Smart Thermostat DR Gets a Makeover: Incorporating price signals and working toward resource adequacy-eligible curtailment

Chelsea Liddell, DNV
Cynthia Austin, SMUD
Amrita Chakraborty, SMUD

ABSTRACT

A west-coast municipal utility is committed to eliminating 100% of greenhouse gas (GHG) emissions from its generation by 2030, while maintaining reliability and low rates. Peak-hour loads present a key barrier to each of these goals; demand response (DR) programs are one way that this utility seeks to reduce these peaks.

In 2022, the utility began a new smart thermostat DR program, My Energy Optimizer Partner. It included two innovative features designed to increase curtailment and reduce curtailment drop-off over event hours. First, in addition to the standard program, in which thermostats are directly controlled during events, the program included a “critical peak pricing” (CPP) option with higher customer electricity prices during event hours, along with direct control. Second, to best curtail peak load and meet the standards for resource adequacy (RA), the utility sought constant curtailment over the event’s three to four hours. This was a departure from usual smart thermostat DR events, which generally start with high curtailment that quickly drops off. To achieve this goal, the program staggered signals sent to different thermostats: some homes began reducing cooling load in the first event hour, and some began in later event hours.

Evaluation of this program for four summer seasons has found that CPP participants curtailed more electricity, though more work is needed to understand if this is a program effect or a result of a different participant population. Staggered events’ success at creating constant curtailment increased from year to year. This paper will describe the magnitude of these differences and best practices for implementing these innovative features.

Introduction

Control of air conditioners has long been a low-hanging fruit for utilities seeking to reduce electric load during system peak demand hours. Air conditioning and electric heating (where used) often make up the majority of a home’s electric usage (EIA 2026), so temporarily reducing these activities can create large reductions in electric loads when applied to many residential customers. For example, a central air conditioner might draw 3 kW (McCabe 2024); temporarily eliminating even one-third of that load for 10,000 customers would drop total load by 10 MW.

As early as the 1970s, utilities created large programs with one-way controllers on air conditioners (Energy Toolbase 2024). When events were called, these switches would turn the device off completely for a specified amount of time, limiting its runtime per hour. While effective in reducing load, this program type was costly to administer since it required the utility to purchase devices and cover installation costs. However, when “smart thermostats” were introduced in the mid-2000’s, utilities began to explore temporarily changing home temperature settings by a few degrees to reduce heating/AC need. Compared to AC switch programs, smart thermostat programs are considerably less costly to administer, with the ability to reach a greater number of customers. These programs also allow more control of temperature, allowing, in theory, higher participation and more curtailment events because of better comfort outcomes for customers (Tomat 2022). However, customers are also able to "override" events, turning temperatures back to their original setting, which introduces uncertainty about the magnitude of load reduction and increases the need for program evaluation.

Sacramento Municipal Utility District (SMUD) is one utility that seeks to incorporate smart thermostat curtailment events ("demand response") into its portfolio of load flexibility. SMUD is a community-owned, not-for-profit municipal utility serving electricity to over 1.5 million people in California's capitol region. Facing the climate emergency, SMUD's elected board of directors adopted a goal of zero carbon emissions from its electricity portfolio by 2030. Part of this emissions reduction will be driven by new technologies and business models, including over 100 MW of demand flexibility, which will lower pressure on grid infrastructure and enable a better match between electrical load and renewable generation (SMUD 2021). Smart thermostat demand response is expected to be an important part of this flexibility.

Program Design

Rolled out in 2022, SMUD's smart thermostat demand response program, called "My Energy Optimizer® Partner," now includes over 30,000 participants[1]. Customers with central AC and either Nest, Sensi, Ecobee, or Honeywell thermostats are eligible to participate.

Customers receive an enrollment incentive of up to $50 for program participation. Participants are then given a choice to either receive an annual $25 end-of-summer bonus or enroll in a Critical Peak Pricing Rate (CPP). Those that sign up for CPP receive an additional $25 one-time incentive and can utilize their distinct rate structure, described below, to maximize bill benefits. In this study, we call non-CPP-enrolled customers "Automatic Demand Response – only" or ADR customers. These customers' rates do not differ from their pre-enrollment rate structures.

A maximum of fifteen events are called during the summer season (June 1–September 30). Events last up to four hours and thermostats are adjusted to higher temperatures during the event, reducing energy use during those hours. Customers can always override adjustments to their thermostats during events. The temperature adjustments are controlled by the thermostat manufacturers, each of which has a different algorithm for reducing air conditioning load while keeping customers as comfortable as possible. Events can be called for both emergency and economic purposes. Summary statistics on events are shown in Table 1.

SMUD's smart thermostat program includes two unique features that will be the focus of this paper. In the first, CPP participants receive electricity rate signals along with automatic thermostat control. That is, they experience higher electricity prices when events are called, and slightly lower prices in all other hours. In theory, this provides extra incentive for customers not to override event settings, and potentially even turn their thermostats to higher temperatures during events or use less electricity from other appliances during events. Initially, SMUD only recruited customers who would be "structural winners" to this part of the program – that is, based on past electricity use patterns, these customers were likely to have lower bills if they enrolled and did not change consumption patterns.

[1]In early 2026, participation has now surpassed 30,000, though that is not shown in the participation table here.

CPP was designed to gather information on how to best implement more complex rate structures, such as dynamic pricing. SMUD sought to know whether bigger impacts could be expected when increased rates were layered on automatic thermostat control and how customers would react to an additional varying component in their rate structure. (Since 2015, all SMUD customers have been defaulted to a time-of-day varying rate). Because, up until 2026, only structural winners were recruited to CPP, any observed differences in impacts may be a result of the different design or could be a result of the different customer segment enrolled. The possible implications of these differences are discussed further below, in the "CPP (Critical Peak Pricing) Results" section.

