REPORT

Xcel Energy Colorado Smart Thermostat Pilot – Evaluation Report

May 12, 2017

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1 Executive Summary

Xcel Energy launched a residential smart thermostat pilot in 2015 and a small business ("SMB") pilot in early 2016. Each pilot component evaluated is summarized in Figure 1-1. The residential pilots included a smart thermostat energy efficiency ("EE") rebate and a "bring your own thermostat" demand response ("BYOT DR") pilot. The SMB pilot was a demand response pilot with direct installation of smart thermostats. Xcel Energy's pilots were designed to test a variety of program models and thermostat manufacturers. The pilots have also provided a strong empirical basis for answering several important research questions and informing the Company's smart thermostat strategy going forward.

Figure 1-1: Smart Thermostat Pilot Components Evaluated

Residential EE rebate	Residential BYOT DR	SMB Direct install DR
$50 rebate	$25 enrollment incentive	Direct install of up to 5 smart tstats
3 smart tstat vendors	2 smart tstat vendors	1 smart tstat vendor
~6,300 devices	~800 devices	~130 devices
Storefront purchase & mail in rebate channels	Cross marketed with EE rebate and marketed by vendors	2 control strategies (50% duty cycling and 3F offset)
Rebate eligible for purhases between Jan 2015 and Dec 2016	17 DR events on 10 days in Jun to Aug 2016	10 DR events on 5 days in Sep 2016
	Multiple control strategies (duty cycling and offsets)	Performance incentives randomly assigned
	$2.50 or $5 per event performance incentives randomly assigned	

Vendors varied across all three pilot components and included Honeywell, Nest, ecobee, Radio Thermostat of America ("RTA"), and EnergyHub. Vendor names have been masked throughout this report to anonymize results.

1.1 Smart Thermostat Energy Efficiency Rebate

The key metric evaluated for the smart thermostat EE rebate was energy savings (kWh and therms). Changes in household energy usage were assessed to identify whether installation of smart thermostats resulted in energy savings for participants. Average usage patterns across participants and device types were also assessed to identify any differences that might help explain differences in energy savings between device vendors. A participant survey assessed participant satisfaction and freeridership for the smart thermostat rebate.

1.1.1 EE Energy savings

The energy efficiency analysis for the residential pilot sought to help answer key questions to inform future program design, in particular:

- What level of energy savings (kWh & peak kW) are attributed to the installation and use of smart thermostats? Can a deemed savings value be determined?
- Is a $50 rebate sufficient to encourage customers to purchase and install a smart thermostat?
- Is it possible to create a cost-effective DSM product using resulting deemed energy-savings values?

The first question sought to quantify energy savings and was answered directly through the energy savings analysis, summarized in Table 1-1. The key findings of this analysis were that though some modest energy savings were found, they were concentrated in distinct populations. In particular, statistically significant energy savings were largely only found for Vendor 3 devices and were on the order of 2.4% annual household electricity use and 2.5% of gas use. In contrast, no significant EE electricity or gas savings were found for Vendor 2 devices. While negative electricity savings were found for Vendor 1 devices, no significant change in gas usage was found for these devices.

For Vendor 3 participants the electricity savings in particular were significantly higher for participants who obtained the rebate using the Xcel Energy online store[1] ("Storefront"). Significant electricity savings of 1.9% were also found for all participants who used the Storefront for all devices, though these savings were substantially less than the 3.6% savings found for Vendor 3 participants who used the Storefront. This suggests that the savings for all participants using the Storefront may actually be concentrated among the Vendor 3 devices. The electricity savings were not significant for Vendor 3 participants who used the mail-in rebate. While the same device was used by Vendor 3 participants who used either channel, there may have been differences in thermostat usage behavior as well as differences in when the thermostat was installed since the mail-in rebate could be requested retroactively. Both of these scenarios can contribute to differences in estimated savings after the rebate application. In addition, the different rebate channels are essentially different program delivery channels that may produce different savings. Xcel Energy could include or exclude a given channel from future program designs to improve cost effectiveness.

Annual gas savings, on the other hand, were somewhat higher for the Vendor 3 mail-in rebate participants compared to Storefront participants, though gas savings for all Vendor 3 participants were still in the range of 2-3%. This is a small effect size analyzed using a relatively small sample size; with a larger sample it would have been possible to detect this smaller effect size with greater confidence.[2]

[1] www.xcelenergystore.com

[2] For example, when analyzed for all residential pilot participants across all thermostat types it is possible to detect statistically significant gas savings of 1.6%. However, these aggregate savings are lower than the 2.5% savings for Vendor 3 devices only, despite being observed within a larger overall sample. This would suggest that that energy savings from

Table 1-1: Annual whole house energy savings by rebate channel and provider[3]

Fuel	Provider	Rebate channel	Impact: % savings	Impact: p-value
Electricity (kWh)	Vendor 1	Mail	-4.3%	0.08
		Store	-3.1%	0.14
		Both	-3.5%	0.03
	Vendor 2	Mail	-0.1%	0.95
		Store	2.0%	0.28
		Both	1.0%	0.46
	Vendor 3	Mail	0.8%	0.63
		Store	3.6%	0.00
		Both	2.4%	0.01
	All	Mail	-0.1%	0.96
		Store	1.9%	0.02
		Both	1.1%	0.12
Gas[4] (therms)	Vendor 1	Mail	-0.4%	0.87
		Store	-0.2%	0.88
		Both	-0.2%	0.83
	Vendor 2	Mail	1.0%	0.41
		Store	0.5%	0.71
		Both	0.7%	0.42
	Vendor 3	Mail	3.2%	0.00
		Store	1.9%	0.01
		Both	2.5%	0.00
	All	Mail	2.2%	0.00
		Store	1.2%	0.04
		Both	1.6%	0.00

The annual energy savings analysis was performed using pre- and post-treatment billing data, which could not be estimated for HVAC specific savings because end-use specific data was not available for the pre- and post-treatment period. In contrast, estimated peak load impacts due to energy savings could not be directly estimated because this would require hourly interval data and no smart meter interval data was available. In the absence of interval data, peak load impacts for summer afternoons were estimated by applying results from a similar smart thermostat study[5] which broke down impacts by summer weekday hour using interval data. By applying the assumption that savings were similarly allocated for Xcel Energy participants, the estimated average peak impact is about 0.25kW on average between the hours of 1 to 5pm.

Vendor 1 and Vendor 2 users, if present at all, are less than savings observed for Vendor 3 users. A larger sample size does not change the size of the impact rather it increases the ability to detect a smaller impact.

[3] Estimates not within the 95% confidence level for statistical significance (p-value at or below 0.05) have been greyed out

[4] Excludes low usage months of June through September when average daily usage is below one therm

[5] Completed as part of the SDG&E Small Customer Technology Deployment (SCTD) program

The second question about whether the $50 rebate is sufficiently compelling can be assessed by considering the volume of rebate applications Xcel Energy processed and the influence of the rebate as reported by participant survey respondents (see Section 8.3 for details). Xcel Energy processed over six thousand rebates and nearly 80% of respondents reported that the $50 rebate was very or extremely important.[6] These data points imply that the $50 rebate was indeed compelling.

Finally, the energy savings analysis was combined with results from a residential participant survey question on freeridership to develop a net savings value summarized in Table 1-2. Importantly, respondents who purchased their smart thermostat online from the Storefront exhibited significantly lower freeridership than participants who purchased their smart thermostat elsewhere and applied for the $50 rebate via the mail-in application. Different net-to-gross ratios were applied to savings for the online and mail-in groups accordingly. Net savings were primarily assessed for Vendor 3 thermostats as these were the only devices to exhibit statistically significant savings. After applying the net-to-gross ratios, annual net savings for Vendor 3 devices via the online channel were estimated to be 278 kWh and 9.6 therms. Net peak load impacts were estimated at 0.2 kW. Annual net savings for all Vendor 3 devices were estimated at 176 kWh and 11.6 therms. If these savings estimates are indeed reliable and if savings persist for multiple years the smart thermostat rebate might be a cost-effective DSM program approach. However, further study may be necessary to develop a reliable savings estimate or deemed savings value. While savings within the range of other smart thermostat evaluations were detected for Vendor 3 devices, these are not reliable due to the variation identified across pilots and the lack of evaluation of savings persistence.

[6] On a 5 point scale 49% gave a rank of 5 “Extremely important.” Another 29% gave a rank of 4.

Table 1-2: Annual whole house EE savings by rebate channel and provider[7]

Fuel	Provider	Rebate channel	Impact: avg daily usage	Impact: p-value	Annual savings[8]	Net savings ratio[9]	Net annual savings
Electricity (kWh)	Vendor 3	Mail	1.10	0.08	82	66%	54
		Store	-0.98	0.00	356	78%	278
		Both	-0.65	0.01	238	74%	176
	All	Mail	0.02	0.96	-6	66%	-4
		Store	-0.50	0.02	182	78%	142
		Both	-0.29	0.12	105	74%	78
Gas[10] (therms)	Vendor 3	Mail	-0.08	0.00	19.9	66%	13.2
		Store	-0.05	0.01	12.4	78%	9.6
		Both	-0.07	0.00	15.7	74%	11.6
	All	Mail	-0.06	0.00	13.7	66%	9.0
		Store	-0.03	0.04	7.5	78%	5.8
		Both	-0.04	0.00	10.1	74%	7.5

Key EE Savings Takeaways

- *Savings not significant for all thermostats, enrollment channels, or populations*
- *Annual electricity savings as high as 3.6% (356 kWh gross, 278 kWh net) for thermostat with highest savings and online Storefront rebate channel*
- *Annual gas savings of 1.9% (15.7 therms gross, 11.6 therms net) for the same thermostat and online Storefront rebate channel*

7 Estimates not within the 95% confidence level for statistical significance (p-value at or below 0.05) have been greyed out

8 Derived by multiplying annual average daily usage impact by 365 for electricity and by 240 for gas (to account for the fact only eight months of usage, from October to May, are reflected in the savings estimate)

9 Based on results of survey, see section 8.3.

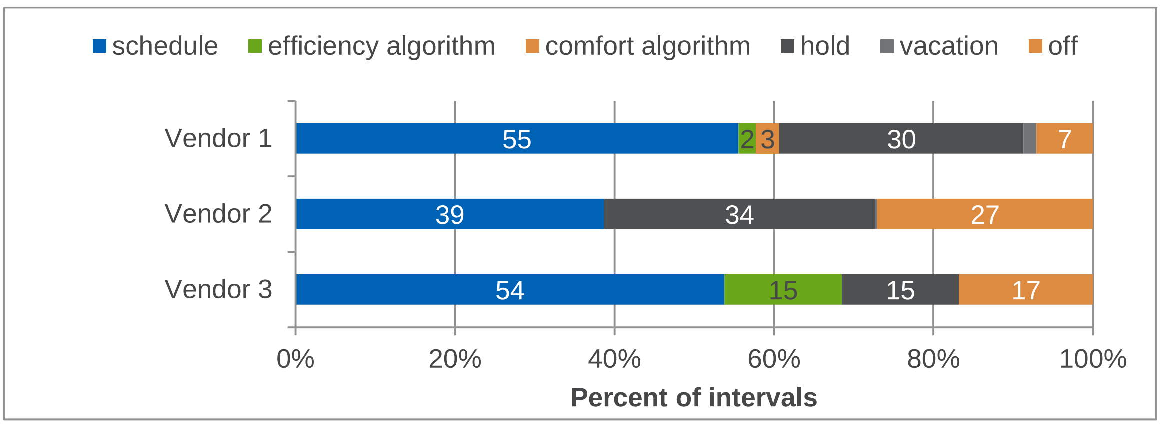
10 Excludes low usage months of June through September when average daily usage is below one therm

1.1.2 Modeling Typical Residential Smart Thermostat Usage

Differences in thermostat functionality are most interesting to the extent that these differences translate to differences in EE savings. As noted above, statistically significant EE savings were only observed for Vendor 3 thermostats. A key question is whether part of the difference in observed EE savings may be explained by the thermostat itself and associated user experience, as opposed to user behavior or other factors. EE savings explained by the thermostat functionality are more likely to persist than are behaviors that may be initially influenced by participation in the pilot.

To provide answers to research questions and potentially link thermostat functionality to EE savings Nexant analyzed temperature setpoints, thermostat programmed "setback" schedules, and other thermostat settings such as temperature holds and vendor / product-specific algorithms triggered by occupancy sensors. For each analysis comparisons were made by device type. The most important finding is that Vendor 3 thermostats do appear to exhibit unique functionality and user experience that could logically result in more EE savings than the other two manufacturers. The two key functionalities which appear to drive the differences are related to the setback program settings for each device and how they work. Figure 1-2 summarizes the setback program settings available for each device type and the percent of intervals spent in each program setting over the 2016 summer months of June through September. The key functional differences for Vendor 3 devices are related to the temperature hold and efficiency algorithm program settings.

Figure 1-2: Percent of Time Intervals Spent in Each Program Setting, by Device, Summer 2016



The first key feature separating Vendor 3 devices is that the devices return automatically to the scheduled setback program once the next schedule period is reached, which on average occurs after half a day for Vendor 3 customers. Perhaps this is partly because Vendor 3 thermostats are in the hold setting about half as much as the other two thermostat vendors (15% of the time in the summer months compared to 30% of the time for Vendor 1 users and 34% of the time for Vendor 2 users). According to device documentation, when users adjust the temperature on their thermostat away from the programmed setback schedule, both Vendor 1 and Vendor 2 provide customers the option of automatic reset to the programmed setback schedule alongside a permanent hold option (i.e., hold this desired temperature forever until the user makes another change) directly on the thermostat. Permanent holds were used much more frequently than temporary holds by Vendor 2 owners. For 20 to 30% of users of Vendors 1 and 2 devices, over 10% of holds deployed lasted more than 24 hours. This was true for only about 1% of users of Vendor 3 devices. Given the multi-day hold durations observed for Vendor 1 and Vendor 2 devices, which likely drives the higher percent of time spent in hold, it is apparent that these users usually do not choose the option to automatically return to the schedule. This is notable because the manual or permanent hold setting tends to be used for comfort (e.g., lowering a cooling temperature setpoint) rather than for efficiency.

In addition to the setback program reset, there is a difference in the way occupancy sensor triggered algorithms work on the Vendor 3 and Vendor 1 devices (this feature was not available for Vendor 2 devices). Specifically, Vendor 3 devices use an occupancy sensor embedded in the thermostat and appear to adjust the temperature to favor efficiency when no occupancy is detected. In contrast, the Vendor 1 uses an embedded occupancy sensor in the thermostat, and has two occupancy sensor triggered algorithm settings: home and away, denoted as efficiency and comfort algorithms in Figure 1-2, respectively. Perhaps even more impactful is the percent of time spent in each setting. The Vendor 1 comfort and efficiency algorithms are seldom deployed whereas the Vendor 3 efficiency algorithm is deployed 15% of the time in the summer and 16% of the time in the winter. In sum, this means that the Vendor 3 thermostat may feasibly provide more opportunity for energy savings because it deploys an efficiency algorithm much more often than Vendor 1, and the Vendor 3 thermostat never deploys a comfort algorithm. The differences in efficiency algorithm deployment may be explained in part by differences in how users are defaulted into the feature, how they are given the option to opt-out, and how the feature itself is triggered—the longer the thermostat waits to trigger the algorithm after non-occupancy is detected the less frequently the algorithm will be triggered.

Another meaningful takeaway is that time spent in each program setting does not necessarily correspond to the frequency with which a thermostat was put in a given setting. Specifically, though Vendor 3 devices spent about half the time in HOLD than did other devices both the usage data and the survey data showed that Vendor 3 owners manually changed the temperature more often (triggering the HOLD setting) than did owners of other devices. This is meaningful in light of the EE savings delivered by Vendor 3 devices because it implies that the frequency of use of the HOLD setting may not impact energy savings as much as the duration of the HOLD setting. Said another way, allowing a thermostat to remaining in HOLD indefinitely may substantially reduce EE savings potential.

Key Thermostat Usage Takeaways

- *Two key features which appear to drive EE savings are time spent in efficiency setting and time spent in holds*
- *Vendor that delivered savings also reverts to efficiency setting more frequently and does not offer an indefinite hold from the thermostat, contrary to other vendors*
- *Reducing the time spent in HOLD may contribute more to EE savings than trying to reduce the frequency of HOLD settings*

1.1.3 Residential Survey: EE Questions

Residential pilot participants were invited to complete a survey that included questions specific to the smart thermostat $50 EE rebate and to demand response enrollment and events. It also asked about perceptions and reported usage behaviors of the smart thermostat. Each question was analyzed in the context of the broader pilot to identify and reinforce key takeaways related to future program design. There were three key takeaways related to the smart thermostat EE rebate, indicating that the online Storefront may be further leveraged to help improve cost effectiveness for future programs.

First, freeridership across respondents averaged 27%, in large part due to the fact that over half of respondents report intending to purchase a smart thermostat in the absence of a $50 rebate. This is possibly indicative of a larger market trend toward interest in smart thermostats. However, freeridership was significantly different for the two rebate channels available to participants. Respondents who purchased their thermostat using the online energy store received an instant rebate and exhibited freeridership of 23%. In contrast, freeridership for respondents who mailed in a rebate form was 34%, significantly higher. It is notable that there is also no way to confirm whether participants from the mail-in rebate group learned about and applied for the $50 rebate after having already purchased their smart thermostat as Xcel Energy has no data to support whether rebate marketing led mail-in participants to purchase the thermostat versus simply applying the rebate. If an EE rebate is made available in the future, limiting that rebate availability to the Storefront or a similar channel will likely reduce freeridership significantly.

Second, results suggest that the Storefront leads to faster rebate processing and higher customer satisfaction. Eighty percent of respondents using the Storefront reported receiving the rebate immediately,[11] while most respondents who used the mail-in rebate (59%) waited more than two weeks to receive their rebate. Those who used the Storefront were also more satisfied with their rebate experience.

[11] Note that this is reflective of respondent recollections. Because the online rebate was by definition immediate, the 20% who didn't report receiving it immediately probably didn't recall or notice the rebate.

Third, the Storefront may provide an opportunity for increasing Xcel Energy DSM program awareness. Smart thermostat rebate recipients who did not also enroll in the Saver's Stat BYOT DR pilot were asked why they did not enroll: lack of awareness was the most commonly reported reason. By increasing and improving cross-program messaging it may be possible to drive customers to sign up in utility programs once at the Storefront. One can imagine a program design that uses a smart thermostat to drive traffic to the Storefront where customers are encouraged to enroll in relevant utility programs, such as a BYOT DR demand response program, or where free thermostat installation is offered if customers also sign-up for a home energy audit at the same time.

Key EE Survey Takeaways

- *Freeridership was significantly different by rebate channel: Storefront purchasers averaged 23% freeridership while mail-in applications exhibited 34% freeridership.*
- *Participants that purchased smart thermostats from the Storefront were more satisfied and received their rebates faster.*
- *The Storefront provides a channel to increase customer awareness of other Xcel Energy DSM programs and customer offerings.*

1.2 Saver's Stat: Demand Response Load Impacts

The primary metric evaluated for the BYOT DR pilot was electric load reductions during DR events. Correlation between reductions and outdoor temperatures during events were explored to assess potential impacts for hot days in particular. Differences in load reductions and participation were evaluated by outdoor weather, device vendor, and control strategy. Participant perceptions of events and of the pilot in general were collected through BYOT DR specific questions on a participant survey.

1.2.1 Residential BYOT DR Pilot Impacts

The key finding from the residential BYOT DR smart thermostat pilot is that there are substantial differences in delivered load reduction impacts by cycling strategy and mean outdoor temperature during the event. Figure 1-3 and Figure 1-4 plot the impacts from each individual event on the average outdoor temperature during the first two hours of each event for each device type. Controlling for other factors, impacts delivered by Vendor 1 devices were also estimated to be 60% higher than delivered by Vendor 2 devices. However, the impact estimate for Vendor 2 devices may not be reliable due to data quality issues.[12] Because of this it may not be valid to compare impact estimates for the two devices.

[12] Vendor 2 data is stored as status changes rather and intervals making it impossible to reliably identify individual missing status changes. Data for some event days was clearly missing for large numbers of thermostats (resulting in zero or flat

Other patterns were observed in the relationship between load impacts and cycling strategy and weather. Because these relationships were observed across device manufacturers they provide the basis for a more reliable comparison. Impacts were 50% higher for most control strategies compared to the 50% duty cycling strategy. Note that the duty cycling strategies did not directly decrease AC cycling through a complex algorithm, rather they imitated load switch functionality by turning the thermostat cooling function off and on at regular time increments. Impacts also appear positively correlated with outdoor temperatures; on hotter days air-conditioner ("AC") units would have otherwise run more often and at least part of this higher load potential does appear to have been captured during the BYOT DR pilot. Because the Colorado 2016 summer DR season was relatively mild, there were only a handful of event days with event window temperatures above 90 degrees and impacts for very hot system days could not be directly assessed. However, the positive weather correlation identified suggests that impacts of at least 1 kW on hot days could be delivered by Vendor 1 devices with higher performing control strategies such as 4 or 6 degree offsets. Data was insufficiently reliable to conclude whether similar impacts could be delivered by Vendor 2 devices. These elements merit further investigation in future pilots.

recorded runtime) and those event days were excluded from the average savings analysis but it is quite possible that thermostat data was also missing from other days but could not be identified. Zero or flat recorded runtime for some thermostats could affect the reliability of the impact estimate.

Figure 1-3: DR Event Impacts by Mean Event Temperature, Vendor 1 Devices

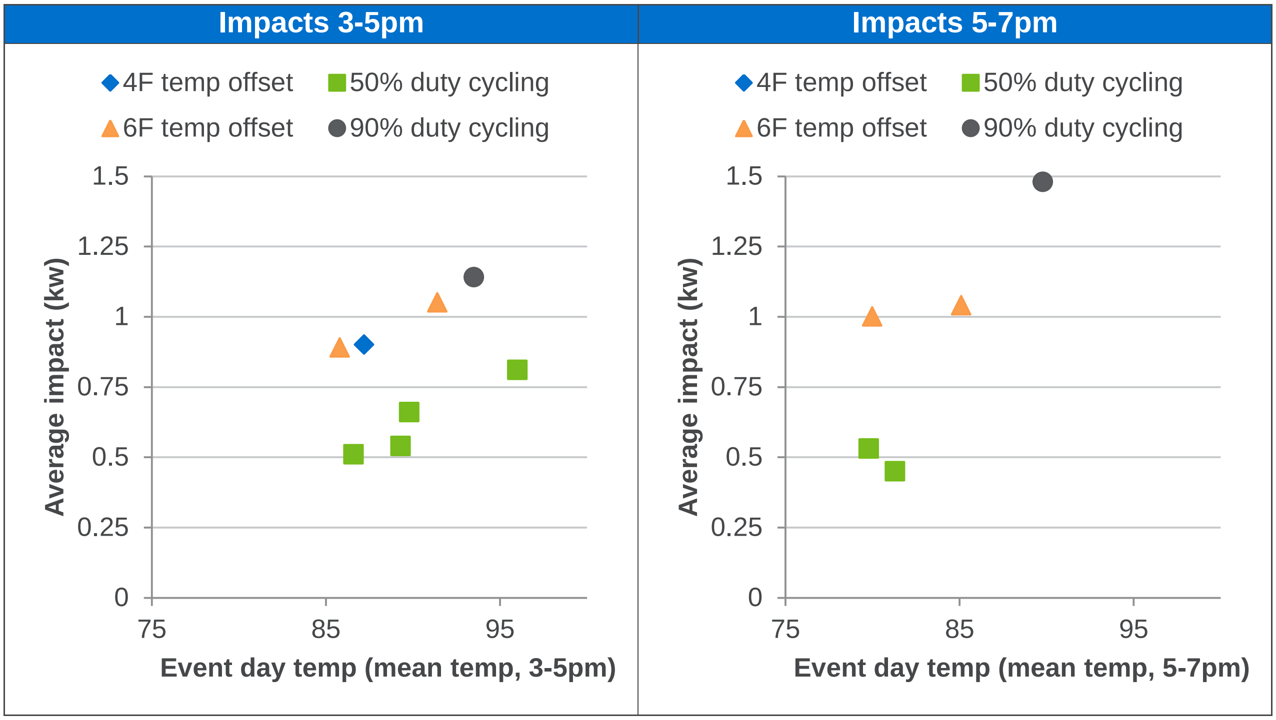
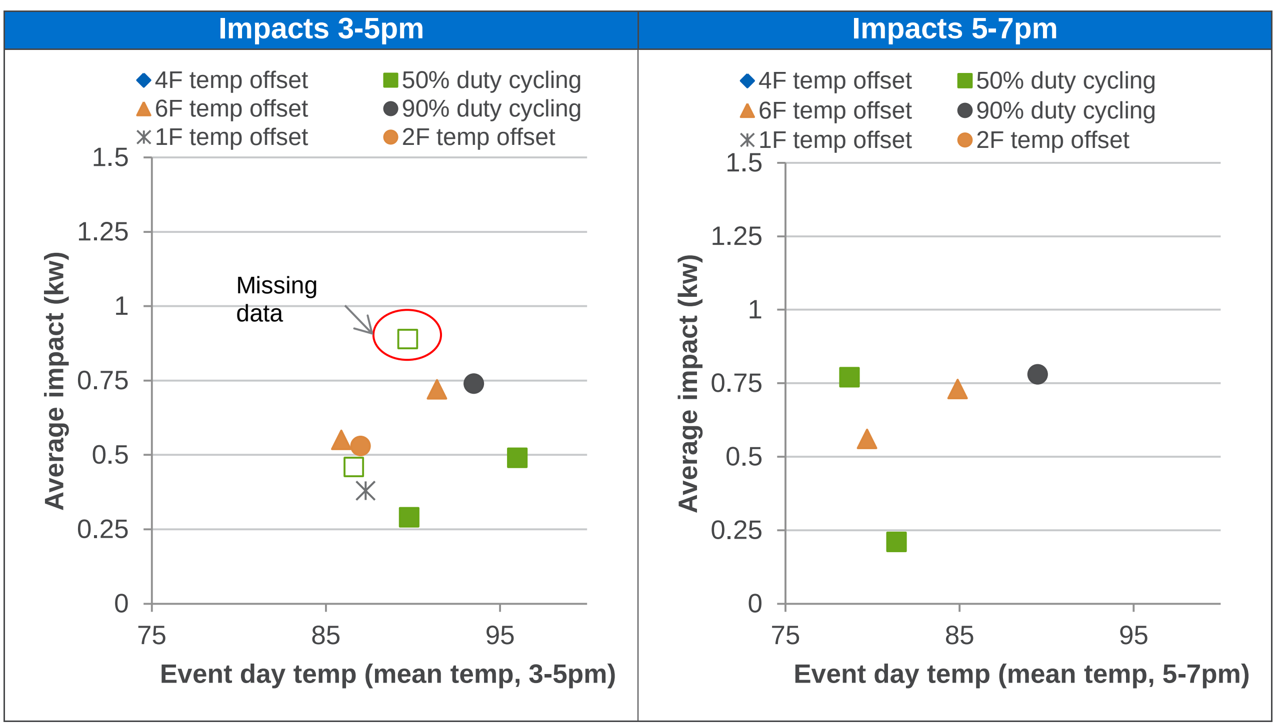


Figure 1-4: DR Event Impacts by Mean Event Temperature, Vendor 2 Devices



Key BYOT DR Impact Takeaways

- *For the smart thermostats tested 4-6 F degree offsets deliver 50% greater impacts than 50% cycling*
- *Event impacts of at least 1 kW per device could be expected on hot days*
- *Data quality rendered results unreliable for one vendor*

1.2.2 Saver's Stat: Assessment of Residential Customer Participation in DR Events

Participation and device availability was assessed in detail for BYOT DR events with the aim of answering the key research questions in Table 1-3.

Table 1-3: Event Participation Research Questions

Topic	Question	Finding
Participation rate summaries	What was the average participation rate across DR events?	Participation in the first 30 event minutes averaged 93% across events and devices. Most non participation was due to devices being offline (not connected) or being off (i.e., not in cooling mode).
	How did participation rate compare across control strategies?	Participation was not meaningfully different for the 50% cycling strategy than for other cycling strategies. The main driver of the slight difference appeared to be device connectivity and data issues for Vendor 2.[13]
Variables affecting participation rates	Was there any correlation between outdoor temperatures and participation?	No correlation was found.
Device availability	When did customers opt-out of events (right after receiving event notification, at the start of event, two hours into event, etc.)?	Participants progressively opted-out during offset events at a rate of roughly 3% to 5% per hour so longer events resulted in more opt-outs by the end of the event.
	What percent of the time were participant devices offline during	Across events, 3% to 10% of devices were typically offline and remained so

[13] For example, devices were only recorded as being off about halfway through the summer when the control strategy switched from 50% cycling to other approaches.

Topic	Question	Finding
	events? In the 15 minutes preceding events?	for the duration of events. Another 7% to 15% of devices were typically connected but not in cooling mode.

Key BYOT DR Participation Takeaways

- *High DR event participation and low opt-out rates across device vendors, control strategies, and mean outdoor temperatures during events*
- *No correlation of participation with weather, though longer events result in more opt-outs*
- *Participation not meaningfully different across control strategies*
- *On average, devices were either offline or not in cooling mode for about 10% to 20% of event minutes*

1.2.3 Residential Survey: BYOT DR Questions

Residential pilot participants were invited to complete a survey which included questions specific to the BYOT DR pilot enrollment and events as well as demographics. Key takeaways related to the Saver's Stat BYOT DR pilot may help identify key customer segments and inform future program design.

Average DR event impacts and event participation rates appear positively correlated with participant income and energy usage. Messaging targeted at these groups could help increase future DR event impacts by tapping into a segment with higher load potential and demonstrated event participation. In addition, 87% of respondents said they would participate again in Saver's Stat next year, indicating that there is likely high potential for reenrolling participants next year were the pilot to continue.

