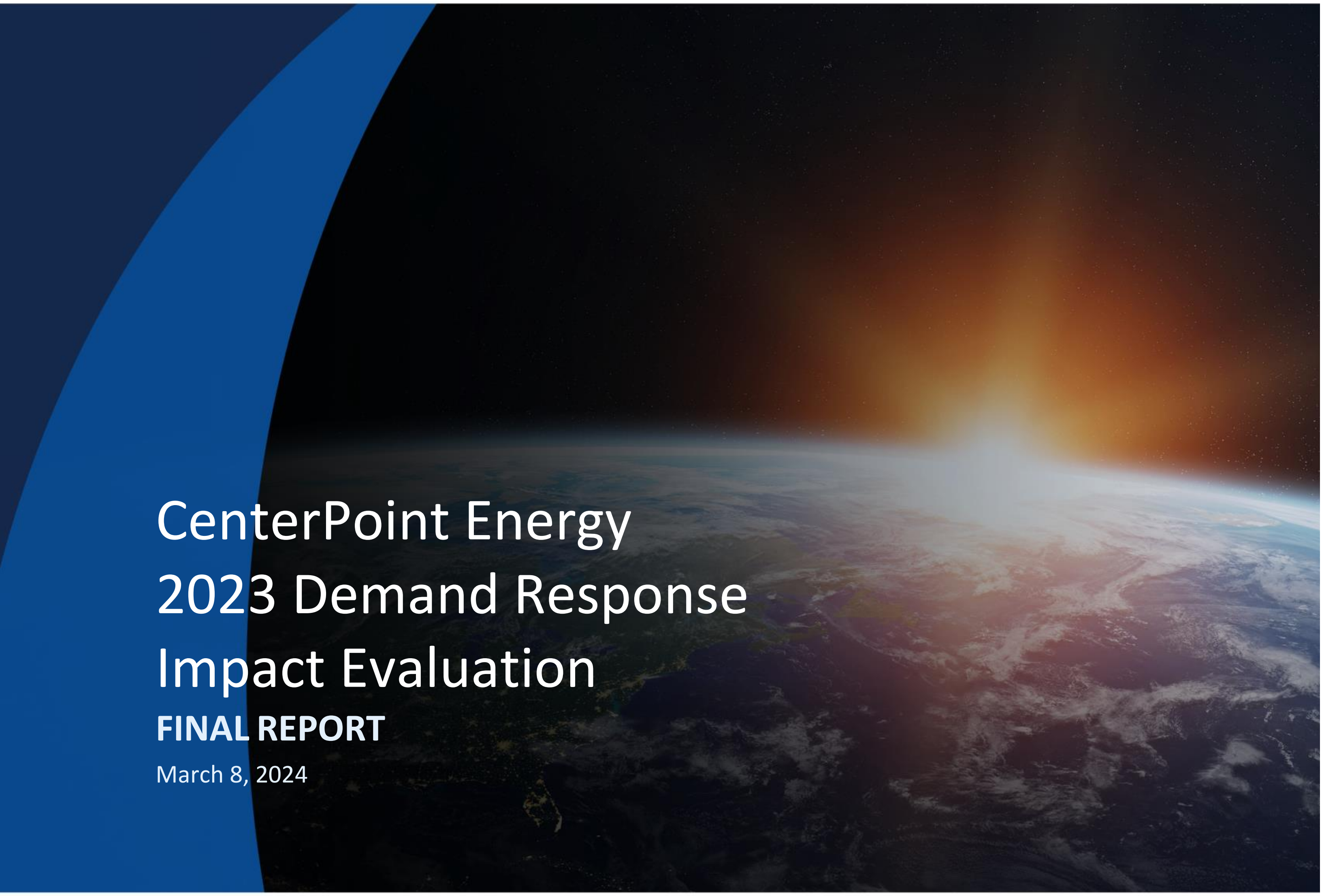

CenterPoint Energy 2023 Demand Response Impact Evaluation

FINAL REPORT

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Executive Summary

CenterPoint Energy operates its demand response programs to reduce residential and small commercial air-conditioning and water-heating electricity loads during summer peak hours. For the Smart Cycle program, CenterPoint Energy enables control of selected residential central air-conditioning loads via smart thermostats. For the Summer Cycler program, CenterPoint Energy uses radio communication equipment and control switches to turn off participating water heaters and to cycle air conditioner compressors during load-control events.

Cadmus conducted a demand response analysis, including Midcontinent Independent System Operator (MISO) event impact forecasting,[1] and energy savings analysis for its impact evaluation of CenterPoint Energy's 2023 demand response programs.

[1] MISO is a not-for-profit Regional Transmission Organization. MISO ensures reliable and least-cost delivery of electricity to 15 U.S. states (including Indiana) and Manitoba, Canada. MISO calls load-control events to manage system demand across the region.

Key Impact Findings

This section highlights the key findings from the 2023 demand response program evaluations.

Energy Savings (total achieved among treatment groups across all summer event days):

- Smart Cycle: 5.290 MWh
- Summer Cycler: 0 MWh – While Summer Cycler did generate statistically significant demand savings during event hours, it did not generate statistically significant energy savings from events across the whole event day. This is likely attributable to several events having statistically significant snapback and the small sample size of the treatment group.[2]

Potential Peak Demand Savings (MW). Had all program participants been included in summer 2023 demand response events (not just the treatment groups), the programs could have achieved peak demand savings of 7.76 MW from Smart Cycle and 6.47 MW from Summer Cycler, as shown in **Table 1**. These estimates are based on the highest single hour of savings that occurred across all summer 2023 events for each event period.

Table 1. Key Impact Findings: Potential Peak Demand Savings

Program	Summer 2023 (MW)	Summer 2022 (MW)	Summer 2021 (MW)
Smart Cycle 2 p.m. - 4 p.m. events	7.76	7.73	5.45
Smart Cycle 3 p.m. - 5 p.m. events	N/A[a]	5.55	N/A[a]
Smart Cycle 4 p.m. - 6 p.m. events	N/A[a]	7.79	N/A[a]
Summer Cycler 2 p.m. - 4 p.m. events	N/A[a]	6.86	8.63[b]
Summer Cycler 3 p.m. - 5 p.m. events	6.47	4.56	N/A[b]
Summer Cycler 4 p.m. - 6 p.m. events	3.54	8.69	N/A[b]

[a] There were no 2 p.m. - 4 p.m. Summer Cycler events in summer 2023, no 4 p.m. - 6 p.m. Smart Cycle events in summers 2021 or 2023, no 3 p.m. – 5 p.m. Smart Cycle events in summer 2023, and data were unavailable to calculate the impact of the single Smart Cycle summer 2021 3 p.m. - 5 p.m. event.

[b] Summer Cycler peak demand savings for the 2021 evaluation were based on predictions used temperature data and impact results from past evaluations.

[2] Snapback is where a building's energy or demand increases in the hours immediately following a demand response event.

Actual Peak Demand Savings (MW). The estimates shown in **Table 2** are based on the highest single hour of savings that occurred across all summer 2023 events, among participants in the treatment groups. The Summer Cycler total MW is much smaller than Smart Cycle due to the small size of the Summer Cycler treatment group.

Table 2. Key Impact Findings: Actual Peak Demand Savings

Program	Summer 2023 (MW)	Summer 2022 (MW)	Summer 2021 (MW)
Smart Cycle 2 p.m. - 4 p.m. events	2.27	2.18	1.69
Smart Cycle 3 p.m. - 5 p.m. events	N/A[a]	1.57	N/A[a]
Smart Cycle 4 p.m. - 6 p.m. events	N/A[a]	2.20	N/A[a]
Summer Cycler 2 p.m. - 4 p.m. events	N/A[a]	0.03	0.02[b]
Summer Cycler 3 p.m. - 5 p.m. events	0.04	0.02	N/A[b]
Summer Cycler 4 p.m. - 6 p.m. events	0.02	0.03	N/A[b]

[a] There were no 2 p.m. - 4 p.m. Summer Cycler events in summer 2023, no 4 p.m. - 6 p.m. Smart Cycle events in summers 2021 or 2023, no 3 p.m. – 5 p.m. Smart Cycle events in summer 2023, and data were unavailable to calculate the impact of the single Smart Cycle summer 2021 3 p.m. - 5 p.m. event.

[b] Peak demand savings for the 2021 evaluation were based on predictions used temperature data and impact results from past evaluations.

Expected MISO Savings. Table 3 and Table 4 show the savings per thermostat (or switch) and overall achievable savings if all enrolled devices were cycled during a MISO event for Smart Cycle and Summer Cycler respectively.

Table 3. Key Impact Findings: Smart Cycle Potential MISO Event Savings Forecasts

Hour of Day	June		July		August		September		Summer Average	
	Per Thermostat (kW)	Achievable (MW)	Per Thermostat (kW)	Achievable (MW)	Per Thermostat (kW)	Achievable (MW)	Per Thermostat (kW)	Achievable (MW)	Per Thermostat (kW)	Achievable (MW)
0	0.21	1.27	0.28	1.70	0.23	1.41	0.10	0.61	**0.20**	**1.24**
1	0.16	0.97	0.22	1.35	0.18	1.11	0.08	0.47	**0.16**	**0.97**
2	0.13	0.79	0.19	1.15	0.15	0.93	0.07	0.42	**0.13**	**0.82**
3	0.11	0.67	0.16	0.99	0.13	0.80	0.07	0.42	**0.12**	**0.72**
4	0.10	0.59	0.14	0.86	0.12	0.71	0.07	0.42	**0.11**	**0.64**
5	0.09	0.54	0.13	0.78	0.11	0.65	0.07	0.42	**0.10**	**0.60**
6	0.09	0.55	0.13	0.78	0.11	0.65	0.07	0.42	**0.10**	**0.60**
7	0.11	0.67	0.14	0.85	0.11	0.66	0.07	0.42	**0.11**	**0.65**
8	0.11	0.68	0.14	0.84	0.11	0.66	0.07	0.42	**0.11**	**0.65**
9	0.14	0.85	0.17	1.05	0.14	0.83	0.08	0.47	**0.13**	**0.80**
10	0.18	1.11	0.22	1.34	0.18	1.12	0.10	0.64	**0.17**	**1.05**
11	0.23	1.41	0.28	1.70	0.24	1.47	0.15	0.91	**0.22**	**1.37**
12	0.30	1.81	0.34	2.09	0.31	1.87	0.21	1.28	**0.29**	**1.76**
13	0.35	2.17	0.41	2.51	0.37	2.26	0.27	1.65	**0.35**	**2.15**
14	0.42	2.55	0.48	2.92	0.42	2.60	0.33	2.00	**0.41**	**2.52**
15	0.48	2.95	0.55	3.39	0.49	3.01	0.40	2.44	**0.48**	**2.95**
16	0.54	3.28	0.61	3.73	0.55	3.36	0.45	2.73	**0.53**	**3.27**
17	0.55	3.37	0.63	3.83	0.56	3.43	0.45	2.77	**0.55**	**3.35**
18	0.54	3.32	0.60	3.67	0.54	3.31	0.42	2.57	**0.53**	**3.22**
19	0.53	3.26	0.59	3.61	0.52	3.16	0.34	2.09	**0.50**	**3.03**
20	0.52	3.15	0.57	3.50	0.49	2.98	0.31	1.87	**0.47**	**2.88**
21	0.46	2.82	0.52	3.19	0.45	2.77	0.26	1.57	**0.42**	**2.59**
22	0.39	2.37	0.45	2.78	0.39	2.39	0.20	1.20	**0.36**	**2.18**
23	0.29	1.77	0.35	2.17	0.30	1.84	0.13	0.81	**0.27**	**1.65**

Table 4. Key Impact Findings: Summer Cycler Potential MISO Event Savings Forecasts