Table 1. Program year summary

Program Year	Number of Events	Average Event Day Maximum Temperature	Number of Automatic Demand Response (ADR) Participants**	Number of CPP Participants
2022	15	99	5,010	42*
2023	8	103	15,534	657
2024	15	103	21,711	606
2025	6	100	28,306	573

**Automatic Demand Response (ADR) participants saw only direct control of thermostats and no price signal
*The 42 CPP participants for the 2022 program season were not sufficient to yield robust impact results. Therefore, we only present ADR impacts for 2022.

The second unique program feature we will describe here is SMUD's effort to dispatch customers in the program such that the overall combined curtailment shape would be constant over event hours. Usually, all customers in a smart thermostat DR program are called upon to raise their temperature setting and reduce energy usage at the same time. In the first hour, air conditioners are largely off, and energy use is much lower than it would otherwise have been. However, this effect decreases over the hours of the event; people trend back toward their normal energy usage levels. There are two primary reasons for this: (1) heat creeps into homes, raising indoor temperatures until they reach the new, higher thermostat setpoint, and air conditioners turn back on to maintain that new setpoint (albeit using less energy to maintain that setpoint) and (2) some customers will get uncomfortably hot and set their temperature settings back to normal levels, causing air conditioners to work harder until the home is reaches its original setpoint, and then returning to normal operations. This results in high curtailment in the first event hour and lower curtailment in subsequent hours. By the fourth hour, curtailment could be only a fraction of what was achieved in the first hour. SMUD seeks to shape this curtailment such that it is constant over all event hours.

There are two reasons that SMUD seeks a constant level of load reduction. First, for SMUD, a thermostat DR program is financially beneficial if (a) it can be considered as part of its Resource Adequacy (RA) resource stack and (b) program costs are lower than RA market prices. An RA resource must demonstrate response over a four-hour period, and its curtailment impact is based on its lowest curtailment over these four hours. Additionally, SMUD modeling software for capacity needs is not capable of accurately incorporating a resource whose curtailment varies over time, so constant curtailment would allow both greater value of thermostat DR in the software's outputs and more accurate modeling of overall capacity needs after thermostat DR has been included.

An example of what this might look like is shown in Figure 1. Pre-cooling before the event results in some additional load (negative curtailment) and re-cooling the house after the event ("snapback") also results in additional load. During the event, however, the average curtailment over all customers is approximately constant (though this would not be the case for any individual customer).

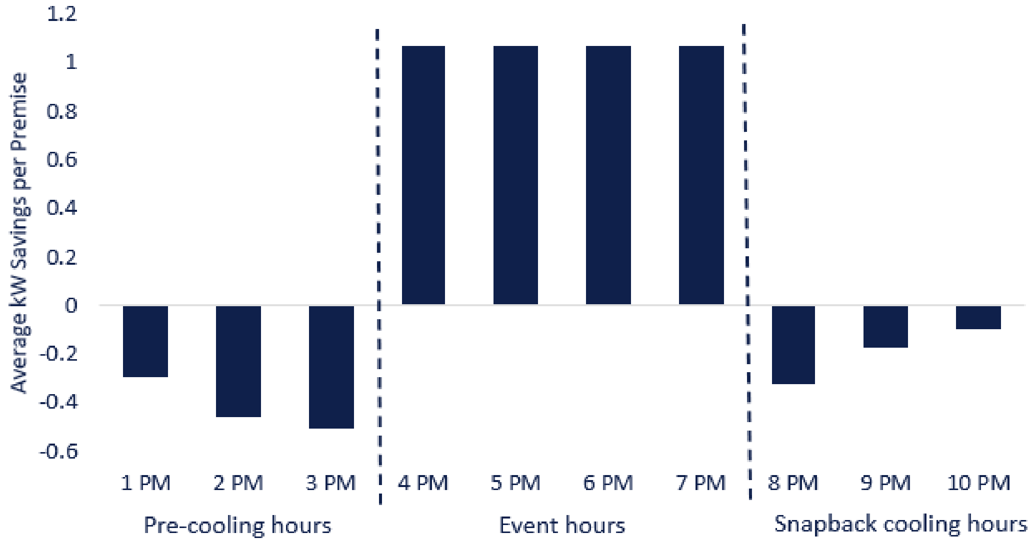

Figure 1: Example of an ideal average curtailment shape for SMUD's resource adequacy goals, for an example event occurring from 4-7 pm

The details of how each of these program components are implemented and how the program has been evaluated are in the Methods section below.

Methods

In this section, we begin by describing the methods that SMUD used to implement the two above-described features of its MEO Partner smart thermostat DR program. We then describe the evaluation methodology used to determine both overall impacts of the program and impacts of these two specific efforts.

Critical Peak Pricing Implementation

As described above, the subset of customers enrolled in the CPP segment of the program experienced both direct thermostat control and a price spike during program events. As shown in Figure 2, CPP enrollees received a discount of $0.02 per kWh during Time-of-Day off-peak and mid-peak periods from June 1 to September 30 but paid an additional $0.50 per kWh during event hours.

