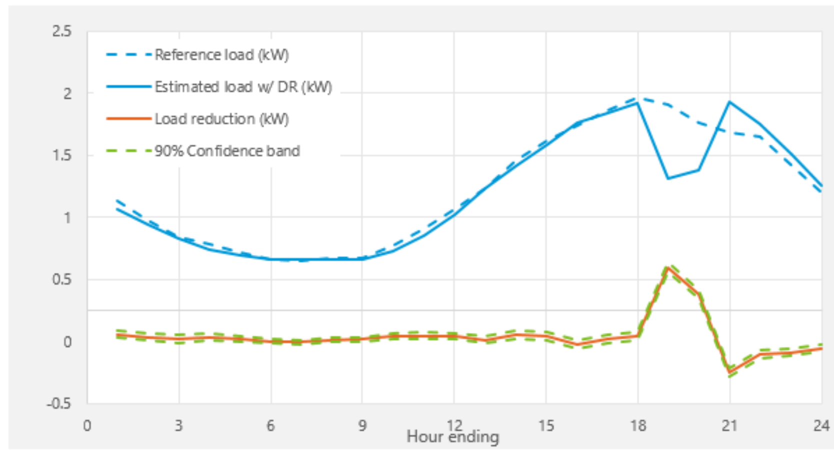


Figure 3-4: ACSDA Residential Summary for Average Event (BYOT)

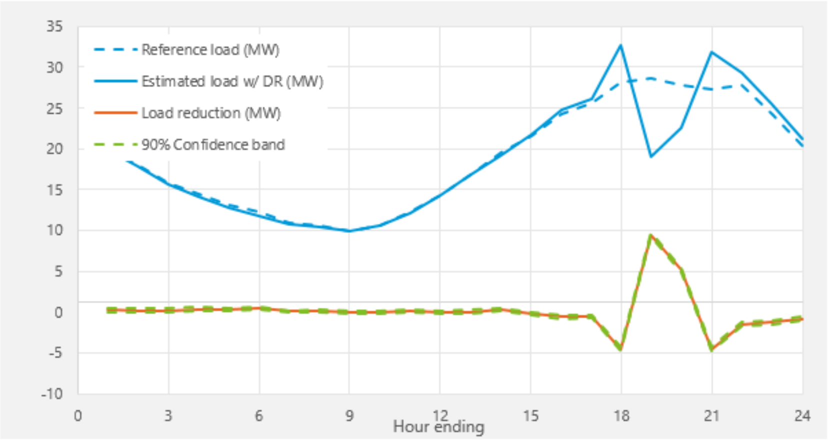
Aggregate (MW)

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, 6-8pm

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total sites	14,796
Total enrolled thermostats	16,107
Total connected thermostats	15,612
Percent of thermostats connected	97%
Avg load reduction 6PM-8PM	7.32
% Load reduction 6PM-8PM	26.0%



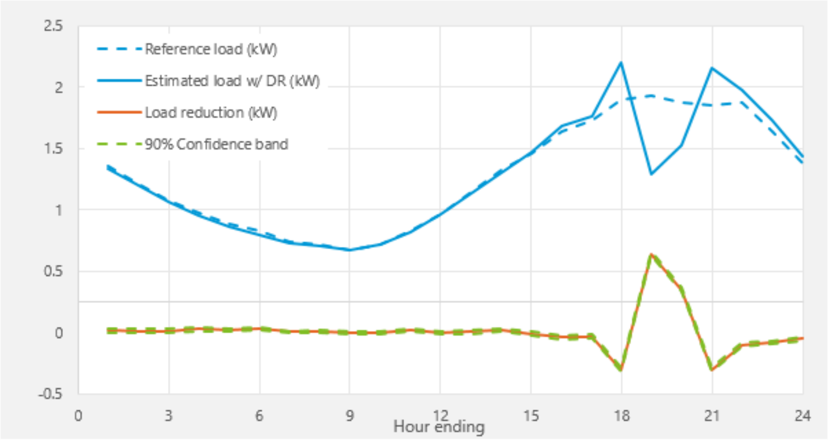
Average Customer (kW)