Hour of Day	June		July		August		September		Summer Average	
	Per Switch (kW)	Achievable (MW)	Per Switch (kW)	Achievable (MW)	Per Switch (kW)	Achievable (MW)	Per Switch (kW)	Achievable (MW)	Per Switch (kW)	Achievable (MW)
0	0.12	2.58	0.18	3.94	0.14	3.02	0.09	1.94	**0.13**	**2.87**
1	0.09	2.01	0.16	3.40	0.11	2.47	0.08	1.65	**0.11**	**2.38**
2	0.09	1.87	0.14	3.02	0.10	2.14	0.07	1.53	**0.10**	**2.14**
3	0.07	1.61	0.12	2.65	0.09	1.94	0.06	1.39	**0.09**	**1.90**
4	0.07	1.47	0.11	2.38	0.08	1.82	0.06	1.33	**0.08**	**1.75**
5	0.06	1.35	0.10	2.11	0.08	1.67	0.06	1.29	**0.07**	**1.61**
6	0.06	1.28	0.09	1.89	0.07	1.59	0.06	1.24	**0.07**	**1.50**
7	0.07	1.54	0.11	2.42	0.08	1.83	0.06	1.29	**0.08**	**1.77**
8	0.09	2.00	0.15	3.18	0.11	2.36	0.06	1.37	**0.10**	**2.23**
9	0.11	2.36	0.17	3.77	0.13	2.74	0.07	1.55	**0.12**	**2.61**
10	0.13	2.90	0.20	4.41	0.15	3.14	0.10	2.11	**0.15**	**3.14**
11	0.16	3.38	0.23	4.93	0.17	3.61	0.13	2.71	**0.17**	**3.66**
12	0.18	3.93	0.26	5.53	0.19	4.00	0.15	3.22	**0.19**	**4.17**
13	0.20	4.41	0.29	6.25	0.20	4.36	0.18	3.81	**0.22**	**4.71**
14	0.22	4.85	0.31	6.68	0.23	4.94	0.20	4.41	**0.24**	**5.22**
15	0.26	5.60	0.33	7.04	0.25	5.48	0.23	5.06	**0.27**	**5.80**
16	0.26	5.70	0.35	7.48	0.27	5.83	0.25	5.33	**0.28**	**6.08**
17	0.26	5.70	0.35	7.61	0.27	5.85	0.25	5.31	**0.28**	**6.12**
18	0.27	5.77	0.34	7.35	0.27	5.87	0.23	5.03	**0.28**	**6.01**
19	0.25	5.34	0.31	6.80	0.24	5.28	0.17	3.66	**0.24**	**5.27**
20	0.21	4.48	0.27	5.83	0.20	4.37	0.13	2.85	**0.20**	**4.38**
21	0.17	3.73	0.25	5.35	0.18	3.97	0.11	2.42	**0.18**	**3.87**
22	0.15	3.14	0.23	4.95	0.16	3.49	0.10	2.14	**0.16**	**3.43**
23	0.12	2.59	0.21	4.53	0.15	3.14	0.09	1.88	**0.14**	**3.03**

Per-Device Savings. Average per-device savings across all summer 2023 events and maximum per-device across all summer 2023 events (across all hours of the events):

Average per-device savings:

- Smart Cycle, all thermostats: 0.95 kW
- Smart Cycle, ecobee thermostats: 1.00 kW
- Smart Cycle, Nest thermostats: 0.92 kW
- Summer Cycler, air conditioners: 0.21 kW

Maximum per-device savings (across both event hours of the event with the highest average savings):

- Smart Cycle, all thermostats: 1.14 kW
- Smart Cycle, ecobee thermostats: 1.18 kW
- Smart Cycle, Nest thermostats: 1.12 kW
- Summer Cycler, air conditioners: 0.47 kW

Total MW across the 2023 Summer Event Season. These totals are the sum of the MW estimates achieved for all event hours among the treatment groups (the Summer Cycler total MW is much smaller than Smart Cycle due to the small size of the Summer Cycler treatment group.) The total MW shown here are the sums of the total achieved program impacts (during event hours) reported in Appendix C and Appendix D:

- Smart Cycle: 13.53 MW
- Summer Cycler: 0.40 MW

Summary of Conclusions and Recommendations

Based on the findings from the 2023 demand response impact evaluation, Cadmus offers the following conclusions and recommendations.

Smart Cycle

Conclusion: Smart Cycle continues to provide substantial and consistent demand reduction capability.

Across all summer 2023 events, ecobee thermostats achieved an average demand reduction of 1.00 kW, and Nest devices achieved 0.92 kW. Because the majority of enrolled devices are Nest, the average reduction per thermostat was 0.95 kW, which is in line with previous years' results (1.0 kW in 2022, 0.92 kW in 2021, 1.1 kW in 2018, and 1.0 kW in the 2016 pilot).

With over 6,100 ecobee and Nest thermostats enrolled as of February 2024 the Smart Cycle program could achieve total forecasted demand savings of more than 3 MW during 2 p.m. - 6 p.m. MISO load curtailment events. In recent years, MISO events have occurred on days that were cooler than average in CenterPoint Energy's Indiana service territory, and Cadmus' achievable savings forecasts for Smart Cycle take this into account. However, if future MISO events were to occur on hotter days when local temperatures exceed 90°F, achievable savings during MISO events could exceed 7 MW.

RECOMMENDATION

Begin building out the IT resources required to collect, store, and transmit the hourly electricity consumption data generated by its AMI meters. Making AMI data available for evaluation will improve the accuracy and precision of program savings estimates and MISO event forecasts. AMI data can also ease the evaluation data transfer process for CenterPoint Energy, as it will not be necessary to request or collect large run-time datasets from EnergyHub.

Conclusion: Ecobee thermostats and Nest thermostats produced the same per-thermostat savings impacts.

Cadmus estimated average first-hour per-thermostat savings impacts of 1.10 kW for ecobee thermostats, and 0.96 kW for Nest thermostats, across all summer 2023 events. Though ecobee first-hour savings were larger than Nest, these differences were never statistically significant, and second-hour savings (0.89 kW) were identical for thermostats. The higher first-hour savings from ecobee thermostats may be due to higher observed average air conditioning demand among the enrolled ecobee population. However, given the smaller size of the ecobee population in comparison to the Nest population, the difference between the two populations in size, average demand, and impacts may not persist as the program grows.

RECOMMENDATION

Now that Smart Cycle is a registered MISO load-modifying resource, ramp up efforts to convert existing Summer Cycler participants to Smart Cycle. Both ecobee and Nest thermostats deliver substantial, consistent demand reduction during events. Smart Cycle delivers substantially larger per-device savings than Summer Cycler's radio-controlled switches, due to differences in the demand response strategy (temperature setbacks for smart thermostats; 50% cycling for Summer Cycler switches) and likely better dispatch system reliability.

Conclusion: Smart Cycle enrollment of other manufacturers' thermostats (including Honeywell, Amazon, Lux Products, Sensi, Alarm.com, and Vivint) has reached more than 1,500 devices.

Neither the summer 2023 nor previous Smart Cycle program evaluations have included enrolled thermostats from other manufacturers. Previously, the total enrollment of these devices was too low to yield a statistically significant comparison of impact estimates with the larger population of enrolled Nest or ecobee thermostats. Though the 2016 Smart Cycle pilot included Honeywell thermostats, these thermostats used a 50% cycling strategy rather than the temperature setback and precooling strategy now employed by Nest, ecobee, Emerson, and possibly other manufacturers.

RECOMMENDATION

Include all other enrolled thermostats in the summer 2024 evaluation. If these thermostats deliver similar per-device savings to Nest and ecobee thermostats, the achievable savings from this population can reach 1.5 MW, increasing Smart Cycle's value in its 2025 MISO registration. If these thermostats do not perform as well as Nest and ecobee thermostats, this finding can inform CenterPoint Energy's program eligibility decisions going forward.

Conclusion: Precooling on event days in the hour before each event does not increase participants' overall energy consumption on event days.

On average, both ecobee and Nest thermostats saved 0.74 kWh on each event day. Both thermostat types employ one hour of precooling before events to improve participants' comfort during the events (when the thermostats increase their setpoints to reduce demand) and increase demand reduction during the event. However, the additional demand due to the precooling hour (0.65 kW on average) is less than demand reductions during the event (0.95 kW.) Additional load following events was relatively modest (0.20 kW in the first hour), which resulted in overall energy savings for participants on event days. Given these energy savings, participants are not expected to experience higher electricity bills due to Smart Cycle events.

RECOMMENDATION

In discussions with stakeholders and in customer-facing program messaging, state that customers will not experience higher bills due to the precooling that thermostats employ in advance of Smart Cycle events. Precooling shifts the load to hours before peak demand conditions, reduces the extent to which indoor temperatures rise above normal during events, and improves demand reduction performance during events. Education on these topics may encourage hesitant customers to enroll and participate.

Summer Cycler

Conclusion: While the Summer Cycler program continues to provide demand reductions from air-conditioning load control, per-unit demand reductions are far lower than Smart Cycle. Hardware limitations of the aging Summer Cycler switch fleet compromise the reliability of the program as a demand response resource.

Load-control events achieved an average event savings of 0.2 kW (27%) per air conditioner, where temperatures averaged 88˚F. Events with the highest outdoor temperature achieved the highest kW savings. Throughout the summer, demand reduction during load-control events was most directly impacted by outdoor temperature, with higher temperatures leading to larger reductions. On most days, the greatest capacity for demand reduction occurred between 3 p.m. and 5 p.m. Demand savings from air-conditioning load control in 2023 were similar to those estimated in 2022, 2021, and 2019. With over 19,000 customers currently enrolled, the Summer Cycler program can achieve total forecasted demand savings of up to 3 MW during MISO load curtailment events.

The per-unit savings, however, are far lower than those estimated for Smart Cycle, and Cadmus' previous evaluations showed high rates of Summer Cycler switch failure. CenterPoint Energy's Summer Cycler switches, some of which are 20 years old, provide only one-way communication. There is no way to verify whether switches have received the curtailment signal during a demand response event, and there is no way of verifying the count of switches (or switch functionality) without a physical site visit. All of these factors compromise the per-unit savings from Summer Cycler, and its reliability if called upon as a MISO load curtailment resource.

RECOMMENDATION

Continue to target Summer Cycler program participants for enrollment in Smart Cycle because Smart Cycle delivers higher per-device demand savings and greater dispatch reliability.

Conclusion: Logger losses were common in 2023 and having fewer data loggers reduces the precision of evaluated results.

During summer 2023, 49 of the 237 data loggers were lost in the field after being installed at a sample of participating households. Because whole-home AMI meter data are not available, the evaluation relies on data loggers. Unfortunately, logger equipment frequently goes missing during the summer, further reducing an already small sample for evaluation.

RECOMMENDATION

As recommended for Smart Cycle, begin building out the IT resources required to collect, store, and transmit the hourly electricity consumption data generated by its AMI meters. The availability of AMI data will reduce or even eliminate the cost of renting, installing, and collecting data from data loggers. AMI data will also improve the accuracy and precision of program savings estimates and MISO event forecasts by allowing much larger sample sizes (similar to those of Smart Cycle or larger). As noted in previous evaluations, Summer Cycler switch failures are common for water heaters (and may also be common for air conditioner switches). Cadmus has applied per-unit savings from previous evaluations for water heaters since 2019 due to the difficulty in accessing water heater data loggers installed within participants' homes. The larger evaluation sample sizes made possible by AMI will provide CenterPoint Energy with the most accurate assessment of the demand reduction performance of its existing Summer Cycler switch population.