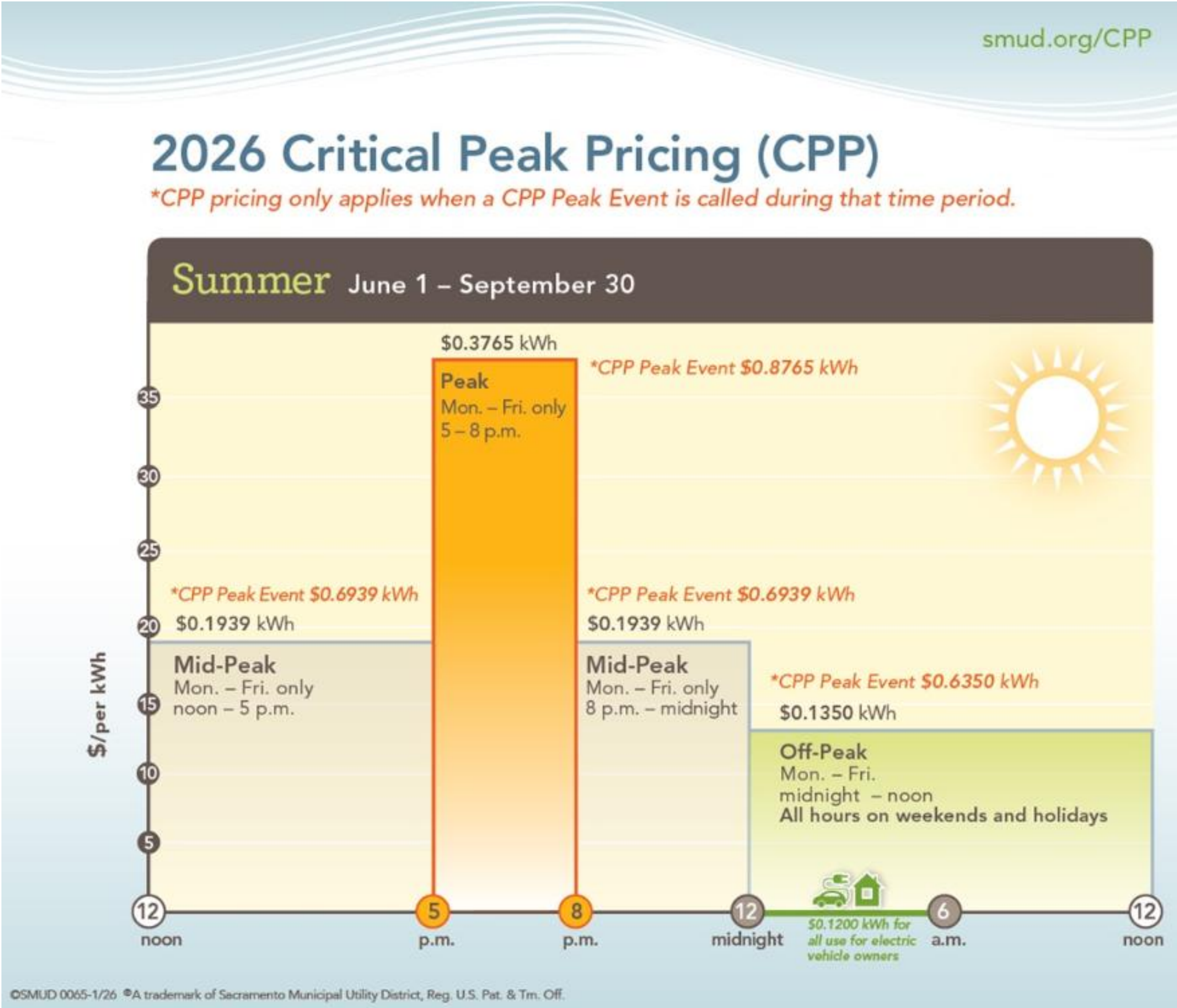

Figure 2: CPP rate structure, for an example event occurring from 5-8 pm

Until 2026, SMUD only recruited customers who would be "structural winners" to this part of the program – that is, based on past electricity use patterns, these customers were likely to have lower bills if they enrolled and did not change consumption patterns. This means that these customers already had relatively low energy use during afternoon peak hours in the summer (the time and season when events are called). However, all customers were eligible to participate if they requested to do so. At least one customer did see higher bills after enrolling in CPP and was subsequently unenrolled. As shown in Table 1, customers were recruited to the CPP rate in the first two years of the program (2022 and 2023) and those customers remained enrolled, but no additional customers were recruited to CPP in the following years. This meant that 42 customers were enrolled in 2022 and 657 in 2023, with slightly declining numbers after that.

For the 2026 season, CPP recruitment was re-started and expanded to include all thermostat DR program participants – regardless of whether they are "structural winners." Customer surveys indicated there were negligible differences in the customer satisfaction rate between CPP and ADR (non-CPP) participants. However, CPP understanding and administration proved to be complex for the program implementer and customers. The 2026 CPP expansion is beyond the scope of this paper but will be studied going forward.

Constant Curtailment Event Implementation

SMUD's effort to pursue constant curtailment, averaged over all participants, began in the second season of the program (2023) and continued in 2024 and 2025. Overall, the strategy to achieve this constant curtailment revolved around staggering the timing of different customers' thermostat adjustments. If done correctly, this would reduce overall curtailment in the first hour, as fewer customers would see the signal in that hour. However, subsequently, when overall average curtailment would usually decline as customers opted out and air conditioners turned back on to maintain the new, higher, temperature setting, a new wave of customers would be called, introducing their high, first-hour curtailment into the average and bringing it up to the level of the first hour. This would be continued for the third and fourth hours, with the number of customers called in each hour optimized to maximize the average curtailment while keeping it constant.

In 2023 and 2024, SMUD requested that the program implementer (which manages customers and event calls) stagger customer event times to achieve this goal. Only some events were managed in this way, as "staggered events" and a subset of customers were managed as normal even during these events, to provide a comparison. Additionally, those customers who were enrolled in CPP were not called at staggered times, as they depend on reducing load during all event hours to minimize the during-event electricity surcharge and keep their electricity bills low.

In 2025, the program implementer managed customer thermostat dispatches on two staggered-event days, while SMUD selected the customers to be dispatched at different times on a third staggered-event day. SMUD assigned enrolled customers to groups based on their historical trend in hourly energy savings during demand response events. For each event, customer energy savings were tracked hour by hour. For example, if a customer saved energy during the first two hours of a previous three-hour event but did not save energy in the third hour, then, in the staggered event, they were assigned to a two-hour participant group instead of the full three-hour group. Customers who consistently saved energy in every hour of prior events remained eligible to participate in the full event duration.

Evaluation

The evaluation included both a process component and impact component. The process evaluation sought to determine customer satisfaction and program understanding, as well as opportunities for improvement in program delivery, both to increase program impact and customer retention. The impact evaluation sought to quantify program impacts, including how those impacts varied for the CPP group and for staggered events.