Finally, respondents who noticed DR performance incentives credited on their monthly Xcel Energy bill reported much higher satisfaction with Saver's Stat incentives than those who did not (57% highly satisfied compared to 17% of those who did not recall). Only about a quarter of respondents reported recalling the on-bill incentives, possibly in part due to not yet receiving those credits on their bill before taking the survey. However, the reported satisfaction with the incentives implies that the incentive level ($2.50 or $5 per event) is sufficient for participants and should be heavily messaged if continued in the future. At the same time, respondents who recalled receiving incentives were only somewhat more likely to report wanting to enroll next year (95% compared to 86% for respondents who did not recall incentives).

All Saver's Stat participants received a $25 gift card for enrolling in the pilot in addition to the performance incentives so it appears that this incentive may have been sufficient for most respondents. Notably, there was no significant difference in satisfaction with incentives between pilot participants who were completely new to Xcel Energy DR programs and those who were also participants in the longstanding Saver's Switch switch-based DR program. A gift card also has the advantage of potentially being noticed by more participants than an on-bill incentive as well as providing the opportunity to share additional messaging with participants. These and other incentive design options may merit further exploration as they can have an important impact on cost effectiveness.

Key BYOT DR Survey Takeaways

- *Average DR event impacts and participation rates appear positively correlated with participant income and energy usage.*
- *Few participants recalled receiving on-bill performance incentives (some may not have received them before taking the survey) but those that did were more satisfied and somewhat more likely to report wanting to re-enroll.*
- *However, re-enrollment intent and incentive satisfaction was still high overall. Incentive approaches merit further research.*

1.3 SMB Demand Response Pilot

The primary metric evaluated for the SMB DR pilot was electric load reductions per device during events. Correlation between reductions and outdoor temperatures during events could not be explored because all events were on days in September with moderate temperatures. Differences in load reductions and participation were also evaluated by control strategy and event window. Participant perceptions of events and of the pilot in general were collected through SMB DR specific questions on a participant survey.

1.3.1 SMB DR Pilot Impacts

The SMB DR pilot was much smaller than the residential pilot with a little over a hundred participating devices across several dozen small business sites. The SMB pilot used Vendor 2 devices and event dispatch software exclusively. It was a direct install pilot, meaning customers received smart thermostats and installation at no cost, instead of a BYOT design. The resulting software implementation, enrollment and installation period took longer than expected and DR events were only dispatched in September, with an average event temperature of 87 F and no event day temperatures above 89 F. As in the residential pilot, different control strategies and event windows were tested, albeit with a narrower scope as necessitated by the size of the pilot.

Table 1-4 summarizes impacts aggregated by control strategy and event window, resulting in four dispatch strategies:

- Three-hour, three-degree (F) temperature offset
- Four-hour, three-degree (F) temperature offset
- Three-hour, 50% duty-cycle
- Four-hour, 50% duty-cycle

Grouping event impacts in this manner enables a few relevant observations. The temperature offset control strategy appears to perform much better than the 50% duty-cycling strategy, mirroring results found for the residential BYOT DR events.

These observations provide confidence that impacts provided at this level of granularity are at least directionally meaningful, despite the imperfect alignment of pre-event predicted and actual loads. Average event impacts are estimated to be 0.46 kW to 0.54 kW for the 3F offset events and about one third of that for the 50% cycling events (0.15 kW to 0.17 kW). Precooling does appear to have delivered substantially higher impacts in the first hour, though impacts in subsequent hours appear lower when comparing to the 3F offset events without precooling (those on September 7 and 8). Given the mild temperatures during SMB DR events and the positive correlation between weather and load impacts observed for residential DR events, it is reasonable to assume that impacts would be higher for SMB DR events dispatched on hotter days.

Table 1-4: Vendor 2 SMB Event Impacts by Dispatch Strategy

Event number	Event date[14]	Control strategy	Event start	Event duration	Mean temp (F)[15]	Average hourly impact (kW)				
						16	17	18	19	Avg
1329.18[16]	7-Sep	3F offset	4 PM	3	85.4	0.34	0.77	0.40	0.22	0.46
1409.53	8-Sep	3F offset	4 PM	3	87.2					
1115.20	19-Sep	3F offset	3 PM	4	88.6	1.19[17]	0.55	0.23	0.18	0.54
1140.14	20-Sep	3F offset	3 PM	4	86.4					
1331.20	7-Sep	50%	4 PM	3	85.1	-0.31	0.28	0.16	0.07	0.17
1412.02	8-Sep	50%	4 PM	3	87.3					
1116.32	19-Sep	50%	3 PM	4	88.7	0.21	0.13	0.12	0.17	0.15
1138.48	20-Sep	50%	3 PM	4	86.3					

14 Impacts not shown for the events on September 1. Estimates not reliable due to the small number of thermostats connected on this day.

15 Average during first two event hours

16 About half of called devices were listed as non-responsive in the dispatch system. These devices were excluded from all analyses because data was not available for them. Applies to both events on this day.

17 Precooling in this hour

Key SMB DR Takeaways

- *Low impacts (~0.5 kW per device) due to mild weather and data challenges*
- *For the smart thermostat tested 3F offset performed much better than 50% duty cycling*

1.3.2 Small Business Survey

The SMB survey was completed by a sample of 26 respondents, well over a third of participants. This small scale survey provides directional insights into participant perceptions of the pilot and implications for future program design. In particular, only 62% of SMB respondents said they would re-enroll—much lower than residential respondents, though it is likely that most SMB participants were unaware of any performance incentives. While half of the remaining 10 (five respondents) said they wouldn't participate for any amount of incentives, the other half (four respondents) said they would consider participating level if event incentives were in the range of $30 to $50 per event. Comfort during events does not appear to be an issue for most respondents as only 17% reported reduced comfort during events. Notably, only 40% of respondents believe the smart thermostat helps save energy which may or may not be reflective of respondent experiences with their Vendor 2 thermostat given the short duration of the pilot. EE savings were not assessed for SMB participants as energy savings were not a goal or focus of the pilot.

Key SMB DR Takeaways

- *62% said they would re-enroll, despite that performance incentives were effectively not communicated to most participants*
- *Comfort not an issue for most participants but those reporting decreased comfort issues were less likely to want to re-enroll*

1.4 Implications for Future Program Design

1.4.1 Smart Thermostat EE Rebate

- The Vendor 3 thermostat appears to have default functionality that reduces the duration of manual temperature holds and increases the deployment of more efficient temperature setpoints due to inactivity in users' homes.
- It may be possible to identify a deemed EE savings value on the order of 250-300 kWh, 0.2 peak kW, and 9-11 therms for smart thermostats with similar functionality and default experiences as Vendor 3, and with a rebate available solely through an online marketplace similar to the Xcel Energy Storefront but this requires further research with more sample size to establish consistency and persistence of savings. Consistent and persistent savings at these levels may be enough to make a $50 rebate cost effective.
- Using the online Storefront exclusively to deliver the rebate and traffic for the rebate to drive awareness in other programs, such as Saver's Stat BYOT DR, could help reduce freeridership for the rebate and increase enrollment in other programs.

1.4.2 Residential Saver's Stat BYOT Demand Response

- Delivered impacts were substantially lower for Vendor 2 devices and for DR events that deployed a 50% duty-cycling control strategy. Research going forward should focus on other control strategies (e.g., temperature offsets with precooling) and other device manufacturers such as Vendor 1 or others not tested in this pilot. Focusing research on fewer control strategies in future pilots will also help produce more data points and greater certainty around impacts.
- Impacts appear to be higher on hotter days and may be 1 kW or more per thermostat on the hottest days for higher performing control strategies and devices. Continued, focused research will help better establish this value.
- Participation appears to drop by about 5% per hour during offset events but these control strategies still perform well, albeit with somewhat lower impacts in the final hours of an event.
- Households with higher energy usage appear to deliver higher impacts. Targeting accounts with energy higher usage, and therefore higher load potential, could increase load impacts per device and improve cost effectiveness.
- Survey respondents were reportedly satisfied enough that the vast majority (86%) would re-enroll next year. This was true even though most respondents did not recall seeing their on-bill performance incentives. Further research into incentive options (e.g., inclusion, levels, determinants) could help improve cost effectiveness. The quarter of respondents who did recall seeing their performance incentives were somewhat more satisfied and more likely to re-enroll. So, if event-based incentives are included going forward, they should be heavily messaged.

1.4.3 Small Business Saver's Stat Direct Install Demand Response

- A 3 degree temperature offset control strategy performs much better than 50% duty-cycling, as also seen in the residential pilot.
- Impacts for this higher performance dispatch strategy were about 0.5 kW per thermostat, which may be low compared to the cost of a direct-install program design.
- Implementation and technical challenges were encountered, adding to the cost and diminishing the performance of the pilot. These should be remedied in future pilots and programs.
- Precooling may deliver higher impacts, even more than 1 kW, but only in the first hour of an event. After the first hour impacts may be lower than average.

1.5 Other Considerations from Program Manager Perspective

The criteria evaluated in this report are directly tied to benefits, customer experience, and satisfaction. Benefits include EE savings, DR load impacts, and how they relate to thermostat usage and DR event participation. However, there are a variety of other considerations from the utility and program manager perspective. As highlighted by the various data related challenges, data sharing, partnership, and support from vendors are also key to delivering and validating program benefits and improving success through future improvements. Program cost is another important consideration; while some technologies may perform better, they may also have higher associated costs to the utility.

In addition, lessons learned from the program manager perspective can complement and reinforce learnings from the evaluation. Table 1-5 summarizes key lessons learned from the Xcel Energy smart thermostat pilots. Some of these reinforce evaluation findings (including customer satisfaction with devices and data related challenges), while many others capture the utility and customer experience beyond the evaluation. All are relevant to future program design.

Table 1-5: Pilot Learnings from the Program Manager Perspective

Things That Worked Well	Challenges Encountered
Ability to purchase device at the **Xcel Energy Store** & receive an instant rebate	**Initial contracting was difficult** because this technology was **outside the normal area of expertise** for the internal teams
Having a choice for eligible **thermostats at different price points**	**Managing six external partners** and coordinating across multiple internal teams required significant labor time
Multiple channels into the program	**Manual processes for reviewing applications** led to long lag times for rebate delivery
Ability to install the thermostats themselves	**Property eligibility rules were confusing** to customers and hard to enforce– led to a lot of customer support requests
Email marketing very successful & exceeded internal benchmarks for open and click- through rates	**Account eligibility** frustrated & confused customers that didn't qualify
Seasonal marketing tactics deployed in combination with the Storefront were very successful	**Significant technical challenges** with several thermostat **manufacturers' ability to deliver data** led to internal team having to manage multiple vendor portals and data streams
Customers were **pleased with the technology** once it was installed	Internal IT & Business Systems teams were unable to respond quickly when critical items popped up, requiring **time intensive manual work-arounds**
Smart thermostats offer a **wide range of DR control strategies**	**Encountered numerous technical challenges with some DR partners** in both residential and SMB pilots resulting in launch delays, unexpected results, and difficulty meeting Company's expectations
Two-way data stream added insight and near-real time performance results for DR events	
Recruiting for DR via the BYOT channel was successful and represented roughly 40% of DR pilot participants	

2 Introduction

As summarized in Table 2-1, Xcel Energy launched a residential smart thermostat pilot in June 2015 and an SMB pilot in early 2016. The residential pilot included a $50 smart thermostat EE rebate and a BYOT demand response pilot. The SMB pilot was a demand response pilot with direct installation of as many as five smart thermostats per participant premise. Vendors varied across all three pilot components and included Honeywell, Nest, ecobee, Radio Thermostat of America ("RTA"), and EnergyHub.[18] Xcel Energy's pilots were designed to test a variety of program models and thermostat manufacturers, and have provided a strong empirical basis for answering several important research questions and informing the Company's smart thermostat strategy going forward.

In particular, the smart thermostat pilots were designed to test the energy-efficiency ("EE") benefits and demand response ("DR") benefits, as well as the capabilities of smart, Wi-Fi connected thermostats. Table 2-2 and Table 2-3 summarize enrollment in each part of the pilot by each of the four thermostat manufacturers including Vendor 1, Vendor 2, Vendor 3, and Vendor 4. Note that Vendor 3 and Vendor 4 only participated in the smart thermostat EE rebate portion of the pilot. Vendor 2 was the only provider for the SMB pilot which included 61 participants and 130 devices. Vendor 4 chose not to offer the EE rebate-eligible CT50 thermostat on the Xcel Energy Storefront, relying solely on the mail-in rebate channel. EE savings were not assessed for the Vendor 4 devices due to their low numbers.

Table 2-1: Overview of Xcel Energy's Smart Thermostat Pilots

Segment	Program Model for EE	Program Model for DR	Per Event Incentive	Pilot Time Period	AC Control Strategy
Residential	$50 rebate	Upfront and event-based incentives	$2.50 or $5	Jun. 2015 to Dec. 2016	Tested a variety of strategies for research purposes including duty cycling (50%, 90%) and temperature offset (1F per hour, 2F per hour, 4F, 6F)
SMB	None	Direct install at no cost	Incentives by AC unit tonnage, only provided to 50% of participants	Feb. 2016 to Dec. 2016	50% duty cycling and 3F temperature setback w/ pre-cooling

[18] Vendor names have been masked throughout this report to anonymize results

Table 2-2: Enrollment in Residential Smart Thermostat EE Rebate Pilot[19]

Thermostat	Total EE
Vendor 1	1,237
Vendor 2	1,258
Vendor 3	3,796
Vendor 4	3
Total	6,294

Table 2-3: Enrollment in Residential Smart Thermostat BYOT DR Pilot

Thermostat	DR only	Both DR & EE	Total
Vendor 1	169	169	338
Vendor 2	337	97	434
Total	506	266	772

2.1 Residential Smart Thermostat Energy Efficiency Rebate

The EE portion of the pilot offered customers a $50 rebate for purchasing and installing a qualifying smart thermostat device. The original participation goal for the EE portion of the pilot was 5,000 customers. Customers could apply for the rebate from June 2015 to December 2016. In return for the rebate participants agreed to give Xcel Energy access to their thermostat usage data for research purposes. Two channels were available to customers applying for the rebate:

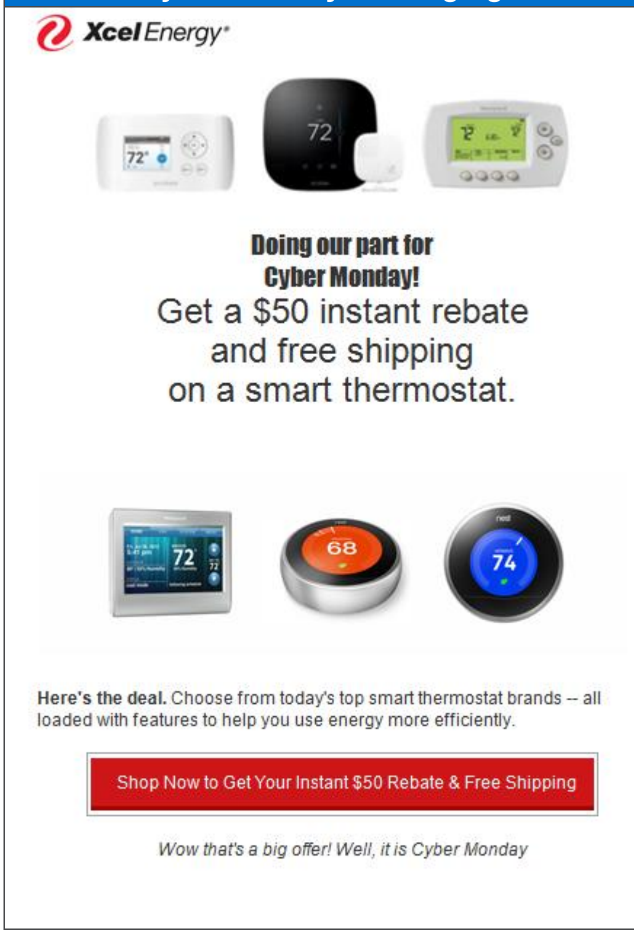
- Mail-in rebate: customers could receive a $50 rebate check by completing a rebate application, which required customers to provide the thermostat's serial number or MAC ID, and proof of purchase demonstrating the device was purchased during the pilot period
- Xcel Energy Storefront: customers could receive a $50 instant rebate applied to their transaction when purchasing the thermostat on the online Storefront

To market and recruit for the EE rebate pilot, Xcel Energy sent customers emails inviting them to purchase a smart thermostat on the Storefront. Two of these communications with different messaging are shown in Figure 2-1.

[19] Rebates processed by December 2016

Figure 2-1: Sample Smart Thermostat Rebate Emails

Cyber Monday messaging	Thermostat benefits messaging



The residential smart thermostat energy efficiency rebate pilot aimed to address the following filed research questions:

- What level of energy savings (kWh & peak kW) are attributed to the installation and use of smart thermostats? Can a deemed savings value be determined?
- Is a $50 rebate sufficient to encourage customers to purchase and install a smart thermostat?
- Is it possible to create a cost-effective DSM product using resulting deemed energy-savings values?

2.2 Residential Smart Thermostat BYOT Demand Response Program

The DR portion of the residential pilots allowed customers to participate in a pay-for-performance DR model. Participating customers received an upfront incentive ($25 gift card) to join the DR pilot, as well as an event-based incentive for each individual control event they participated in. DR participants were split into two groups that received different per-event incentives ($2.50/event or $5/event in CO). Note that the pilot was designed so that participants were not aware of the different incentive levels and groups; they were marketed to with an offer of “up to $50 in performance incentives” and a brief explanation of what event performance meant. All DR events were voluntary and all participant groups had the option to opt-out of any and all DR events with no penalty accrued.

Enrollment in the BYOT DR pilot was a multi-step process unlike the smart thermostat EE rebate. The first two steps in the BYOT DR enrollment process were to have an eligible smart thermostat installed (if not already installed) and to enroll in the pilot via online enrollment portals provided for each of the participating manufacturers, Vendor 1 and Vendor 2. Participants that received the $50 EE rebate for a new smart thermostat could not begin the DR pilot enrollment process before installing their smart thermostat. For participants with an eligible smart thermostat already installed, they would start at the online enrollment portal. Each thermostat manufacturer had their own enrollment portal that would collect and/or verify the following information:

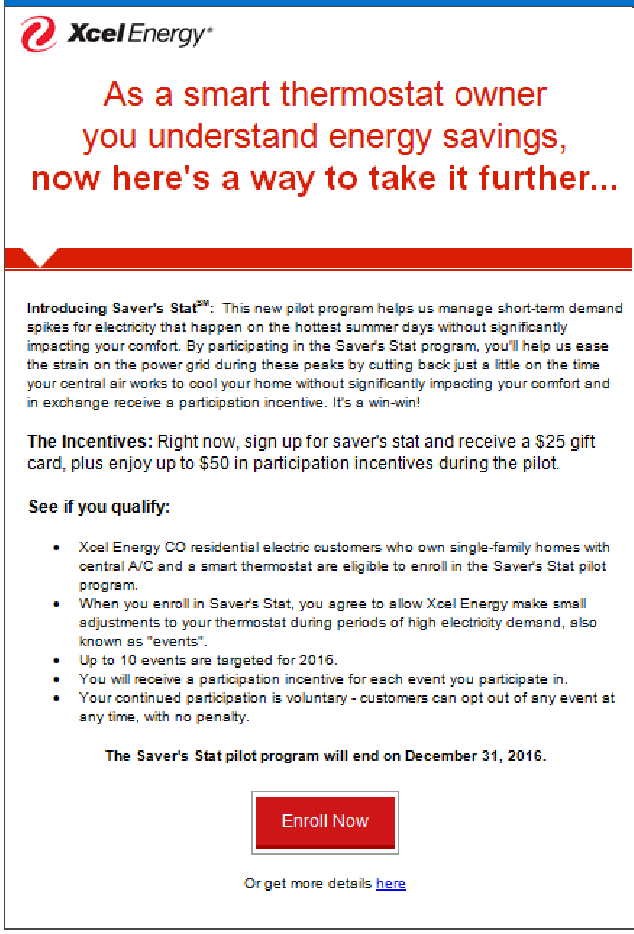
- Enrollee had an operational eligible smart thermostat and accompanying account registered with that manufacturer
- Enrollee authorized their selected thermostat(s) to be available and accessible for DR events, including all accompanying thermostat data needed for M&V
- Enrollee confirmed they met the pilot’s eligibility criteria and agreed to program terms and conditions

Xcel Energy would process enrollments by verifying enrollees’ account status and other relevant information as needed. Once approved, Xcel Energy’s DR aggregator partner would connect the device to their DR dispatch portal. This step provided an additional confirmation that the customer did indeed have an eligible, functioning smart thermostat. Once the connection was confirmed the enrollment was finalized and the participant was sent a $25 gift card enrollment incentive via email.

As shown in the sample emails in Figure 2-2 Xcel Energy sent messaging about the BYOT DR pilot both to customers known to have smart thermostats (aka “existing smart thermostat owners”) and to other customers with cross marketing of the smart thermostat EE rebate (aka “new smart thermostat owners”). Figure 2-3 shows sample emails that Xcel’s DR partners sent to their own customer base of existing smart thermostat owners within Xcel Energy’s Colorado service territory.

Figure 2-2: BYOT Pilot Messaging Sent by Xcel Energy to Customers

Targeting existing smart thermostat owners	Targeting new smart thermostats with cross marketing offer of smart thermostat EE rebate



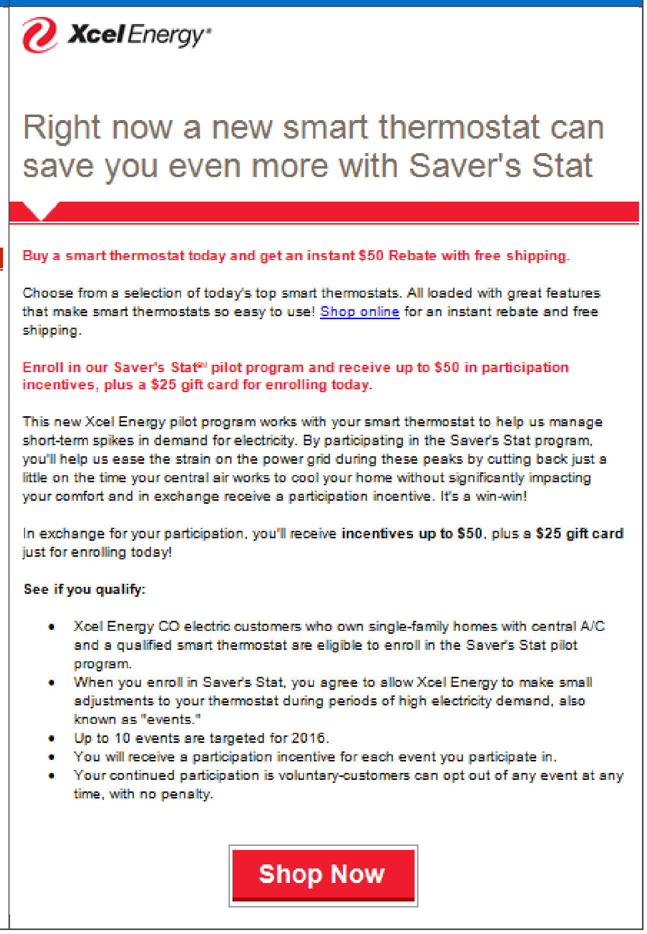
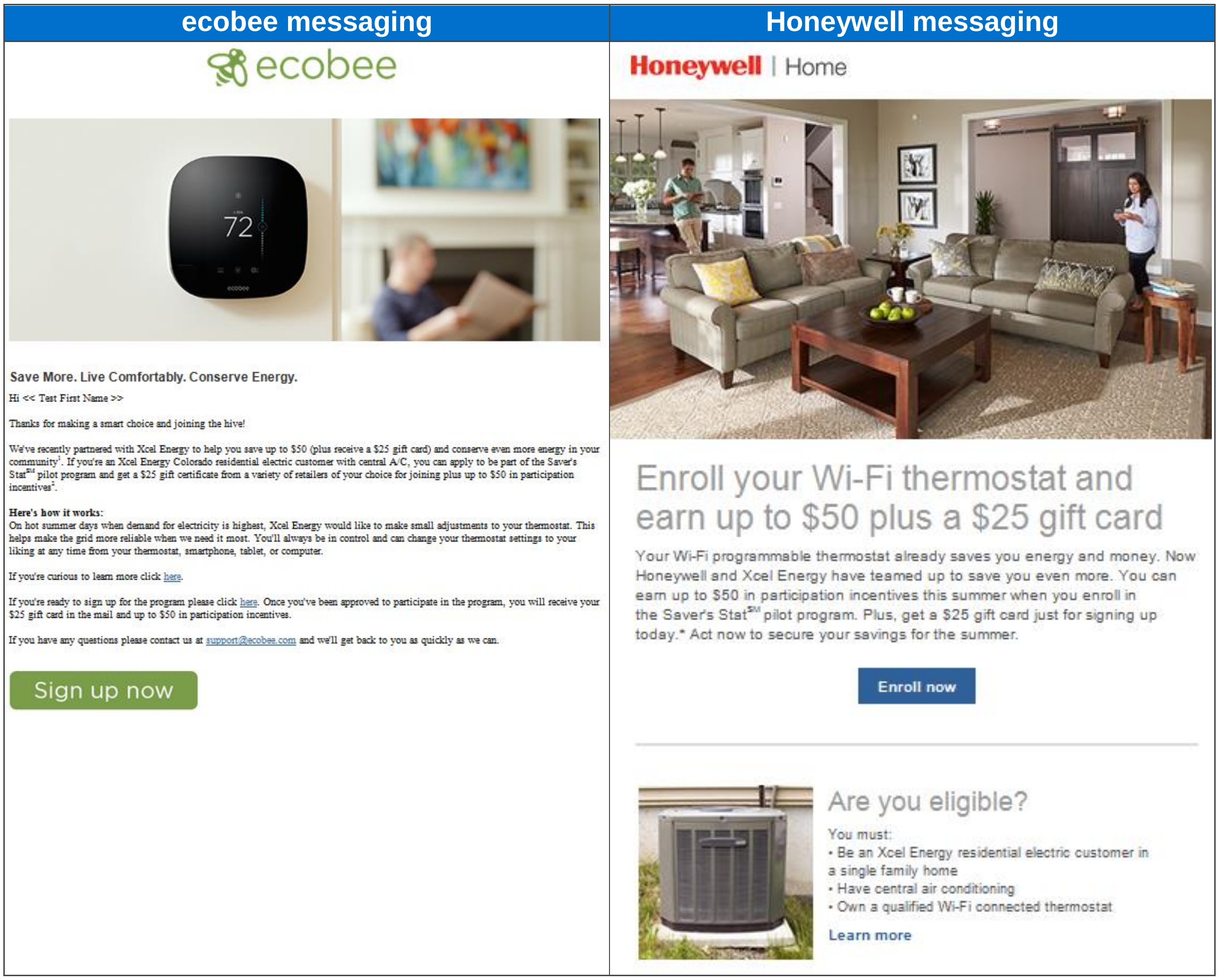


Figure 2-3: BYOT Pilot Messaging Sent by Providers to Existing Customers



The residential smart thermostat DR pilot aimed to address the following research questions:

- Will a pay-for-performance compensation structure encourage consistent participation in demand response events?
- What incentive levels are needed to optimize participation and demand savings during control events?
- To what degree are customers interested in a "bring your own device" type of demand response program model?

2.3 Small Business Smart Thermostat Demand Response Pilot

The SMB DR Pilot was focused on the DR benefits available through smart thermostats utilized by small and medium-sized businesses. A total of 61 participants were enrolled and a total of 130 thermostats were installed. While the pilot allowed as many as five smart thermostats installed for each participant's premise, participants averaged installing about two thermostats per premise. Eligible participants needed to have an annual peak demand of 100kW or less, experience summer weekday cooling loads, and have no more than five existing thermostats per premise. Participants were allowed to enroll multiple premises.

The pilot was a direct-install model, supplying devices and installation to customers at no cost. In return, customers were enrolled into the DR pilot. The SMB pilot partnered exclusively with Vendor 2 for devices and DR dispatch software that included online enrollments and access to thermostat data. Figure 2-4 shows sample communications used by Xcel Energy to message the pilot to customers, including an email and a flier used as a handout at an in-person event for commercial DSM programs.

Figure 2-4: SMB Pilot Messaging Used by Xcel Energy

Email to SMB customers

Xcel Energy

Get up to 5 smart thermostats installed at no cost just in time for cooling season.

Xcel Energy is excited to offer the Saver's Stat pilot program to qualified Colorado small business customers with central cooling systems. As a participant in the program you'll receive up to five WiFi connected Honeywell WiFi 9000 smart thermostats installed at your business or facility at no charge. You agree to allow Xcel Energy to make adjustments to your thermostat during hot summer days. When the demand for electricity is highest, you'll help Xcel Energy manage these peaks by cutting back just a little on the time the central air works to cool your business, known as events. Participating customers are free to opt-out of any and all events they choose without any penalty.

Program benefits

- **Free** - Receive up to five Honeywell WiFi 9000 smart thermostats (estimated retail value $200 per thermostat) plus installation for free.
- **Control** - Adjust the temperature as you like and watch the smart thermostat respond to your business' schedule.
- **Convenience** - Access anytime, anywhere to quickly check the status of your business - via a mobile app or the Internet using your smart phone, computer or tablet.
- **Optimize Energy Use** - The combination of easy scheduling, remote control, and access to equipment data means you can optimize your business's HVAC energy usage and maximize comfort.
- **Benefit to the Community** - By helping to reduce the electricity demand during hot summer days so everyone has power.

Take advantage of this terrific offer and sign-up today.