2. Demand Response Program Overview

CenterPoint Energy can initiate load-control events through the Smart Cycle and Summer Cycler programs to reduce residential and small commercial electric loads for these reasons:

- Balancing utility system supply and demand
- Alleviating transmission or distribution constraints
- Conducting evaluation, measurement, and verification (EM&V)

In Summer 2023, Summer Cycler offered an additional benefit to CenterPoint Energy as loads enrolled in this long-running program were also registered with MISO, the regional electricity transmission grid authority, for participation in its load curtailment events. CenterPoint Energy registered Smart Cycle, which launched as a program in 2018 following a pilot in 2016, for load curtailment with MISO in on February 1, 2024. Going forward, both programs are enrolled in MISO load curtailment events.

The following sections provide an overview of each program's implementation in summer 2023.

2.1. Smart Cycle

The Smart Cycle program uses smart thermostats, primarily Nest and ecobee,[3] to curtail residential central air conditioner loads during hours of system peak demand. Smart Cycle is implemented by EnergyHub. CenterPoint Energy notifies participants in advance of events via messages on their thermostat display and via thermostat manufacturer's smartphone app, and they may opt out of individual events by changing the thermostat setpoint.

Smart Cycle has two enrollment channels: direct installation by CenterPoint Energy, and Bring Your Own Thermostat (BYOT) self-enrollment. Direct install participants received a free smart thermostat and installation by Schneider Electrical, while BYOT participants installed compatible smart thermostats on their own, without CenterPoint Energy's involvement, and received a one-time $75 bill credit for enrolling their device in the Smart Cycle program. In addition, all Smart Cycle participants received a $5 bill credit per month and per thermostat enrolled from June through September. At the end of 2023, 4,522 Smart Cycle participants had Nest thermostats, 1,596 had ecobee thermostats, and 1,300 participants had other thermostats (including Honeywell, Amazon, Lux Products, Sensi, Alarm.com, and Vivint). Previously, because the sample of all other thermostats (omitting Nest and ecobee) was too small to yield meaningful, statistically significant comparisons of impact by brand, Cadmus recommended that CenterPoint Energy exclude them from the evaluation until their sample size reached approximately 500 devices.

[3] Smart Cycle has also enrolled 1,501 devices from other manufacturers, primarily Honeywell, but Nest and ecobee devices account for the majority of the program population.

2.1.1. Smart Cycle Load-Control Event Summary

In 2023, CenterPoint Energy initiated four Smart Cycle load-control events for EM&V purposes. CenterPoint Energy called the load-control events primarily on days with high forecasted temperatures in its service territory (85˚F or higher), simulating days with higher system peak demand than usual. Table 5 lists the 2023 Smart Cycle load-control events. On average, temperatures during event days were similar in 2023 (89˚F) to 2022 (88˚F). The maximum temperature across all events in 2023 was 91˚F.

Table 5. 2023 Smart Cycle Program Load Control Events

Event	Event Date	Day of the Week	Time	Average Outside Temperature during Event
1	Jul 12, 2023	Wednesday	2:00 pm - 4:00 pm	88°F
2	Aug 11, 2023	Friday	2:00 pm - 4:00 pm	88°F
3	Aug 21, 2023	Monday	2:00 pm - 4:00 pm	91°F
4	Sep 22, 2023	Friday	2:00 pm - 4:00 pm	87°F

2.2. Summer Cycler

The Summer Cycler program uses radio communication equipment and control switches installed on customer equipment to cycle air conditioner compressors and turn off water heaters during load-control events. CenterPoint Energy does not provide program participants with advance notification of events. Residential and small commercial customers qualify for the program, with customers receiving a bill credit of up to $28 (if a water heater is enrolled in addition to an air conditioner) per cooling season as an incentive for participation.

CenterPoint Energy has closed Summer Cycler to new enrollees and encourages would-be participants to enroll in Smart Cycle instead. However, since Smart Cycle remains a newer program, Summer Cycler remains substantially larger with 25,322 customers than Smart Cycle with 6,118 thermostats.[4] Table 6 shows the number of customers and premises enrolled in the program. A single premise may have more than one air conditioner or water heater. Some premises have multiple switches installed.

Table 6. Number of Residential Customers and Premises in the 2023 Summer Cycler Program

Load Control	Customers	Premises	Switches
Air Conditioners	19,239	19,237	21,608
Water Heaters	6,083	6,083	6,211
Total	**25,322**	**25,320**	**27,819**

4 This count only consists of the Nest and ecobee thermostats included in the evaluation, not the other brands enrolled in smaller quantities leading up to summer 2023.

2.2.1. Summer Cycler Load-Control Event Summary

In 2023, CenterPoint Energy initiated four load-control events for EM&V purposes. Table 7 lists the load-control events in the 2023 Summer Cycler program. On average, temperatures during event days were similar in 2023 (88 ˚F) as they were in 2022 (90˚F), 2021 (89˚F), and in 2019 (89˚F). The maximum temperature across all events was 93˚F.

Table 7. 2023 Summer Cycler Program Load Control Events

Event	Event Date	Day of the Week	Time	Average Outside Temperature during Event
1	Aug 11, 2023	Friday	2:00 pm - 4:00 pm	88°F
2	Aug 23, 2023	Monday	3:00 pm - 5:00 pm	93°F
3	Sep 22, 2023	Friday	3:00 pm - 5:00 pm	86°F
4	Sep 29, 2023	Friday	2:00 pm - 4:00 pm	85°F

3. Methodology

This section describes the methodology Cadmus used to estimate 2023 demand and energy savings from CenterPoint Energy load-control events. Both the Smart Cycle and Summer Cycler programs were implemented as randomized controlled trials. For each program, Cadmus randomly selected groups of treatment and control customers—those who would experience load curtailment during load-control events and those who would not—in advance of the summer 2023 event season. The treatment groups received load curtailment during the events and the control groups did not.

3.1. Smart Cycle

3.1.1. Participant Assignment

Prior to the beginning of the summer 2023 event season, Cadmus randomly assigned half the thermostats enrolled in Smart Cycle to a treatment group and half to a control group. Cadmus used historic billing data to divide the population into lowest, low, medium, high, highest, and unreported strata according to the home's average daily consumption during the summer months. Cadmus then randomly assigned homes within each stratum to the treatment or control group for each brand of thermostat. If customers had multiple thermostats enrolled, Cadmus assigned all of their enrolled thermostats to the same treatment or control group.

3.1.2. Data Collection and Preparation

Cadmus collected program tracking data from CenterPoint Energy, thermostat run-time data from EnergyHub, and local hourly weather data for the Evansville Regional Airport from the National Oceanic and Atmospheric Administration.

Cadmus compared CenterPoint Energy's customer database to the pre-season treatment or control group assignments and to EnergyHub's run-time data to determine if the data were complete or if significant amounts of data were missing. Table 8 shows the sample populations (number of thermostats).

Table 8. 2023 Smart Cycle Analysis Sample Size

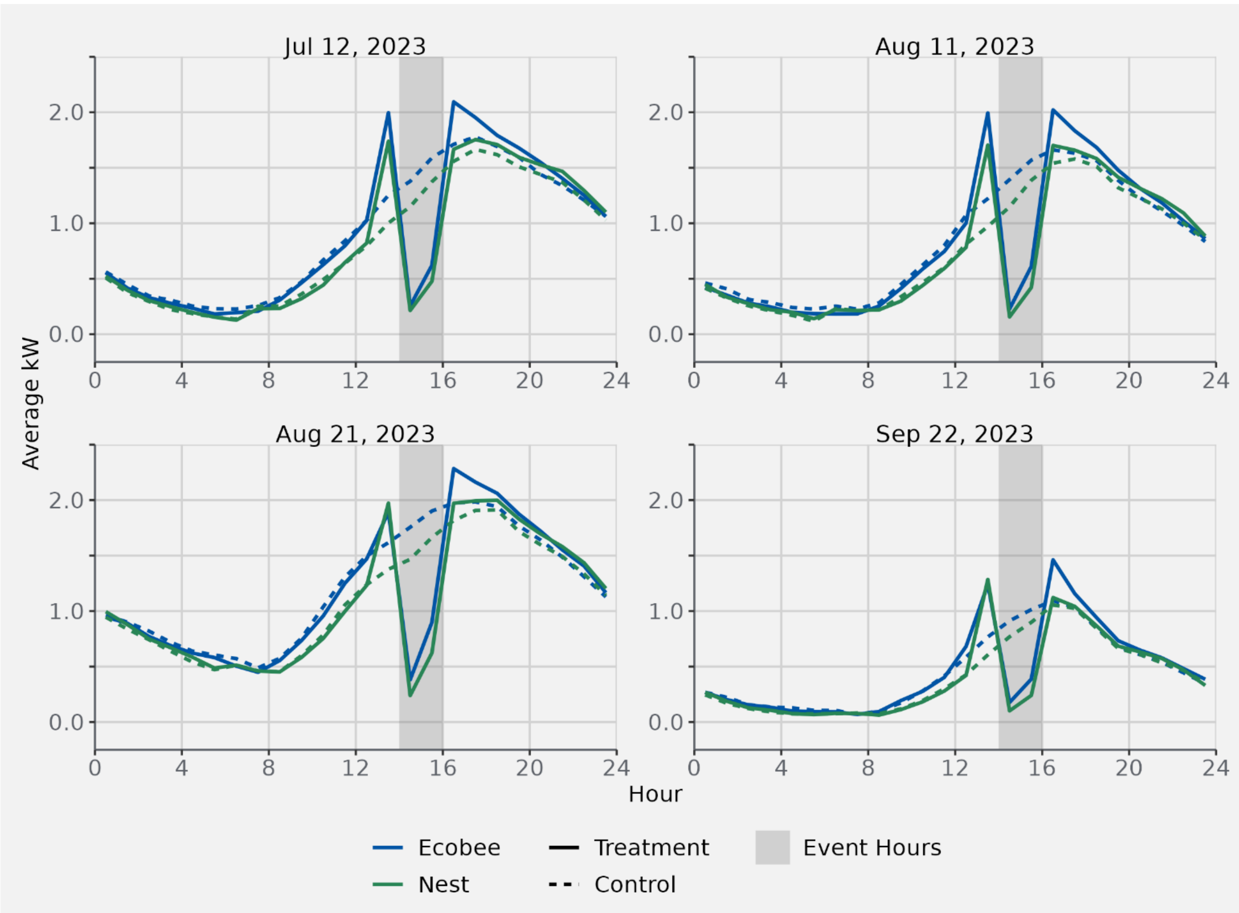
	Treatment			Control			Total		
	ecobee	Nest	Total	ecobee	Nest	Total	ecobee	Nest	Total
EnergyHub Run-Time Data Population	629	1,210	1,839	613	2,627	3,240	1,242	3,837	5,079
Analyzed Population	**611**	**1,181**	**1,792**	**585**	**1,877**	**2,462**	**1,196**	**3,058**	**4,254**

3.1.2.1. Conversion of Run Time to Kilowatt-Hour

To estimate the load impacts, Cadmus used an engineering formula to convert run-time minutes per hour to average kW per hour for each central air conditioner.[5] For full details of this calculation, refer to *Appendix A*.

Before proceeding with the impact analysis, Cadmus reviewed the average hourly energy consumption for each event day, as shown in Figure 1**Error! Reference source not found.**. Reductions in demand among the treatment groups due to load-control events were visible in all cases, confirming that the event list CenterPoint Energy provided was accurate and that the program's summer 2023 event dispatches proceeded as planned.

Figure 1. Smart Cycle Average Hourly Air Conditioning Energy Consumption by Event Day, Thermostat Manufacturer, and Control/Treatment Group



[5] Cutler, D., et al. January 2013. *Improved Modeling of Residential Air Conditioners and Heat Pumps for Energy Calculations.* NREL Technical Report, NREL/TP-5500-56354. http://www.nrel.gov/docs/fy13osti/56354.pdf

3.1.3. Demand Savings Estimation

Cadmus used a post-only regression model to estimate average demand impacts per thermostat for the hours before, during, and after each event. Regression analysis is a means of modeling savings by comparing the consumption of test and control customers while controlling for exogenous factors, such as weather. Refer to *Appendix A* for further detail of Cadmus' specific regression analysis variables.