The process evaluation included both a pre- and post-season customer survey. Overall, customers were highly satisfied with the program. Fewer than 18% of responding participants reported any level of dissatisfaction with any of 18 different program components. Only 6% of ADR participants and 4% of CPP participants stated they were unlikely to stay in the program.

The impact evaluation was designed to provide the most accurate, least biased estimate of energy curtailment. For residential demand response, baselines like the 5-of-10 (or other X-of-Y) are often used to easily provide an estimate of impacts just after an event occurs. (They are frequently called “settlement baselines” for situations where customers are paid by amount of curtailment.) However, these methods, which calculate the counterfactual baseline as participant usage on the X hottest non-event days in the Y days preceding the event, often provide biased results, as event days are systematically different (usually hotter) than any non-event days. This means the true no-event counterfactual energy usage is higher than the amount in the X hottest preceding days, so the X-of-Y baseline underestimates event impact.

In contrast, the method we used, described below, involves finding a matched group of non-participants, whose energy use informs the event day counterfactual load. We also use a difference-in-difference method to correct for any systematic differences that remain between participants and this selected group of non-participants. This method is described in detail below, and Figure 5 shows how it improves the baseline estimate. In the second panel of that figure, the blue line represents what would have been used as the baseline in a simple 5-of-20 estimate, and the dotted black line is the actual baseline used for calculating impacts in this study.

The impact evaluation was composed of three primary steps:

1. Data ingestion and cleaning
2. Matched comparison group selection
3. Difference-in-difference load impact estimation

An overview of steps 2 and 3 is shown in Figure 3, below.

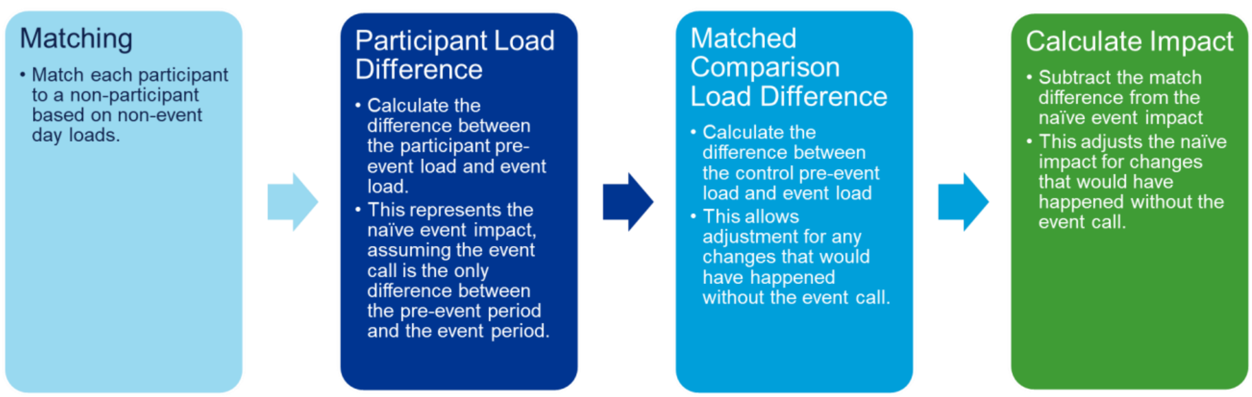

Figure 3. Impact evaluation analysis matching and difference-in-difference process

The first step, data cleaning, involves mostly removing customers who had some other load-shift event that SMUD can identify. This includes participants in any other demand response programs or those who installed major electrification technologies during the study period.

The second step is finding the matched comparison group. In this step, each participant is matched with one control premise, allowing the impact calculation to control for differences between pre-event day usage and event day usage, in the absence of an event.

DNV used different matching parameters for ADR and CPP participants based on the different characteristics of the two programs. Table 2 summarizes the matching method for each program. Matching was performed on a per-event basis to account for differing participant groups in each event, based on when customers signed up for the program and whether they participated in a given event.

Table 2. Matching parameters by program

Parameter	ADR	CPP
Match day range	Previous 20 weekdays prior to event, excluding other events and holidays	Weekdays during month of May (excluding Memorial Day, 5/27) Since CPP affects rates on non-event days starting on June 1st, it may also affect behavior on non-event days after that date, so they should not be used for matching.
Hours for matching	3-9 PM	All 24 hours
Match day selection criteria	5 days in match day range with daily high temperature closest to that of the event day	
Match stratification	For participants who started the season with an EV and/or home batteries, their pool of control premises for matching is limited to those that share that characteristic	

With the parameters outlined in Table 2 in place, each participating premise was matched with the one nonparticipant with the most similar hourly energy usage on the match days for that event. However, we allowed for a control premise to be used as a match for only one participant per event; if a participant's match was already "taken," they were matched to the next closest control not already matched to a participant. This method was executed using the k-nearest-neighbor computational algorithm. This algorithm essentially plots each premise along feature dimensions 1 through n and sequentially finds the control "neighbor" (q) with the minimum Euclidean distance (d) from each participant premise (p). n equals the number of match days multiplied by the range of hours used for matching, which is 3 to 9 PM for ADR and all 24 hours for CPP.

Figure 4 shows the load shapes, by program, for the ADR participant and matched control groups during the pre-event matching period for the event called on July 22, 2023. The load at a given hour for the pre-period was calculated by first averaging loads across the five match days for that hour at the premise-level, and then averaging again across all premises in the group (participant or control).