Get started

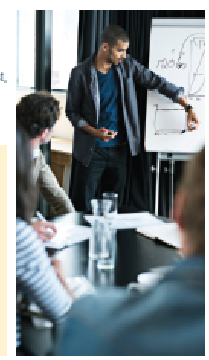
Flier used at DSM program event

Xcel Energy
RESPONSIBLE BY NATURE

Colorado Saver's Stat℠ Smart Thermostat Pilot Program for your business

Receive a smart thermostat and installation for free

About the program:
By participating in the program you'll receive up to five WiFi connected Honeywell WiFi 9000 smart thermostats installed at your business at no charge by an Xcel Energy participating contractor. You agree to allow Xcel Energy to make adjustments to your thermostat during blistering-hot summer days. When the demand for electricity is highest, you'll help us manage these peaks by cutting back just a little on the time your central air works to cool your business. You'll have the ability to opt out of these events, at your thermostat and return to your normal settings.



Saver's Stat smart thermostat program offers:

- **Free** – Receive up to five Honeywell WiFi 9000 smart thermostats (estimated retail value $200 per thermostat) plus installation for free.
- **Control** – Adjust the temperature as you like and watch the smart thermostat respond to your business' schedule.
- **Convenience** – Access anytime, anywhere—via a mobile app or the Internet using your smart phone, computer or tablet.
- **Benefit to the community** – By helping to reduce the electricity demand during blistering-hot summer days so everyone has power.

Details:

1) To participate in Saver's Stat you must receive business electric service through Xcel Energy and have central air conditioning. Evaporative coolers do not qualify.
2) You must also have a local WiFi network that the Honeywell WiFi 9000 can communicate with.
3) If approved, a representative from Xcel Energy's participating contractor will contact you to schedule the smart thermostat installation. In order to be eligible, your annual peak demand must be 100 kW or less, you must have summer weekday cooling loads, and no more than five thermostats at the desired premise.
4) There will be approximately ten event days scheduled this summer and you'll have the opportunity to opt out of these events.

If you are interested in enrolling or have additional questions send an email to SmartThermostat@xcelenergy.com.

Yes, I'm interested to learn more:

Name: ____________________ Email: ____________________

Address: ____________________

State: __________ Zip: __________

- ☐ I have central AC in my business and a local WiFi network available for the smart thermostats.
- ☐ My facility's annual peak demand is less than 100 kW and experiences summer weekday cooling loads.
- ☐ My facility currently does not have more than five thermostats.
- ☐ I'm interested in receiving smart thermostats and installation, and participating in the Saver's Stat Program.

Daytime phone: ____________________

Evening phone: ____________________

Please note: To qualify, you must be an Xcel Energy business electric customer with central air conditioning in Colorado. You will need an Internet-connected wireless network. Other restrictions may apply.

Participants were split into two groups: one group received an event-based, pay-for-performance incentive for every event they participated in, while the other group received no pay-for-performance incentive (beyond the thermostats at no cost) for participating in events. Marketing materials did not promote performance incentives to customers. Additionally, two different load management strategies were deployed. Approximately half of pilot participants were controlled through a duty cycling strategy while the other half were controlled using a temperature offset strategy that also utilized precooling ahead of some of the DR events. All DR events were voluntary and all participant groups had the option to opt-out of any and all DR events with no penalty accrued.

The CO SMB DR Pilot aimed to address the following research questions:

- For the cooling loads typically seen for this customer segment in this climate, what level of demand response does this technology deliver (kW/ton)?
    - When using a cycling strategy?
    - When enabling pre-cooling and temperature set-up strategy?
- Will customers consistently participate in DR events?
    - Without an incentive beyond the value of the smart thermostat?
    - With a pay-for-performance compensation structure?
- Are small business customers interested in this type of program?
- Can a direct install deployment method be cost-effectively administered?
- Could smart thermostats be effectively delivered within the Lighting – Small Business product's direct install approach?

2.4 Report Organization

The remainder of the report is organized as follows:

- Section 3 provides a methodology overview for each analysis component of the evaluation of the Xcel Energy smart thermostat pilots.
- Sections 4 and 5 provide results for the assessment of energy savings and DR load impacts, respectively.
- Sections 6 and 7 cover the analysis of BYOT event participation and modeling of smart thermostat functionality and how these devices were used by customers.
- Sections 8 and 9 provide detailed results for the residential and SMB surveys.

3 Evaluation Methods

The impact of installing a smart thermostat can be broken into two discrete types. The first type of impact is energy savings and was only estimated for residential energy efficiency pilot participants.[20] These long-term impacts on energy usage during typical days when no DR events are called ("nonevent days") may reduce energy usage (kWh and therms) year round. Sections 3.1 and A.3, respectively, describe the different methodological approaches used to estimate energy savings (kWh) and nonevent day load reductions (kW).

The second type of impact is the incremental demand reductions resulting from controlling the thermostat during DR events. This short-term impact appears only during a select few hours on a small set of days when DR events were dispatched ("event days"). Section 3.2 describes the approach used to estimate these event-based load reductions (kW).

3.1 Estimating Residential Energy Efficiency Savings

The key goal of the EE savings analysis was to estimate both annual electric and gas savings (kWh and therms) and nonevent day electric load reductions (kW), which together represent the primary EE benefits of the residential smart thermostat EE rebate. The primary approach to estimating these residential EE savings was to use a combination of matched control group and difference-in-differences regression. Estimation of nonevent day peak load impacts for EE participants was triangulated by using two complementary data sources: observed energy savings for Xcel Energy pilot participants and hourly energy savings observed in another study of smart thermostats where hourly interval data was available[21].

A net savings adjustment was applied to these gross estimates to account for any freeridership. Both gross and net savings estimates were combined with thermostat usage data including set points and thermostat settings and participant information collected in the survey to assess how various factors interact to influence the impact of the pilot. Magnitude and consistency of EE savings, as demonstrated through statistical significance, was also assessed to identify whether a deemed savings value can be claimed for thermostats benefitting from an energy efficiency rebate.

3.1.1 Constructing a Matched Control Group for Energy Savings Estimate

The first step in estimating residential electric and gas energy savings was to develop a matched control group. The matched control group of nonparticipants was comprised of the counterfactual for the estimation, which in this case refers to what electric and gas usage would have been in absence of the pilot.

Figure 3-1 summarizes the input, analysis, and output for developing the matched control group. Nexant developed the matched control group using pre-treatment usage data for electricity and gas.[22] Since gas usage might have logically differed significantly during summer and winter

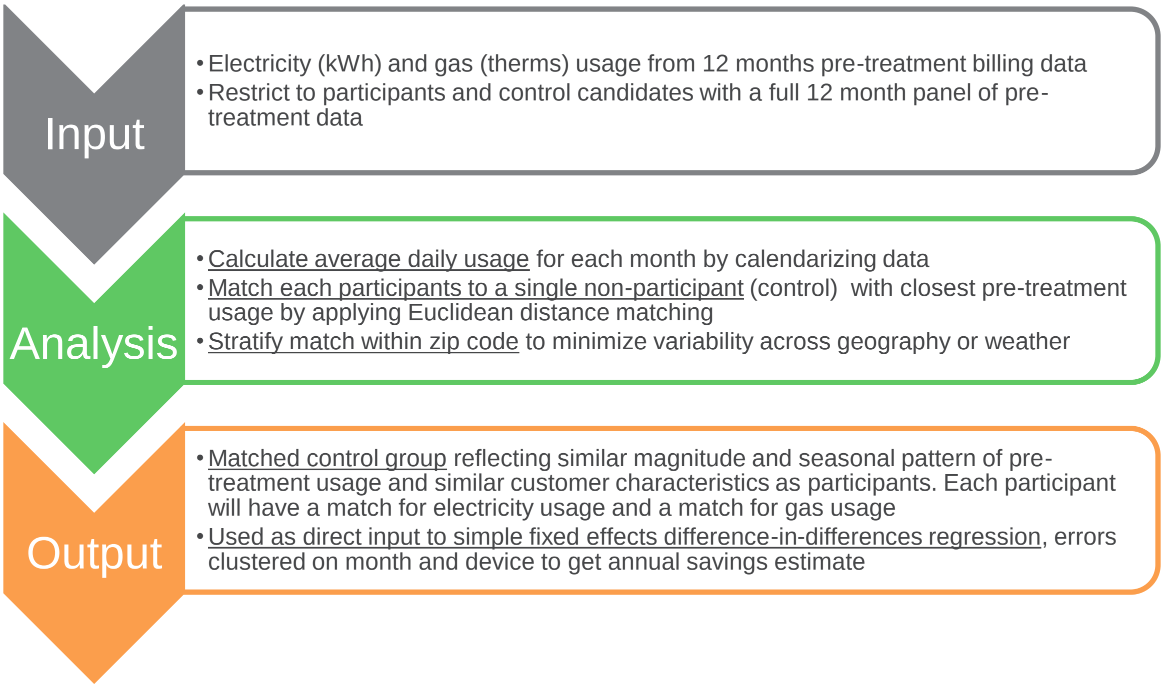
[20] SMB customers only participated in the demand response component of the smart thermostat pilot

[21] Completed as part of the SDG&E Small Customer Technology Deployment (SCTD) program

[22] For peak winter months (Dec through February) and summer months (July through August) for electricity usage and non-summer months (October through May) for gas

months, Nexant focused the match on periods of highest space conditioning energy usage. Multiple matching approaches[23] were assessed to determine the superior match.

Figure 3-1: Matched Control Group Approach



This general approach was used to develop a matched control group that resembles the participant population in terms of pre-treatment monthly consumption patterns within the same geographic area. Specifically, Euclidean distance matching was used to find for each participant a single nonparticipant who is the most similar to the participant in terms of monthly consumption prior to the installation of the thermostat. These pre-treatment differences were calculated by adding up the squared differences in average daily consumption between the participant and the match candidate. Because a match could be pulled from the entire pool of more than 1.2 million residential Xcel Energy account premises in Colorado, it was possible to perform the matching within groups stratified by close geographic proximity (e.g., within zip code). This approach helped ensure that there weren't any exogenous differences between the treatment and matched control groups that would produce differences in energy usage other what can be attributed to the smart thermostats.

To ensure the closest match and to accommodate stratifying matches within the non-usage characteristics detailed above, a large pool of data for potential control group matches was required. Nexant pulled candidates from all residential Xcel Energy Colorado customers who

[23] Including matching on all 12 pre-treatment months and restricting match only to the months of July and August when air conditioning usage is typically highest.

were active at any time during the energy efficiency pilot and who had a full 12 months of pre-treatment electricity and gas usage data.[24,25]

Once the match was selected impacts were estimated using a fixed effects difference in difference regression. This approach, covered in detail in Appendix A, enabled pooling of monthly impacts across a fluctuating monthly sample to derive an aggregate annual impact estimate in addition to monthly estimates. The annual estimate was in turn used to derive a net savings value by applying a net-to-gross adjustment.

3.1.2 Net-to-Gross Adjustment and Deemed Savings Value

Nexant estimated the pilot's net energy savings by adjusting for freeridership. Net savings are the savings directly attributable to a program and account for the actions that the participant would have taken in absence of the program (freeridership). A program net-to-gross ratio (NTG) equals the net program energy impact divided by the gross program energy impact. Nexant derived net savings by adjusting the realized gross energy-savings estimates determined during the impact evaluation to account for freeridership. Nexant utilized an approach for NTG methodology based on guidance from relevant industry documents:

- EPA's Energy Efficiency Program Impact Evaluation Guide (the EPA Guide).[26]
- The National Renewable Energy Laboratory Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific (the "NREL Guide"). Chapter 23—Estimating Net Savings: Common Practices.[27]
- Energy Trust of Oregon Freeridership Methodology, Phil Degens and Sarah Castor, June 4, 2008.

The general principles outlined in these publications have formed the foundation for determining freeridership for many years and are widely accepted by the evaluation industry.

The preferred definition of the NTG ratio is shown in Equation 3-1:

Equation 3-1: Net-to-Gross Calculation

$$NTG = 1 - Freeridership$$

Freeridership refers to a participant who, on some level, would have acquired the energy-efficient equipment or taken action to reduce their energy use in the program's absence. The effect of freeriders reduces the gross savings attributable to the program. Freeriders

24 Because participants obtained their smart thermostats across a span of several months, the pre-treatment period is specific to each participant and the determination of pre-treatment data availability was done separately for each participant.

25 Ideally, Nexant would have selected matches only among nonparticipants who fulfilled the criteria required to qualify for the rebate (aside from purchase of a smart thermostat following criteria). This includes pulling from a matching pool of nonparticipants (1) with a central air conditioning unit, (2) in a single family home (including townhomes, but excluding typical multifamily condos), (3) with a home WiFi network, (4) and to be willing to share their anonymized data with Xcel. However, these are unobservable for the match candidate pool as Xcel customer data does not track any of these customer characteristics.

26 http://energy.gov/sites/prod/files/2013/11/f5/emv_ee_program_impact_guide.pdf, Chapter 5.

27 http://www.nrel.gov/docs/fy14osti/62678.pdf.

are customers who receive the $50 rebate, but would have purchased the device regardless of the rebate's existence. The net savings estimates were adjusted for customers who indicated in the participant survey that the rebate had little to no influence on their decision to purchase a smart thermostat. In the standard freeridership calculation protocol, an average adjustment factor was calculated at the individual participant level across a sample of survey respondents. Then, the average factor was applied to average energy savings. However, this implicitly assumes that there was no difference in savings between freeriders and participants who were influenced by the pilot. If this was not the case, though, applying the same freeridership factor to all energy savings could result in an under or overestimation of net savings. For example, if freeriders also delivered lower energy savings, applying an average factor to all participants will underestimate savings.

Because the analysis was conducted at the individual customer level, it allows for estimation of gross and net savings by thermostat provider and other factors. In addition, with individual customer analysis, freeridership factors were applied at the individual participant level, essentially removing these freeriders (and their associated control group match) from the net savings estimation. This is particularly important for development of a deemed savings value that reflects that program design that Xcel Energy may choose to use going forward. If savings or freeridership vary significantly by elements that are under Xcel Energy's control, such as thermostats' user experience or enrollment and rebate application channel, Xcel Energy can design a program that minimizes freeridership and maximizes savings. Any deemed savings value should reflect this.

For the estimation of freeridership, Nexant followed an industry standard approach where the overall freeridership score was derived from two independently calculated elements, each of which is worth half of the total score: a stated intention score and an influence score. Program participants were surveyed and the responses were rated on a scale of zero to one and resulted in a participant being considered a full free-rider (1), partial free-rider (spectrum between 0 and 1), or non-free-rider (0). There was an inherent risk of "self-report bias" in the self-report survey approach commonly used for estimating freeridership because the respondents were asked to describe hypothetical actions of what they would have done in the absence of the utility program. To address and mitigate the effects of self-report bias, Nexant used an industry standard, two-step survey approach to estimate freeridership levels for each participant surveyed:

1. **Assess intention.** These questions asked respondents about the likelihood of carrying out the energy-efficiency measure (e.g., purchasing a smart thermostat) without the program's support (e.g., the $50 rebate); this is also known as counterfactual information (scored between 0 and 0.5).

2. **Assess influence.** These questions gathered information regarding the rationale behind taking the energy-efficiency action to determine the program's direct influence (scored between 0 and 0.5).

Participant level freeridership was calculated as the sum of the *intention* and *influence* components, resulting in a value between 0 and 1.0:

Freeridership = Intention + Influence

The intention and influence questions are two standard evaluation questions[28] and were included the residential participant survey, summarized in Table 3-1 (the full survey instrument is provided in Appendix D and the analysis is provided in detail in Section 8). The first question (Q3) gauges each respondent's intention, or what they would have done in the absence of the program. The pilot's "intention score" for each respondent is the score (in brackets) corresponding to their selection. The second question (Q4) gauges the influence each program element had on each respondent's choice to participate. The pilot's "influence score" for each respondent is the score corresponding to the maximum influence rating for any program element (where the maximum rating is 5: Extremely important).

The total freeridership factor for each respondent is the sum of the intention and influence scores. This represents the portion of savings that should be discounted to account for freeridership. For example, if the freeridership factor is 0.25, net savings will be 75% of gross savings.

[28] For background on standard freeridership protocols, see *Evaluation Framework for Pennsylvania Act 129 Phase Ii Energy Efficiency And Conservation Programs*, Appendix F.

Table 3-1: Freeridership Survey Questions and Scoring

<table>
<tr><th>#</th><th>Type</th><th colspan="7">Question Text [scores in brackets]</th></tr>
<tr><td>Q3</td><td>Intention</td><td colspan="7">You were offered a $50 rebate for purchasing a smart thermostat. <u>Imagine you had never learned that Xcel Energy was offering a rebate</u> for the purchase of a smart thermostat.
Which of the following best describes what you <u>would have done</u>?
1. I would <u>not have purchased</u> a thermostat at all [0]
2. I would have purchased a <u>standard thermostat</u> (e.g. without smart capabilities) [0.125]
3. I would have purchased a <u>smart thermostat</u> without the rebate [0.5]
4. I would have purchased a <u>smart thermostat</u> without the rebate a year or more later [0]
5. Don’t know [0.25]</td></tr>
<tr><td rowspan="6">Q4</td><td rowspan="6">Influence</td><td colspan="7">Please indicate on a scale of 1-5 how important each of the following was in <u>your decision to purchase a smart thermostat</u>.
I purchased my smart thermostat because…</td></tr>
<tr><td></td><td>1: Not at all important [0.5]</td><td>2 [0.375]</td><td>3 [0.25]</td><td>4 [0.125]</td><td>5: Extremely important [0]</td><td>Don’t know [0.25]</td></tr>
<tr><td>…the rebate lowered the cost of the thermostat.</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
<tr><td>…it was easy for me to purchase the thermostat through Xcel.</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
<tr><td>…it was easy for me to apply for / receive the rebate through Xcel.</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
<tr><td>…the Xcel offer made me think this smart thermostat could help me save energy.</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
</table>

Assessment of a deemed savings value for the pilot is one reason why Nexant segmented results by thermostat provider and by pilot elements. Table 3-2 summarizes segmentation variables Nexant used to assess results. Inclusion of these segmentation variables and any others Xcel Energy may request is contingent upon availability of sufficient data. Comparing results for two very small segments will not yield meaningful results because small sample size will diminish the ability to compare segments.

Table 3-2: Segmentation Variables for Assessing Consistency of Results

Source	Variable	Segments
Program Elements	Thermostat Provider	Vendor 1, Vendor 2, Vendor 3
	Participation	EE only, dual enrollment (EE plus DR)
	Rebate Channel	Mail-in, online storefront

3.2 Estimating Ex Post Impacts of Demand Response Events

Demand response event impacts were estimated for participants in the two demand response pilots, the residential Saver's Stat pilot and SMB pilot. Load impacts were evaluated on demand response event days.

As described above, a critical component in evaluation design is determination of the counterfactual—what would have happened in the absence of the pilot. In the case of a demand response event, the counterfactual, or reference load, is what the electric load would have been had the event not been called. To estimate reference demand loads, Nexant used observed demand loads from nonevent days with similar weather during the pilots' control event season, aka "event proxy days."

The data inputs, analysis, and outputs for Nexant's evaluation approach for BYOT DR load impacts are summarized in Figure 3-2. Similar to the EE savings analysis, Nexant used a matched control group approach to derive a counterfactual for the impact assessment.[29] However, there were three primary differences for the DR impacts analysis. First, the matched control was constructed by comparing DR pilot participant and nonparticipant loads on nonevent days during the DR event season, rather than by comparing load in a pre-treatment period.

Second, rather than pull the matched control group from customers who had not participated in either pilot (as in the EE savings analysis) the match for the DR analysis was pulled from among customers who had participated in the energy efficiency rebate pilot but not in the BYOT DR pilot. This was possible because runtime data was also available for energy efficiency participants. In addition, it ensured that the control group was pulled from a pool of customers with similar characteristics to participants: the same technology was present, air conditioning was likely present, and there was a demonstrated interest in utility programs. Because the available pool of control candidates was small,[30] the match was not stratified by other characteristics such as zip code.

Third, since the matched control group was developed using data from within the DR season there was no need to correct for systematic differences between pre- and post-treatment periods with a difference-in-differences regression. Unlike the EE savings impacts, which were estimated using a panel regression, the DR impacts were simply calculated by taking the difference between control and participant loads during event hours. In this approach, electric loads for each control group customer during the DR event hours are the reference load, meaning the estimate of what electric loads would have been for each DR participant on event days. Impacts were estimated by simply subtracting observed loads from DR pilot participants from these reference loads from matched control group participants. The key input to both the matching analysis and the impact assessment were post-treatment AC interval loads constructed from thermostat runtime data and other data sources, as described in Appendix C.2. Event day participation data enabled Nexant to calculate impacts for each event only

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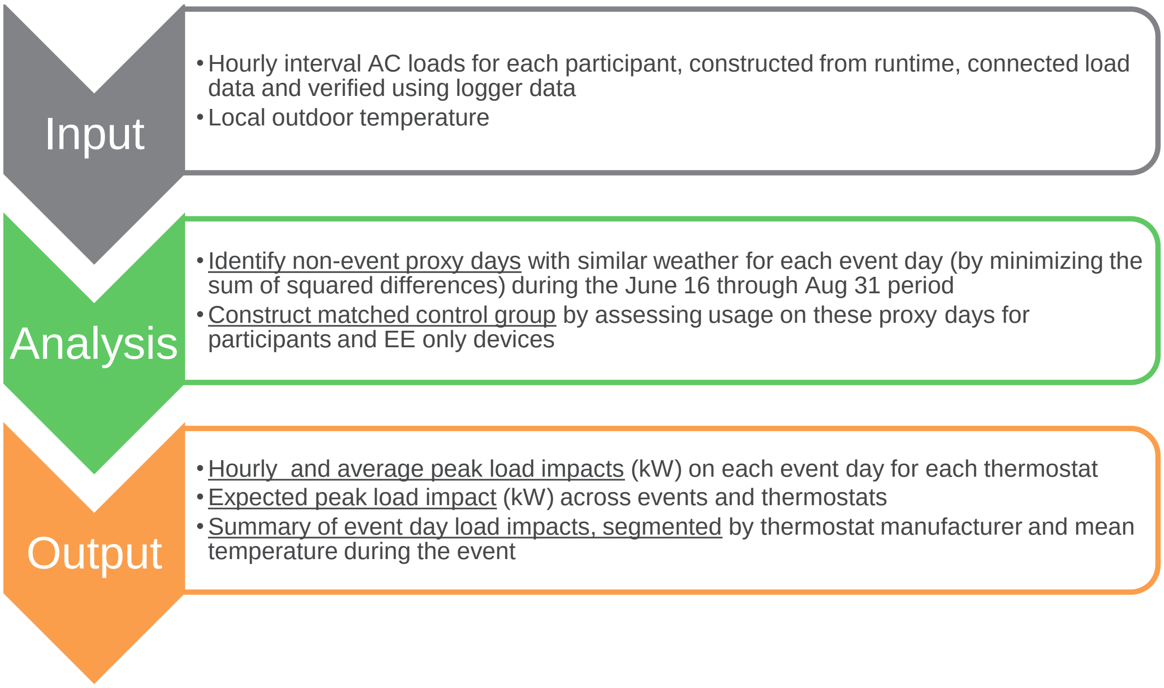
[29] The approach used to estimate SMB DR impacts also included development of proxy day loads but relied on a within subjects pre / post regression approach rather than a matched control group approach because a control group pool was not available. The SMB methodology is addressed in detail in Appendix B.

[30] Hundreds of customers, for a pool roughly twice the size of the participant pool, compared to the hundreds of thousands of customers available for the control candidate pool for the energy savings analysis.

among the subset of participants called during that day, a key step given that participants were subdivided into various dispatch groups by thermostat manufacturer and incentive level.

Figure 3-2: Estimation Approach for DR Event Impacts



3.2.1 Constructing a Matched Control Group

Similarly to the EE savings analysis, the first step in estimating residential electric load impacts was to develop a matched control group. The matched control group of nonparticipants comprised the counterfactual for the estimation, which in this case refers to what electric load would have been in absence of the event.

The DR impact analysis consists of proxy days for each event—nonevent days with similar weather, and identifying for each participant for each event a control customer who was not called. Given that the control customer and participant had similar loads on nonevent days with similar weather, the control customer's load was used as a reference load for estimating impacts on event days.

Because runtime data was only available for Vendor 2 devices enrolled in the BYOT DR pilot, the matched control group was pulled from EE participants with Vendor 1 devices for the assessment of impacts for both Vendor 1 and Vendor 2 devices. Table 3-3 summarizes the number of devices included in the matching analysis. Note that the process of constructing a matched control group was done individually for each participant and each event so a given participant may have a different match for each event.

Table 3-3: Devices Used in DR Matching Analysis[31]

Participant Group	Used in Matching	Total Vendor 1 Devices	Total Vendor 2 Devices	Vendor 1 Devices after Matching Analysis	Vendor 2 Devices after Matching Analysis
DR (includes dual participants)	Treatment	282	349	281	349
EE	Control	386	--	336	--

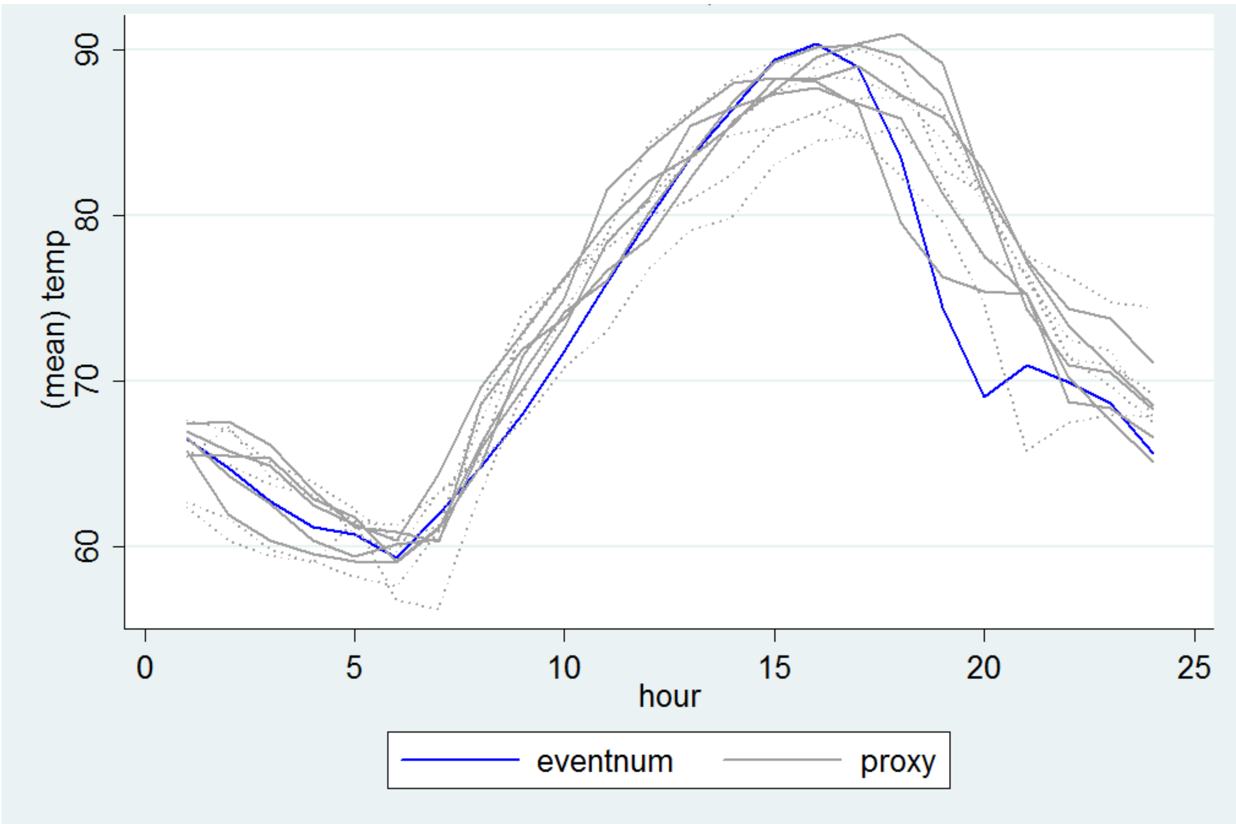
Next, proxy days were selected for each event. Because some respondents were not called on every event day, proxy days for a given event and participant could be drawn from any day on which that participant was not called.[32] This also means that it was not practical to summarize proxy days in a simple table. In addition, for individual participants the exact event days may have varied somewhat due to data availability.

Figure 3-3 shows the event day and proxy day temperatures for June 28, 2016, which was the second event day called in Colorado. The event day temperatures are shown in dark blue, temperatures for the five closest proxy days are shown in grey and temperatures for the next closest days are indicated with dotted lines.

[31] Total devices include devices for which interval data was available for June through August was available (full panel not required) and for which participation (DR vs EE vs both) could be determined. Devices after matching analysis includes has fewer devices for Vendor 2 because matching was done with replacement so a single control device can be matched with more than one treatment device.

[32] A substantial amount of DR and EE participants were also enrolled in Xcel's Saver's Switch DR program. The two control days June 21 and Aug 3 were removed from the analysis. As June 21 was also a Saber's Stat event day impacts for that day exclude Saver's Switch participants.

Figure 3-3: Event Day and Proxy Day Hourly Temperatures for Event Day June 28, 2016



The match was performed by comparing treatment and control loads in hours 9 through 22 (9am through 10pm MDT), the results of which are shown in Figure 3-4 and Figure 3-5. These figures show average proxy day load shapes for Vendor 1 and Vendor 2 participant devices, respectively. Note that the treatment and control load shapes are very closely matched, especially for the Vendor 1 devices. Matches for Vendor 2 devices are also reasonably close for the matching period (hours 9 through 22). The deviation in other hours should not substantially affect results.