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, 6-8pm

Table 2: Event day information

Event start	6:00 PM
Event end	8:00 PM
Total sites	14,796
Total enrolled thermostats	16,107
Total connected thermostats	15,612
Percent of thermostats connected	97%
Avg load reduction 6PM-8PM	0.49
% Load reduction 6PM-8PM	26.0%



3.4 EX ANTE LOAD IMPACTS

A key objective of the 2022 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 87 to 90 max daily temperature, average cooling load per thermostat for residential ACSDA devices is about 1.0 to 1.3 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

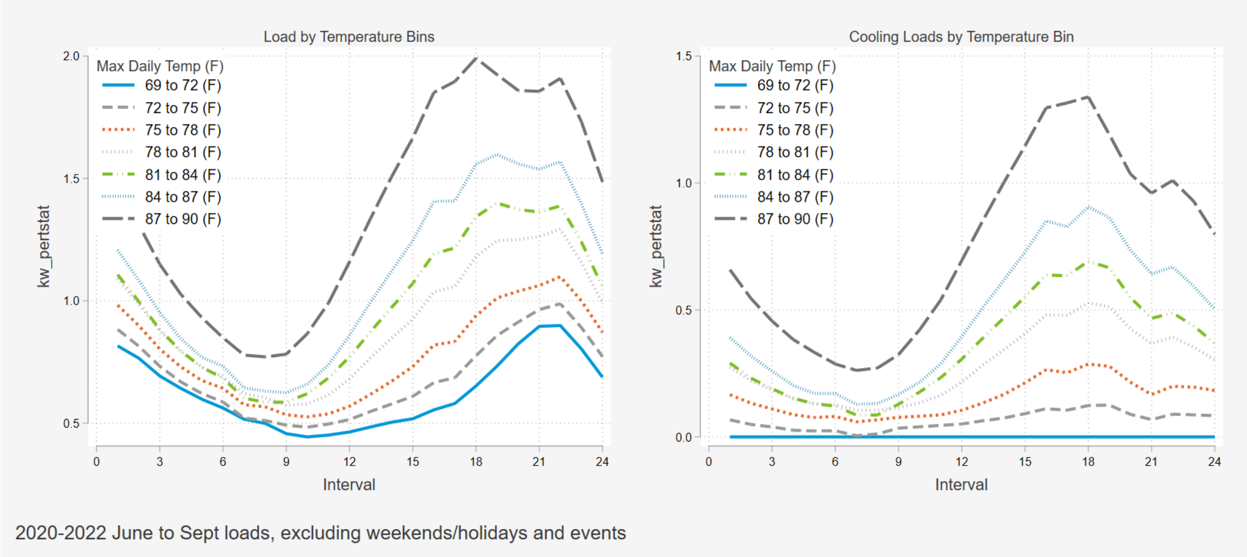
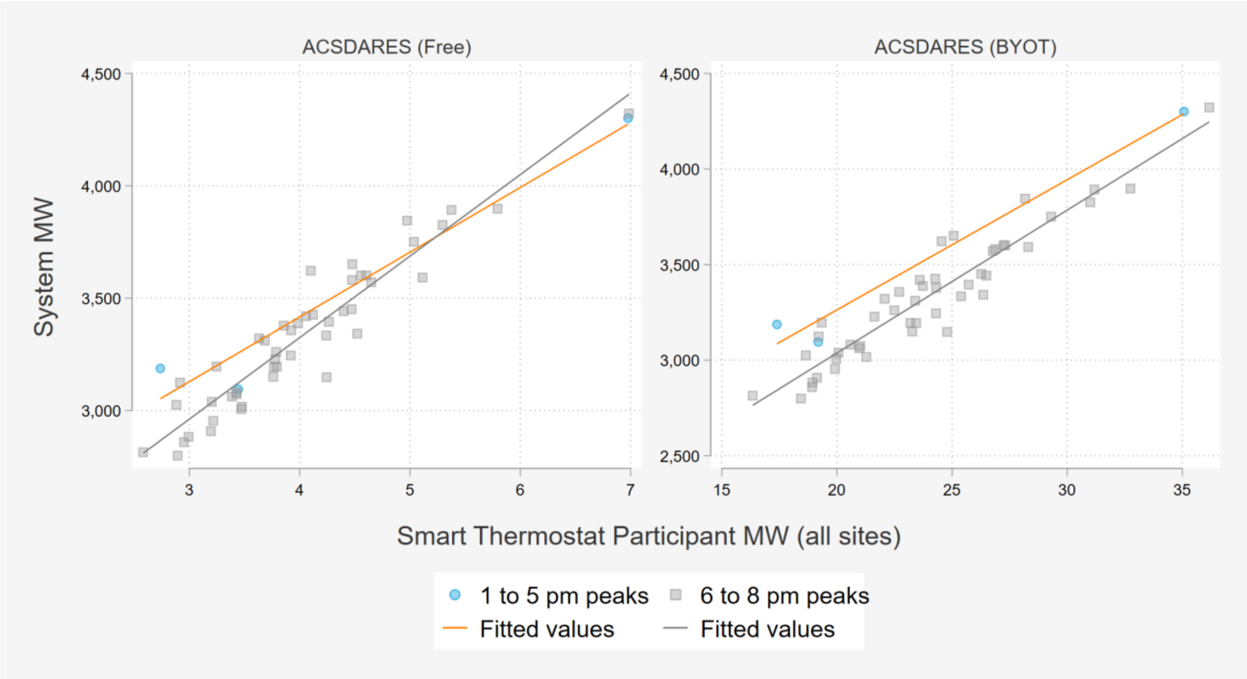