3.1.4. Energy Savings Estimation

Cadmus estimated energy savings from Smart Cycle air-conditioning load-control events by aggregating the hour interval kWh to daily kWh for each thermostat and then estimating a regression model for daily kWh. Cadmus controlled for fixed effects by capturing effects specific to a day. The daily regression models include an indicator for treatment customer event days to estimate possible event day kWh savings. *Appendix A* describes the regression model specification and estimation procedures.

3.2. Summer Cycler

3.2.1. Participant Assignment

At the beginning of summer 2023, CenterPoint Energy's installation contractor (Schneider Electric) installed end-use meters (loggers) on a random and representative sample of residential air conditioners in the Summer Cycler program. Cadmus randomly assigned air conditioners in the logger analysis sample to a treatment or control group, first by dividing the sample into low, medium, and high strata according to the home's air-conditioning energy use on non-event weekday afternoons in 2022 (using logger data from the 2022 evaluation), then by randomly assigning homes within each stratum to the treatment or control group. There was also an unreported stratum for the group of loggers that did not have any available logger data from 2022. Approximately half the metered air conditioner customers were assigned to the treatment group and half to the control group. As some customers have multiple air conditioners, this resulted in more loggers in each group than premises.

Due to difficulty accessing water heaters for data logger installation and retrieval in previous evaluations (likely only exacerbated by the COVID-19 pandemic), Cadmus did not plan to conduct a water heater field experiment in 2023. Instead, Cadmus planned to apply fixed per-unit demand and energy savings for water heaters. This methodology was supported by the results of Cadmus' previous Summer Cycler evaluations, which showed that water heater savings were stable and consistent across program years and load-control events. For this reason, the following sections on the Summer Cycler methodology concern only the evaluation of air conditioners. For water heaters, Cadmus applied fixed values demand and energy savings values from the 2019 evaluation.

3.2.2. Data Collection and Preparation

To prepare the data for analysis, Cadmus first cleaned the logger data provided by CenterPoint Energy. The analyzed treatment and control groups were not identical in size as some loggers were damaged, missing, or inaccessible for data collection after the summer event season concluded. Table 9 presents the attrition of the logger data (based on the loggers Cadmus originally assigned to treatment and control groups before the summer season began). Forty-one of the originally assigned loggers went missing after installation at participating homes in 2023, as did an additional eight loggers that CenterPoint Energy had rented to increase the logger sample (a total of 49 lost). An additional 43 did not record any data at all or recorded an insufficient amount of data for inclusion in the analysis.

Table 9. 2023 Summer Cycler Analysis Sample Size

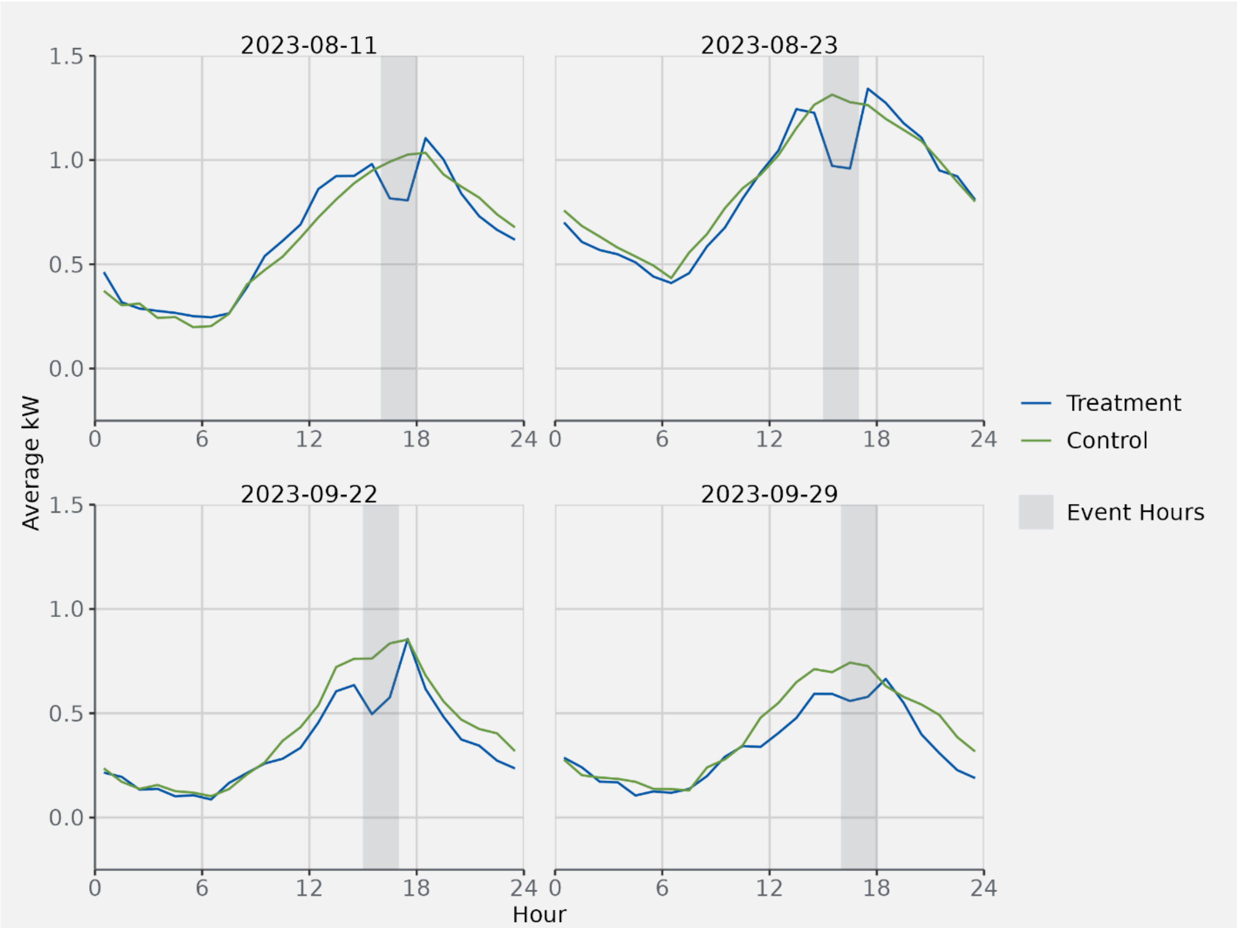
Sample Group/Logger Status	Air Conditioner Loggers		
	Treatment	Control	Total
Randomized	**124**	**135**	**259**
Out of Date Range[a]	4	1	5
Bad[b]	17	21	38
Can't Access	0	0	0
Gone	23	18	41
Analyzed	**80**	**95**	**175**

[a] Loggers that did not have any usage data available between June 1, 2023, and October 1, 2023.

[b] A logger was defined as "bad" if it had only negative or extreme consumption (greater than 6 kWh per hourly reading), less than two weeks of usage data, or no usage data on at least one event day.

Before proceeding with the impact analysis, Cadmus reviewed the average hourly energy consumption for each event day (Figure 2). Demand reduction among those in the treatment group due to load-control events was visible in all cases, confirming that the event list CenterPoint Energy provided was accurate and that the program's summer 2023 event dispatches proceeded as planned.

Figure 2. Average Hourly Air Conditioning Energy Consumption by Event Day and Control/Treatment Group



3.2.3. Demand Savings Estimation

Cadmus estimated demand savings from CenterPoint's Summer Cycler program using data from the logger analysis sample. The methodology included these elements (*Appendix A* provides more details):

- Pooling logger electricity-demand data and estimating a model the air conditioning end use
- Defining the analysis sample period as June 1, 2023, to September 30, 2023, and using data for all loggers and hours during this period
- Estimating savings from air-conditioning load control as a post-only model of demand per hour, which effectively compared the change in demand between event and non-event hours of treatment and control group units[6]

[6] The post-only analysis offered two benefits: it resulted in more precise savings estimates than standard regression analysis, and it controlled for non-program energy-use impacts correlated with events.

- Modeling demand per hour as a function of these variables—hour of the day, average non-event day usage, and indicators for hours during and after events. The model of air conditioner allowed the effects of hour of the day and average non-event day usage to differ between treatment and control units.[7]

3.2.4. Energy Savings Estimation

Cadmus estimated energy savings from air-conditioning load control by aggregating the hour interval kWh to daily kWh for each air conditioner unit and then estimating a regression daily kWh. Cadmus controlled for fixed effect by capturing effects specific to a day. The daily regression models include an indicator for treatment customer event days to estimate possible event day kWh savings. *Appendix B* describes the regression model specification and estimation procedures.

7 This is not necessary for the model of water heater as water heating load curtailment is not dependent on outdoor temperatures.

4. Detailed Smart Cycle Impact Evaluation Findings

This section presents Cadmus' detailed findings from the 2023 Smart Cycle program impact evaluation. Table 10 summarizes the 2023 Smart Cycle impacts—a negative impact indicates a reduction in usage (and therefore savings). Across all four events, ecobee devices achieved average demand savings of 1.00 kW per device and energy savings (per event day) of 0.74 kWh. Nest devices achieved average demand savings of 0.92 kW and energy savings (per event day) of 0.74 kWh. Note that despite the increase in consumption due to precooling in the hour before the events, the events still produced daily energy savings due to the higher thermostat setpoints during the events. This produced greater savings than the increase in consumption due to precooling.

The average demand reduction across all devices was 0.95 kW and 0.74 kWh per device. On average, each event produced total demand savings of 1,700 kW and energy savings of 1,322 kWh. Had all enrolled thermostats been curtailed during load-control events (instead of just the treatment groups), the program could have achieved average demand savings of 5,804 kW and 4,515 kWh per event day.

Table 10. 2023 Smart Cycle Program Evaluated Energy and Demand Savings

	Ecobee	Nest	Average	Total Achieved Program Impact (n=1,792)[a]	Total Achievable Program Impact (n=6,118)[b]
Average Event kW Impact	**-1.00**	**-0.92**	**-0.95**	**-1.70**	**-5.80**
Average Event kW Hour 1	-1.10	-0.96	-1.01	-1.80	-6.16
Average Event kW Hour 2	-0.89	-0.89	-0.89	-1.60	-5.45
Average Precooling kW Impact	0.57	0.69	0.65	1.16	3.95
Average Post-Event Hour 1 kW Impact	0.36	0.12	0.20	0.37	1.25
Average Event Energy kWh Savings	**-0.74**	**-0.74**	**-0.74**	**-1.32**	**-4.51**

[a] Number of thermostats in the assigned test group. Number of test group customers is 1792, some customers have multiple thermostats. (both assigned and in tracking)

[b] Number of Nest and ecobee thermostats currently enrolled in the Smart Cycle Program (including control customers) as of the end of 2023.

Table 11 lists historical per-unit air conditioner savings from Smart Cycle load-control events (when average outside temperatures were 85˚F or higher). Negative numbers indicate demand or energy savings. Smart Cycle's summer 2023 demand and energy impact estimates are consistent with previous seasons.

Table 11. Historical Smart Cycle Program Evaluated Energy and Demand Savings

Load-Control Event Impacts	Per Thermostat				
	2016[a]	2018	2021	2022	2023
Average Event Temperature	88˚F	89˚F	92˚F	88˚F	89˚F
Average Event kW Impact	-1.0	-1.1	-0.9	-1.0	-0.95
Average Post-Event Hour 1 kW Impact	0.30	0.37	0.22	0.28	0.20
Average Event Energy kWh Impact	-1.16	-0.88	-0.75	-0.71	-0.74

[a] The 2016 results shown are for just the Nest thermostats included in the pilot. The Honeywell thermostats included in the 2016 pilot used a cycling strategy that produced substantially lower savings.