Figure 3-4: Proxy Day Loads for Vendor 1 Participant Devices and Matched Control

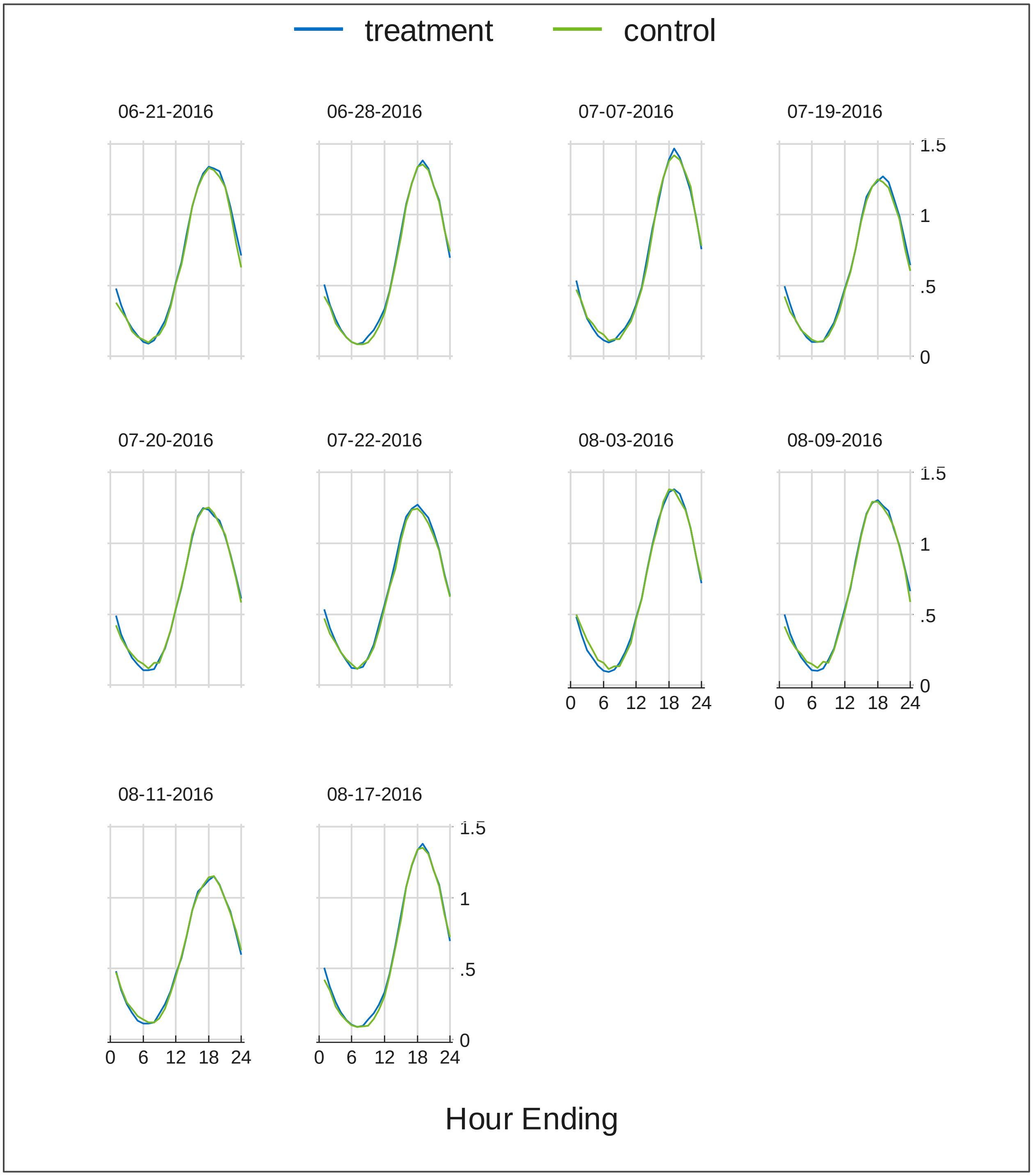
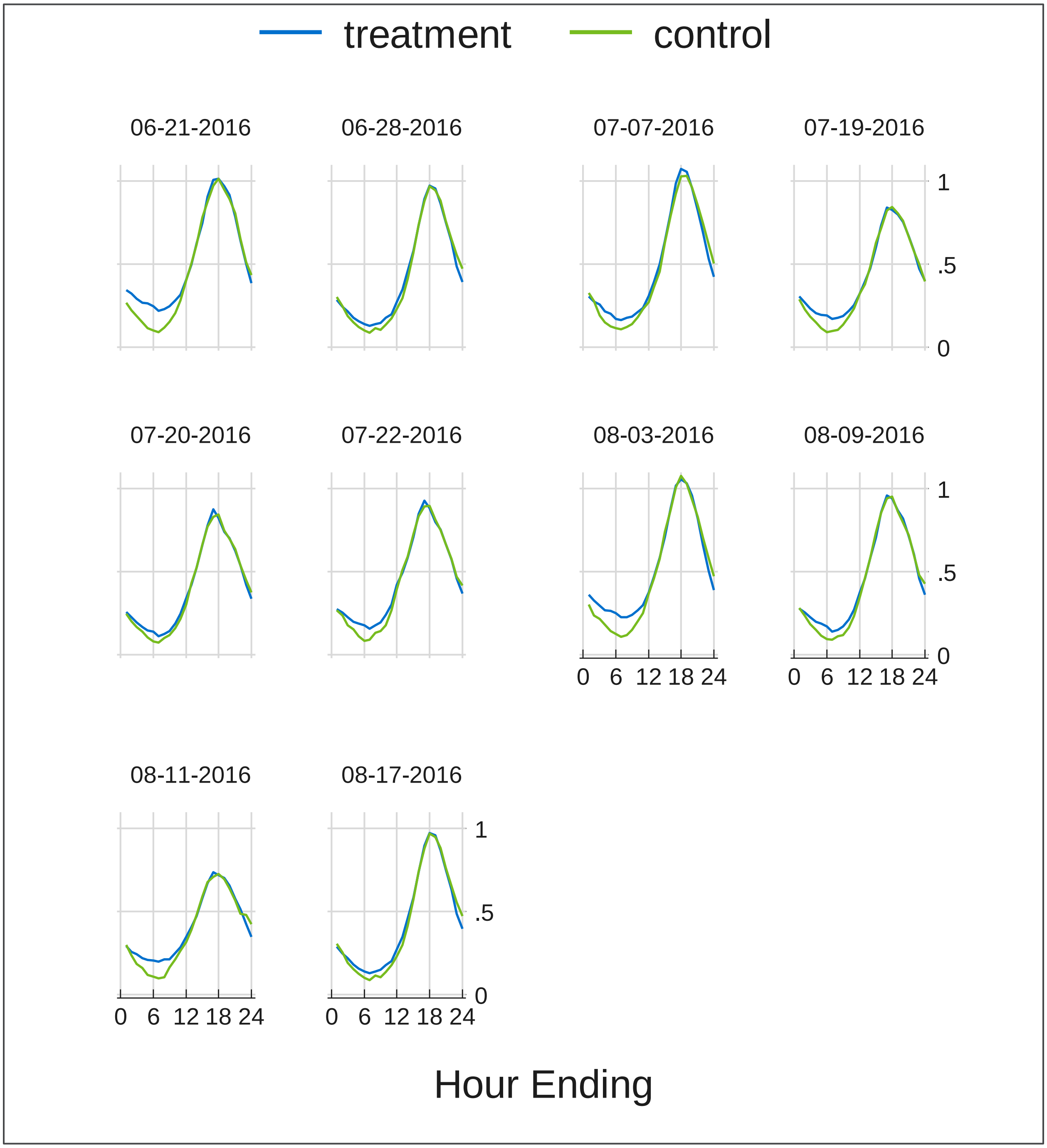


Figure 3-5: Proxy Day Loads for Vendor 2 Participant Devices and Matched Control



3.2.2 DR Ex Post Impact Estimation

DR ex post impacts were estimated by subtracting the observed load on event days from the estimated control load. Because a match was found for each participant individually, impact estimates were pooled for any level of aggregation required for the analysis.

Using this approach, Nexant generated many comparisons and segmentations of the results by incentive level, thermostat manufacturer, state, and other variables of interest. This granular, disaggregated analysis that leveraged results from all participants served as valuable input into the cost-effectiveness assessment.

3.3 Customer Surveys

To accompany the residential and SMB evaluations, Nexant conducted surveys with each group, including questions specific to each pilot (residential EE smart thermostat rebate, residential Saver's Stat BYOT DR, and SMB DR with smart thermostat direct install). Details regarding the sampling and fielding used for each are covered in sections 8.1 and 9.1. Full survey instruments are included in Appendix D.

4 Smart Thermostat Rebate: Residential EE Savings Estimate

The EE savings analysis sought to help answer key questions to inform future program design, in particular:

- Is a $50 rebate sufficient to encourage customers to purchase and install a smart thermostat?
- What level of EE savings (kWh & peak kW) are attributed to the installation and use of smart thermostats? Can a deemed savings value be determined?
- Is it possible to create a cost-effective DSM product using resulting deemed energy-savings values?

The first question about whether the $50 rebate is sufficiently compelling can be assessed by considering the volume of rebate applications Xcel Energy processed and the influence of the rebate as reported by participant survey respondents (see Section 8.3 for details). Xcel Energy processed over six thousand rebates and nearly 80% of respondents reported that the $50 rebate was very or extremely important.[33] These data points imply that the rebate was indeed compelling.

The second question sought to quantify EE savings and was answered directly through the EE savings analysis. The key findings of this analysis were that though some modest EE savings were found, they were concentrated in distinct populations, and EE savings could not be estimated over the entire pilot population with statistical significance. In particular, statistically significant EE savings were only found for Vendor 3 devices and were on the order of 2.4% annual household electricity use and 2.5% of gas use. The electric EE savings in particular were significantly higher for participants who obtained the rebate using the Xcel Energy online Storefront. The EE savings for this group were 3.6% of electricity use while savings were not significant for the participants who used the mail-in rebate. Gas savings on the other hand were somewhat higher for the mail-in participants compared to Storefront users, though gas savings for both groups were still in the range of 2-3%.

The EE savings analysis was performed using billing data, which could not be used to estimate nonevent day peak load impacts due to EE savings due to the lack of smart meter interval data. In the absence of interval data, nonevent day peak load impacts for summer afternoons were estimated by applying results from a similar study which broke down impacts by summer weekday hour using interval data. By applying the assumption that savings were similarly allocated for Xcel Energy participants, the estimated average peak load reduction from EE savings is about 0.25 kW on average between the hours of 1 to 5pm.

Finally, the EE savings analysis was combined with results from a residential participant survey question on freeridership to develop a net EE savings value. Importantly, respondents who used the online Storefront exhibited significantly lower freeridership and different net-to-gross ratios were applied to savings for the Storefront and mail-in groups accordingly. Net EE savings were primarily assessed for Vendor 3 thermostats as these were the only devices to exhibit

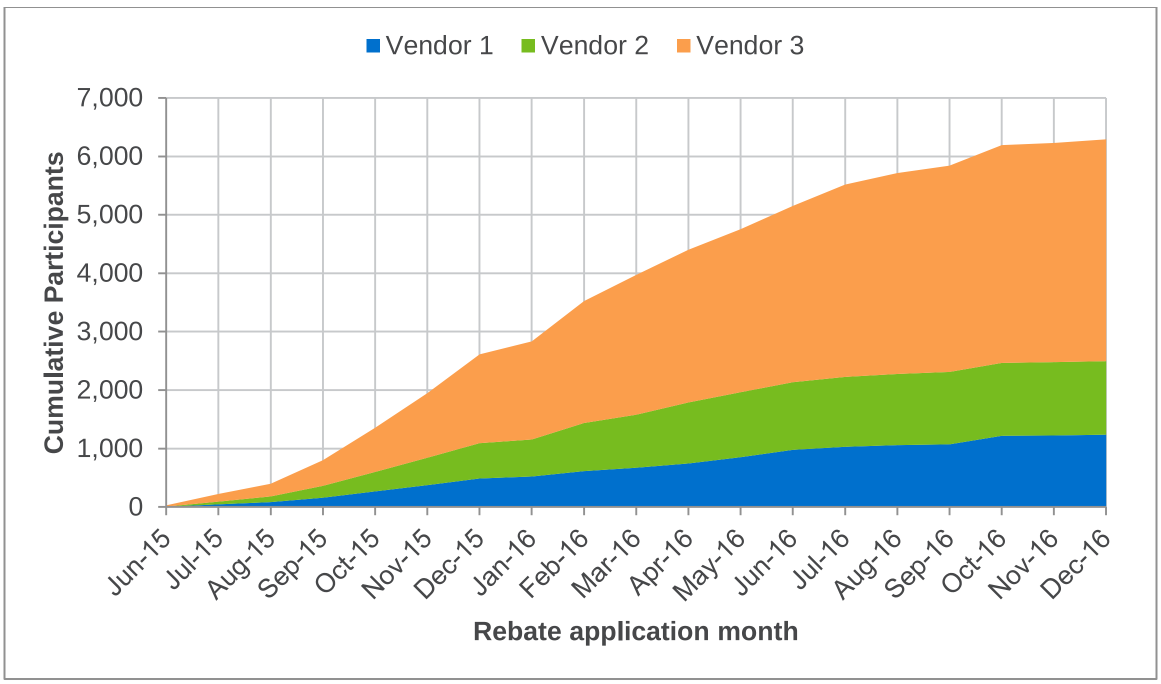
[33] On a 5 point scale 49% gave a rank of 5 “Extremely important”. Another 29% gave a rank of 4.

statistically significant savings. After applying the net-to-gross ratios, annual net savings for Vendor 3 devices via the Storefront were estimated to be 278 kWh and 9.6 therms. Annual net savings for all Vendor 3 devices were estimated at 176 kWh and 11.6 therms. If these savings estimates are indeed reliable and if savings persist for multiple years the smart thermostat rebate might be a cost-effective DSM program approach. However, further study may be necessary to develop a reliable savings estimate or deemed savings value. While savings within the range of other smart thermostat evaluations were detected for Vendor 3 devices, these are not reliable due to the variation identified across pilots and the lack of evaluation of savings persistence.

4.1 Energy Efficiency Savings

Energy efficiency participants received a rebate in return for the purchase and installation of an eligible smart thermostat. Though the rebate application period began in June 2015, fewer than half of participants applied for their rebate before the end of that year as shown by the cumulative enrollment counts in Figure 4-1. Also, rebate applications were discontinued after September 2016 once the program became fully subscribed.

Figure 4-1: Cumulative Smart Thermostat Rebate Applications



Underlying these cumulative EE rebate applications is a population of participants who presumably installed smart thermostats and for whom energy savings were estimated. This population was in flux each month as new participants received and installed their smart thermostat and others closed their Xcel Energy account or moved. To address this variability EE savings were estimated separately within each month for the participants who had previously applied for the rebate and who had 12 months of energy usage data prior to the rebate application (to serve as pre-treatment data for the statistical matching). Annual EE savings were also estimated using an analogous estimation model that effectively weighted savings estimates for each month by the number of usable participant sample points in that month. The month in which the rebate application was received and the month directly following it were excluded from the analysis to account for the latency between rebate application and device installation. These months were also analyzed but shown to deliver no energy usage impacts.

Table 4-1 summarizes the results of the EE savings analysis, showing impacts within thermostat provider and rebate channel (Storefront instant rebate versus mail-in rebate). To standardize the analysis and enable comparison across months, impacts were calculated in terms of change in average daily usage. Negative impacts (i.e., EE savings) represent a drop in daily average usage, which would correspond to a positive percent EE savings value. Impacts lacking statistical significance at the 95% confidence level have been greyed out. Overall significant electricity usage savings were only found for Vendor 3 devices (2.4%) and for all participants who used the online Storefront as opposed to the mail-in rebate (1.9%). By digging further into each sample cell it appears that most of these electricity savings are concentrated in the intersection of these two characteristics: Vendor 3 devices obtained via the online rebate (3.6%).

While electricity EE savings were not significant overall for all participants, gas EE savings were statistically significant overall (1.6%) for all pilot participants. Like electricity EE savings, gas EE savings also appear largely concentrated within Vendor 3 devices (2.5% savings). Devices from both rebate channels produced gas EE savings, with savings somewhat higher for the mail-in channel (3.2%) than for the online Storefront (1.9%).

When interpreting these results it is important to note that within comparable cells the sample of Vendor 3 devices was more than triple the sample available for each of the other manufacturers. The fact that significant EE savings were detected on an aggregate level across all devices (within the online rebate channel for electricity savings and within all rebate channels for gas savings) but not within some smaller segments (e.g., within Vendor 1 or Vendor 2 devices alone) highlights a basic principle of statistical impact evaluation: the ability to reliably detect statistically significant EE savings is driven both by the effect size (i.e., magnitude of EE savings) and by the sample size (pilot population with verifiable data set). Here we have both a relatively small effect size and small sample sizes so potentially a larger sample size would have been able to detect a smaller level of EE savings with greater confidence. However, it is also notable that aggregate savings are lower than savings for Vendor 3 devices only (where EE savings appear to be concentrated), despite being observed within a larger overall sample. A larger sample size does not change the size of the impact rather it increases the ability to detect a smaller impact.

Table 4-1: Annual Whole House EE Savings by Rebate Channel and Provider[34]

Fuel	Provider	Rebate channel	% savings	Impact		Reference usage (avg daily usage)	N
				avg daily usage	p-value		
Electricity (kWh)	Vendor 1	Mail	-4.3%	1.10	0.08	25.88	144
		Store	-3.1%	0.79	0.14	25.31	252
		Both	-3.5%	0.89	0.03	26.84	708
	Vendor 2	Mail	-0.1%	0.04	0.95	26.34	1,104
		Store	2.0%	-0.49	0.28	25.30	327
		Both	1.0%	-0.26	0.46	24.90	325
	Vendor 3	Mail	0.8%	-0.22	0.63	26.78	837
		Store	3.6%	-0.98	0.00	26.06	1,489
		Both	2.4%	-0.65	0.01	25.48	471
	All	Mail	-0.1%	0.02	0.96	25.08	577
		Store	1.9%	-0.50	0.02	26.81	1,545
		Both	1.1%	-0.29	0.12	26.18	2,593
Gas[35] (therms)	Vendor 1	Mail	-0.4%	0.01	0.87	2.46	145
		Store	-0.2%	0.00	0.88	2.59	251
		Both	-0.2%	0.01	0.83	2.58	682
	Vendor 2	Mail	1.0%	-0.03	0.41	2.56	1,078
		Store	0.5%	-0.01	0.71	2.56	319
		Both	0.7%	-0.02	0.42	2.57	318
	Vendor 3	Mail	3.2%	-0.08	0.00	2.73	798
		Store	1.9%	-0.05	0.01	2.66	1,435
		Both	2.5%	-0.07	0.00	2.53	464
	All	Mail	2.2%	-0.06	0.00	2.58	569
		Store	1.2%	-0.03	0.04	2.66	1,480
		Both	1.6%	-0.04	0.00	2.62	2,513

Figure 4-2 and Table 4-2 detail the monthly and annual electricity EE savings estimated for 2016 for the smart thermostat EE rebate participants who used Vendor 3 devices and obtained their rebate through the online Storefront. The savings vary by month along with seasonal weather patterns with the highest savings observed in the winter (5-7%) and summer (3-4%). EE savings are not statistically significant for a handful of spring and fall months when energy and space conditioning usage is also lower.

Note that the number of sample points (N) in each month varies because of ramping of participation and customer account changes and move-ins / move-outs which affect the availability of pre-treatment and treatment data. For example, the analysis for each month included only participants for whom there was 12 months of pre-treatment data at that point. This excluded about 20% of participants and it was observed that many of those excluded

34 Estimates not within the 95% confidence level for statistical significance (p-value at or below 0.05) have been greyed out

35 Excludes low usage months of June through September when average daily usage is below one therm

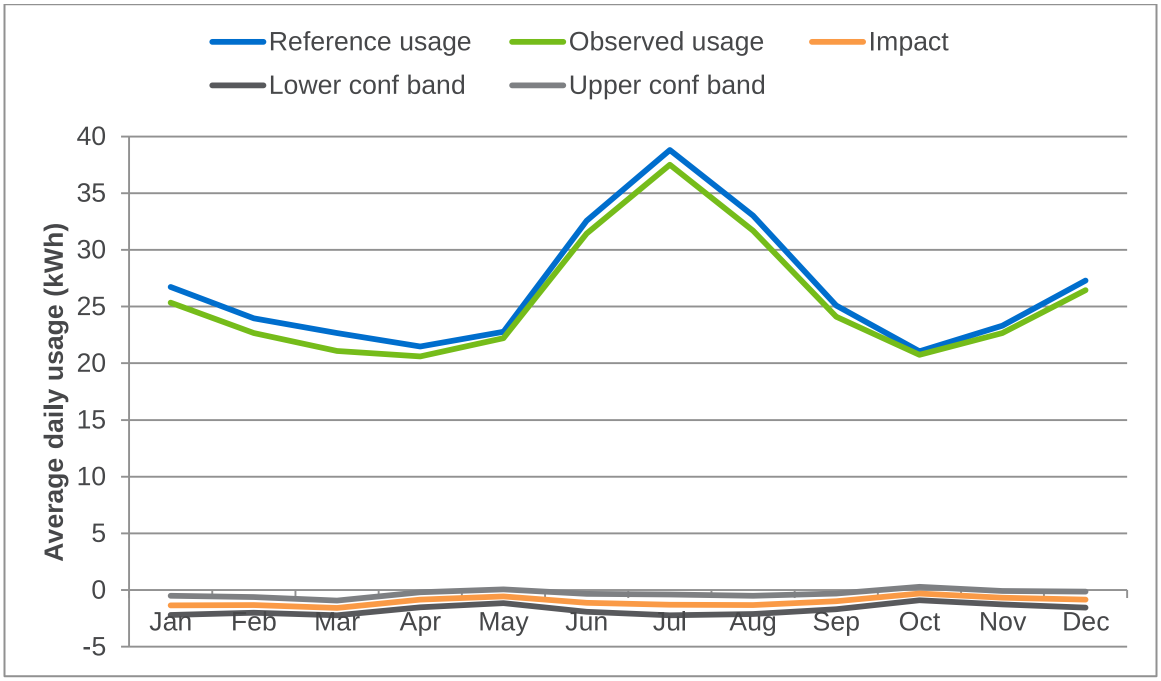
applied for the EE rebate only a few weeks after starting services at their premise. That said, structuring the analysis on a monthly basis enabled the inclusion of far more sample points than would have been the case had the analysis been restricted to, say, a full annual panel (e.g., to participants that also had treatment data for all 12 months in 2016).[36]

Table 4-2: Electricity Usage Impacts by Month, Vendor 3 Devices with Storefront Rebate

2016 period	% savings	Impact		Reference usage (avg daily kWh)	N
		avg daily usage	p-value		
Jan	5.1%	-1.36	0.01	26.71	371
Feb	5.5%	-1.31	0.00	23.97	494
Mar	7.0%	-1.58	0.00	22.66	547
Apr	4.0%	-0.85	0.03	21.47	618
May	2.4%	-0.55	0.13	22.76	686
Jun	3.5%	-1.13	0.02	32.57	727
Jul	3.3%	-1.30	0.02	38.81	754
Aug	4.0%	-1.31	0.01	33.01	783
Sep	3.9%	-0.99	0.02	25.08	786
Oct	1.5%	-0.31	0.38	21.05	818
Nov	2.9%	-0.67	0.06	23.31	810
Dec	3.1%	-0.85	0.05	27.30	799
Annual	3.6%	-0.98	0.00	26.78	837

36 An alternative analysis approach was also explored to address these challenges. In the approach, this energy savings analysis adjusted the month variable in the billing data to represent the month relative to rebate application. This approach is effective at picking up on effects that are driven by customer behavior relative to the treatment, as opposed to seasonal effects more driven by calendar month. In addition, this approach maximizes the number of customers that are analyzed in a given month because not all customers applied for the rebate at the same time. However, savings detected using this approach were smaller and less statistically significant than those derived using the calendar month approach. Given the seasonal nature of the observed savings this is not surprising.

Figure 4-2: Energy Usage Impacts by Month, Vendor 3 Devices Purchased via Storefront



As shown in Table 4-1, a statistically significant increase in electricity usage was estimated for Vendor 1 devices. Table 4-3 and Figure 4-3 summarizes the monthly energy usage impacts estimated for Vendor 1 devices, demonstrating that statistically significant energy usage increases on the order of almost 4 to 8% were identified in the spring and fall. Marginally significant[37] energy usage increases of 3.6% and 4.1% were detected for June and July. No monthly summary is provided for Vendor 2 devices because no statistically significant change in electricity or gas usage was detected for Vendor 2 devices.

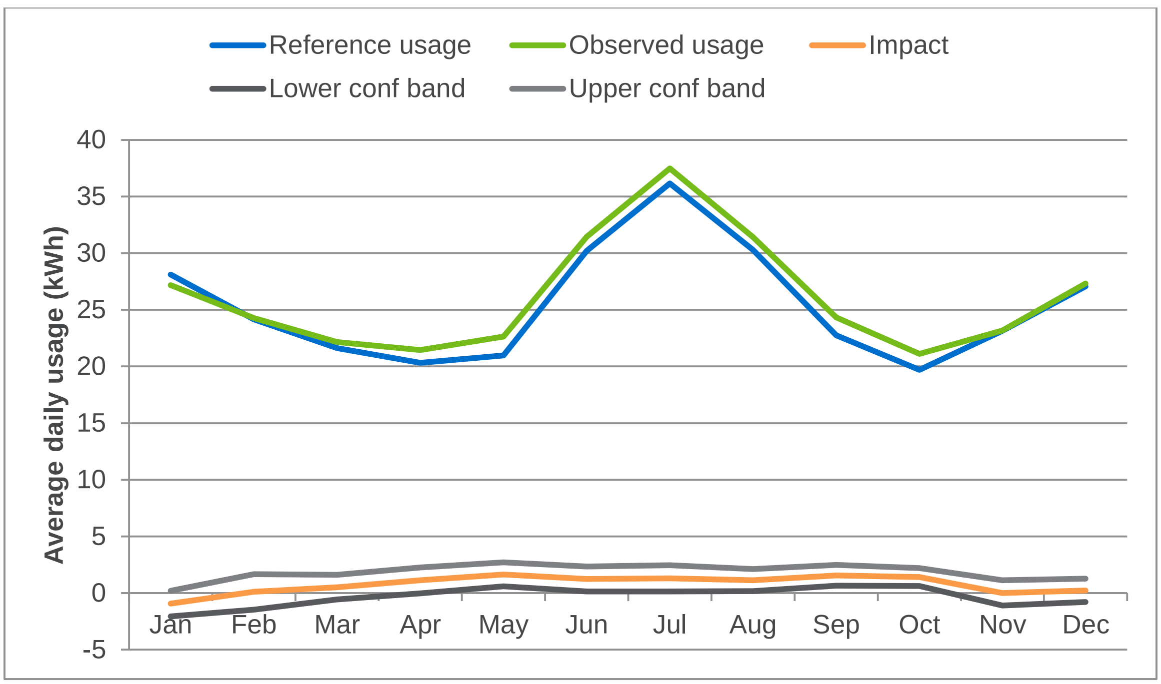
Section 7 uses analysis of deployed thermostat programs and setpoint data to explore thermostat functionality and user behaviors that might potentially explain differences in EE savings between manufacturers. Key differences between Vendor 3 and Vendor 1 were identified, in particular related to the deployment of efficiency algorithms and the duration of customer-chosen temperature holds.

37 Here a p-value of 0.06 means that there is a 6% probability that impacts are different from zero only due to random chance. This os be statistically significant within the 90% confidence level.

Table 4-3: Electricity Usage Impacts by Month, Vendor 1 Devices, Both Rebate Channels

2016 period	% savings	Impact		Reference usage (avg daily kWh)	N
		avg daily usage	p-value		
Jan	3.3%	-0.92	0.18	26.71	371
Feb	-0.5%	0.11	0.91	28.10	176
Mar	-2.4%	0.53	0.43	24.15	240
Apr	-5.5%	1.13	0.11	21.62	270
May	-7.9%	1.65	0.01	20.32	299
Jun	-4.1%	1.25	0.06	20.98	338
Jul	-3.6%	1.30	0.06	30.20	375
Aug	-3.8%	1.14	0.05	36.16	398
Sep	-6.9%	1.57	0.01	30.27	443
Oct	-7.1%	1.41	0.00	22.75	447
Nov	0.0%	0.01	0.99	19.70	456
Dec	-0.9%	0.24	0.71	23.15	448
Annual	-3.5%	-0.89	0.03	25.48	471

Figure 4-3: Energy Usage Impacts by Month, Vendor 1 Devices Purchased via Storefront



4.2 Nonevent Day Peak Load (kW) Savings

As discussed in the methodology Appendix A.3, the most relevant information available regarding hourly demand savings on nonevent days from smart thermostats comes from a recent pilot evaluation from San Diego Gas and Electric (SDG&E) utility. While this evaluation found modest annual EE electricity savings, of less than 1%, it also found that these savings were highly concentrated in weekday afternoon hours.

Hourly estimates were possible in this case because SDG&E has widely deployed smart meters that provide access to customer interval energy usage data. While this granular data is not available for Xcel Energy customers it may be assumed that smart thermostats function similarly in different territories and that savings are also similarly distributed across hours of the day.

Table 4-4 shows estimates for average daily load impacts in each month based on the average daily EE savings identified for Vendor 3 thermostats purchased via the Storefront. Impacts are only presented for this group because they were the most reliably significant for Vendor 3 devices purchased through the Storefront. These estimates also assume that EE savings are concentrated across hours of the day similarly to what was found in the SDG&E evaluation. Those allocations are in parentheses and the estimated average load impact is simply the daily usage impact (kWh) multiplied by the hourly EE savings allocation (kW) for a given window divided by the number of hours in the window. Negative values represent load reductions.