Figure 3-6 shows the relationship between aggregate loads for ACSDA sites and SDG&E daily peak loads. Daily system peaks that occurred before 5pm (typically at 4 or 5pm) are shown in blue and those that occurred later are shown in grey. The patterns are similar for ACSDA sites with free thermostats and 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 2022 event impacts are utilized to build the ex ante model.

Figure 3-7 shows hourly event percent reductions for PY 2022 weekday events as a function of hourly temperatures for sites for the free and BYOT programs. In the bottom-left corner of each panel appear the event impacts for September 9th, which were both uncharacteristically low on a percent basis and occurred on a day with anomalous weather. Because event reductions were so small and participant-weighted event temperatures were so cool, including event reductions from the September 9th event in the ex ante model made impacts extremely weather sensitive. The slope of the orange fitted line in the panel represents the weather sensitivity of percent reductions when including the September 9 event and the slope of the blue fitted line represents the weather sensitivity of percent reductions when excluding the September 9 event. Due to both the uncharacteristic weather observed on this day and the unusually small event reductions, the evaluation team opted to exclude the September 9th event from the ex ante impact model. With this event excluded, both the Free and BYOT percent reductions show a fairly flat, and even slightly negative, weather sensitivity. This means that percent reductions diminish slightly with warmer temperatures. Because cooling loads increase with higher temperatures absolute reductions still increase with higher temperatures, but to a lesser degree than loads.

Figure 3-7: 2022 ACSDA Hourly Reductions and Temperatures[13]