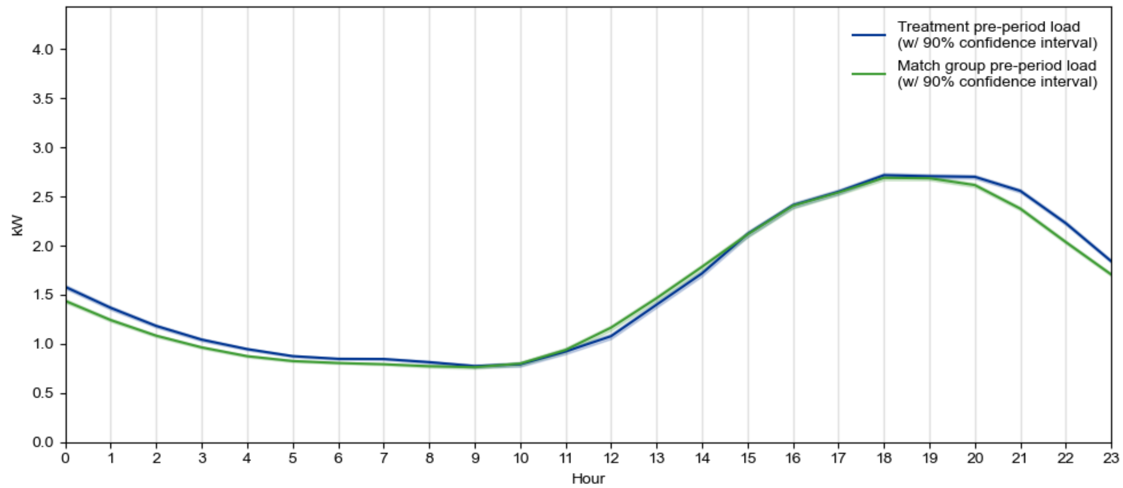

Figure 4: Example of match quality (pre-period for 7/22/23 event)

In the last step of the impact evaluation analysis, the difference-in-difference calculation, the matches found for every program participant were used to correct for differences between the pre-period and the event day. This was especially important because events tend to be called on days that are the hottest of the season and therefore not well represented by any other days. For example, if the matched customer load is higher during the event period than the load calculated for the pre-event matching days, then the difference between the participant pre-event matching load and the participant's event load is adjusted upward. To make this adjustment, DNV takes the pre-vs-event usage difference for program participants and subtracts that difference observed in the match group, yielding a delta between actual event day usage versus what we would have expected for participants in the absence of the demand respond program. Formally, load curtailment is therefore calculated for each hour on event days as:

$$curtailment = (t_0 - t_1) - (c_0 - c_1)$$

where

t_0 = hour-specific participant load, averaged over pre-event matching days
t_1 = hour-specific participant load during event
c_0 = hour-specific match group load, averaged over pre-event matching days
c_1 = hour-specific match group load during event

Curtailment estimates were calculated for each hour. In the Impacts section, we explore the curtailment estimates along multiple dimensions, including program, thermostat device brand, and event type.

Figure 5 depicts the average per customer curtailment experienced during the 7/22/2023 event for ADR.

The top frame shows the match group's pre-event consumption (blue) and event day consumption (green). Event consumption is higher than pre-event matching consumption, so the difference results in a higher adjusted participant baseline load, which is plotted as the dashed black line in the bottom frame.

The bottom frame shows the treatment group's pre-event matching consumption (blue), the adjusted participant baseline load (dashed black line), and the actual event-day consumption (green). Event curtailment was calculated as the hourly delta between the treatment event-day load (green line) and the adjusted baseline load (dashed black line).