The greatest estimated load impacts are load reductions of 0.26 kW during weekdays between 3 and 5pm during the peak cooling season months of July and August. Note that these are average daily load impacts during daily peak hours as opposed to peak day impacts for a load impact program that are only observed on a handful of peak days in the season.

Table 4-4: Estimated Electricity Average Load Impacts by Month, Vendor 3 Devices Purchased via Storefront

2016 period	Usage impact (kWh)		Average load impact (kW)		
	avg daily usage impact	p-value	1-3pm (37%)	3-5pm (40%)	5-7pm (9%)
Jun	-1.13	0.02	-0.21	-0.23	-0.05
Jul	-1.30	0.02	-0.24	-0.26	-0.06
Aug	-1.31	0.01	-0.24	-0.26	-0.06
Sep	-0.99	0.02	-0.18	-0.20	-0.04

4.3 Freeridership and Deemed Savings Value

Table 4-5 shows how the EE savings analysis can be combined with the results from the freeridership section of the residential participant survey to derive an annual net EE savings value for electricity and gas usage. Note that separate values are provided each thermostat provider and rebate channel combination that yielded statistically significant savings. The net EE savings ratio is discussed more in detail in section 8.3 and is differentiated by rebate channel for two reasons. First, there were statistically significant differences measured for freeridership between respondents using the Storefront and mail-in rebate channels. Second, the mail-in and Storefront rebate channels are really two separate enrollment channels that Xcel Energy can choose to include or exclude from future smart thermostat offerings. For example, freeridership measured for respondents who used the Storefront channel was lower than for those who used the mail-in channel. To reduce freeridership in future program offerings, Xcel Energy could choose to only offer the EE rebate through the Storefront.

Based on this estimate, annual net EE savings for Vendor 3 devices with the online rebate was 278 kWh and 9.6 therms. For Vendor 3 devices using both rebate channels annual net EE savings were estimated to be 176 kWh and 11.6 therms. At an illustrative cost of $0.06 per kWh and $0.80 per therms this suggests an annual bill savings of $20 to $24 or 40 to 50% of the $50 rebate value. Applying the same approach to the peak load impacts described above would result in 0.2 kW in net peak load impacts for Vendor 3 devices purchased through the Storefront. In this illustrative example it would take two to three years for the savings to surpass the rebate cost, assuming the savings persist at a similar rate for multiple years.

This illustrative example demonstrates why understanding whether EE savings are reliable and persistent from year to year is an important EE program design input. However, while EE savings were detected for Vendor 3 devices and they are in range with savings identified in other evaluations of smart thermostat EE savings, the variation in savings identified across pilots[38] and the lack of evaluation of EE savings persistence means further study may be needed to develop a reliable savings estimate or deemed savings value.

[38] A recent emerging technologies pilot conducted by PG&E (http://www.etcc-ca.com/reports/smart-thermostat-study) estimated annual electricity savings of 4 to 5% for three different manufacturers and 4% annual gas savings for just one manufacturer (and 0% for the other two). A recent SDG&E Small Customer Technology Deployment (SCTD) program pilot estimated electricity savings of just under 1% and gas savings of less than 0.5%. These studies suggest an annual savings range of 0 to 5% for electricity and gas usage.

Table 4-5: Annual Whole House EE Savings by Rebate Channel and Provider[39]

Fuel	Provider	Rebate channel	Impact		Annual savings[40]	Net savings ratio[41]	Net annual savings
			avg daily usage	p-value			
Electricity (kWh)	Vendor 3	Mail	1.10	0.08	82	66%	54
		Store	-0.98	0.00	356	78%	278
		Both	-0.65	0.01	238	74%	176
	All	Mail	0.02	0.96	-6	66%	-4
		Store	-0.50	0.02	182	78%	142
		Both	-0.29	0.12	105	74%	78
Gas[42] (therms)	Vendor 3	Mail	-0.08	0.00	19.9	66%	13.2
		Store	-0.05	0.01	12.4	78%	9.6
		Both	-0.07	0.00	15.7	74%	11.6
	All	Mail	-0.06	0.00	13.7	66%	9.0
		Store	-0.03	0.04	7.5	78%	5.8
		Both	-0.04	0.00	10.1	74%	7.5

39 Estimates not within the 95% confidence level for statistical significance (p-value at or below 0.05) have been greyed out

40 Derived by multiplying annual average daily usage impact by 365 for electricity and by 240 for gas (to account for the fact only eight months of usage, from October to May, are reflected in the savings estimate)

41 Based on results of survey, see section 8.3.

42 Excludes low usage months of June through September when average daily usage is below one therm

5 Saver's Stat: Residential & SMB Demand Response Load Impacts

Load impacts were assessed for Xcel Energy's residential bring-your-own-thermostat (BYOT) and small business (SMB) Saver's Stat smart thermostat demand response pilots. Seventeen BYOT were called on ten days between June and August 2016 while ten SMB events were called on five days in September 2016. About 434 Vendor 2 and 338 Vendor 1 devices participated in the BYOT DR pilot and they were dispatched through the DR event portal. The BYOT pilot allowed new enrollments until mid-July, meaning the participant population was still growing after the first event was called. All devices participating in the SMB pilot were Vendor 2 thermostats and events were dispatched using Vendor 2's online dispatch portal. Many of the 130 participating SMB devices were not dispatched for the first two events due to technical issues, as described in detail in Section 5.5.

For both pilots, different numbers of thermostats were called for different events following a dispatch strategy that tested various control approaches, incentive levels, and event windows. Table 5-1 summarizes the control strategies deployed for the BYOT and SMB DR pilots. All strategies were deployed by controlling participant thermostats either by increasing the temperature setpoint or by turning the thermostat cooling function off and on at regular time increments to imitate the functionality of a load control switch.

Table 5-1: DR Control Strategy Summary

DR Program	Control strategy	Description
BYOT	50% duty cycling	Thermostat based imitation of switch based duty cycling. Thermostat alternates between 15 minutes off, 15 minutes on for event duration.
	90% duty cycling	Thermostat based imitation of switch based duty cycling. Thermostat alternates between 27 minutes off, 3 minutes on for event duration.
	4F offset	Thermostat setpoint is increased by 4 degrees F for the duration of the event.
	6F offset	Thermostat setpoint is increased by 6 degrees F for the duration of the event.
	1F stacked offset	Thermostat setpoint is increased by 1 degree F each hour for the duration of the event.
	2F stacked offset	Thermostat setpoint is increased by 2 degrees F each hour for the duration of the event.
SMB	50% duty cycling	Thermostat based imitation of switch based duty cycling. Thermostat alternates between 15 minutes off, 15 minutes on for event duration.
	3F offset	Thermostat setpoint is increased by 3 degrees F for the duration of the event.

Xcel Energy also has a long standing AC one-way paging residential switch-based demand response program, Saver's Switch, and about 24% of the Saver's Stat BYOT DR participants were also enrolled in that program. By the pilot's terms, Saver's Switch customers were allowed to participate in the Saver's Stat pilot, but their switches were disabled during the pilot's control season and those participants forfeited their annual $40 Saver's Switch bill credit in favor of the performance incentives earned through the Saver's Stat pilot. Data for the two Saver's Switch control event days, called on June 21 and August 8, were excluded from the analysis.

5.1 Residential DR Impacts for Individual Events

Table 5-2 summarizes the seventeen DR events called on 10 calendar days during Summer 2016. Different numbers of devices were dispatched on different days and for some events, devices from only one manufacturer were dispatched. Of note is the mean temperature during events. Only during four events did mean temperatures surpass 90 degrees F. The mild summer weather of 2016 means it was not possible to directly assess impacts of extreme weather days. Also, a handful of technical challenges are noted for some events, in particular the lack of data for participating Vendor 2 devices for two events[43] and premature dispatch for another two events.[44] These events have been largely excluded from the results analysis.

Table 5-2: BYOT DR Event Summary

Event number	Event date	Control strategy	Incentive level[45]	Event start	Event duration	Mean temp (F)[46]	Devices called[47]	
							Vendor 1	Vendor 2
4374	21-Jun	50%	Both	3 PM	4	93.3	238	341
4386[48]	28-Jun	50%	$2.50	3 PM	2	89.5	123	163
4388	28-Jun	50%	$5	5 PM	2	79.1	119	179
4401[49]	7-Jul	50%	Both	3 PM	4	86.6	273	346
4452	19-Jul	50%	Both	3 PM	2	89.8	135	177
4453	19-Jul	50%	Both	5 PM	2	81.4	140	169
4456[50]	20-Jul	4F offset	Both	1 PM	4	91.0	--	346

43 Vendor 2 data is stored as status changes rather and intervals making it impossible to reliably identify individual missing status changes. Data for some event days was clearly missing for large numbers of thermostats (resulting in zero or flat recorded runtime) and those event days were excluded from the average savings analysis. It is also quite possible that thermostat data was also missing from other days but could not be identified. Zero or flat recorded runtime for some thermostats could affect the reliability of the impact estimate.

44 Events dispatched on July 20 and 22 were dispatched 2 hours early (1pm MDT instead of 3pm MDT) due to a time zone error on the dispatcher's computer.

45 Xcel Energy assigned participants to one of two semi-random groups, one of which received $2.50 per event for verified event participation, while the other received a $5 per event incentive. Differences in participation by event incentive level were also explored but the difference was not statistically significant.

46 Average during entire event

47 Excludes participants also enrolled in the Saver's Switch program

48 Includes 6 devices that were queued separately under event id 4387, also, data was largely missing for Vendor 2 devices.

49 Data largely missing for Vendor 2 devices

Event number	Event date	Control strategy	Incentive level[45]	Event start	Event duration	Mean temp (F)[46]	Devices called[47]	
							Vendor 1	Vendor 2
4475[51]	22-Jul	4F offset	Both	1 PM	4	89.5	275	346
4517	3-Aug	90%	Both	3 PM	2	93.5	135	177
4518	3-Aug	90%	Both	5 PM	2	89.6	140	169
4536	9-Aug	6F offset	Both	3 PM	2	91.4	140	169
4537	9-Aug	6F offset	Both	5 PM	2	85.0	135	177
4559	11-Aug	6F offset	Both	3 PM	2	85.9	135	177
4560	11-Aug	6F offset	Both	5 PM	2	79.9	140	169
4595	17-Aug	4F offset	Both	3 PM	4	87.2	275	--
4596	17-Aug	1F offset	Both	3 PM	3	87.3	--	177
4597	17-Aug	2F offset	Both	3 PM	3	87.1	--	169

5.1.1 Vendor 1 Devices

Table 5-3 summarizes hourly and average impacts from hour ending 16 to 19 (3pm to 7pm MDT) for Vendor 1 devices for events with no dispatch issues. Figure 5-1 shows average load shapes for treatment and control devices (dispatch issues are noted with an asterisk). Average event impacts varied between 0.45 kW and 1.48 kW per thermostat and were high later in the day. These average impacts are across all devices dispatched including those that were offline or which opted-out. Impacts for fully participating devices would presumably be higher. As discussed below, variation was largely driven by temperature and control strategy, with the lowest impacts for 50% duty cycling events. Substantial snap back can be observed in Figure 5-1 for Vendor 1 devices for nearly all events.

50 Premature dispatch

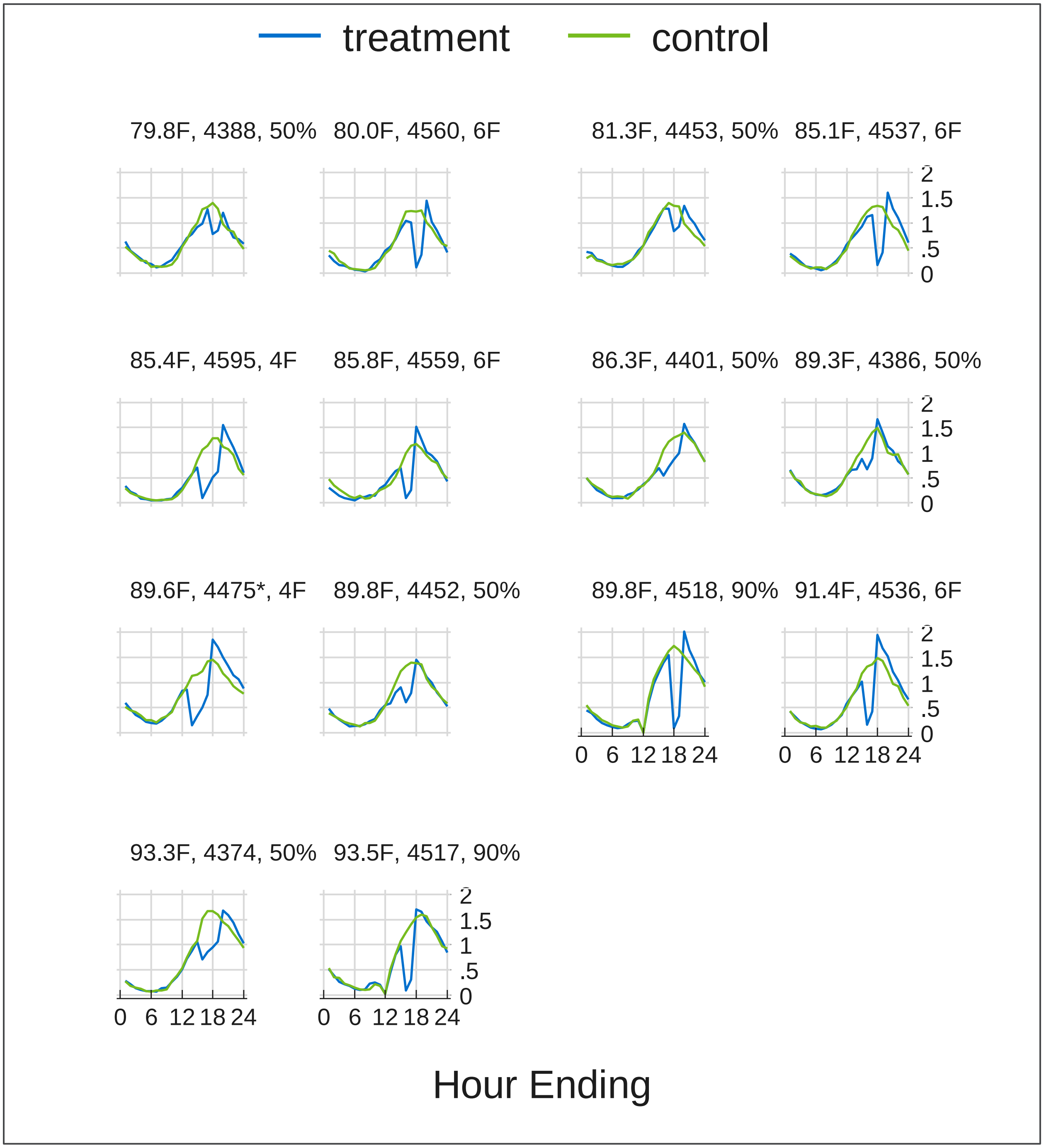
51 Premature dispatch

Table 5-3: Vendor 1 BYOT Event Impacts

Event number	Event date	Control strategy	Event start	Event duration	Mean temp (F)[52]	Average hourly impact (kW)				
						16	17	18	19	Avg
4374	21-Jun	50%	3 PM	4	93.3	0.812	0.815	0.717	0.545	0.722
4452	19-Jul	50%	3 PM	2	89.8	0.716	0.602	--	--	0.659
4453	19-Jul	50%	5 PM	2	81.4	--	--	0.513	0.396	0.454
4517	3-Aug	90%	3 PM	2	93.5	1.167	1.105	--	--	1.136
4518	3-Aug	90%	5 PM	2	89.6	--	--	1.645	1.316	1.480
4536	9-Aug	6F offset	3 PM	2	91.4	1.158	0.941	--	--	1.049
4537	9-Aug	6F offset	5 PM	2	85.0	--	--	1.175	0.909	1.042
4559	11-Aug	6F offset	3 PM	2	85.9	0.896	0.878	--	--	0.887
4560	11-Aug	6F offset	5 PM	2	79.9	--	--	1.111	0.885	0.998
4595	17-Aug	4F offset	3 PM	4	87.2	0.963	0.833	0.788	0.671	0.814
Average	--	--	--	--	87.5	0.952	0.862	0.991	0.787	0.898

[52] Average during entire event

Figure 5-1: Event Day Treatment and Matched Control Group Loads, Vendor 1 Devices (Mean Temp, Event Id, Control Strategy)



5.1.2 Vendor 2 Devices

Table 5-4 summarizes hourly and average impacts from hour ending 16 to 19 (3pm to 7pm MDT) for Vendor 2 devices for events with no dispatch issues. Figure 5-2 shows average load shapes for treatment and control devices (dispatch issues are noted with an asterisk). Average event impacts varied between 0.29 kW and 0.78 kW and were high later in the day. These average impacts are across all devices dispatched including those that were offline or which opted-out. Impacts for fully participating devices would presumably be higher. Impacts for Vendor 2 devise were roughly 50% lower than impacts for Vendor 1 devices. However, the impact estimate for Vendor 2 devices may not be reliable due to data quality issues.[53] Because of this it may not be valid to compare impact estimates for the two devices. As discussed below, variation was largely driven by temperature and control strategy, with the lowest impacts for 50% duty cycling events.

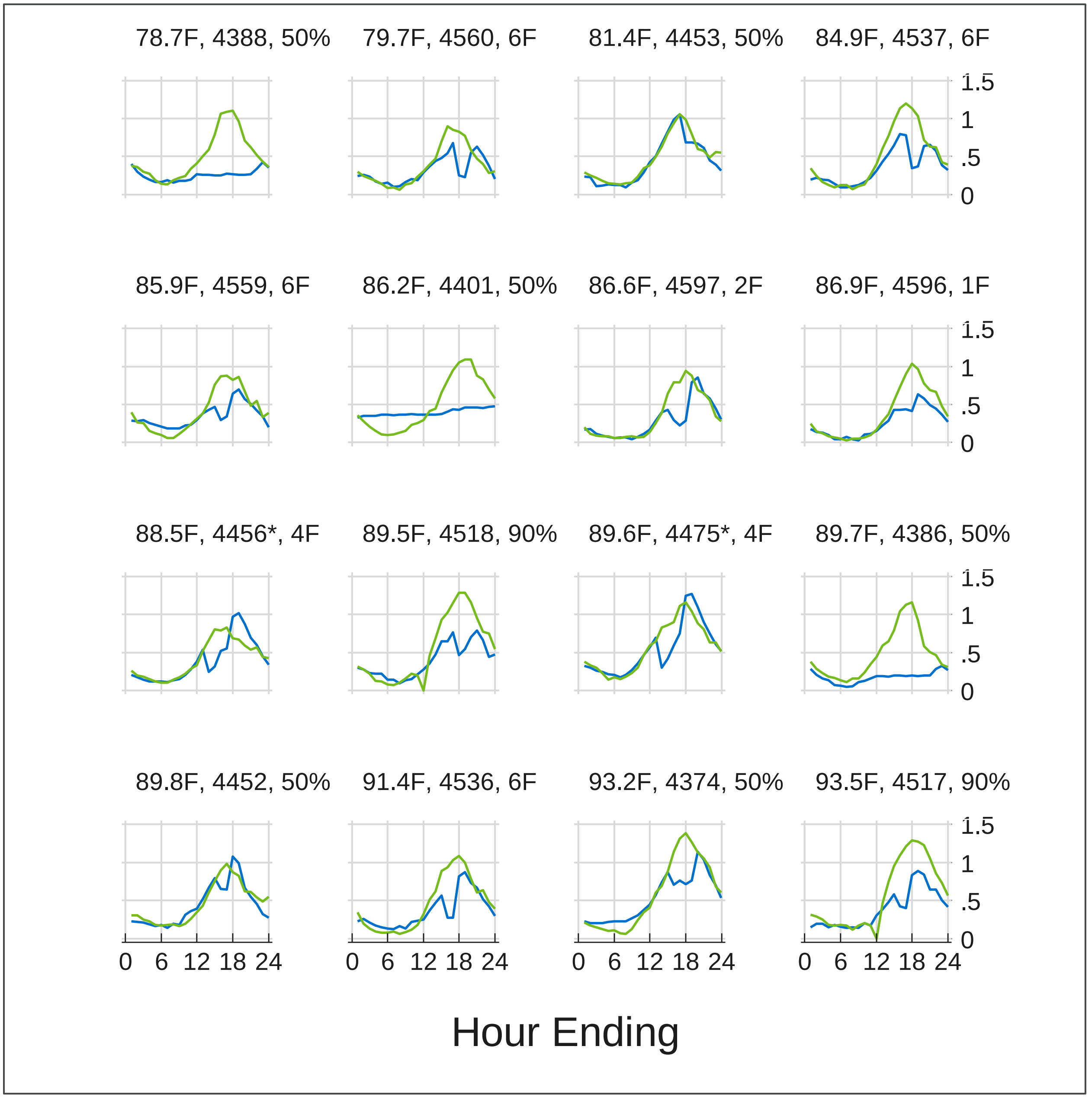
Table 5-4: Vendor 2 BYOT DR Event Impacts

Event number	Event date	Control strategy	Event start	Event duration	Mean temp (F)[54]	Average hourly impact (kW)				
						16	17	18	19	Avg
4374	21-Jun	50%	3 PM	4	93.3	0.434	0.549	0.667	0.499	0.537
4452	19-Jul	50%	3 PM	2	89.8	0.247	0.333	--	--	0.290
4453	19-Jul	50%	5 PM	2	81.4	--	--	0.300	0.113	0.206
4517	3-Aug	90%	3 PM	2	93.5	0.665	0.809	--	--	0.737
4518	3-Aug	90%	5 PM	2	89.6	--	--	0.821	0.741	0.781
4536	9-Aug	6F offset	3 PM	2	91.4	0.661	0.760	--	--	0.710
4537	9-Aug	6F offset	5 PM	2	85.0	--	--	0.793	0.662	0.728
4559	11-Aug	6F offset	3 PM	2	85.9	0.574	0.534	--	--	0.554
4560	11-Aug	6F offset	5 PM	2	79.9	--	--	0.578	0.543	0.560
4596	17-Aug	1F offset	3 PM	3	87.3	0.299	0.464	0.622	--	0.462
4597	17-Aug	2F offset	3 PM	3	87.1	0.496	0.570	0.658	--	0.575
Average	--	--	--	--	87.5	0.482	0.574	0.634	0.512	0.551

53 Vendor 2 data is stored as status changes rather and intervals making it impossible to reliably identify individual missing status changes. Data for some event days was clearly missing for large numbers of thermostats (resulting in zero or flat recorded runtime) and those event days were excluded from the average savings analysis. It is also quite possible that thermostat data was also missing from other days but could not be identified. Zero or flat recorded runtime for some thermostats could affect the reliability of the impact estimate.

54 Average during entire event

Figure 5-2: Event Day Treatment and Matched Control Group Loads, Vendor 2 Devices (Mean Temp, Event Id, Control Strategy)



5.2 Residential DR Impacts by Control Strategy

Table 5-5 and Table 5-6 summarize hourly and average impacts from hour 16 to 19 by control strategy for Vendor 1 and Vendor 2 devices for events with no dispatch issues. These tables show that the control strategy which delivered the largest impacts is the 90% duty cycling strategy (1.3 kW for Vendor 1 and 0.76 kW for Vendor 2) while the 50% duty cycling strategy delivered the smallest impacts (0.64 kW for Vendor 1 and 0.39 kW for Vendor 2). The 4 and 6 degree temperature offset events also delivered substantially higher load impacts than the 50% duty cycling events though lower than the 90% duty cycling events. However, the two 90% duty cycling events were both called on hotter days on average than the other duty cycling strategies. This relationship between weather and impacts is discussed in the next section.

Table 5-5: Vendor 1 BYOT DR Event Impacts by Control Strategy

<table>
<tr><th rowspan="2">Event number</th><th rowspan="2">Event date</th><th rowspan="2">Control strategy</th><th rowspan="2">Event start</th><th rowspan="2">Event duration</th><th rowspan="2">Mean temp (F)[55]</th><th colspan="5">Average hourly impact (kW)</th></tr>
<tr><th>16</th><th>17</th><th>18</th><th>19</th><th>Avg</th></tr>
<tr><td>4374</td><td>21-Jun</td><td>50%</td><td>3 PM</td><td>4</td><td>93.3</td><td rowspan="3">0.764</td><td rowspan="3">0.708</td><td rowspan="3">0.615</td><td rowspan="3">0.471</td><td rowspan="3">0.639</td></tr>
<tr><td>4452</td><td>19-Jul</td><td>50%</td><td>3 PM</td><td>2</td><td>89.8</td></tr>
<tr><td>4453</td><td>19-Jul</td><td>50%</td><td>5 PM</td><td>2</td><td>81.4</td></tr>
<tr><td>4517</td><td>3-Aug</td><td>90%</td><td>3 PM</td><td>2</td><td>93.5</td><td rowspan="2">1.167</td><td rowspan="2">1.105</td><td rowspan="2">1.645</td><td rowspan="2">1.316</td><td rowspan="2">1.308</td></tr>
<tr><td>4518</td><td>3-Aug</td><td>90%</td><td>5 PM</td><td>2</td><td>89.6</td></tr>
<tr><td>4536</td><td>9-Aug</td><td>6F offset</td><td>3 PM</td><td>2</td><td>91.4</td><td rowspan="4">1.027</td><td rowspan="4">0.910</td><td rowspan="4">1.143</td><td rowspan="4">0.897</td><td rowspan="4">0.994</td></tr>
<tr><td>4537</td><td>9-Aug</td><td>6F offset</td><td>5 PM</td><td>2</td><td>85.0</td></tr>
<tr><td>4559</td><td>11-Aug</td><td>6F offset</td><td>3 PM</td><td>2</td><td>85.9</td></tr>
<tr><td>4560</td><td>11-Aug</td><td>6F offset</td><td>5 PM</td><td>2</td><td>79.9</td></tr>
<tr><td>4595</td><td>17-Aug</td><td>4F offset</td><td>3 PM</td><td>4</td><td>87.2</td><td>0.963</td><td>0.833</td><td>0.788</td><td>0.671</td><td>0.814</td></tr>
</table>

Table 5-6: Vendor 2 BYOT DR Event Impacts by Control Strategy

<table>
<tr><th rowspan="2">Event number</th><th rowspan="2">Event date</th><th rowspan="2">Control strategy</th><th rowspan="2">Event start</th><th rowspan="2">Event duration</th><th rowspan="2">Mean temp (F)[56]</th><th colspan="5">Average hourly impact (kW)</th></tr>
<tr><th>16</th><th>17</th><th>18</th><th>19</th><th>Avg</th></tr>
<tr><td>4374</td><td>21-Jun</td><td>50%</td><td>3 PM</td><td>4</td><td>93.3</td><td rowspan="3">0.340</td><td rowspan="3">0.441</td><td rowspan="3">0.484</td><td rowspan="3">0.306</td><td rowspan="3">0.393</td></tr>
<tr><td>4452</td><td>19-Jul</td><td>50%</td><td>3 PM</td><td>2</td><td>89.8</td></tr>
<tr><td>4453</td><td>19-Jul</td><td>50%</td><td>5 PM</td><td>2</td><td>81.4</td></tr>
<tr><td>4517</td><td>3-Aug</td><td>90%</td><td>3 PM</td><td>2</td><td>93.5</td><td rowspan="2">0.665</td><td rowspan="2">0.809</td><td rowspan="2">0.821</td><td rowspan="2">0.741</td><td rowspan="2">0.759</td></tr>
<tr><td>4518</td><td>3-Aug</td><td>90%</td><td>5 PM</td><td>2</td><td>89.6</td></tr>
<tr><td>4536</td><td>9-Aug</td><td>6F offset</td><td>3 PM</td><td>2</td><td>91.4</td><td rowspan="4">0.617</td><td rowspan="4">0.647</td><td rowspan="4">0.686</td><td rowspan="4">0.602</td><td rowspan="4">0.638</td></tr>
<tr><td>4537</td><td>9-Aug</td><td>6F offset</td><td>5 PM</td><td>2</td><td>85.0</td></tr>
<tr><td>4559</td><td>11-Aug</td><td>6F offset</td><td>3 PM</td><td>2</td><td>85.9</td></tr>
<tr><td>4560</td><td>11-Aug</td><td>6F offset</td><td>5 PM</td><td>2</td><td>79.9</td></tr>
<tr><td>4596</td><td>17-Aug</td><td>1F offset</td><td>3 PM</td><td>3</td><td>87.3</td><td>0.299</td><td>0.464</td><td>0.622</td><td>--</td><td>0.462</td></tr>
<tr><td>4597</td><td>17-Aug</td><td>2F offset</td><td>3 PM</td><td>3</td><td>87.1</td><td>0.496</td><td>0.570</td><td>0.658</td><td>--</td><td>0.575</td></tr>
</table>

55 Average during entire event

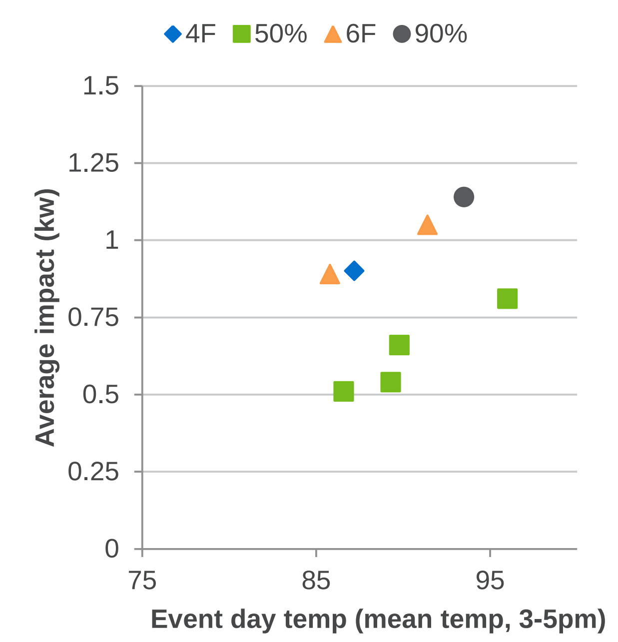
56 Average during entire event

5.3 Residential Impacts by Weather Pattern

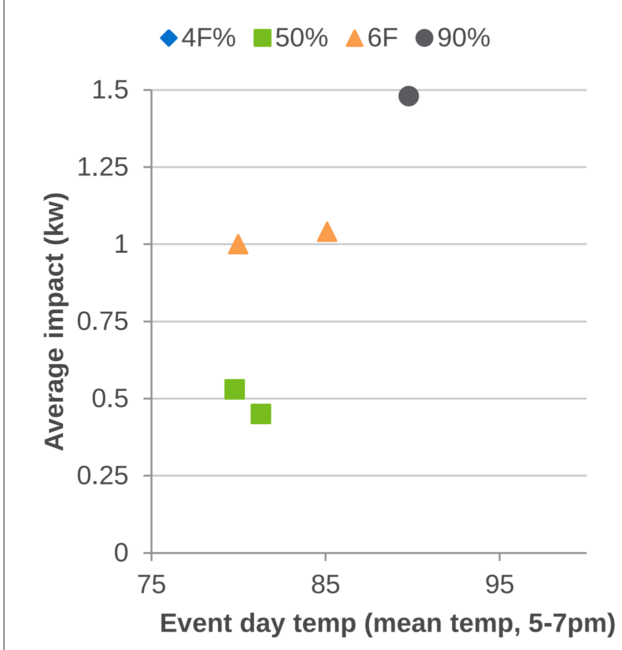
Figure 5-3 and Figure 5-4 plot the DR impacts from each individual event on the average outdoor temperature during the first two hours of each event[57] for each device type. A few key observations emerge when summarizing impacts in this manner. First, impacts from 50% duty cycling are indeed lower than the other strategies even controlling for temperature, device type, and event window. In contrast, outdoor temperature variation appears to explain most of the variation in impacts between other control strategies though there are fewer data points available to confirm this observation. In addition, there appears to be an observable positive correlation between measured impacts and outdoor temperature when controlling for factors such as dispatch window, device type, and control strategy. This can be seen most clearly when there are more data points, such as Vendor 1 devices in the 3-5pm event window or by looking across devices and event windows.