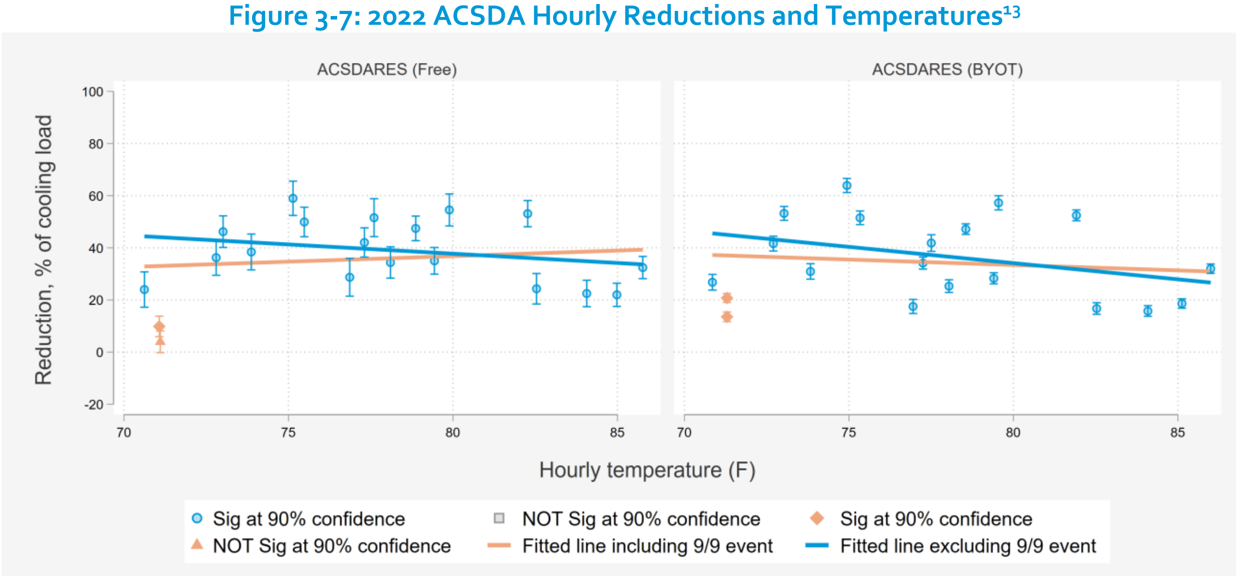


Figure 3-8 shows the same percent reduction points as in Figure 3-7 but is formatted to highlight the trends for the first, second, and third event hour. There is a notable decline in load reductions for each event hour, especially for the BYOT program. This comparison is more robust. The implication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

[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.

declining trend is that as reductions are estimated for the five-hour ex ante resource adequacy window, modeled impacts follow the observed trend and diminish substantially by the third, fourth, and fifth hour. The September 9th event is excluded from this figure as it was excluded as an input to the ex ante impact model.

Figure 3-8: 2022 ACSDA Hourly Reductions and Temperatures with Event Hour Trend[14]

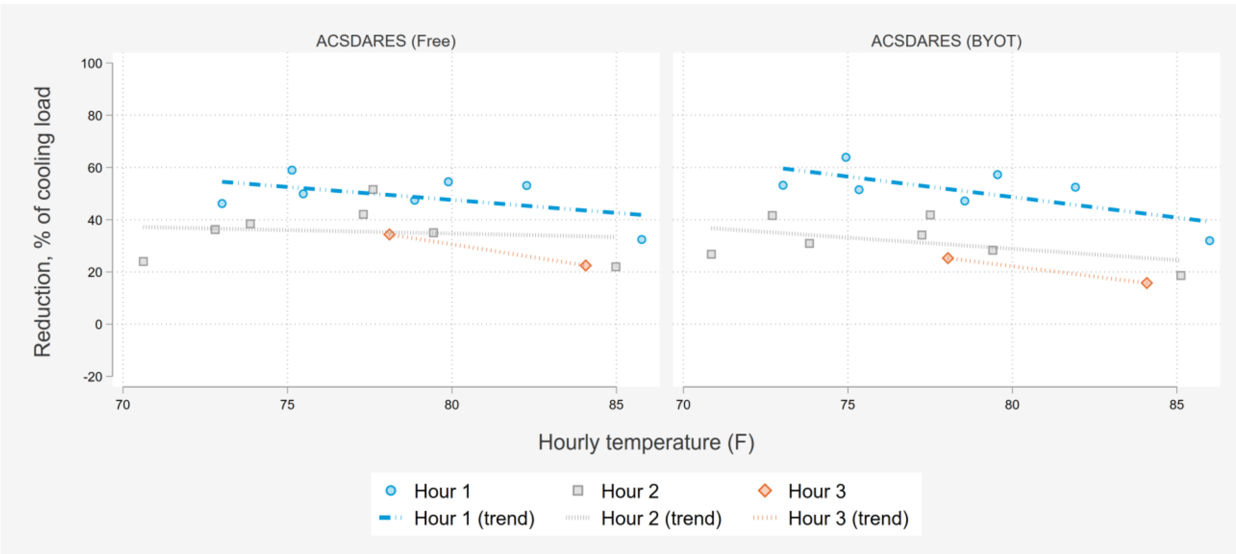


Table 3-11 shows the same data points averaged by event hour with trendlines added. Hourly reductions, as a percentage of cooling load, decrease with each subsequent event hour. This trend is typical for load control programs but the steepness of the decline can be modulated by adapting the control strategy. 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.