4.1. Demand Savings

Across the four 2023 Smart Cycle events, the average demand reduction per thermostat was 1.01 kW in the first event hour and 0.89 kW in the second event hour, an average savings of 0.95 kW per thermostat across the two event hours. The estimated average demand savings in each event hour was statistically different from zero at the 90% confidence level. The precooling impact was a 0.65 kW increase per thermostat, which was statistically significant at the 90% confidence level. Rebound of air-conditioning loads for these events was modest (0.20 kW per thermostat in the first hour after the events) but statistically significant. Estimated rebound impacts decreased with each hour after the event.

Figure 2 shows the average load shapes and impact estimates by thermostat manufacturer and control/treatment group for summer 2023 events. Customers with ecobee thermostats had slightly higher average consumption compared to customers with Nest thermostats.[8] During the hour before the event, ecobee thermostats showed smaller precooling impacts (0.57 kW versus 0.69 kW), but larger post-event impacts (0.36 kW versus 0.12 kW) than Nest thermostats. During the events, both thermostat brands showed considerable savings during the first hour and slightly smaller savings in the second hour. Nest thermostats had slightly higher persistence in savings than ecobee thermostats, likely due in part to Nest devices' additional precooling before the event. These findings (slightly higher savings for ecobee thermostats than Nest thermostats, and slightly higher savings in the first hour of each event) are generally consistent with Cadmus' findings from other utilities that offer Nest and ecobee smart thermostat demand response programs.

The figure shows hourly impacts for each brand by the columns beneath the event day load shape. Each column's error bars show the 90% confidence intervals for each impact estimate.

8 This may be due to the smaller sample of ecobee devices relative to Nest devices, rather than systematic differences in air-conditioning consumption by ecobee and Nest households. However, this pattern has held constant across all recent previous Smart Cycle impact evaluations.

Figure 2. 2023 Smart Cycle Average Event Day Load Shapes and Impact Estimates by Thermostat Manufacturer and Control/Treatment Group

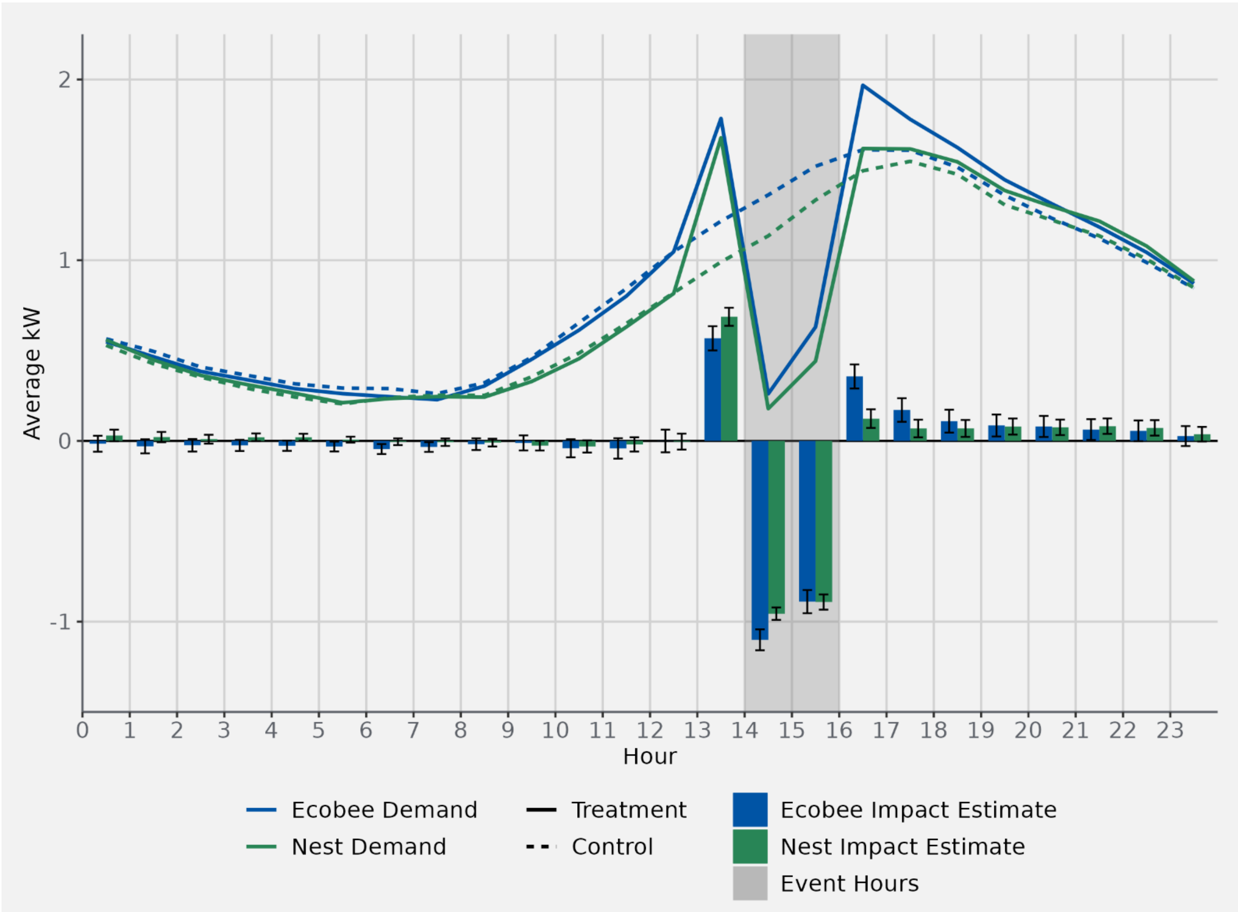


Table 12 shows the average hourly demand reduction across the four evaluated Smart Cycle events in the 2023 season with 90% confidence intervals. In the first hour of the event, ecobee devices show greater demand reduction compared to Nest devices, which was statistically different at the 90% confidence level. However, in the second hour of the event, both thermostats produced identical demand reductions of 0.89 kW.

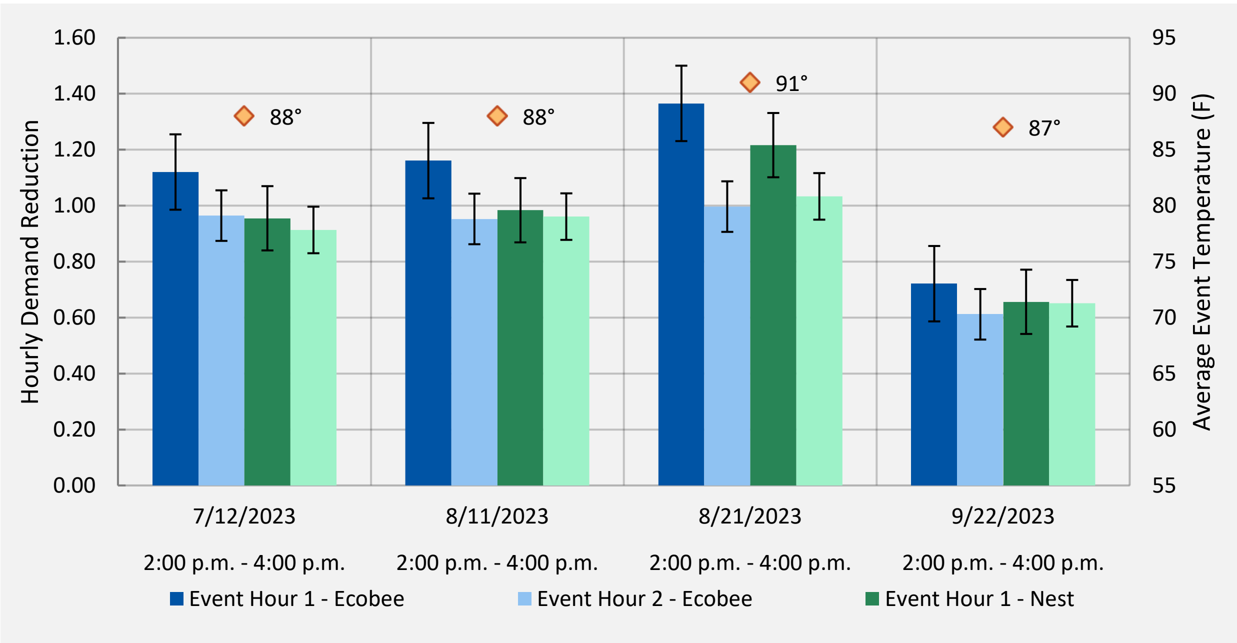
Table 12. Smart Cycle Average Event Demand Reduction

Event Hours	Number of Events	Average Event Temperature	Thermostat Type	Hour Beginning	Impact per Thermostat (kW)	90% Confidence Intervals (kW)		Total Achievable Program Impact[a] (kW)
						Lower Bound	Upper Bound	
2 p.m. - 4 p.m.	4	89°F	Ecobee	Event hour 1	-1.10	-1.16	-1.04	-1757
			Ecobee	Event hour 2	-0.89	-0.95	-0.82	-1419
			Nest	Event hour 1	-0.96	-0.99	-0.92	-4324
			Nest	Event hour 2	-0.89	-0.93	-0.85	-4031
			Average	Event hour 1	-1.01	-1.05	-0.96	-6159
			Average	Event hour 2	-0.89	-0.94	-0.84	-5449

Note: A negative impact indicates a reduction in usage (and therefore savings).
[a] Total achievable program impact among all thermostats currently enrolled in the Smart Cycle program (including control customers) as of the end of 2023

Figure 3 shows the estimated demand savings for each event hour and the average outdoor temperature (°F) during each event. Error bars show the 90% confidence interval for each impact estimate.

Figure 3. 2023 Smart Cycle Average Air-Conditioning Demand Reduction by Event and Hour



As seen in previous Smart Cycle evaluations, ecobee devices achieved higher first-hour savings estimates than Nest devices across all events, though the differences were not statistically significant. Previous Smart Cycle evaluations also showed that demand reductions increased with outdoor temperature. In 2023, the hottest event (August 21, 2023 at 91°F) had the highest demand reductions (1.37 kW per ecobee thermostat and 1.22 kW per Nest thermostat in the first hour.) The coolest event (September

22, 2023 at 87°F) had the lowest demand reductions (0.72 and 0.66 kW, respectively, in the first hour). These demand reductions were far lower than any of the previous events, though the temperature was just one degree less than the first two events. This result suggests that factors beyond just temperature may affect the impacts. Occurring toward the end of September, outdoor humidity during the last event was lower than the previous events, which may have reduced participants demand for air conditioning. Likewise, with school in session, fewer participants may have been at home during this event, and some participants could have switched off their air conditioning for the season.

In addition to demand reduction during the two hours of each program event, the events affected energy consumption in the hours following each event. Figure 1 shows the event day load shape for each event. There was a visible rebound effect following the event hours for both ecobee and Nest devices across all events, as the treatment group consumed more electricity than the control group to re-align indoor temperatures with the thermostat setpoint. The rebound effect persisted for several hours, especially the first, following the event. As shown, ecobee devices had much higher post-event impacts than Nest devices for all events. *Appendix C* shows the average hourly impacts, including six hours before and after the event start time by brand for each event.