Figure 5-3: BYOT DR Event Impacts by Mean Event Temperature, Vendor 1

Impacts 3-5pm

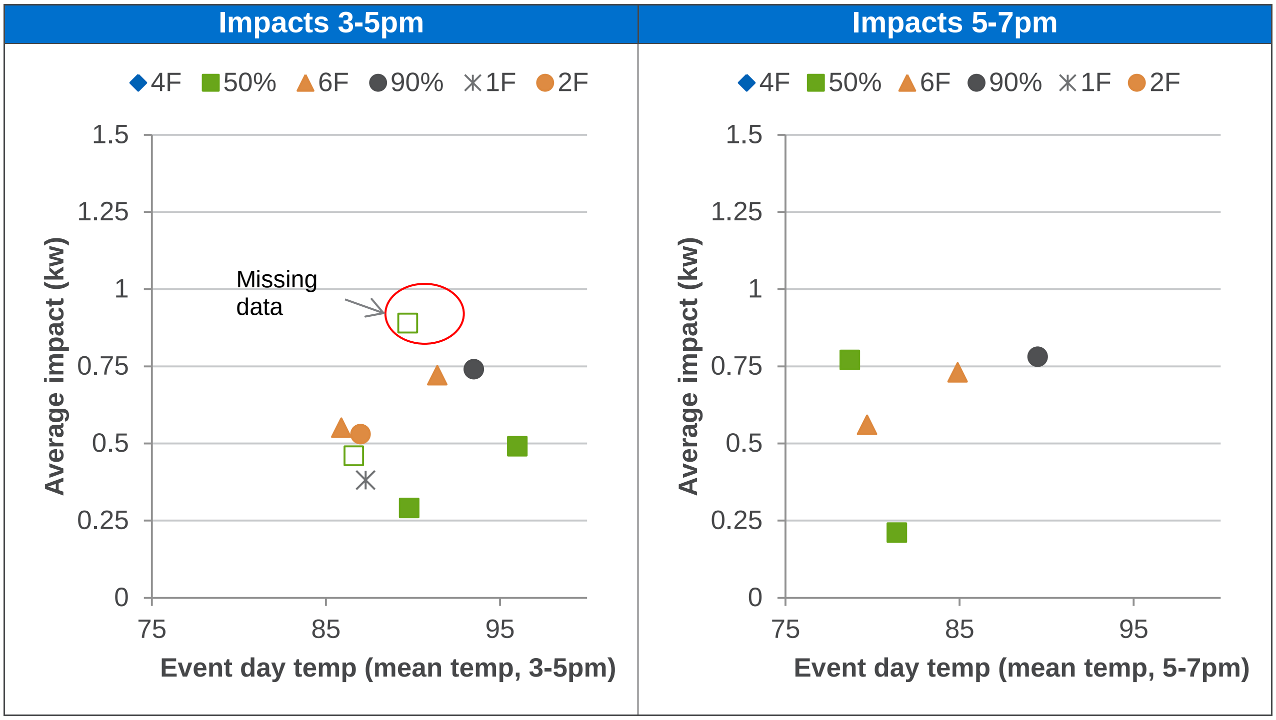


Impacts 5-7pm



[57] Note that the tables above show temperature during the entire event. Here temperatures and impacts during the first two hours of each event are shown for comparability purposes: temperatures tend to be lower and impacts tend to be higher later in the day.

Figure 5-4: BYOT DR Event Impacts by Mean Event Temperature, Vendor 2

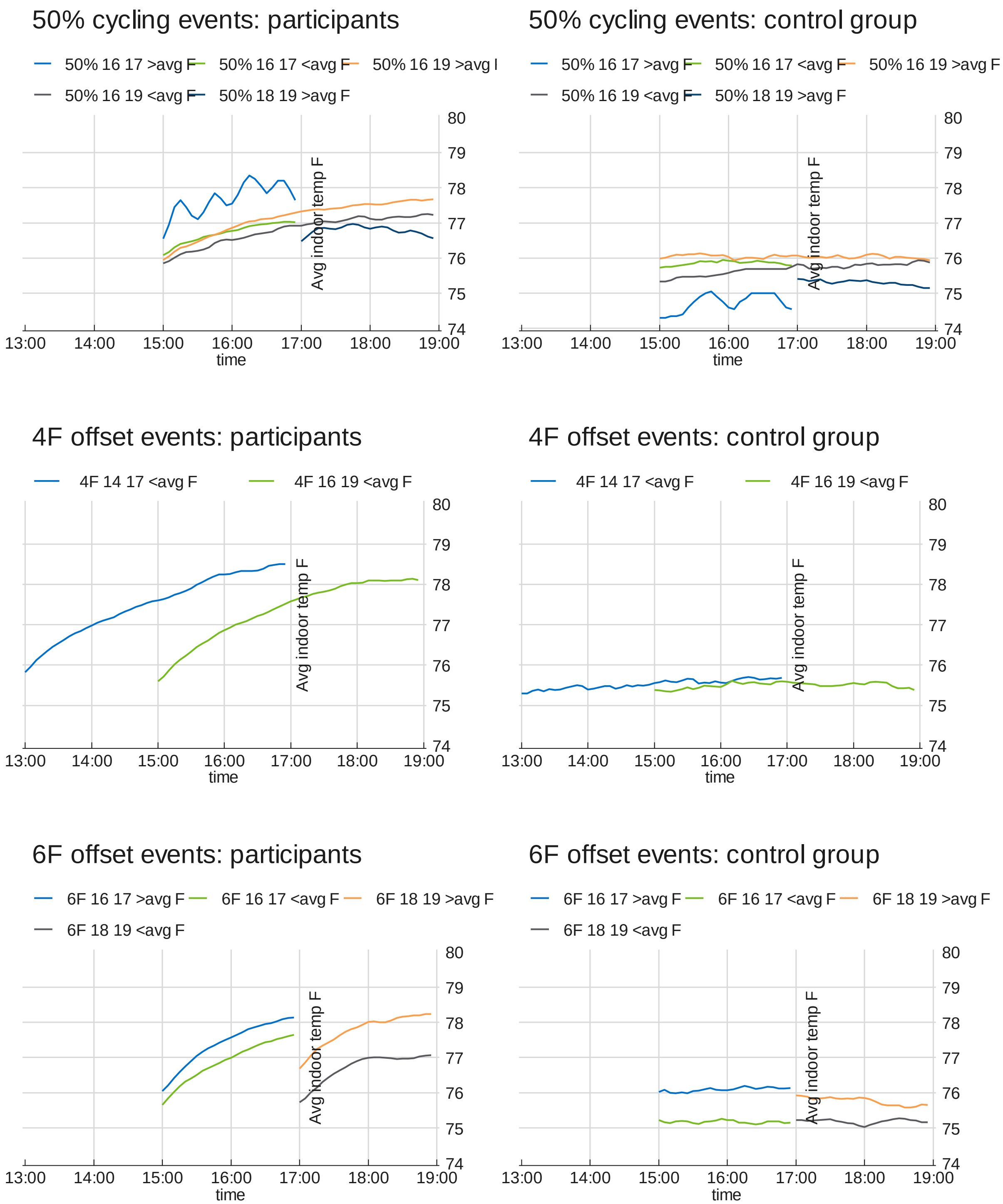


5.4 Indoor Temperature Changes During Events

Thermostat data also includes indoor temperature. Nexant used this data stream to estimate average rise of indoor temperatures for each event by charting temperatures over time for the period leading up to, during, and directly after each event. This analysis was segmented by event characteristic (e.g., duration, control strategy), by thermostat manufacturer, and by mean outdoor temperature during each event. It only includes devices that participated for the full duration of the event, because the focus was to determine how the indoor temperature changes in response to the control strategy and under different weather conditions without conflating with other factors such as participation rate, which may also vary by control strategy and weather.

Figure 5-5 shows the analysis of indoor temperature changes homes with for Vendor 1 devices. This analysis was not performed for Vendor 2 devices due to data quality issues which are exacerbated at this level of granularity. To portray the pace at which indoor temperature changes in response to an event average indoor temperature during each event was summarized at 5 minute intervals, the smallest level of granularity available for thermostat data. To avoid confounding with nonparticipation, this analysis is shown specifically for participants who participated for the full event. The figure clearly shows that temperatures rise steadily for participants during the course of events while they remain flat for the control group. Interestingly, the temperature gain per hour appears to be the same for both 4F and 6F offset events, about 1 degree per hour in the first hour and slightly less per hour thereafter. In contrast the temperature rise during the 50% duty cycling events (left most panel) is much smaller, indicative of the smaller impacts estimated evens using this control strategy.

Figure 5-5: Indoor Temperatures During Events, Vendor 1[58]



58 From 5 minute interval data from Vendor 1 thermostats, fully participating devices only. Above and below average events are defined as those with event temperatures above and below 90 degrees, respectively.

5.5 Small Business Impacts for Individual Events

Load impacts were also assessed for the ten SMB events dispatched on five calendar days, summarized in Table 5-7. Similarly to the BYOT DR events, SMB events were differentiated by both control strategy and event window, though fewer combinations were tested—the SMB pilot tested two control strategies (3 degree F offset and 50% cycling[59]) and two event windows (3-7pm versus 4-7pm). Unique to the SMB events was that precooling was tested in two events. Specifically, during the two temperature offset events on September 19 and 20 precooling was dispatched an hour before the 3-7pm event window. The first two SMB event days also faced challenges in that about half of devices were either not yet loaded into the system[60] (on September 1) or reported as unresponsive[61] (September 7).

Table 5-7: SMB DR Event Summary

Event number	Event date	Control strategy	Precool[62]	Event start	Event duration	Mean temp (F)[63]	Device count	
							Called	Analyzed
1045.27[64]	1-Sep	4F offset	No	3 PM	4	83.1	42	36
1329.18[65]	7-Sep	4F offset	No	4 PM	3	85.4	71	36
1409.53	8-Sep	4F offset	No	4 PM	3	87.2	71	57
1115.20	19-Sep	4F offset	Yes	3 PM	4	88.6	71	59
1140.14	20-Sep	4F offset	Yes	3 PM	4	86.4	71	59
1050.00	1-Sep	50%	No	3 PM	4	82.9	30	27
1331.20	7-Sep	50%	No	4 PM	3	85.1	59	27
1412.02	8-Sep	50%	No	4 PM	3	87.3	59	53
1116.32	19-Sep	50%	No	3 PM	4	88.7	59	52
1138.48	20-Sep	50%	No	3 PM	4	86.3	59	52

A key challenge with the evaluation of impacts for SMB DR events was the small sample size across devices and events. Individual customer regressions were used to develop predicted loads for event days, thereby forming the basis of the impact estimate when compared to actual

59 Implemented on a time basis, e.g.,15 minutes off followed by 15 minutes on, etc.

60 Due to a vendor issue getting the full list of devices into the dispatch portal so they could function as controllable resources

61 Though the full list of devices was loaded into the dispatch portal at this point those added since the September 1 event were labelled as "Non Responsive Devices" due to a vendor error. The vendor couldn't confirm but does not believe these devices received the DR event dispatch signal

62 Xcel assigned participants two one of two semi-random groups, one of which received $2.50 per event for verified participation, while the other received a $5 per event incentive. Differences in participation by event incentive level were also explored but the difference was not statistically significant.

63 Average during first two event hours

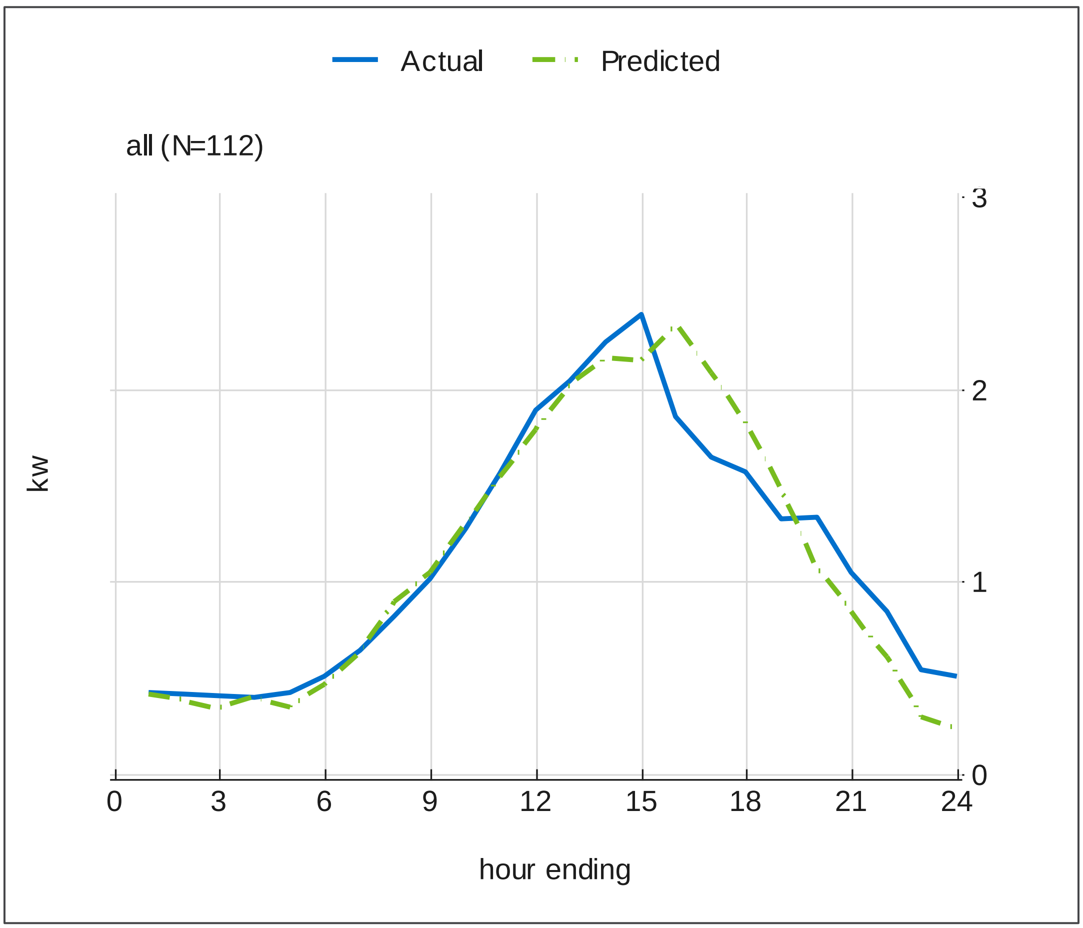
64 Several devices were not yet in the dispatch system on this day. Applies to both events on this day.

65 About half of called devices were listed as non-responsive in the dispatch system. These devices were excluded from all analyses because data was not available for them. Applies to both events on this day.

event day loads. However, device loads are inherently noisy at the individual level so when averaged across fewer data points (events or individual devices) the resulting loads are also noisy. To demonstrate this Figure 5-6 and Figure 5-7 show average event days loads and individual event day loads, respectively. Note that when averaging across all events and the 112 devices included in the analysis[66], predicted and actual load line up reasonably well. Load reductions can be observed for the 3 to 7pm event window on most days and a precooling spike can even be observed in hour 15 despite that this was only dispatched during two of the ten events.

In contrast, Figure 5-7 shows that the actual loads for individual events exhibit a lot more variability, resulting in poor pre-event alignment between actual and predicted loads. Because of this assessing quantitative impacts at this level of granularity may not be very meaningful. On the other hand averaging across all events obscures visually observable differences in impacts by dispatch strategy. To address this, reported impacts were aggregated across events with similar dispatch strategies.

Figure 5-6: Average SMB Event Day Loads, All Events



66 A total of 130 devices were enrolled, 1 was ineligible, 5 were missing interval data, 12 had insufficient data on proxy days to be included in the analysis so a total of 112 deices were included in the analysis. Some devices were also flagged as "Non responsive" in the data so devices analyze on each day may not sum to 112.

Figure 5-7: Average SMB Event Day Loads for Individual Events

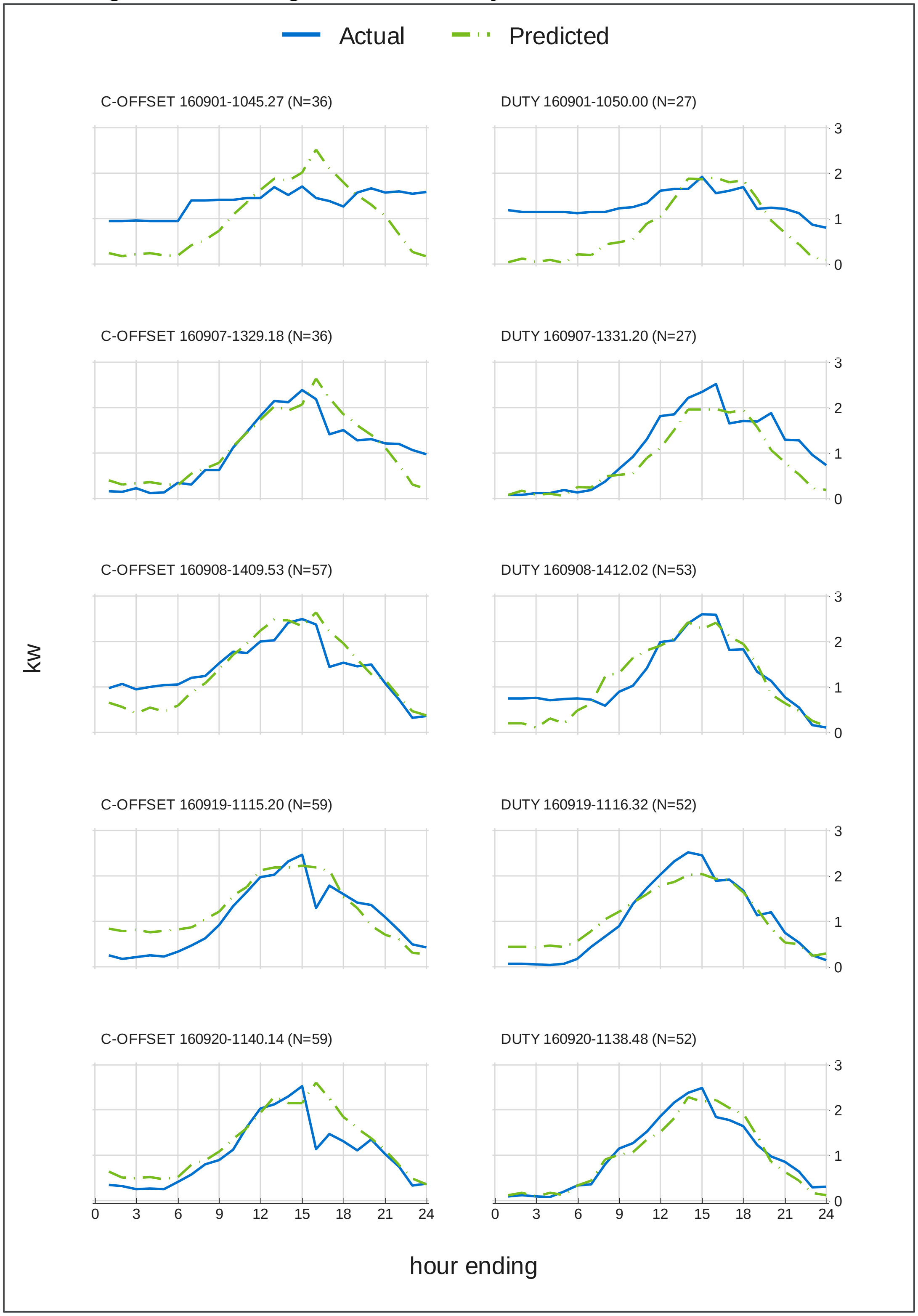


Table 5-8 summarizes impacts aggregated by control strategy and event window, resulting in four dispatch strategies. Note that impacts for the events on September 1 are excluded from the 4 hour event window group due to the data irregularities demonstrated in Figure 5-7. Impacts are shown for hours 16 through 19 and pre-event impacts in hour 16 for the 3 hour events have been greyed out. Average impacts are for event hours only. Figure 5-8 shows the average predicted and actual load shapes corresponding to the dispatch strategies. Recall that the 3F degree temperature offset events on September 19 and 20 include an hour of precooling.

Grouping DR event impacts in this manner enables a few relevant observations. The temperature offset control strategy appears to perform much better than the 50% duty cycling strategy, mirroring results found for the BYOT DR events. The later dispatch window can also be observed for the events on September 7 and 8. Although predicted cooling load peaks around hour 16 for the 3F offset group, an earlier spike in hour 15 is observed for the events on September 19 and 20, corresponding to the precooling dispatched in that hour.

These observations provide confidence that impacts provided at this level of granularity are at least directionally meaningful, despite the imperfect alignment of pre-event predicted and actual loads. Average event impacts are estimated to be 0.46 kW to 0.54 kW for the 3F offset events and about one third of that for the 50% cycling events (0.15 kW to 0.17 kW). Given the small amount of data points, it is not possible to determine if the difference in average impact by event window are meaningful, though it appears that for all dispatch strategies impacts are substantially higher during the first hour of the event so the dispatch window may have a greater effect on how impacts are distributed across hours. Precooling does appear to have delivered substantially higher impacts in the first hour, though impacts in subsequent hours appear lower when comparing to the 3F offset events without precooling (those on September 7 and 8). Both sets of events were called on days with comparable temperatures so differences in weather are probably not a factor.

Table 5-8: Vendor 2 SMB Event Impacts by Dispatch Strategy

Event number	Event date[67]	Control strategy	Event start	Event duration	Mean temp (F)[68]	Average hourly impact (kW)				
						16	17	18	19	Avg
1329.18[69]	7-Sep	3F offset	4 PM	3	85.4	0.34	0.77	0.40	0.22	0.46
1409.53	8-Sep	3F offset	4 PM	3	87.2					
1115.20	19-Sep	3F offset	3 PM	4	88.6	1.19[70]	0.55	0.23	0.18	0.54
1140.14	20-Sep	3F offset	3 PM	4	86.4					
1331.20	7-Sep	50%	4 PM	3	85.1	-0.31	0.28	0.16	0.07	0.17

[67] Impacts not shown for the events on September 1. Estimates not reliable due to the small number of thermostats connected on this day.

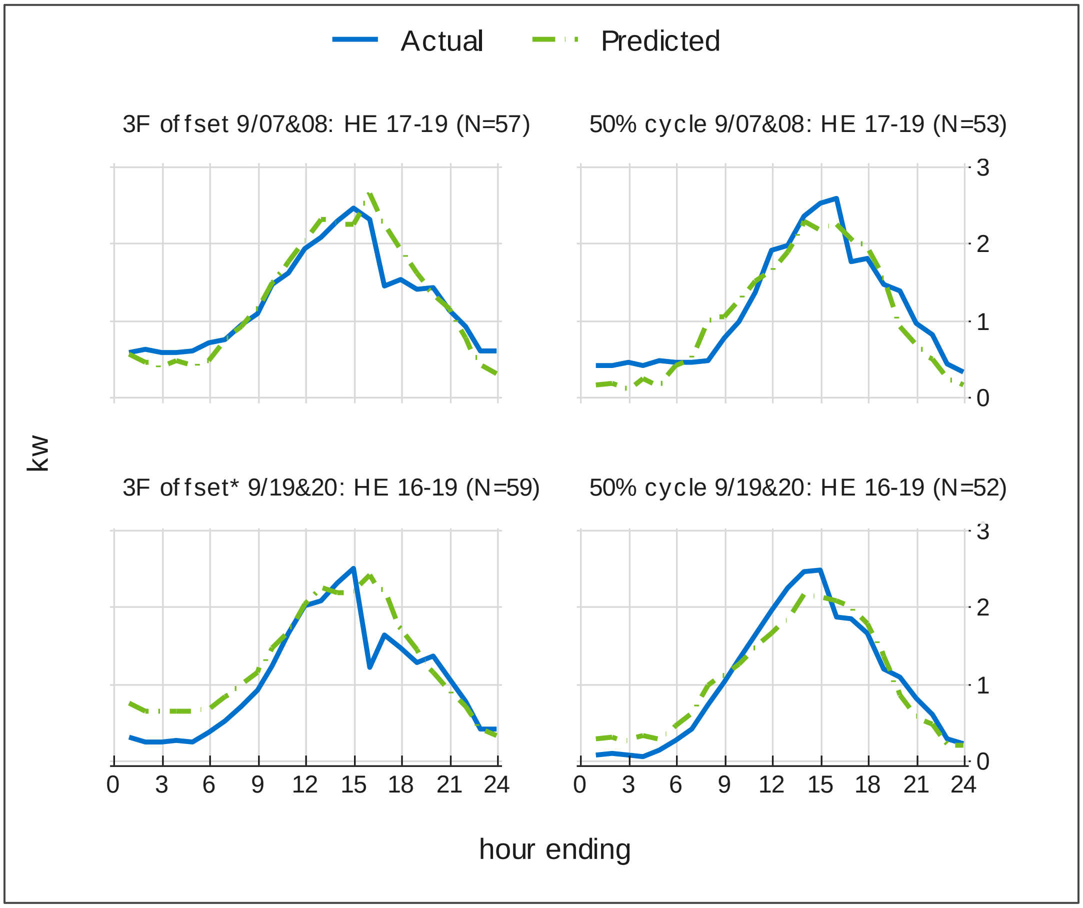
[68] Average during first two event hours

[69] About half of called devices were listed as non-responsive in the dispatch system. These devices were excluded from all analyses because data was not available for them. Applies to both events on this day.

[70] Precooling in this hour

Event number	Event date[67]	Control strategy	Event start	Event duration	Mean temp (F)[68]	Average hourly impact (kW)				
						16	17	18	19	Avg
1412.02	8-Sep	50%	4 PM	3	87.3					
1116.32	19-Sep	50%	3 PM	4	88.7	0.21	0.13	0.12	0.17	0.15
1138.48	20-Sep	50%	3 PM	4	86.3					

Figure 5-8: Average SMB Event Day Loads by Dispatch Strategy



6 Saver's Stat: Assessment of Customer Participation in DR Events

Understanding drivers of DR event participation is an important input to assessing program impacts and cost effectiveness. If certain program characteristics improve event participation this may mean that a program designed around these characteristics would be more cost effective, assuming that increased load reduction benefits outweigh any incremental costs, or alternatively, that cost reductions outweigh any decrease in load reduction benefits.

Nexant thoroughly assessed various program participation metrics for BYOT DR events using event participation data from Xcel Energy's DR provider. Participation for SMB DR events was assessed using participation data provided by Vendor 2 whose portal was used to dispatch devices.

Table 6-1 summarizes the four types of participation statuses recorded in the event participation data for participant devices. The 15 minute interval data records the amount of time a given device was in each of these mutually exclusive statuses during event hours to which that device was dispatched. For the purposes of incentive qualification, Xcel Energy defined participation in a given event as full participation for at least the first 30 minutes of the event. Because there was some latency between when a dispatch signal was sent and when it was received by thermostats, both "participating" and "waiting for dispatch" statuses count toward this definition. Nexant used the same definition for the participation analysis.