[14] 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 3-11: Average Hourly Reduction as Percentage of Cooling Load

		Event Hour			
		1	2	3	4
Free	Percent Impact (%)	48.9%	35.6%	28.4%	26.5%
	Temperature (F)	78.6	76.7	81.1	79.7
	Number of Event Hours	7	7	2	2
BYOT	Percent Impact (%)	51.1%	31.8%	20.5%	17.1%
	Temperature (F)	78.5	76.7	81.1	79.7
	Number of Event Hours	7	7	2	2

3.4.2 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 3-9 summarizes the enrollment model architecture.

Figure 3-9: ACSDA Enrollment Model Architecture

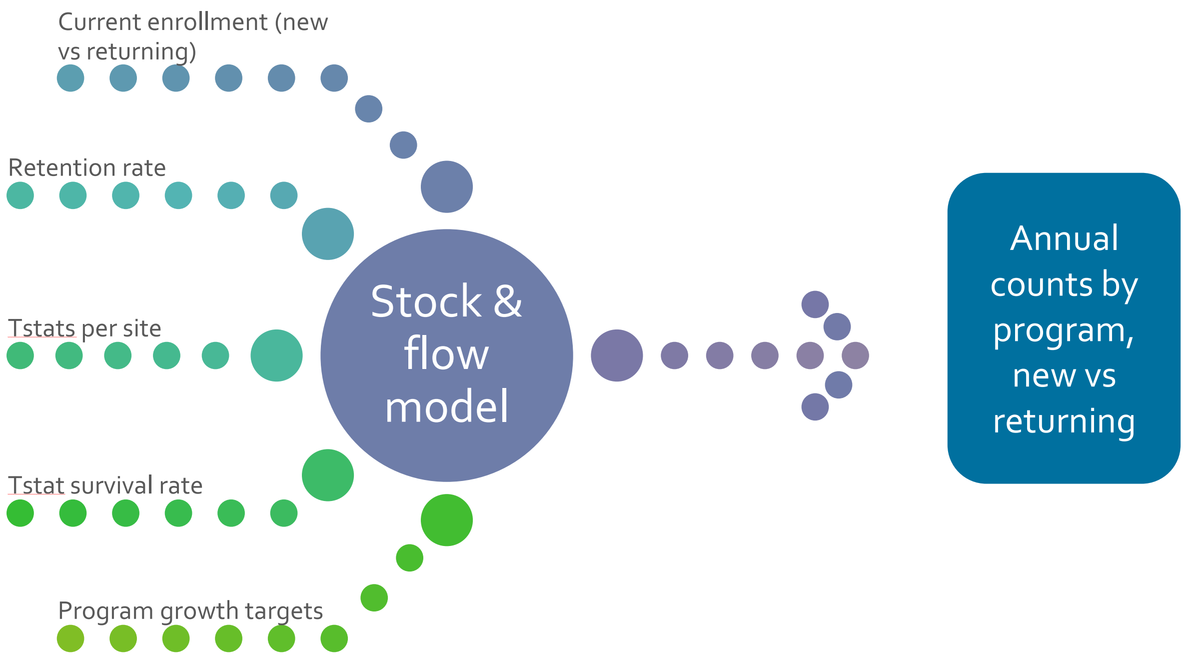


Table 3-12 summarizes retention, connectivity, thermostats per site, and annual new site enrollments used to derive the enrollment forecasts for PY 2022 using the enrollment model described above. Note that site attrition and device connectivity rates are the same figures described in section 3.1

Table 3-12: Residential TD Program Enrollment Forecast Assumptions

Program	Program Type	Site retention rate	Tstat failure rate	Tstats per site (current)[15]	Tstats per site (capped)[16]	Projected New Enrollment
ACSDARES (Free)	ACSDARES	97%	1.2%	1.1	1.2	0
ACSDARES (BYOT)	ACSDARES	97%	1.2%	1.1	1.1	6,408

Table 3-13 below summarizes key assumptions incorporated into the forecast used.