4.1.1. Potential MISO Impact

Though the Smart Cycle program was not enrolled with MISO for demand reduction in summer 2023, CenterPoint Energy registered Smart Cycle with MISO on February 1, 2024. To provide CenterPoint Energy with accurate forecasts for its Smart Cycle MISO registration next year, Cadmus assessed the program's potential impacts should it be called upon by MISO for a load curtailment event. Table 13 shows the expected savings per thermostat per month and hour, as well as the seasonal average, for potential MISO events. Positive numbers reflect savings (demand reductions). In assessing potential MISO event savings forecasts, Cadmus used average (rather than peak) weather conditions, so the resulting forecasts are much lower than the typical EM&V event results reported previously as CenterPoint Energy calls EM&V events on the summer's hotter days. However, MISO rarely calls upon Summer Cycler, and the few events it has called in the past five years were not hot days. Therefore, the MISO event savings forecasts provide conservative estimates so that CenterPoint Energy's MISO registration will not overstate savings should MISO events be called on days when air conditioning demand is relatively modest. Note that these savings estimates assume MISO events last two hours. In practice, Smart Cycle events produce slightly higher savings in the first event hour than in the second event hour. The savings in Table 13 represent the average savings across the two-hour MISO event.

Table 13. Smart Cycle Potential MISO Event Savings Forecasts

Hour of Day	June		July		August		September		Summer Average	
	Per Thermostat (kW)	Achievable (MW)	Per Thermostat (kW)	Achievable (MW)	Per Thermostat (kW)	Achievable (MW)	Per Thermostat (kW)	Achievable (MW)	Per Thermostat (kW)	Achievable (MW)
0	0.21	1.27	0.28	1.70	0.23	1.41	0.10	0.61	**0.20**	**1.24**
1	0.16	0.97	0.22	1.35	0.18	1.11	0.08	0.47	**0.16**	**0.97**
2	0.13	0.79	0.19	1.15	0.15	0.93	0.07	0.42	**0.13**	**0.82**
3	0.11	0.67	0.16	0.99	0.13	0.80	0.07	0.42	**0.12**	**0.72**
4	0.10	0.59	0.14	0.86	0.12	0.71	0.07	0.42	**0.11**	**0.64**
5	0.09	0.54	0.13	0.78	0.11	0.65	0.07	0.42	**0.10**	**0.60**
6	0.09	0.55	0.13	0.78	0.11	0.65	0.07	0.42	**0.10**	**0.60**
7	0.11	0.67	0.14	0.85	0.11	0.66	0.07	0.42	**0.11**	**0.65**
8	0.11	0.68	0.14	0.84	0.11	0.66	0.07	0.42	**0.11**	**0.65**
9	0.14	0.85	0.17	1.05	0.14	0.83	0.08	0.47	**0.13**	**0.80**
10	0.18	1.11	0.22	1.34	0.18	1.12	0.10	0.64	**0.17**	**1.05**
11	0.23	1.41	0.28	1.70	0.24	1.47	0.15	0.91	**0.22**	**1.37**
12	0.30	1.81	0.34	2.09	0.31	1.87	0.21	1.28	**0.29**	**1.76**
13	0.35	2.17	0.41	2.51	0.37	2.26	0.27	1.65	**0.35**	**2.15**
14	0.42	2.55	0.48	2.92	0.42	2.60	0.33	2.00	**0.41**	**2.52**
15	0.48	2.95	0.55	3.39	0.49	3.01	0.40	2.44	**0.48**	**2.95**
16	0.54	3.28	0.61	3.73	0.55	3.36	0.45	2.73	**0.53**	**3.27**
17	0.55	3.37	0.63	3.83	0.56	3.43	0.45	2.77	**0.55**	**3.35**
18	0.54	3.32	0.60	3.67	0.54	3.31	0.42	2.57	**0.53**	**3.22**
19	0.53	3.26	0.59	3.61	0.52	3.16	0.34	2.09	**0.50**	**3.03**
20	0.52	3.15	0.57	3.50	0.49	2.98	0.31	1.87	**0.47**	**2.88**
21	0.46	2.82	0.52	3.19	0.45	2.77	0.26	1.57	**0.42**	**2.59**
22	0.39	2.37	0.45	2.78	0.39	2.39	0.20	1.20	**0.36**	**2.18**
23	0.29	1.77	0.35	2.17	0.30	1.84	0.13	0.81	**0.27**	**1.65**

4.2. Energy Savings

In addition to demand impacts, Cadmus evaluated the energy savings resulting from the load-control events. Energy savings from load-control events depended on the relative magnitudes of event-hour demand savings, precooling energy consumption, and the post-event rebound in energy demand.

Cadmus aggregated the hour interval kW to daily kWh for each thermostat and then estimated a regression using the aggregated daily kWh. *Appendix A* describes the regression model specification and estimation procedures.

Smart Cycle achieved average 2023 event-day energy savings of 0.74 kWh for both ecobee and Nest thermostats. These estimates were statistically significant at the 90% confidence level. Despite increased consumption due to precooling in the hour before each event, the reduction in demand during events resulted in an overall decrease in daily energy consumption on event days. Therefore, precooling due to events is not expected to increase participants' electricity bills.

5. Detailed Summer Cycler Impact Evaluation Findings

This section presents Cadmus' detailed findings from the 2023 Summer Cycler program impact evaluation. Table 14 summarizes the 2023 Summer Cycler program impacts—a negative impact indicates a reduction in usage (and therefore savings). Based on current program enrollments, Cadmus estimates that the Summer Cycler program could have generated up to 4.6 MW in peak demand savings from residential air-conditioning load control and 0.6 MW in peak demand savings from residential water-heating load control during 2023 standard load-control events.

Table 14. 2023 Summer Cycler Program Evaluated Energy and Demand Savings

Hour Beginning Average	Standard Load-Control Events			
	Air Conditioners		Water Heaters	
	Per Unit	Total Achievable Program Impact[b]	Per Unit	Total Achievable Program Impact[b]
Average Event kW Impact	**-0.214**	**-4,630.22**	**N/A**	**-645.94**
Average Event kW Hour 1	-0.231[a]	-4,988.04	N/A	-543.46
Average Event kW Hour 2	-0.198[a]	-4,272.40	N/A	-748.43
Average Post-Event Hour 1 kW Impact	0.131[a]	2,832.46	N/A	630.42
Average Event Energy kWh Impact	**-0.638**	**-13,795.59**	**N/A**	**-1,676.97**

[a] This estimate is statistically significant at the 10% level.

[b] The total achievable program impact represents possible program savings if CenterPoint Energy had cycled all Summer Cycler customers instead of just the treatment group of the program.

Table 15 lists historical per-unit air conditioner savings from Summer Cycler load-control events (when average outside temperatures were 85˚F or higher).[9]

Table 15. Historical Summer Cycler Program Evaluated Energy and Demand Savings

Load-Control Event Impacts	Per Air Conditioner					
	2015	2017	2019	2021[a]	2022	2023
Average Event Temperature (F)	90˚F	91˚F	89˚F	89˚F	90˚F	88˚F
Average Event kW Impact	-0.2[b]	-0.5[b]	-0.3[b]	-0.3[b]	-0.3[b]	-0.2[b]
Average Post-Event Hour 1 kW Impact	-0.05	0.01	0.03	-0.02	0.10[b]	0.13[b]
Average Event Energy kWh Impact	-0.37	-0.45	-0.78	N/A	0.48	0.64

[a] Cadmus used historical data to make predictions on demand impacts for the 2021 evaluation because the randomized-control experiment failed to execute.

[b] This estimate is statistically significant at the 10% level.

From the results of the impact analysis, Cadmus found the following:

- **Air conditioners.** Demand savings from air-conditioning load control in 2023 were similar to those estimated in 2022, 2021, and 2019.
- **Rebound.** The previous program year's findings suggest that CenterPoint Energy can call air conditioner demand response events without resulting in substantially greater demand during

[9] Cadmus did not evaluate MISO Proxy Event impacts during the 2015, 2017, and 2022 evaluations.

the hours following the event. Across most 2023 events, Cadmus found no significant post-event impacts (rebound) from air conditioner cycling, like past evaluations. However, Cadmus did find significant post-event impacts for several events occurring later in the afternoon. Overall, across all events, Cadmus estimated small but statistically significant post-event impacts.

- **Energy savings.** The program primarily targets demand reduction. Similar to previous program years, there were mainly no statistically significant energy savings due to the 2023 Summer Cycler load control events. Cadmus observed only one event with statistically significant energy savings.

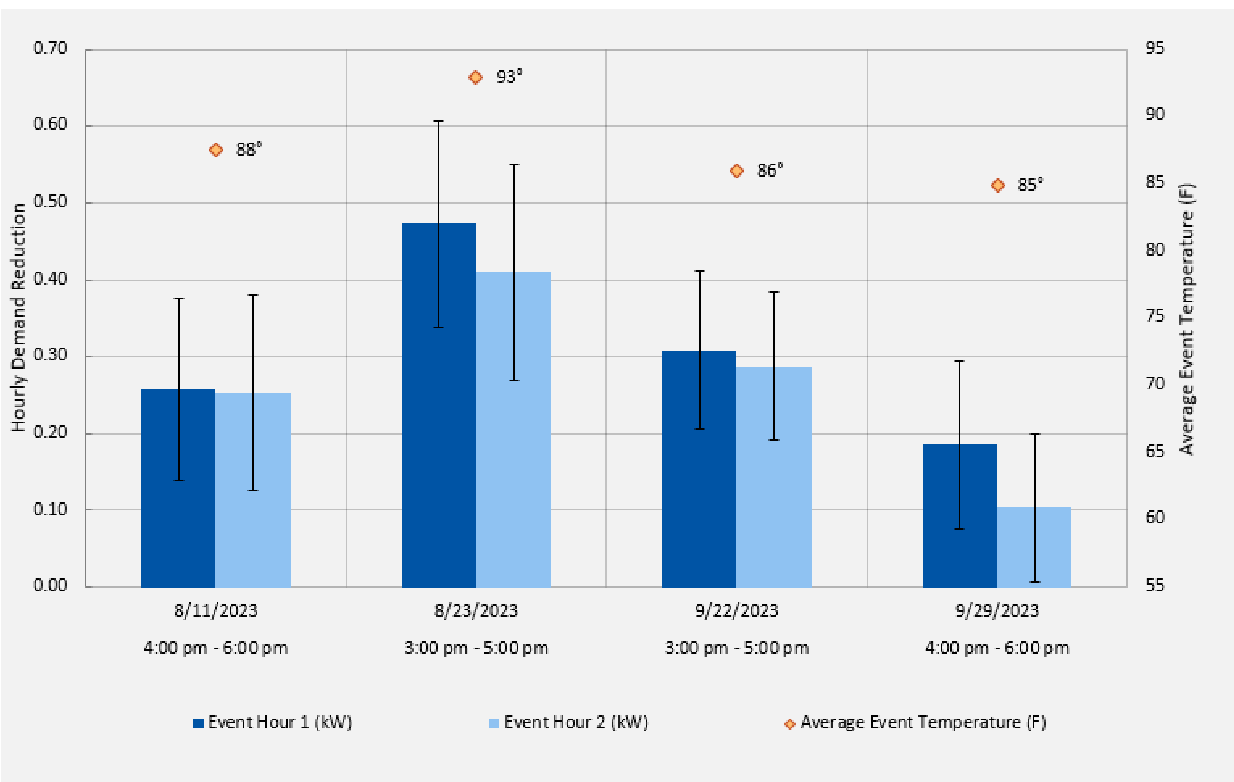
5.1. Demand Savings

Cadmus evaluated demand reduction from the 2023 Summer Cycler load-control events for air conditioners and water heaters.

5.1.1. Air Conditioners

Figure 4 shows the savings for each event hour as well as the average outdoor temperature during each event. Please note the events are listed chronologically by the date the event occurred. Across all event hours, event impacts ranged from 0.10 kW to 0.47 kW. The 0.47-kW savings impact took place on August 23, 2023 (Event 2) when there was an average temperature of 93°F in the Evansville area during the event.