In addition, it is very important to note a key inconsistency in the DR event data used for the participation analysis. Specifically, devices that were not in cooling mode during and event were recorded as participating until about halfway through the DR event season. This data showed that about 7% of Vendor 1 devices and 15% of Vendor 2 devices were not in cooling mode during the events in the latter part of the season. While this data was not captured in the first part of the season it is likely that a similar portion of devices were not in cooling mode. In the absence of more complete data the participation numbers shown in this analysis count devices not in cooling mode as participating, to ensure a like to like comparison across events.

Table 6-1: DR Event Participation Variables

Status	Description
Participating	Device is participating in an event
Offline	Device is not on or is not connected to participant's WiFi
Incompatible Mode	Device is connected but is not in cooling mode (usually because it is off).
Opted Out	Participant has opted-out of an event
Waiting for Dispatch	Device is connected and ready to respond to an event signal

Table 6-2 summarizes participation related research questions and describes how Nexant used the DR participation data to answer each question.

Table 6-2: Event Participation Research Questions

Topic	Question
Participation rate summaries	What was the average participation rate across DR events?
	What was the average participation rate for each individual DR event?
	How did participation rates compare across control strategies?
	How did participation rates change during the 2016 event season?
Variables affecting participation rates	How was participation affected when events were called on back-to-back days?
	Was there any correlation between outdoor temperatures and participation?
	How did event duration affect participation?
Device availability	When did customers opt-out of events (right after receiving event notification, at the start of event, two hours into event, etc.)?
	What percent of the time were participant devices offline during events? In the 15 minutes preceding events?

6.1 BYOT DR Participation Rate Summaries

During the 2016 control event season 17 events were called on 10 calendar days for residential Saver's Stat participants between June 21 and August 17. Table 6-3 summarizes participation rates along with various dispatch characteristics for each event. As stated above participating devices are those that were not offline and that did not opt-out for the first 30 minutes of an event. It includes devices that were dispatched regardless of whether they were in cooling mode or not and about of Vendor 1 devices and 15% of Vendor 2 devices were likely not in cooling mode during events, though data to confirm this is incomplete.

The average participation rate across all events was 93%, and was similar for Vendor 1 devices (94%) and for Vendor 2 devices (92%).

Table 6-3: Event Participation Summary

Event number	Event date	Control strategy	Incentive level[71]	Event start	Event duration	Mean temp (F)[72]	Event participation rate[73]		
							Vendor 1	Vendor 2	Overall
4374	21-Jun	50%	Both	3 PM	4	93.3	94%	93%	93%
4386[74]	28-Jun	50%	$2.50	3 PM	2	89.5	93%	94%	93%
4388	28-Jun	50%	$5	5 PM	2	79.1	92%	94%	93%
4401	7-Jul	50%	Both	3 PM	4	86.6	94%	95%	94%
4452	19-Jul	50%	Both	3 PM	2	89.8	94%	94%	94%
4453	19-Jul	50%	Both	5 PM	2	81.4	96%	95%	95%
4456[75]	20-Jul	4F offset	Both	1 PM	4	91.0	NA	94%	94%
4475[76]	22-Jul	4F offset	Both	1 PM	4	89.5	94%	91%	93%
4517	3-Aug	90%	Both	3 PM	2	93.5	93%	92%	93%
4518	3-Aug	90%	Both	5 PM	2	89.6	93%	90%	91%
4536	9-Aug	6F offset	Both	3 PM	2	91.4	94%	92%	93%
4537	9-Aug	6F offset	Both	5 PM	2	85.0	93%	86%	89%
4559	11-Aug	6F offset	Both	3 PM	2	85.9	96%	88%	91%
4560	11-Aug	6F offset	Both	5 PM	2	79.9	92%	89%	90%
4595	17-Aug	4F offset	Both	3 PM	4	87.2	93%	NA	93%
4596	17-Aug	1F offset	Both	3 PM	3	87.3	NA	89%	89%
4597	17-Aug	2F offset	Both	3 PM	3	87.1	NA	89%	89%
Average	--	--	--	--	--	87.5	94%	92%	93%

When assessing the effects of different characteristics on an outcome it is necessary to have a sufficient number of data points corresponding to each characteristic to be able to isolate each individual effect from possible confounding factors. Because there were a variety of event characteristics across events, including control strategy, incentive level, dispatch window, and mean outdoor temperature, there were not enough data points to be allow for isolation of small differences in participation by these some of these criteria. However, it does appear that event participation varied consistently by control strategy. In particular, participation appears to be

71 Xcel assigned participants two one of two semi-random groups, one of which received $2.50 per event for verified participation, while the other received a $5 per event incentive. Differences in participation by event incentive level were also explored but the difference was not statistically significant.

72 Average during first two event hours

73 Percent of called devices fully participation (participating or waiting for dispatch) or not in cooling mode during each event based on DR event participation intervals. This same definition was used by Xcel to qualify participants for event participation incentives. The average across all events is the simple average and is not weighted for number of participants called in each.

74 Includes 6 devices that were queued separately under event id 4387

75 Event dispatched prematurely

76 Event dispatched prematurely

higher for events using the 50% duty cycling strategy. The 50% and 90% duty cycling strategies implemented through the thermostats via manufacturer algorithms were meant to mimic the functionality of an AC cycling switch via a simple time-based on / off control. Other control strategies tested include 4 and 6 degree temperature offsets, and 1 and 2 degree stacked offsets, where the participant's setpoint was raised by that increment each hour of the event.

Table 6-4 summarizes the differences in event participation by control strategy. To control for some of the variation across other characteristics, participation rates are shown for the first two hours of each event. Six of the seventeen events were dispatched using the 50% duty cycling and the other five control strategies were dispatched across the remaining eleven events, resulting in one to four data points per specific control strategy. Because there were fewer data points per individual control strategy and because the most notable difference in impacts was between 50% duty cycling and the other control strategies participation for all others have been grouped together as well.

This summary analysis reveals that participation was quite close overall, only 3 percentage points higher for events deploying the 50% cycling strategy compared to all other events. This is meaningful because the BYOT DR impact analysis in Section 5 showed that impacts for 50% duty cycling events were generally lower than for other control strategies, controlling for dispatch type, event window, and weather. It also showed that indoor temperatures increase more with other control strategies—also consistent with higher delivered impacts. However, this participation analysis shows that the higher delivered impacts and temperature increase did not result in higher significantly different participation rates.

However, there is also a notable difference by thermostat vendor. In particular, while there was only a 1% difference in participation among Vendor 1 devices for between 50% duty cycling and other control strategies, participation among Vendor 2 devices was about 5% higher for Vendor 2 devices. As shown in Section 6.3 this is largely due to differences in device availability rather than to opt-out rates.

In addition, because all 50% cycling events were called during the first half of the season and all other events were called during the second half it is not valid to compare events from the beginning of the season to the end to track how participation changed over the course of the season. This is because it is impossible to isolate the effect of the cycling strategy from the effect of the timing during the event season.

Table 6-4: DR Event Participation by Control Strategy, First Two Event Hours

Control strategy	Event start	Number of events	Event participation rate[77]			Difference between 50% cycling and other strategies		
			Vendor 1	Vendor 2	Overall	Vendor 1	Vendor 2	Overall
50% cycling	3pm	4	94%	94%	94%	0%	4%	2%
All other	3pm	6	94%	90%	92%			
50% cycling	5pm	2	94%	95%	94%	1%	6%	4%
All other	5pm	3	93%	88%	90%			
50% cycling	3pm or 5pm	6	94%	94%	94%	1%	5%	3%
All other	3pm or 5pm	9	93%	89%	91%			

6.2 Variables Affecting BYOT DR Participation

Three key variables were assessed to determine if there was a notable influence on participation: dispatching on consecutive days, outdoor temperature, and event duration. The first, consecutive dispatches (i.e., dispatching DR events on back-to-back days), could not be assessed due to lack of data. The second, event temperature, did not appear to substantially affect participation. The third, event duration, showed that fewer participants were still participating at the end of 4-hour events compared to 2-hour events, but that the pace of opt-outs remained the same regardless of event duration. Put another way, the rate of opt-outs over time appeared to be relatively constant over the duration of event, so that resulted in roughly twice as many opt outs over the course of an event lasting twice as long.

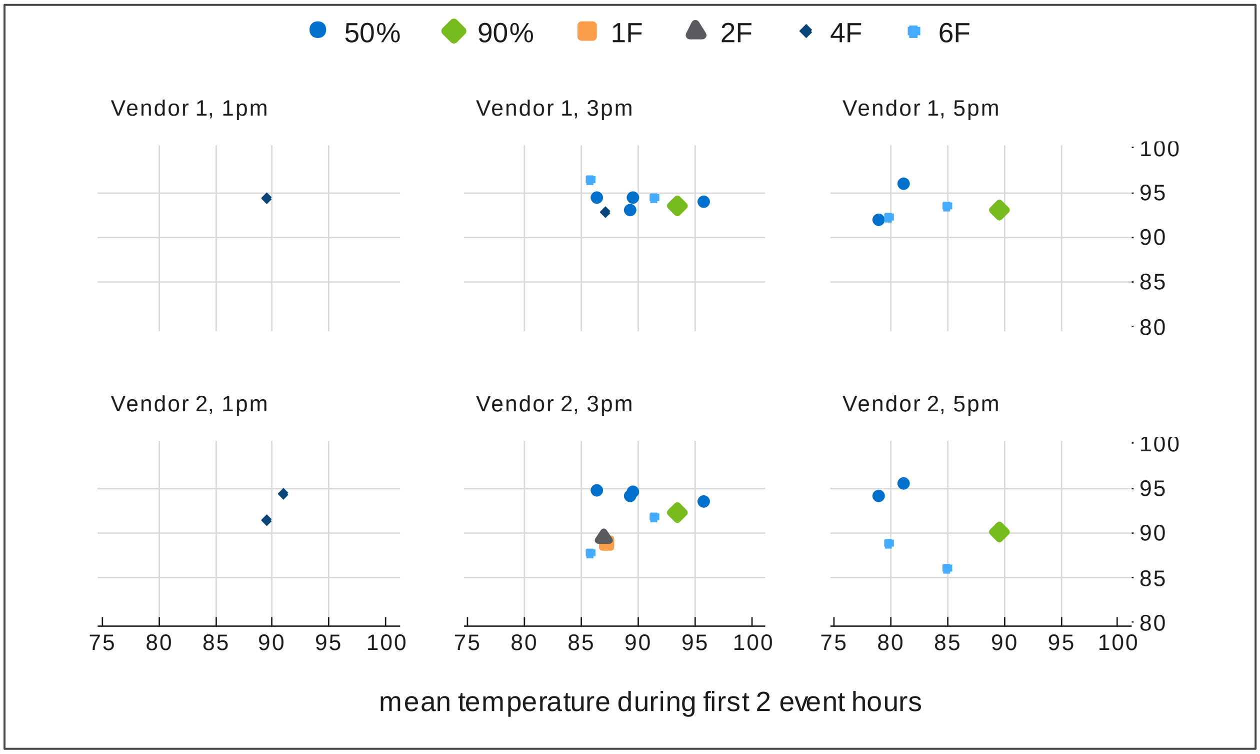
There was only one instance where the same group of participants was called on two consecutive days (July 19 and July 20). However, there were two differences between these two events which preclude valid comparison to determine if dispatching two events in a row results in different participation rates on the second day. First, the group dispatched on both days was dispatched at 3 PM on July 19 but at 1 PM on July 20 due to a time zone error on the dispatcher's computer. Perhaps more notable, though is that on the first day a 50% cycling strategy was used while a 4 degree temperature offset strategy was used on the second day. It has already been established that participation rates are significantly higher for 50% cycling events and any incremental difference in participation on these two days due to the consecutive dispatch cannot be differentiated from the effect of the control strategy.

To assess if any weather effect could be identified on participation rates it was necessary to separate out other factors such as device type and control strategy that were also shown to

[77] Percent of called devices fully participation (participating or waiting for dispatch) during each event based on DR event participation intervals. This same definition was used by Xcel to qualify participants for event participation incentives.

impact participation. Figure 6-1 plots participation rates for each event on mean event temperature, separated by device and hour of dispatch. Different control strategies are portrayed with different colored points. Figure 6-1 is a visual portrayal of the same information that is in Table 6-3, demonstrating that there is no particular trend in participation by event temperature.

Figure 6-1: Participation in Events by Weather and Control Strategy[78]



6.3 Device Availability

Three factors affect the availability of devices to deliver DR impacts during an event: participant opt-outs, whether the device is in cooling mode (or if it is in a mode incompatible with AC load control), and technology issues causing the device to be offline. Table 6-5 shows the average time spent in opted-out or offline status, by vendor and control strategy. Time spent in incompatible mode is not shown because this data was not consistently captured across events as described further below. Note also that this summary data is not directly comparable to participation rates which were assessed based on the first thirty minutes of an event. The key point underscored by the data in Table 6-5 is that there is no substantial difference in opt out rate between Vendor 1 and Vendor 2, even when controlling for control strategy. In contrast, there is a notable difference in device availability: device availability for Vendor 2 devices is both more variable and about 5% to 12% higher than for Vendor 1 devices.

78 Each point equals one event

Table 6-5: DR Event Device Availability by Vendor and Control Strategy

Provider	Control strategy	% devices in each status	
		opted-out	offline
Vendor 1	50% cycling	4%	3%
Vendor 1	4F & 6F	6%	5%
Vendor 2	50% cycling	2%	15%
Vendor 2	4F & 6F	7%	10%

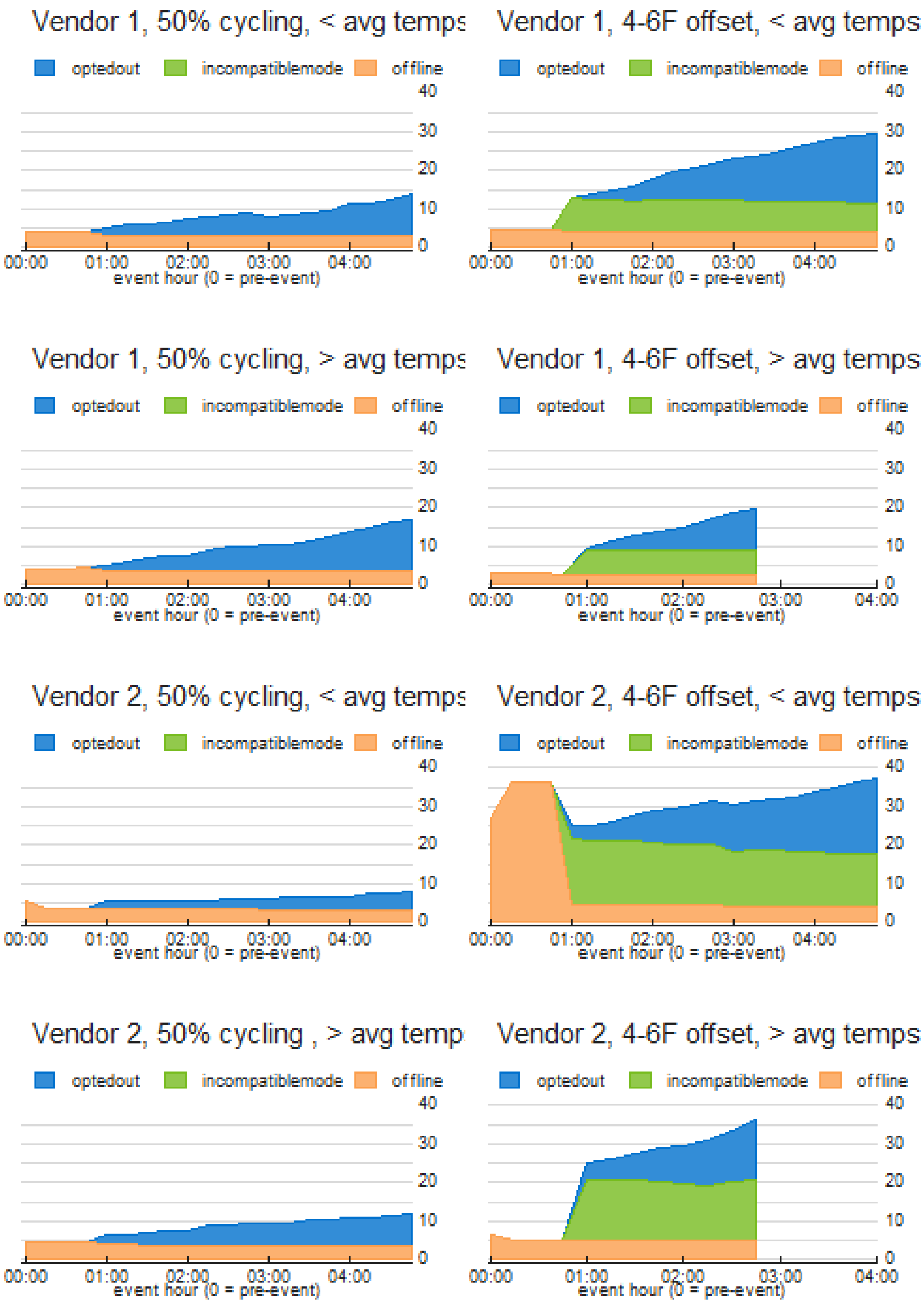
Figure 6-2 shows the percent of called devices in each of these states, by vendor and control strategy. The blue region in Figure 6-2 shows the percent of devices opted out at each 15 minute interval just preceding and during events. The 4 and 6 degree temperature offset events for both vendors and the 50% cycling events for Vendor 1 appear to have a relatively consistent shape showing a consistent opt-out trend over the course of the events at a pace of roughly 3% to 5% per hour. In contrast, the 50% cycling events for Vendor 2 appear flat implying that opt outs are limited over the course of these events. Another difference for Vendor 2 is the difference in when the first opt-outs initially occurred. Opt-outs largely did not occur until after the start of most events, indicating that opt-outs happened largely during an event as opposed to far before. The exception to this is 4F and 6F offset events for Vendor 2: by the beginning of 4F and 6F offset events about 5% of Vendor 2 devices had opted-out. This is in part by design because only Vendor 2 users had the option to opt-out of an event before it began (via email). Vendor 1 users had to wait until the event started before they could opt-out. Also, during 50% cycling events opt-outs are somewhat higher for Vendor 1 devices than for Vendor 2 devices. In contrast, opt-outs were not consistently higher for either vendor during events called when temperatures were above 90 degrees.

The green region in Figure 6-2 shows the percent of devices which were in incompatible mode. Devices are considered incompatible when the thermostat is not in cooling mode. The fact that a substantial number of devices (about 7% of Vendor 1 and 15% of Vendor 2 devices) were logged as being in incompatible mode during the events that did not use 50% cycling was simply due to a discrepancy in how DR event data was recorded. Prior to July 21 devices that were not in cooling mode were recorded as participating instead of as incompatible. By chance, events prior to this date used the 50% duty cycling control strategy and event after this date did not and any correlation with the change in data recording is purely coincidental. Because there was no record of whether devices were "incompatible" during the 50% duty cycling events participation for other events includes devices in incompatible mode to ensure a like to like comparison. There is no reason to believe that a similar percentage of devices, about 7% or Vendor 1 devices and 15% of Vendor 2 devices, were incompatible during the 50% cycling events but they are not identified in the DR event data.

The orange region in Figure 6-2 shows the percent of devices which are offline at each interval. About 3% to 10% of devices were offline during events across cycling strategies, thermostat manufacturer, and mean event temperatures.

Note that although rates of opt-out were slightly higher for the 4F and 6F offset events than they were for the 50% cycling events, especially for Vendor 2 devices, impacts were substantially higher for these control strategies than they were for the 50% cycling events as discussed in depth in Section 5.2. Impacts were assessed for all devices called (e.g., offline devices and devices deemed to be in "incompatible mode") so the reported impacts already incorporate the effects of opt-outs and technical failures. While the opt-out rate appears somewhat higher for offset events, impacts are still higher on average for offset events despite this small possible behavioral effect.

Figure 6-2: Percent of Devices Opted Out or Offline During Events, by Control Strategy[79]



[79] Average temp determined by averaging local temperature between 3-5pm on event days. Average event temperature during Colorado events was 90 degrees F.

6.4 SMB DR Event Participation

Participation in SMB DR events was analyzed using data delivered from the Vendor 2 DR dispatch portal. Device status was recorded as percent of minutes spent in each of three statuses: participating, opted-out, or offline. The average participation summaries below show that average of these figures across devices and correspond to the average time devices spent in each status.

Table 6-6 provides a summary for each of the ten SMB DR events including the average time devices spent participating, opted-out, or offline. Participation rates ranges from 74% to 94% while opt-out and offline rates each ranged from 0% to 14%. Note that each event on September 7 excludes 29 devices flagged as "non-responsive" in the dispatch portal.

Table 6-6: SMB DR Event Participation

Event number	Event date	Control strategy	Precool[80]	Event start	Event duration	Mean temp (F)[81]	Percent of Devices		
							Participating	Opted-out	Offline
1045.27[82]	1-Sep	4F offset	No	3 PM	4	83.1	84%	6%	9%
1329.18[83]	7-Sep	4F offset	No	4 PM	3	85.4	81%	6%	14%
1409.53	8-Sep	4F offset	No	4 PM	3	87.2	89%	4%	7%
1115.20	19-Sep	4F offset	Yes	3 PM	4	88.6	82%	7%	11%
1140.14	20-Sep	4F offset	Yes	3 PM	4	86.4	74%	14%	11%
1050.00	1-Sep	50%	No	3 PM	4	82.9	94%	3%	3%
1331.20	7-Sep	50%	No	4 PM	3	85.1	93%	0%	7%
1412.02	8-Sep	50%	No	4 PM	3	87.3	97%	0%	3%
1116.32	19-Sep	50%	No	3 PM	4	88.7	90%	5%	5%
1138.48	20-Sep	50%	No	3 PM	4	86.3	83%	12%	5%

Table 6-7 summarized device statuses by dispatch strategy, which included control approach (offset or duty cycling) and event window (3pm to 7pm or 4pm to 7pm). Average device participation rate is about 7% to 10% higher during shorter events indicating, echoing the BYOT DR participation analysis which showed that participants tend to opt out gradually over the course of an event, leading to more opt-outs during longer events. Control strategy has a similar effect, with temperature offsets leading 8% to 11% more opt-outs. This also mirrors findings

80 Xcel assigned participants two one of two semi-random groups, one of which received $2.50 per event for verified participation, while the other received a $5 per event incentive. Differences in participation by event incentive level were also explored but the difference was not statistically significant.

81 Average during first two event hours

82 Several devices were not yet in the dispatch system on this day. Applies to both events on this day.

83 About half of called devices were listed as non-responsive in the dispatch system. These devices were excluded from all analyses because data was not available for them. Applies to both events on this day.

from the BYOT DR pilot though the discrepancy between duty cycling and temperature offsets is more pronounced for SMB DR participants.

Table 6-7: SMB DR Event Participation by Dispatch Strategy

Event number	Event date	Control strategy	Precool	Event start	Event duration	Mean temp (F)	Percent of Devices		
							Participating	Opted-out	Offline
1329.18	7-Sep	4F offset	No	4 PM	3	85.4	85%	5%	10%
1409.53	8-Sep	4F offset	No	4 PM	3	87.2			
1115.20	19-Sep	4F offset	Yes	3 PM	4	88.6	78%	11%	11%
1140.14	20-Sep	4F offset	Yes	3 PM	4	86.4			
1331.20	7-Sep	50%	No	4 PM	3	85.1	96%	0%	4%
1412.02	8-Sep	50%	No	4 PM	3	87.3			
1116.32	19-Sep	50%	No	3 PM	4	88.7	86%	9%	5%
1138.48	20-Sep	50%	No	3 PM	4	86.3			

In addition to control strategy and dispatch window, the SMB DR pilot was also designed to test the impact of performance incentives. Table 6-8 shows device status by control stratus and incentive assignment both of which were randomly assigned. However, this incentive randomization was done in the dispatch portal and did not necessarily assign the same incentive status to all devices at given premise. In addition, messaging of incentives was limited given that not all participants received incentives. Finally, because all SMB DR events were called in September participants who did receive incentives only received them after the DR events, further limiting any effect incentives may have on participation or load reductions. Because of these implementation challenges which limited participant awareness, no conclusions can be drawn about the influence of performance incentives on participant behavior. It is therefore not surprising that participation rates and opt-out rates varied by a negligible amount—just 1% to 3%--between incentive groups. Not only does it not appear that any meaningful effect from incentives was observed, participation was high and opt-outs were low in general. Though no conclusions can be made about the effect of performance incentive on participation this does not preclude the possibility that load reductions or participation might have been higher had incentives been effectively messaged.

Table 6-8: SMB DR Event Participation by Dispatch and Incentive Strategy

Control strategy	Incentivized	percent of devices		
		participating	opted-out	offline
50%	Yes	90%	3%	7%
50%	No	92%	6%	2%
4F offset	Yes	82%	6%	12%
4F offset	No	81%	9%	9%

7 Modeling Typical Residential Smart Thermostat Usage

7.1 Data Sources for Modeling

As a complement to the EE savings analysis, Nexant analyzed participant thermostat usage patterns. The goal was to gain a better understanding of how participants actually use their thermostat by modeling the typical usage for smart thermostats by residential pilot participants. Ultimately, this may reinforce the hypothesis that smart thermostat owners use smart thermostats efficiently and as-intended by deploying setback schedules (included automated schedules as defined by the thermostat), using efficient temperature setpoints, and avoiding keeping thermostats in “hold” mode at inefficient temperatures over long periods of time.

As summarized in Figure 7-1, various data streams (represented by the horizontal grey boxes) were used to answer research questions across four topics (columns), meaning a significant amount of thermostat usage data was transferred, validated, and managed. To accomplish this, it was necessary to collect and standardize data from three different thermostat manufacturers, each of which had separate data transfer processes, data formats and structures, and data dictionaries for data fields. This was an extensive process that took multiple months to coordinate and execute. Among the most intensive efforts were

- Matching of device ids to customer premise ids: premise ids or account ids were not captured as part of the Storefront purchase or mail-in rebate process, in part to avoid creating a barrier to participation for customers. However, this meant that it was necessary to rely on address matching via coded string parsing to match addresses on Storefront purchases or rebate applications to customer premises. Device ids were also sometimes not captured or captured erroneously or could not be successfully tied to premises for both rebate applications and DR applications.
- Transferring data: there is relatively wide variation in data transfer capabilities and terms and conditions across vendors. One vendor could only provide data access to the evaluator or utility via an API, which required knowledge of basic programming skills and the ability to install a coding package. Another vendor attempted to set up automated delivery of data but repeatedly sent empty or partial files. A third vendor prepared and shared a dataset without issue but had internal policies which precluded combining thermostat data with customer ids, making it impossible to segment EE savings or other impacts by survey responses or thermostat usage. This diminished the ability to establish correlation between impacts and certain reported or demonstrated behaviors.
- Standardizing thermostat data formats and time zones: In particular, data must be in interval format for analysis of load impacts, participation, and thermostat usage patterns. While most data was in this format, data from one vendor was instead captured as status changes. Custom programming was required to convert this data to interval data, in which time spent in a given status is captured for each consecutive time interval (either 5 or 15 minute intervals). Unfortunately, the resulting interval dataset was still relatively unreliable. It was possible to identify substantial data gaps on a handful of days because there were no status changes for a majority of devices; these days were removed from the analysis. In addition, it is likely that data was missing for some thermostats on other days but there was no way of identifying a missing status change; if two days pass between status changes it may be that status actually remained the same for two days or that intermediary status changes were not captured.

Figure 7-1 Thermostat Modeling Research Topics and Data Streams

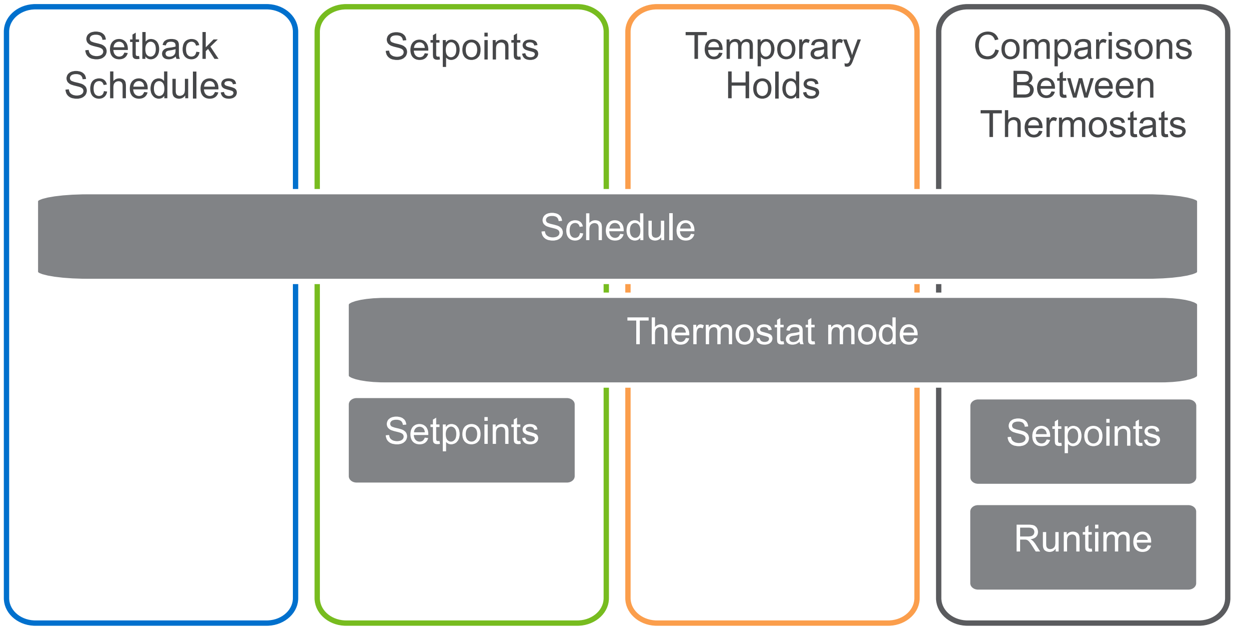


Table 7-1 summarizes the data streams and specific variable types available for each provider. These data streams were used to answer questions for each research topic. For each research question, Nexant assessed patterns by month, weather, hour of day, day of week, customer segment, and thermostat manufacturer.