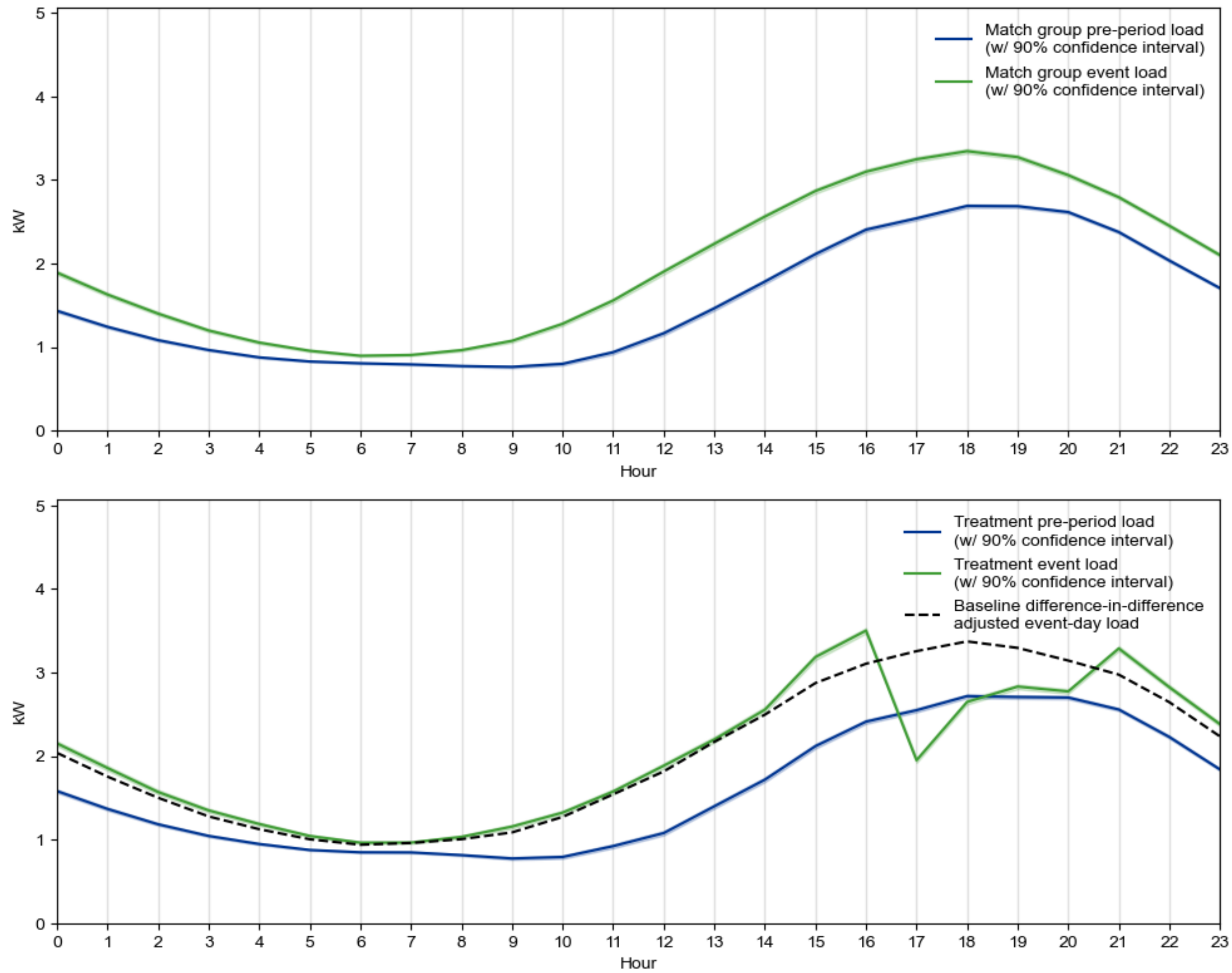

Figure 5: Difference in difference illustration (7/22/23 event)

Results

SMUD's Partner program has been operating successfully for four years, with large increases in participation and a high level of satisfaction.

CPP (Critical Peak Pricing) Results

Before reviewing the differences between the ADR (automatic thermostat DR only) and CPP (critical peak pricing + automatic thermostat DR) groups, it is important to note that the CPP group consisted of SMUD-selected or self-selected customers. Those who were selected by SMUD had, by design, different loadshapes than other participants – lower load during summer afternoons and higher load in other times. These customers are therefore, by definition, different than ADR participants, so we would expect different levels of program impact.

On one hand, these customers are self-selected as people who are more invested in shifting their energy load and willing to do so during events, possibly altering usage of devices beyond air conditioners. This would suggest that they are more likely to have larger reductions in energy use during event hours. However, SMUD selected customers for the program who already had lower energy use during summer afternoons, meaning it is likely harder for them to reduce that use further during events. It is therefore unclear whether we would expect higher or lower curtailment from these customers, but we do know that they are different from other (ADR-only) enrolled customers.

In each season, we ultimately saw higher curtailment from CPP participants, as shown in Table 3 and Figure 6. On average, over every event hour in the three years, CPP participants curtailed 0.25 kW, or 34% more than ADR participants. That means that, approximately, for every three participating CPP participants, four ADR participants would be needed to provide equivalent curtailment.

This could represent important increases in program capacity per participant. However, again, more study is needed to understand what fraction of this difference is a result of the different program design and what is a result of different participant types.

Table 3: ADR vs CPP – Average premise-level kW impact across event hours by year (excluding staggered events).

	ADR (kW)			CPP (kW)		
Program Year	Expected load w/o event (kW)	Observed event load (kW)	*Event impact (kW)*	Expected load w/o event (kW)	Observed event load (kW)	*Event impact (kW)*
2023	3.07	2.36	*0.71*	2.81	1.81	*1.00*
2024	2.98	2.21	*0.77*	2.68	1.73	*0.95*
2025	3.04	2.26	*0.78*	2.65	1.67	*0.99*
Average over events	3.03	2.29	*0.74*	2.74	1.76	*0.98*

Note that the average is over all event hours, so, as different years have different numbers of event hours, it is not a simple average of the values in each year.

Figure 6 shows these differences by hour of event. During event hours, we see that the smallest difference is in the first hour, with larger differences during subsequent hours. In particular, CPP participants averaged approximately twice the curtailment of ADR participants in the fourth, lowest-impact hour of events. This could suggest fewer overrides, better-insulated homes, or curtailment arising from reduced use of other devices in later event hours. While the participants did not vary much from 2023–2025, the average pre-cooling and post-event snapback for CPP participants is different from year-to year. In the first two years, we see much higher snapback for CPP folks, but in the third year we see similar or lower snapback usage. In 2023, we see similar CPP and ADR pre-cooling, but in 2024 and 2025 we see higher CPP pre-cooling. While these differences do not have a simple explanation, higher energy use during the pre-cooling or snapback period is consistent, which must be included in the value calculation for a CPP program as compared to ADR.

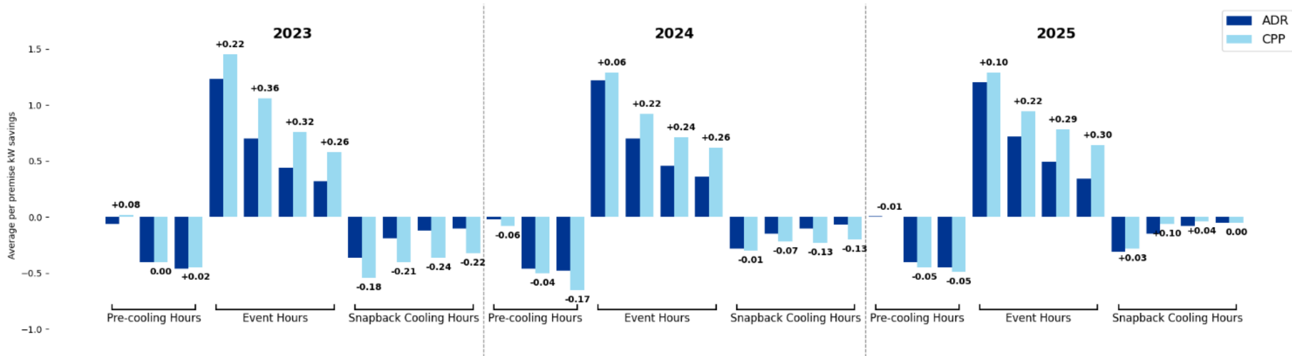

Figure 6: ADR vs CPP- Average premise-level kW impact by hour by year (excluding staggered events)

The evaluation also examined the financial impacts for SMUD of these programs. These calculations included impacts on wholesale power purchases, SMUD revenue impacts from differences in electricity sold, and annual participation incentive costs (initial enrollment incentives were excluded). Other program implementation costs – including those of SMUD support staff and program operation by an external vendor – were excluded. It is important to remember here that CPP participants did not receive an annual participation incentive. Additionally, only event-day SMUD revenue impacts were calculated for ADR participants, with the assumption that energy consumption impacts would be minimal on non-event days.