Figure 4. 2023 Summer Cycler Average Air-Conditioning Demand Reduction by Event and Hour



5.1.1.1. Standard Load-Control Events

Table 16 lists estimates of the average kW impact per air conditioner during the standard load-control events. A negative impact indicates a reduction in usage (and therefore savings). Average demand reductions range from 0.15 kW to 0.28 kW across the event windows. Overall, the event that occurred on August 23, 2023 achieved the highest estimated savings because this event had a high average outdoor temperature. Across all hours, standard load-control events achieved an average reduction of 0.21 kW per air conditioner and estimated average achievable savings (had all Summer Cycler participants been cycled during the event, instead of just the treatment group) of 4,630 kW total.

Table 16. Average Summer Cycler Air-Conditioning Demand Reduction during Standard Load-Control Events

Event Hours	Number of Events	Average Event Temperature	Hour Beginning	Impact per Air Conditioner (kW)	90% Confidence Intervals (kW)		Total Achievable Program Impact[a] (kW)
					Lower Bound	Upper Bound	
3 p.m. - 5 p.m.	2	89°F	Event hour 1	-0.30	-0.40	-0.20	-6,371
			Event hour 2	-0.27	-0.36	-0.17	-5,650
			Average	**-0.28**	**-0.38**	**-0.19**	**-6,011**
4 p.m. - 6 p.m.	2	86°F	Event hour 1	-0.16	-0.25	-0.08	-3,486
			Event hour 2	-0.13	-0.22	-0.05	-2,828
			Average	**-0.15**	**-0.23**	**-0.06**	**-3,157**

[a] The total achievable program impact represents possible program savings if CenterPoint Energy had cycled all Summer Cycler customers instead of just the treatment group of the program

5.1.1.2. Potential MISO Impact

The Summer Cycler program is enrolled with MISO for demand reduction. Though there were no MISO events in 2023, Cadmus assessed its potential impacts to give CenterPoint Energy accurate forecasts should the program be called upon by MISO in the future. Table 17 shows the expected savings per switch per month and hour as well as the seasonal average for a MISO event. Positive numbers reflect savings (demand reductions).

Table 17. Summer Cycler Potential MISO Event Savings Forecasts

Hour of Day	June		July		August		September		Summer Average	
	Per Switch (kW)	Achievable (MW)	Per Switch (kW)	Achievable (MW)	Per Switch (kW)	Achievable (MW)	Per Switch (kW)	Achievable (MW)	Per Switch (kW)	Achievable (MW)
0	0.12	2.58	0.18	3.94	0.14	3.02	0.09	1.94	**0.13**	**2.87**
1	0.09	2.01	0.16	3.40	0.11	2.47	0.08	1.65	**0.11**	**2.38**
2	0.09	1.87	0.14	3.02	0.10	2.14	0.07	1.53	**0.10**	**2.14**
3	0.07	1.61	0.12	2.65	0.09	1.94	0.06	1.39	**0.09**	**1.90**
4	0.07	1.47	0.11	2.38	0.08	1.82	0.06	1.33	**0.08**	**1.75**
5	0.06	1.35	0.10	2.11	0.08	1.67	0.06	1.29	**0.07**	**1.61**
6	0.06	1.28	0.09	1.89	0.07	1.59	0.06	1.24	**0.07**	**1.50**
7	0.07	1.54	0.11	2.42	0.08	1.83	0.06	1.29	**0.08**	**1.77**
8	0.09	2.00	0.15	3.18	0.11	2.36	0.06	1.37	**0.10**	**2.23**
9	0.11	2.36	0.17	3.77	0.13	2.74	0.07	1.55	**0.12**	**2.61**
10	0.13	2.90	0.20	4.41	0.15	3.14	0.10	2.11	**0.15**	**3.14**
11	0.16	3.38	0.23	4.93	0.17	3.61	0.13	2.71	**0.17**	**3.66**
12	0.18	3.93	0.26	5.53	0.19	4.00	0.15	3.22	**0.19**	**4.17**
13	0.20	4.41	0.29	6.25	0.20	4.36	0.18	3.81	**0.22**	**4.71**
14	0.22	4.85	0.31	6.68	0.23	4.94	0.20	4.41	**0.24**	**5.22**
15	0.26	5.60	0.33	7.04	0.25	5.48	0.23	5.06	**0.27**	**5.80**
16	0.26	5.70	0.35	7.48	0.27	5.83	0.25	5.33	**0.28**	**6.08**
17	0.26	5.70	0.35	7.61	0.27	5.85	0.25	5.31	**0.28**	**6.12**
18	0.27	5.77	0.34	7.35	0.27	5.87	0.23	5.03	**0.28**	**6.01**
19	0.25	5.34	0.31	6.80	0.24	5.28	0.17	3.66	**0.24**	**5.27**
20	0.21	4.48	0.27	5.83	0.20	4.37	0.13	2.85	**0.20**	**4.38**
21	0.17	3.73	0.25	5.35	0.18	3.97	0.11	2.42	**0.18**	**3.87**
22	0.15	3.14	0.23	4.95	0.16	3.49	0.10	2.14	**0.16**	**3.43**
23	0.12	2.59	0.21	4.53	0.15	3.14	0.09	1.88	**0.14**	**3.03**

5.1.2. Water Heaters

Due to historical difficulty accessing water heaters for data logger installation and retrieval (likely only exacerbated by the COVID-19 pandemic), Cadmus did not conduct a water heater field experiment in 2023. Instead, Cadmus applied fixed per-unit demand and energy savings for water heaters estimated from the 2019 summer evaluation (and applied in 2022 and 2021). This methodology is supported by the results of Cadmus' previous Summer Cycler evaluations, which showed that water heater savings were stable and consistent across program years and load-control events. In 2019, Cadmus estimated an average per water heater impact of 0.12 kW from 3 p.m. to 5 p.m. and 0.09 kW from 4 p.m. to 6 p.m. This was used for the summer 2023 evaluation to estimate an average total achievable program impact of 645.94 kW for water heaters.

5.2. Energy Savings

Energy impacts from the 2023 Summer Cycler events depended on the relative magnitude of event hour demand impact and the post-event rebound in energy demand. Cadmus estimated energy savings (a decrease in energy consumption on event days due to events) of 0.64 kWh per air conditioner, but the estimate was not statistically significant.

Appendix A. Detailed Smart Cycle Analysis Methodology

A.1.Conversion of Run Time to kW

To estimate the load impacts from Smart Cycle demand response for each air conditioner, Cadmus converted EnergyHub air conditioner run time per hour to kWh per hour. The formula estimates the instantaneous kW for the unit, including power for the unit's condenser and evaporator fans and compressor, as a function of unit size (tonnage), efficiency, and indoor wet-bulb and outdoor dry-bulb temperatures. Cadmus assumed an indoor wet-bulb temperature of 67°F, the Air Conditioning, Heating, and Refrigeration Institute (AHRI) standard, as indoor wet-bulb temperatures were not available in the thermostat data. Cadmus used outdoor dry-bulb temperatures collected from the Evansville Regional Airport weather dataset, as the thermostats did not collect home-specific outdoor temperatures and EnergyHub's thermostat data were anonymized for Nest devices (not linkable to CenterPoint Energy customer data or premise zip codes for more granular weather mapping).

Cadmus used a standard engineering formula to make the conversion.[10] The formula estimates the instantaneous kW for the unit, including power for the unit's condenser and evaporator fans and compressor, as a function of unit size (tonnage), efficiency, and indoor wet-bulb and outdoor dry-bulb temperatures:

$$Instantaneous\ System\ kW = \frac{(Tons * 12{,}000 * CAP * \frac{3.413}{EER} * EIR)}{3413}$$

Where:

Tons	=	Tonnage of central air conditioner (assumed to be 2.42 based upon primary data collection from direct install participants in previous evaluations)
12,000	=	Conversion factor to convert tons to Btu
EER	=	Energy efficiency rating (EER) of central air conditioner unit (assumed to be 10.035 based on primary data collection from direct install participants in previous evaluations)

$$CAP = a_{CAP} + (b_{CAP} * EWB) + (c_{CAP} * EWB^2) + (d_{CAP} * ODB) + (e_{CAP} * ODB^2) + (f_{CAP} * EWB * ODB)$$

$$EIR = a_{EIR} + (b_{EIR} * EWB) + (c_{EIR} * EWB^2) + (d_{EIR} * ODB) + (e_{EIR} * ODB^2) + (f_{EIR} * EWB * ODB)$$

10 Cutler, D., et al. January 2013. *Improved Modeling of Residential Air Conditioners and Heat Pumps for Energy Calculations.* NREL Technical Report, NREL/TP-5500-56354. http://www.nrel.gov/docs/fy13osti/56354.pdf

In the CAP (total capacity) and EIR (energy input ratio) equations above, terms "*a*" through "*f*" are standardized performance curve coefficients obtained from the Cutler study.[11] Terms ODB and EWB are the outdoor dry-bulb and indoor wet-bulb temperatures, respectively.

For each hour, Cadmus multiplied the central air conditioner run time by the instantaneous kW to estimate the unit's kWh per hour.

A.2. Detailed Demand Reduction Analysis Methodology

Cadmus estimated demand reduction from load-control events by estimating the following regression of hourly electricity (kWh) use of central air conditioners. Cadmus estimated the model as post-only, including only data from event days in the model (but controlling for non-event day average hourly consumption with an explanatory variable):

$$kWh_{it} = \alpha_{ih} + \tau_t + \beta Test_i * Datetime_t + \varepsilon_{it}$$

Where:

kWh_{it} = Hourly electricity use of central air conditioner 'i,' i=1, 2, …, N, in datetime 't', t=1, 2, …, T of the estimation period.

α_{ih} = Observable average hourly, customer-specific non-event day electricity use for central air conditioner 'i' and hour of the day 'h', h=1, 2, …, 24.

τ_t = Hour of the analysis sample fixed effect. This variable captures effects specific to an hour, such as weather on central air conditioner electricity use.

$Test_i$ = Indicator variable for whether central air conditioner i is in the treatment group. $Test_i$ equals 1 if central air conditioner i is in the treatment group and equals 0 if it is in the control group.

$Datetime_t$ = Indicator variable for date-hour. This variable equals 1 for each datetime 't' and equals 0 otherwise.

β = Average impact of an event on hourly electricity use of central air conditioners.

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[11] Cutler, D., et al. January 2013. *Improved Modeling of Residential Air Conditioners and Heat Pumps for Energy Calculations.* NREL Technical Report, NREL/TP-5500-56354. http://www.nrel.gov/docs/fy13osti/56354.pdf

A.3. Detailed Energy Savings Estimation Methodology

Cadmus estimated energy savings from load-control events by aggregating hour-interval kWh to daily kWh for each thermostat and estimating the following regression of daily electricity (kWh) use of central air conditioners:

$$kWh_{id} = \alpha_i + \tau_d + \beta Test_i * Event_d + \varepsilon_{id}$$

Where:

kWh_{id}	=	Daily electricity use of central air conditioner 'i,' i=1, 2, …, N, on day 'd', d=1, 2, …, D of the estimation period.
α_i	=	Unobservable, time-invariant average electricity use for central air conditioner 'i.' These effects are controlled for with central air conditioner fixed effects (i.e., the regression includes a separate dummy variable for each central air conditioner).
τ_d	=	Day of the analysis sample fixed effect. This variable captures effects specific to a day, such as weather on central air conditioner electricity use.
$Test_i$	=	Indicator variable for whether central air conditioner 'i'' is in the treatment group. $Test_i$ equals 1 if central air conditioner 'i'' is in the treatment group and equals 0 if it is in the control group.
$Event_d$	=	Indicator variable for an event day. This variable equals 1 if day 'd' is an event day and equals 0 otherwise.
β	=	Average impact of an event day on daily electricity use of central air conditioners.