[15] Reflects average thermostat counts for existing participants. This is the figure applied to current enrollments
[16] 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 3-13: 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%.
Long term flattening out of enrollments	Assume enrollments stabilize starting in 2029 (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[17]. 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

3.4.3 Ex Ante Load Impacts

Table 3-14 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 2029), 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 2029 then slowly decrease over time as thermostats become disconnected.

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

Table 3-14: Portfolio Impacts for SDG&E 1-in-2 Weather Conditions, August Monthly Peak Day

Year	ACSDA - Residential		Total
	Free	BYOT	
2022	0.81	3.20	4.01
2023	0.78	4.00	4.78
2024	0.75	5.16	5.91
2025	0.72	6.36	7.08
2026	0.69	7.65	8.34
2027	0.67	9.02	9.68
2028	0.64	10.46	11.10
2029	0.62	10.86	11.49
2030	0.62	10.73	11.34
2031	0.61	10.59	11.20
2032	0.60	10.46	11.06
2033	0.59	10.33	10.93

Table 3-15 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 2029. The number of thermostats connected reflects the decline in connectivity observed historically and overlays this decline on the total population of installed thermostats.

Table 3-15: 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
2022	18,049	19,821	19,534	1.71	4.01	4.26	4.01	4.36
2023	21,981	24,092	23,595	1.72	4.80	5.08	4.78	5.19
2024	27,769	30,377	29,523	1.72	5.96	6.28	5.91	6.40
2025	33,820	36,949	35,671	1.72	7.15	7.52	7.08	7.66
2026	40,342	44,032	42,260	1.73	8.43	8.86	8.34	9.01
2027	47,320	51,612	49,270	1.73	9.80	10.27	9.68	10.45
2028	54,742	59,674	56,686	1.73	11.25	11.78	11.10	11.97
2029	57,265	62,415	58,713	1.73	11.64	12.18	11.49	12.38
2030	57,265	62,415	57,984	1.73	11.49	12.03	11.34	12.23
2031	57,265	62,415	57,264	1.73	11.35	11.88	11.20	12.08
2032	57,265	62,415	56,553	1.73	11.21	11.74	11.06	11.93
2033	57,265	62,415	55,851	1.73	11.07	11.59	10.93	11.78

3.4.4 COMPARISON OF EX POST AND EX ANTE LOAD IMPACTS

Table 3-16 compares the demand reductions from 2022 events to the PY 2022 reductions expected for the 1-in-2 weather conditions used for planning. Results are shown for the 4 to 9 pm resource adequacy window. Ex post event temperatures were all sufficiently hot to be comparable to ex ante conditions, so all events included in the average weekday 6-8pm event definition were used for comparison.

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 2022, residential ACSDA customers delivered 8.65 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 (1.45 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 slightly higher for 1-in-2 planning conditions than for the PY 2022 events. Percent reductions for the event period were 26.1%[18], over the full resource adequacy window, this value dropped to 4.5%. Ex ante predictions show a 12.3% to 13.1% 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.

[18] The ex post average weekday 6-8 pm event excludes August 17th due to dispatch issues during that event.