For CPP, the reduced cost of wholesale power purchases and event day revenue impact (from higher electricity prices during events) was more than offset by revenue loss from lower prices during non-event summer hours. For ADR, incentive costs were the dominant financial impact. Both programs yielded a net positive per-participant cost to SMUD, with higher costs for CPP.

Staggered Event Results

Staggered events, whose goal was to yield constant average curtailment over all event hours, saw mixed results, as shown in Figure 7 and Figure 8. In 2024, staggered event impacts were much more constant over event hours for the staggered group as compared to those called in the first hour. Additionally, as described in Table 4, the lowest-curtailment hour saw higher curtailment in the staggered group as opposed to the non-staggered group (that is, the minimum was higher). However, the maximum curtailment was much lower, leading to overall lower average curtailment across event hours. In 2025, not all events had a comparison group held out and controlled as normal. Additionally, in the August 22 events, a specific group, for which different behavior might be expected, was held out and called as normal. Nevertheless, the shape and magnitude of the average staggered group curtailment was relatively similar to that observed in 2024.

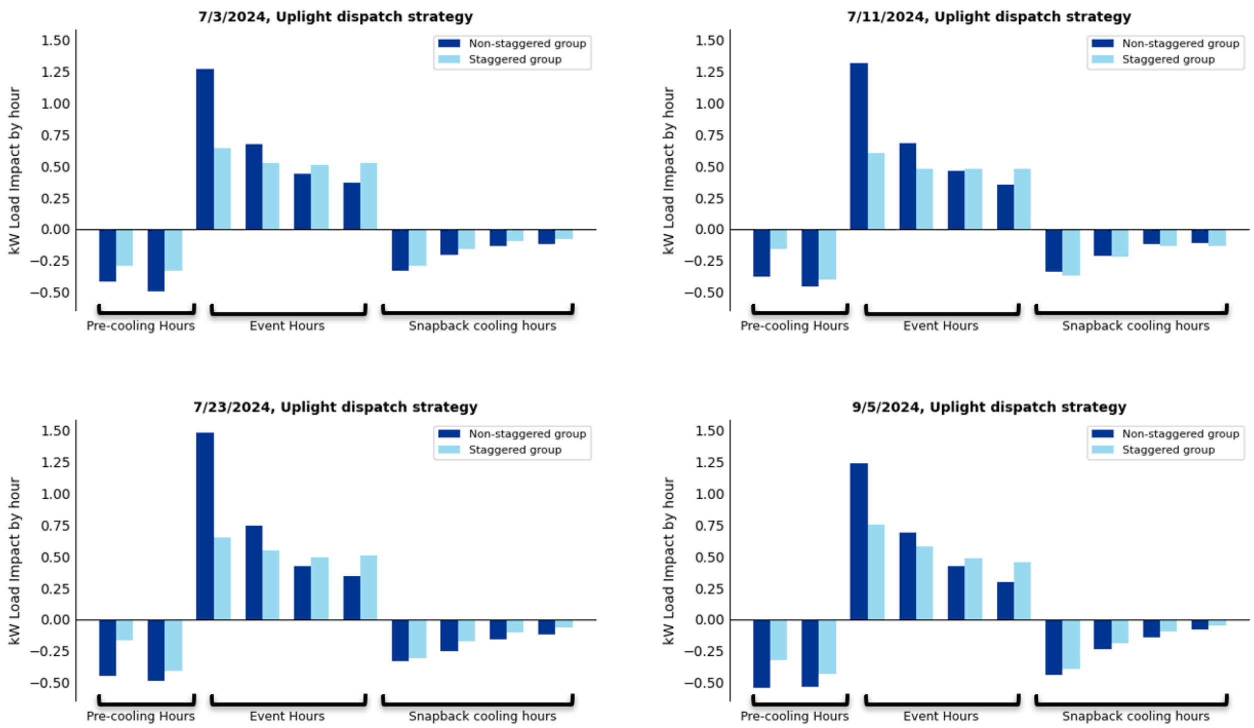

Figure 7: Staggered and non-staggered impacts for four-hour events in 2024

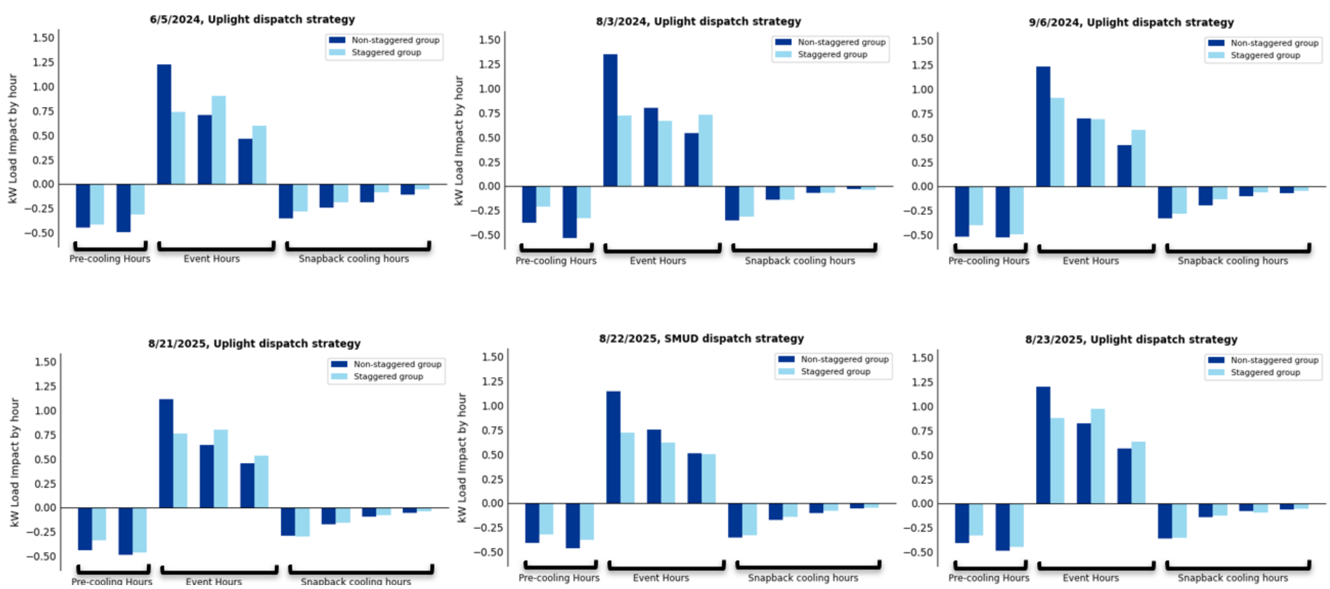

Figure 8: A comparison of staggered and non-staggered impacts for three-hour events in 2024 and 2025

Table 4: Minimum and maximum curtailment, averaged over events, for the staggered and non-staggered groups

<table>
<tr><th rowspan="2">Year</th><th rowspan="2">Number of events</th><th colspan="2">Average Highest Hour</th><th colspan="2">Average Lowest Hour</th><th colspan="2">Average Across Event Hours</th></tr>
<tr><th>Staggered group</th><th>Non-staggered group</th><th>Staggered group</th><th>Non-staggered group</th><th>Staggered group</th><th>Non-staggered group</th></tr>
<tr><td>2024 (four-hour events)</td><td>4</td><td>0.66</td><td>1.32</td><td>0.48</td><td>0.34</td><td>0.54</td><td>0.70</td></tr>
<tr><td>2024 (three-hour events)</td><td>3</td><td>0.85</td><td>1.26</td><td>0.61</td><td>0.48</td><td>0.72</td><td>0.82</td></tr>
<tr><td rowspan="2">2025 (three-hour events)*</td><td>2 (Uplight managed)</td><td colspan="2">0.88</td><td colspan="2">0.58</td><td colspan="2">0.76</td></tr>
<tr><td>1 (SMUD managed)</td><td>0.72</td><td>1.14</td><td>0.50</td><td>0.50</td><td>0.61</td><td>0.80</td></tr>
</table>

*8/22 was the only 2025 event in which the staggered and non-staggered groups were broken out in the data. The other two events with staggered dispatch (8/21 and 8/23) were managed by Uplight.

Conclusions and Recommendations

Overall, SMUD's MEO Partner smart thermostat demand response program has been successful at curtailing air conditioning load during the hottest summer afternoons. The two unique program elements, critical peak pricing (CPP) and staggered events have yielded informative results and merit additional study.

CPP (Critical Peak Pricing)