Appendix B. Detailed Summer Cycler Analysis Methodology

B.1. Detailed Demand Reduction Analysis Methodology

Cadmus estimated demand reduction from load-control events by estimating the following regression of hourly electricity (kWh) use of central air conditioners. Cadmus estimated the model as post-only, including only data from event days in the model (but controlling for non-event day average hourly consumption with an explanatory variable):

$$kWh_{it} = \alpha_{ih} + \tau_t + \beta Test_i * Datetime_t + \varepsilon_{it}$$

Where:

kWh_{it}	=	Hourly electricity use of central air conditioner 'i,' i=1, 2, …, N, in datetime 't', t=1, 2, …, T of the estimation period.
α_{ih}	=	Observable hourly, customer-specific - electricity use for central air conditioner 'i' and hour of the day 'h' h=1, 2, …, 24.
τ_t	=	Hour of the analysis sample fixed effect. This variable captures effects specific to an hour, such as weather on central air conditioner electricity use.
$Test_i$	=	Indicator variable for whether central air conditioner i is in the treatment group. $Test_i$ equals 1 if central air conditioner i is in the treatment group and equals 0 if it is in the control group.
$Datetime_t$	=	Indicator variable for date-hour. This variable equals 1 for each datetime 't' and equals 0 otherwise.
β	=	Average impact of an event on hourly electricity use of central air conditioners.

B.2. Detailed Energy Savings Estimation Methodology

Cadmus estimated energy savings from load-control events by aggregating hour-interval kWh to daily kWh for each thermostat and estimating the following regression of daily electricity (kWh) use of central air conditioners:

$$kWh_{id} = \alpha_i + \tau_d + \beta Test_i * Event_d + \varepsilon_{id}$$

Where:

kWh_{id}	=	Daily electricity use of central air conditioner 'i,' i=1, 2, …, N, on date 'd', d=1, 2, …, D of the estimation period.

α_i	=	Unobservable, time-invariant electricity use for central air conditioner 'i.' These effects are controlled for with central air conditioner fixed effects (i.e., the regression includes a separate dummy variable for each central air conditioner).
τ_d	=	Day of the analysis sample fixed effect. This variable captures effects specific to a day, such as weather on central air conditioner electricity use.
$Test_i$	=	Indicator variable for whether central air conditioner i is in the treatment group. Testi equals 1 if central air conditioner i is in the treatment group and equals 0 if it is in the control group.
$Event_d$	=	Indicator variable for an event day. This variable equals 1 if day 'd' is an event day and equals 0 otherwise.
β	=	Average impact of an event day on daily electricity use of central air conditioners.

Appendix C. Smart Cycle Thermostat kW Impacts

Table C-1 shows estimates of the demand impacts for Smart Cycle air conditioners during each event hour and each of the six post-event hours.

Table C-1. Smart Cycle Demand Impact Estimates for Each Event Hour

Event Day	Hour Beginning	Hour Type	Ecobee	Nest	Average	Total Achieved Program Impact (MW) (n=1,792)	Total Achievable Program Impact (MW) (n=6,118)
1	8	Pre-Event Hour 6	-0.01	-0.02	-0.01	-0.02	-0.08
1	9	Pre-Event Hour 5	0.00	-0.03	-0.02	-0.04	-0.13
1	10	Pre-Event Hour 4	-0.03	-0.04	-0.04	-0.07	-0.25
1	11	Pre-Event Hour 3	-0.04	0.01	-0.01	-0.01	-0.04
1	12	Pre-Event Hour 2	0.01	0.01	0.01	0.02	0.08
1	13	Pre-Event Hour 1	0.75	0.72	0.73	1.31	4.47
1	14	Event Hour 1	-1.12	-0.95	-1.01	-1.81	-6.19
1	15	Event Hour 2	-0.96	-0.91	-0.93	-1.67	-5.70
1	16	Post-Event Hour 2	0.38	0.09	0.19	0.34	1.15
1	17	Post-Event Hour 2	0.16	0.06	0.09	0.17	0.57
1	18	Post-Event Hour 3	0.09	0.06	0.07	0.13	0.45
1	19	Post-Event Hour 4	0.07	0.05	0.06	0.10	0.35
1	20	Post-Event Hour 5	0.08	0.05	0.06	0.11	0.36
1	21	Post-Event Hour 6	0.03	0.06	0.05	0.08	0.29
2	8	Pre-Event Hour 6	-0.02	0.02	0.00	0.01	0.03
2	9	Pre-Event Hour 5	-0.03	-0.02	-0.02	-0.04	-0.14
2	10	Pre-Event Hour 4	-0.03	-0.01	-0.02	-0.03	-0.09
2	11	Pre-Event Hour 3	-0.05	0.01	-0.01	-0.02	-0.06
2	12	Pre-Event Hour 2	-0.07	-0.02	-0.04	-0.07	-0.23
2	13	Pre-Event Hour 1	0.78	0.74	0.75	1.35	4.61
2	14	Event Hour 1	-1.16	-0.98	-1.05	-1.87	-6.40
2	15	Event Hour 2	-0.95	-0.96	-0.96	-1.72	-5.86
2	16	Post-Event Hour 2	0.36	0.16	0.23	0.40	1.38
2	17	Post-Event Hour 2	0.19	0.06	0.11	0.19	0.65
2	18	Post-Event Hour 3	0.11	0.06	0.07	0.13	0.46
2	19	Post-Event Hour 4	0.07	0.07	0.07	0.13	0.45
2	20	Post-Event Hour 5	0.05	0.06	0.06	0.10	0.35
2	21	Post-Event Hour 6	0.04	0.06	0.05	0.09	0.32
3	8	Pre-Event Hour 6	-0.01	0.01	0.01	0.01	0.03
3	9	Pre-Event Hour 5	-0.01	0.00	0.00	-0.01	-0.02
3	10	Pre-Event Hour 4	-0.08	-0.01	-0.03	-0.06	-0.21
3	11	Pre-Event Hour 3	-0.05	-0.04	-0.04	-0.08	-0.26

Event Day	Hour Beginning	Hour Type	Ecobee	Nest	Average	Total Achieved Program Impact (MW) (n=1,792)	Total Achievable Program Impact (MW) (n=6,118)
3	12	Pre-Event Hour 2	-0.02	0.00	0.00	-0.01	-0.02
3	13	Pre-Event Hour 1	0.29	0.60	0.49	0.88	3.02
3	14	Event Hour 1	-1.37	-1.22	-1.27	-2.27	-7.76
3	15	Event Hour 2	-1.00	-1.03	-1.02	-1.83	-6.24
3	16	Post-Event Hour 1	0.31	0.15	0.21	0.37	1.27
3	17	Post-Event Hour 2	0.17	0.07	0.10	0.19	0.64
3	18	Post-Event Hour 3	0.11	0.08	0.09	0.16	0.54
3	19	Post-Event Hour 4	0.09	0.09	0.09	0.17	0.56
3	20	Post-Event Hour 5	0.05	0.07	0.06	0.12	0.39
3	21	Post-Event Hour 6	0.03	0.06	0.05	0.09	0.30
4	9	Pre-Event Hour 6	0.02	0.00	0.01	0.01	0.04
4	10	Pre-Event Hour 5	0.04	0.01	0.02	0.03	0.11
4	11	Pre-Event Hour 4	0.01	0.01	0.01	0.01	0.05
4	12	Pre-Event Hour 3	0.00	0.00	0.00	0.00	-0.01
4	13	Pre-Event Hour 2	0.11	0.00	0.04	0.07	0.25
4	14	Pre-Event Hour 1	0.49	0.69	0.62	1.11	3.78
4	15	Event Hour 1	-0.72	-0.66	-0.68	-1.22	-4.15
4	16	Event Hour 2	-0.61	-0.65	-0.64	-1.14	-3.90
4	17	Post-Event Hour 1	0.37	0.07	0.17	0.31	1.06
4	18	Post-Event Hour 2	0.12	0.00	0.05	0.08	0.28
4	19	Post-Event Hour 3	0.09	0.01	0.04	0.07	0.24
4	20	Post-Event Hour 4	0.04	0.00	0.01	0.02	0.08
4	21	Post-Event Hour 5	0.01	-0.01	0.00	0.00	0.00
4	22	Post-Event Hour 6	0.00	0.01	0.00	0.01	0.03

Appendix D. Summer Cycler Air Conditioner kW Impacts

Table D-1 shows estimates of the demand impacts for Summer Cycler air conditioners during each event hour and the first hour following each event. As discussed previously, the 2023 evaluation found statistically significant impacts (additional air conditioning energy consumption due to curtailment during events) after the first post-event hour for several events. As such, Cadmus estimated and reported impacts for those hours following 2023 events.

Table D-1. Summer Cycler Demand Impact Estimates for Each Event Hour

Event Date	Hour Type	Hour Beginning	Average Temperature	Average Impact per Air Conditioner	Total Achieved Program Impact (MW)	Total Achievable Program Impact (MW)
8/11/2023	EventHour1	16	88	-0.26	-0.04	-5.56
8/11/2023	EventHour2	17	87	-0.25	-0.04	-5.46
8/11/2023	PostHour1	18	87	0.12	0.02	2.52
8/11/2023	PostHour2	19	85	0.16	0.03	3.35
8/11/2023	PostHour3	20	81	0.05	0.01	1.02
8/11/2023	PostHour4	21	78	-0.04	-0.01	-0.90
8/11/2023	PostHour5	22	77	-0.07	-0.01	-1.57
8/11/2023	PostHour6	23	77	-0.07	-0.01	-1.62
8/23/2023	EventHour1	15	94	-0.47	-0.08	-10.22
8/23/2023	EventHour2	16	92	-0.41	-0.07	-8.87
8/23/2023	PostHour1	17	92	0.04	0.01	0.86
8/23/2023	PostHour2	18	91	0.12	0.02	2.57
8/23/2023	PostHour3	19	89	0.10	0.02	2.17
8/23/2023	PostHour4	20	85	0.07	0.01	1.48
8/23/2023	PostHour5	21	83	0.00	0.00	-0.07
8/23/2023	PostHour6	22	81	0.04	0.01	0.85
9/22/2023	EventHour1	15	86	-0.31	-0.05	-6.67
9/22/2023	EventHour2	16	86	-0.29	-0.04	-6.22
9/22/2023	PostHour1	17	85	0.02	0.00	0.47
9/22/2023	PostHour2	18	81	0.01	0.00	0.26
9/22/2023	PostHour3	19	75	0.02	0.00	0.46
9/22/2023	PostHour4	20	71	-0.01	0.00	-0.22
9/22/2023	PostHour5	21	68	-0.02	0.00	-0.37
9/22/2023	PostHour6	22	66	-0.10	-0.02	-2.22
9/29/2023	EventHour1	16	85	-0.19	-0.03	-4.00
9/29/2023	EventHour2	17	85	-0.10	-0.02	-2.23
9/29/2023	PostHour1	18	84	0.14	0.02	3.11
9/29/2023	PostHour2	19	74	0.09	0.01	2.00
9/29/2023	PostHour3	20	72	-0.06	-0.01	-1.21

Event Date	Hour Type	Hour Beginning	Average Temperature	Average Impact per Air Conditioner	Total Achieved Program Impact (MW)	Total Achievable Program Impact (MW)
9/29/2023	PostHour4	21	68	-0.12	-0.02	-2.49
9/29/2023	PostHour5	22	67	-0.12	-0.02	-2.50
9/29/2023	PostHour6	23	67	-0.09	-0.01	-2.05

Appendix E. Summer Cycler Water Heater kW Impacts

Due to historical difficulty accessing water heaters for data logger installation and retrieval, Cadmus did not conduct a water heater field experiment in 2023. Instead, Cadmus applied fixed per-unit demand and energy savings for water heaters. This methodology is supported by the results of Cadmus' previous Summer Cycler evaluations, which showed that water heater savings were stable and consistent across program years and load-control events.