Table 3-16: Residential ACSDA Comparison of Ex Post and Ex Ante Load Impacts for 2022

Result Type	Day Type and Period	Sites	Tstats connected	Load without DR (MW)	Load Reduction (MW)	% Reduction	Daily Max Temp (F)	Event Avg Temp (F)
Ex Post Avg. Weekday**	Event Period (6pm to 8pm)	17,528	18,662	33.19	8.65	26.1%	86.5	75.7
	Resource Adequacy Period (4 to 9pm)	17,528	18,662	32.49	1.45	4.5%	86.5	77.1
Ex ante SDG&E	1-in-2 Weather August Peak (4 to 9pm)	18,049	19,534	32.66	4.01	12.3%	89.9	83.2
Ex ante CAISO	1-in-2 Weather August Peak (4 to 9pm)	18,049	19,534	30.58	4.01	13.1%	87.0	80.9

*Table shows portfolio impacts. To avoid double counting, it excludes customers dually enrolled in other DR programs.
**Ex post includes sites enrolled through beginning of October, but ex-ante site counts also include sites who enrolled through November

3.4.5 Ex Ante Load Impact Slice-of-Day Tables

Table 3-17 and Table 3-18 show the 2022 ex ante aggregate hourly impacts for each month under CAISO and SDG&E monthly peaking conditions, respectively. The tables are designed to enable the CPUC's Slice-of-Day Resource Adequacy requirements. The estimated reductions are greatest in August and September as there is the most amount of cooling load available to be curtailed. Pre-cooling and snap-back both cause visible load increases on either end of the 4 to 9 pm Resource Adequacy window for which load impacts are forecasted.

Table 3-17: Slice of Day Table for CAISO 1-in-2 Weather Year Monthly Peak Day (Aggregate Impacts (MW))

Hour Ending	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	-0.13	-0.08	-0.23	-0.35	-0.42	-0.44	-0.41	-0.20	0.00
16	0.00	0.00	0.00	-1.29	-0.76	-2.19	-3.35	-4.05	-4.24	-3.91	-1.93	0.00
17	0.00	0.00	0.00	2.64	1.75	4.37	6.68	7.49	7.61	6.81	3.83	0.00
18	0.00	0.00	0.00	2.31	1.50	3.68	5.60	6.05	6.20	5.40	3.37	0.00
19	0.00	0.00	0.00	1.58	1.08	2.58	3.84	4.10	4.08	3.41	2.55	0.00
20	0.00	0.00	0.00	0.86	0.59	1.42	1.97	1.95	2.07	1.67	1.41	0.00
21	0.00	0.00	0.00	0.34	0.21	0.54	0.54	0.46	0.37	0.18	0.54	0.00
22	0.00	0.00	0.00	-1.28	-0.75	-2.14	-3.30	-3.99	-4.16	-3.87	-1.94	0.00
23	0.00	0.00	0.00	-0.51	-0.30	-0.86	-1.33	-1.61	-1.68	-1.56	-0.79	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Demand reductions are positive (Blue)

Load increases are negative (Orange)

Table 3-18: Slice of Day Table for SDG&E 1-in-2 Weather Year Monthly Peak Day (Aggregate Impacts (MW))

Hour Ending	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	-0.20	-0.17	-0.22	-0.41	-0.47	-0.57	-0.37	-0.21	0.00
16	0.00	0.00	0.00	-1.92	-1.60	-2.12	-3.95	-4.52	-5.49	-3.58	-1.98	0.00
17	0.00	0.00	0.00	3.73	3.12	4.18	7.86	7.90	8.65	6.11	4.09	0.00
18	0.00	0.00	0.00	3.12	2.55	3.44	6.57	6.21	6.51	4.73	3.62	0.00
19	0.00	0.00	0.00	2.05	1.70	2.25	4.38	3.96	3.92	3.08	2.75	0.00
20	0.00	0.00	0.00	1.24	0.96	1.15	2.21	1.77	1.49	1.64	1.53	0.00
21	0.00	0.00	0.00	0.49	0.39	0.39	0.54	0.20	-0.24	0.36	0.56	0.00
22	0.00	0.00	0.00	-1.89	-1.57	-2.07	-3.90	-4.42	-5.40	-3.56	-1.99	0.00
23	0.00	0.00	0.00	-0.76	-0.63	-0.83	-1.58	-1.78	-2.18	-1.44	-0.80	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Demand reductions are positive (Blue)

Load increases are negative (Orange)

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[19] from the dispatch portal.

- **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 since 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.

[19] Currently devices disconnected for more than one year are periodically removed and unenrolled