Critical peak pricing yielded promising results in how SMUD may be able to curtail additional load through this program. Table 5 summarizes the benefits and challenges to SMUD from the program so far. While the cost of CPP was higher and it was more complex for customers and staff, it did see more load shed and equivalent customer satisfaction.

Table 5: A comparison of overall benefits and challenges of CPP

<table>
<tr><th>CPP vs ADR</th><th>Benefit</th><th>Challenge</th><th>Discussion</th></tr>
<tr><td>Cost to SMUD</td><td></td><td>X</td><td>SMUD pays CPP customers $25 more to enroll in CPP after program enrollment.
Annual on-bill CPP savings vary per year depending on weather.</td></tr>
<tr><td>Load Shed</td><td>X</td><td></td><td>Load shed is 25% higher in hours 2–4 of an event (a difference of about 1.5 MWs per 10K customers).</td></tr>
<tr><td>Operations</td><td></td><td>X</td><td>Our evaluation last year concluded that CPP can be complex for customers and staff.</td></tr>
<tr><td>Customer satisfaction</td><td colspan="2">No difference</td><td>Market research showed negligible difference between CPP and non-CPP customer satisfaction.</td></tr>
</table>

However, results so far may indicate more about the participant segment than the program design. Additional research is needed into how to verify program effects and, possibly, to lower costs.

Recommendations #1: Randomized Control Trial

To determine whether the program design – that is, higher electricity prices during events – is responsible for higher curtailment, we need to compare similar participants in both program designs. The gold standard for this measurement of program design effect is a randomized control trial, where customers enroll in the program and are then randomly assigned to either the CPP or ADR design.

Recommendation #2: Additional Financial Impacts Study

In program year 2023, CPP proved more costly per customer than ADR, primarily because of lower electricity prices during off-peak summer non-event hours. It may be worth studying whether program effects would change if that discount were reduced. These results indicate that this could be implemented while still creating an overall net positive financial impact for customers.

Staggered Events

Staggered events in SMUD's smart thermostat program have, so far, yielded mixed success. While many have yielded flatter curtailment shapes than non-staggered events, the average curtailment amounts have been dramatically reduced. Technological improvements may be needed to determine whether these events can meet both the goal of flat curtailment shapes and curtailment levels. One possible approach for technological improvements is a gradual step-down of air-conditioning (slow increases in temperature set-point over multiple hours), rather than a single initial, large increase in set-point.

It is also worth considering that the need for a flat curtailment shape is the result of technological systems, not the electric grid. If the resource adequacy requirements could assign value to a resource that provided curtailment for a single hour, the highest-curtailment hour of the non-staggered events could provide that. Similarly, if the software used for utility modeling of needed capacity resources were able to accept time-varying curtailment as an input, SMUD could assess the value of non-staggered events in its capacity stack.

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