Table 7-1: Thermostat Data Stream Descriptions and Availability

Data Stream	Variable	Description	Vendor 1	Vendor 2	Vendor 3
Runtime	Runtime	Heating or cooling runtime duration in a given interval	✓	✓	✓
	System mode	HVAC system activity (e.g., heat / cool / off) as recorded by the thermostat	✓	✓	✓
Setpoints	Average indoor temperature (F)	Temperature as measured by thermostat (triggers AC if rises above cooling set point or heat if falls below heating setpoint)	✓	✓	✓
	Cooling set point (F)	Maximum temperature (above which AC will turn on)	✓	✓	✓
	Heating set point (F)	Minimum temperature (below which heater will turn on)	✓	✓	✓
Schedule & thermostat mode	Thermostat mode	Periods used for defining setpoints (following schedule, home, away, hold, vacation)	✓	✓	✓
	Schedule settings	Scheduled setpoints for each mode in each interval	-[84]	✓	✓
	Hold triggers	Indication of what triggered a hold (e.g., manual, web, algorithm)	✓	-	✓[85]

[84] Scheduled setpoints are not historically archived by Vendor 1 making fields unavailable for analysis, for the purposes of analysis a proxy for scheduled setpoint was derived by identifying the most frequent (mode) cooling and heating setpoints in intervals where the thermostat program indicated a schedule was being followed (within each month, day of week type, and hour).

[85] Only split of manual versus web is available for Vendor 3.

7.2 Research Questions and Approach

Thermostat usage by participants was analyzed in detail to assess whether observed differences in EE savings can be explained by differences in thermostat usage or functionality. In particular, thermostat program schedules, temperature setpoints, and the deviation from both via both manual holds and algorithm based setbacks were explored. The research questions in Table 7-2 were developed to guide this exploratory analysis and the following three sections are organized to cover the three research topics.

Table 7-2: Thermostat Modeling Questions

Topic	Question
Schedules & Other Program settings	Are setback schedules typically deployed? How long do customers spend in setback schedules vs. putting thermostats on hold?
	What are typical hours used for setback schedules and subsequent periods (away, home, etc.)?
	How often are thermostats put in hold mode?
	How long does a typical “hold” persist?
	Do smart thermostat owners take action to return to the setback schedule or is that automated?
Setpoints	What are typical setpoints used by customers for setback schedules, by period?
	Are these programmed setpoints changed often?
	What are typical setpoints deployed when thermostats are on hold?
	When customers put their thermostat on hold, is it typically done to save energy or increase comfort?[86]
Potential link to energy savings	What is the typical usage and energy savings profile of users for each type of thermostat deployed?
	If users of a particular thermostat save more, what are the likely causes?

Each thermostat manufacturer uses different algorithms, data structures, and program names which complicates the task of evaluating seemingly simple concepts such as setbacks and schedules. Because of this data for each thermostat manufacturer was analyzed separately with special care given to describing thermostat program settings and functionality. Also, due to the large scale of the data[87] the analysis in this section is based on a random sample of 400 devices from each manufacturer. Finally, the in depth analysis in this section is provided only for cooling setpoints during summer months (June through September). However, the analysis was

[86] In the Vendor 1 data structure only the other program settings are explicitly logged, so their absence implies the default or scheduled settings are being followed.

[86] Here summer is defined as June through September, a

also explored for heating setpoints during winter months and the conclusions were directionally the same.

7.3 Schedules and Other Program Settings

Observing the time thermostats spend in various program settings and how they return to the schedule setting provides insight into the extent to which thermostat operation is automated and designed to return to schedule or to a more efficient AWAY temperature setting. This section is organized by thermostat manufacturer to introduce the different approaches to program settings used by each, how often each is deployed, when, and for how long.

7.3.1 Vendor 1

Vendor 1 thermostats can be in one of the seven mutually exclusive program modes described in Table 7-3. HOME and AWAY can be triggered either by the user manually setting the program or by the occupancy sensors which are part of the thermostat. A temperature hold ("HOLD") can be set either manually, through web portal, or verbally home assistant device. The Vendor 1 algorithm also uses a feature to pre-heat or pre-cool the home so that the scheduled setpoint is reached at the beginning of a scheduled period, but this feature can be used in conjunction with any of the program settings below.

Table 7-3: Vendor 1 Thermostat Program Settings

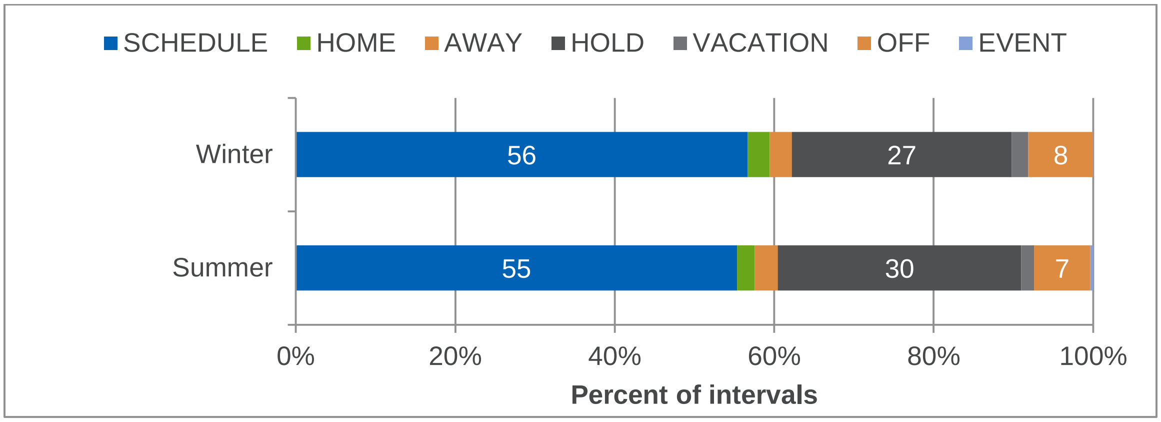
Program setting	Description
SCHEDULE	No explicit program is set[88] and default or scheduled temperature settings will be followed
HOME	Dwelling is occupied and default or scheduled temperature setting is algorithmically or manually adjusted for comfort
AWAY	Dwelling is not occupied and default or scheduled temperature setting is algorithmically or manually adjusted for efficiency
HOLD	Scheduled or default temperature setting is directly overridden by the user
VACATION	Dwelling will be unoccupied for a specified period of time during which temperature is adjusted for efficiency
OFF	Thermostat is set to off and no heating or cooling occur
EVENT	Thermostat is controlled for the duration of a demand response event (until overridden)

The Vendor 1 devices analyzed spent most of the time in SCHEDULE or HOLD settings, shown in Figure 7-2. About 55% of the time, Vendor 1 devices were spent in the SCHEDULE setting

[88] In the Vendor 1 data structure only the other program settings are explicitly logged, so their absence implies the default or scheduled settings are being followed.

and 30% of the time in the HOLD setting, with no meaningful difference by season[89] or by day of week. Thermostats were off about 7% of the time.

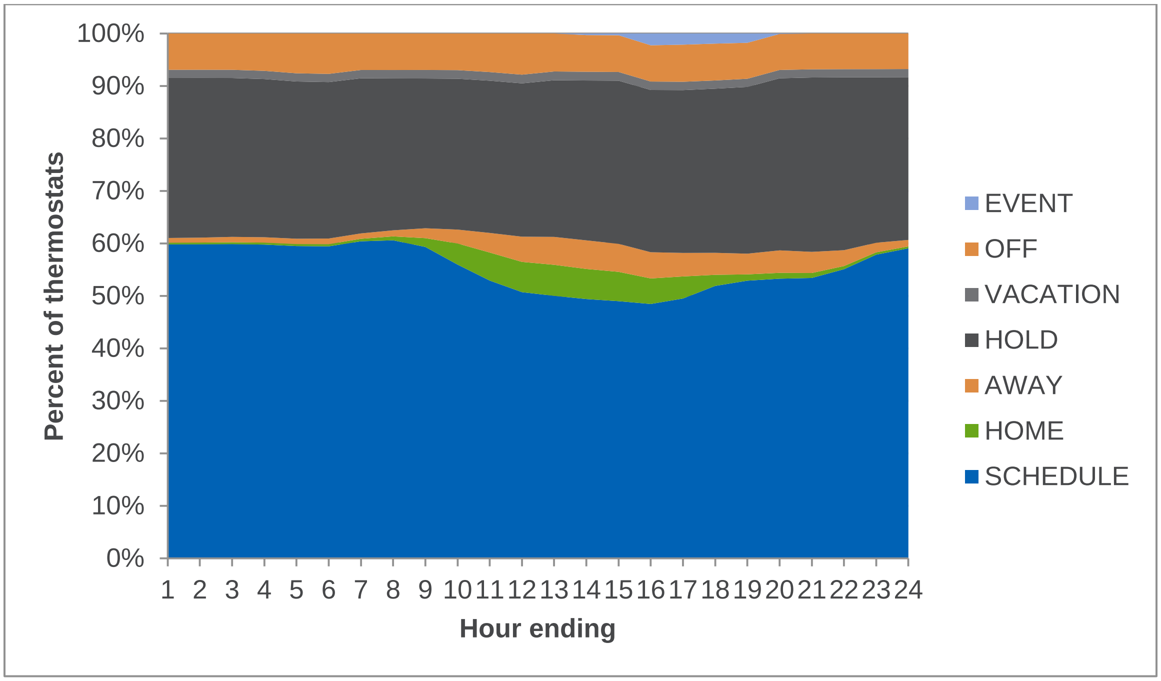
Figure 7-2: Percent of Intervals Spent in Each Vendor 1 Program Setting



Assessing the difference in settings by hour of day paints a fuller picture of how Vendor 1 devices are used. Figure 7-3 shows the hourly variation of time spent in each program setting. There is very little differentiation by hour. Most notably, thermostats were about as likely to be in the HOLD setting in any hour of the day. The only noticeable hourly differentiation was with the HOME, AWAY, and EVENT settings. The EVENT setting reflects the 3pm to 7pm event window for most events while the HOME and AWAY settings were most typically deployed during the day and early evening. It is important to note that the HOME and AWAY settings are essentially a type of HOLD, deployed manually or through occupancy sensors, in that they alter the temperature setpoint from the SCHEDULE setting. This is important because other thermostats may use similar names for program settings which may actually exhibit very different functionality.

[89] Here summer is defined as June through September, and winter as December through March

Figure 7-3: Percent of Thermostats in Vendor 1 Program Settings, Hourly (Summer)



One can observe how a thermostat is used by assessing how long a thermostat typically remains in a given program setting. Figure 7-4 shows the number of days Vendor 1 thermostats typically spend in each setting.[90] Note that the durations shown are the average across intervals where thermostats were in each setting as opposed to the average time spent in each setting across all devices and intervals. For example, when thermostats were in the VACATION setting, they remained there on average for seven days, but this does not mean that all thermostats spent seven days in vacation mode. Similarly, though Vendor 1 devices analyzed were on average only in the OFF program setting for about 7% of intervals during summer months (as shown in Figure 7-2), when devices were off they were typically off for the entire season. In fact, devices in the OFF setting were off for seven to eight months at a time on average (shown as durations over 200 days long in Figure 7-4) regardless of whether the OFF program setting began in summer or in winter. This implies that about 7% of thermostats were simply off all the time, a number that corresponds to the data on “incompatible mode” discussed in the participation analysis in Section 6.3.

In contrast to the OFF program setting, the other program settings typically had much shorter durations. Thermostats typically remained in the SCHEDULE setting for about 4 days at a time during the summer. The SCHEDULE setting was interrupted to put the device in home mode for about 0.6 days and the away mode for 1.3 days. As one may expect, programmed vacations typically lasted for 7 days. Notably, holds typically lasted for 10.7 days, implying that Vendor 1 thermostats do not automatically return to the schedule setting once placed in hold. In fact, Vendor 1 devices allow for users to select the duration of their hold, including an option to

[90] Only includes intervals when thermostats were in that setting, so NOT weighted for the percent of time spent in each setting.

automatically revert to the SCHEDULE setting at the end of the current period and an option to remain in the hold until the user manually ends the hold. The data suggests that most users choose to the latter option, resulting in devices remaining in hold for days at a time, on average.

Figure 7-4: Average Consecutive Days When in Each Vendor 1 Program

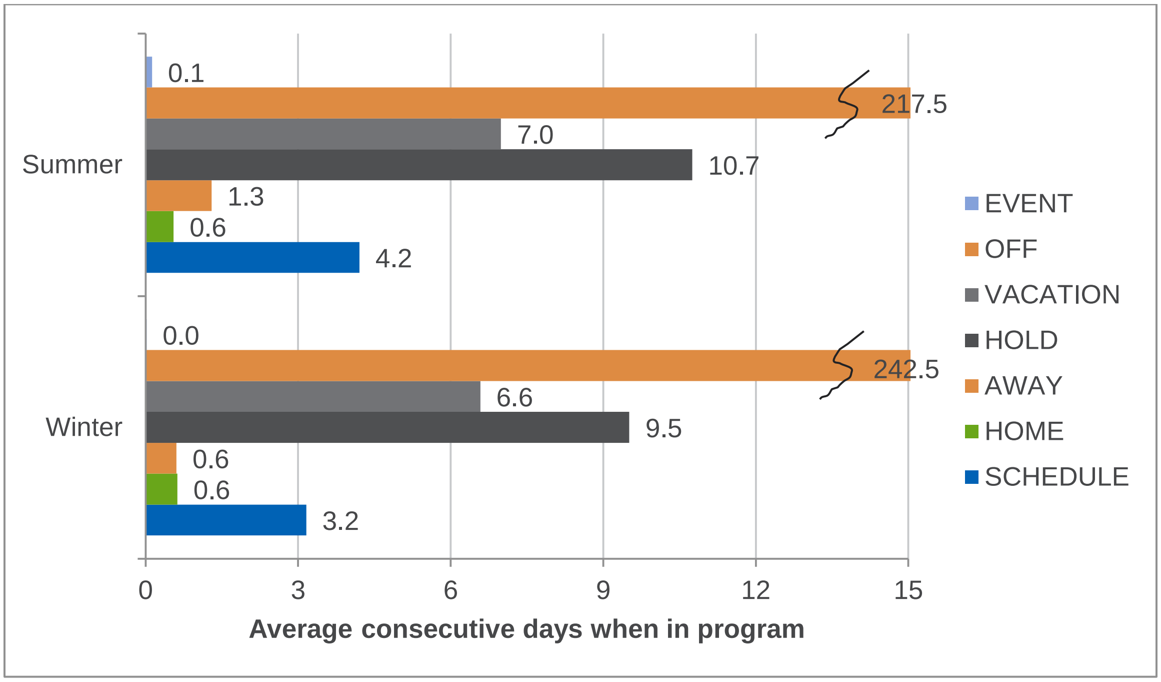
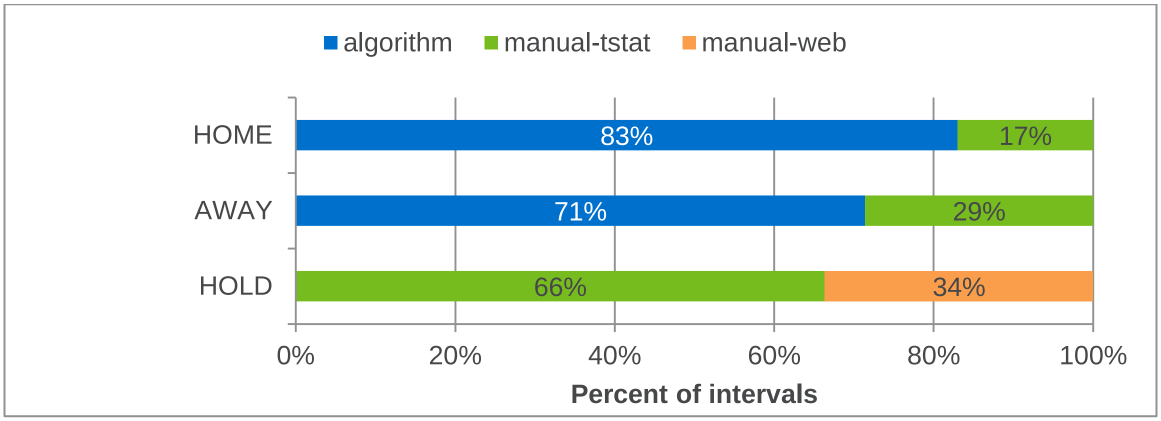


Figure 7-5 shows the source of Vendor 1 HOLD related settings, demonstrating that the HOME and AWAY settings are usually triggered by an algorithm while the HOLD setting is entirely triggered manually by the user. When users create a hold (e.g., by changing the temperature) they do so directly at the thermostat about two thirds of the time and remotely via the Vendor 1 web portal or mobile app about one third of the time. In light of the typical duration for each of these settings, it is likely that the thermostat returns to the SCHEDULE setting automatically from the AWAY and HOME settings but not from the HOLD setting.

Figure 7-5: Source of Hold Settings-Vendor 1, Summer



7.3.2 Vendor 2

Vendor 2 thermostats can be in one of the five mutually exclusive program settings described in Table 7-4. Unlike Vendor 1 devices, Vendor 2 devices in the pilot have two separate HOLD settings. When in TEMPORARY HOLD, unlike PERMANENT HOLD, the device automatically returns to the SCHEDULE setting in the next schedule period.

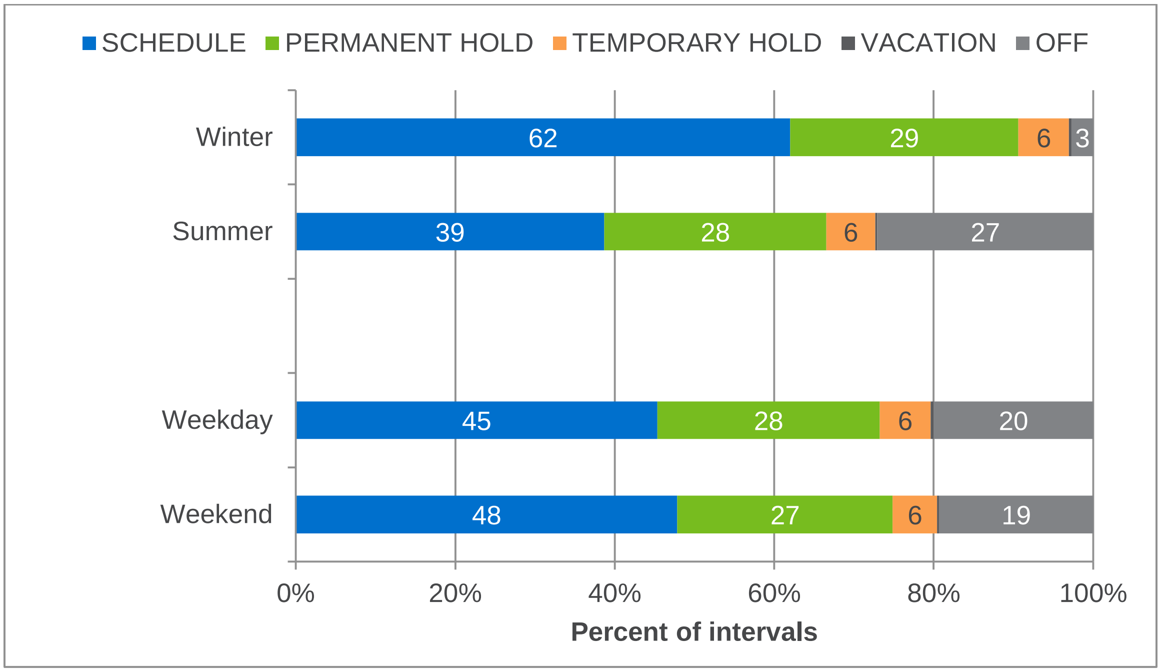
Table 7-4: Vendor 2 Thermostat Programs

Program setting	Description
SCHEDULE	Default or scheduled temperature settings will be followed
PERMANENT HOLD	Default or scheduled temperature setting has been overridden and will remain so until the user removes the hold
TEMPORARY HOLD	Default or scheduled temperature setting has been overridden and but will automatically return to the schedule at the next scheduled period
VACATION	Dwelling will be unoccupied for a specified period of time during which temperature is adjusted for efficiency
OFF	Thermostat is set to off and no heating or cooling occur

During the summer months (June through September), the Vendor 2 devices analyzed spent most of the time in SCHEDULE, PERMANENT HOLD, or OFF settings, as shown in Figure 7-6. About 39% of the time Vendor 2 devices were in the schedule setting and 28% of the time in the PERMANENT HOLD setting with no meaningful difference by day of week. Thermostats appeared to be OFF about 27% of the time, though this could possibly be due in part to missing data for reasons explained in Section 7.1. As a point of external validation for this missing data, the participation analysis in section 6.3 showed that about 15% of Vendor 2 devices were not in cooling mode during events, implying that the number of Vendor 2 devices typically in the OFF setting at a given time may be lower than 27%. Though Vendor 2 devices have a TEMPORARY HOLD setting, the PERMANENT HOLD setting is much more commonly used than the TEMPORARY HOLD setting, implying that the difference in available settings may not translate to much of a difference in how the thermostats typically function.

Unlike Vendor 1 devices, Vendor 2 devices exhibited a notable seasonal[91] difference in program settings. During winter months (December through March), Vendor 2 devices were following the SCHEDULE about 62% of the time (compared to 39% in the summer) and OFF only about 3% of the time (compared to 27% in the summer). This means that devices were set to provide space conditioning about 97% of the time in the winter but only about 73% of the time in the summer.

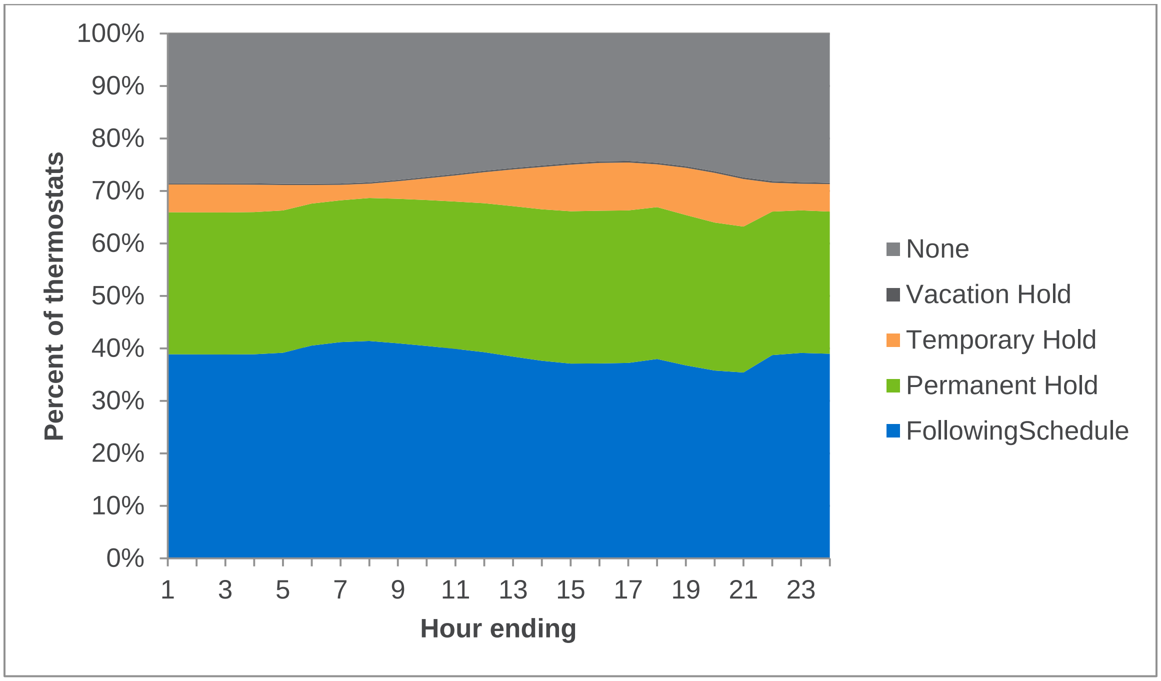
Figure 7-6: Percent of Intervals Spent in Each Vendor 2 Program Setting



Assessing the difference in settings by hour of day paints a fuller picture of how Vendor 2 devices are used. Figure 7-7 shows the hourly variation of time spent in each program setting. Similarly to Vendor 1 devices, there is very little differentiation by hour for Vendor 2 devices, though TEMPORARY HOLD is somewhat more likely to be deployed during the afternoon and evening hours. Most notably, thermostats were about as likely to be in the HOLD setting in any hour of the day. Also, the time spent in TEMPORARY HOLD appears to mirror more or less the time spent following the schedule. Said another way, the fluctuations in the time spent following the schedule appear to be mostly explained by the time spent in TEMPORARY HOLD.

91 Here summer is defined as June through September, and winter as December through March

Figure 7-7: Percent of Thermostats in Vendor 2 Program Settings, Hourly (Summer)

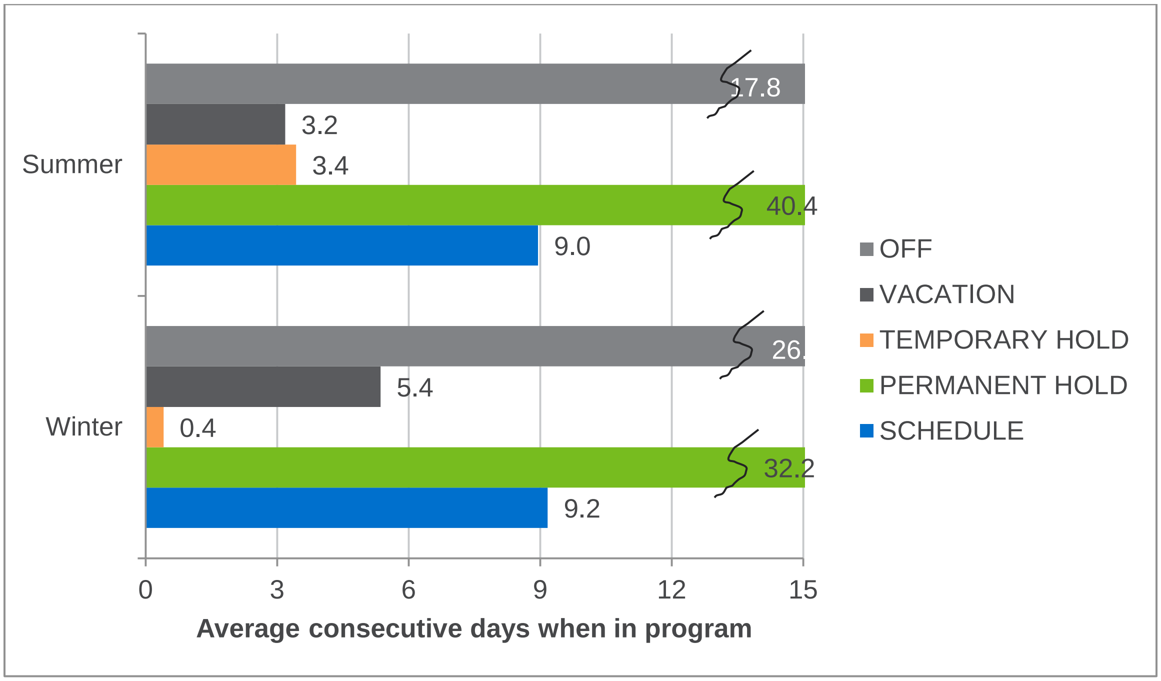


One can observe how a thermostat is used by assessing how long a thermostat typically remains in a given program setting. Figure 7-8 shows the number of days Vendor 2 thermostats typically spend in each setting.[92] For example, Vendor 2 devices analyzed were in the OFF program setting for about 27% of the time during summer months and when devices were off they were typically off for about 18 days at a time. This means that individual thermostats were turned off and on throughout the summer, in contract to Vendor 1 devices which typically remained off for the whole season when turned off. Interestingly, devices were typically left in the PERMANENT HOLD setting for much longer than they were left OFF. PERMANENT HOLDS during the summer typically lasted for about 40 days.

In contrast to the OFF and PERMANENT HOLD program settings, VACATION and TEMPORARY HOLD were typically much more brief, each lasting a little over 3 days on average during the summer—about half as long as the Vendor 1 vacation setting. Vendor 2 thermostats typically remained in the SCHEDULE setting for about 9 days at a time during the summer—over twice as long as the Vendor 1 thermostats. The most notable seasonal difference is that TEMPORARY HOLDS were usually much shorter in the winter, only lasting about 0.4 days (about 10 hours) instead of 3.4 days in the summer.

[92] Only includes intervals when thermostats were in that setting, so NOT weighted for the percent of time spent in each setting.

Figure 7-8: Average Consecutive Days When in Each Vendor 2 Program



7.3.3 Vendor 3

Vendor 3 thermostats can be in one of the four mutually exclusive program settings described in Table 7-5. Vendor 3 data reflects a single non-vacation HOLD setting and does not differentiate between permanent and temporary holds. Unlike Vendor 1 or Vendor 2 devices, the Vendor 3 device does not directly provide users with the option to set a permanent hold from the thermostat.[93] This means that when a hold is set the device automatically returns to the schedule in the next schedule period.

[93] Though it is possible to do so by navigating through menu options from the web portal or mobile app this functionality is not readily presented on the thermostat itself, which is the source of most holds.

Table 7-5: Vendor 3 Thermostat Programs

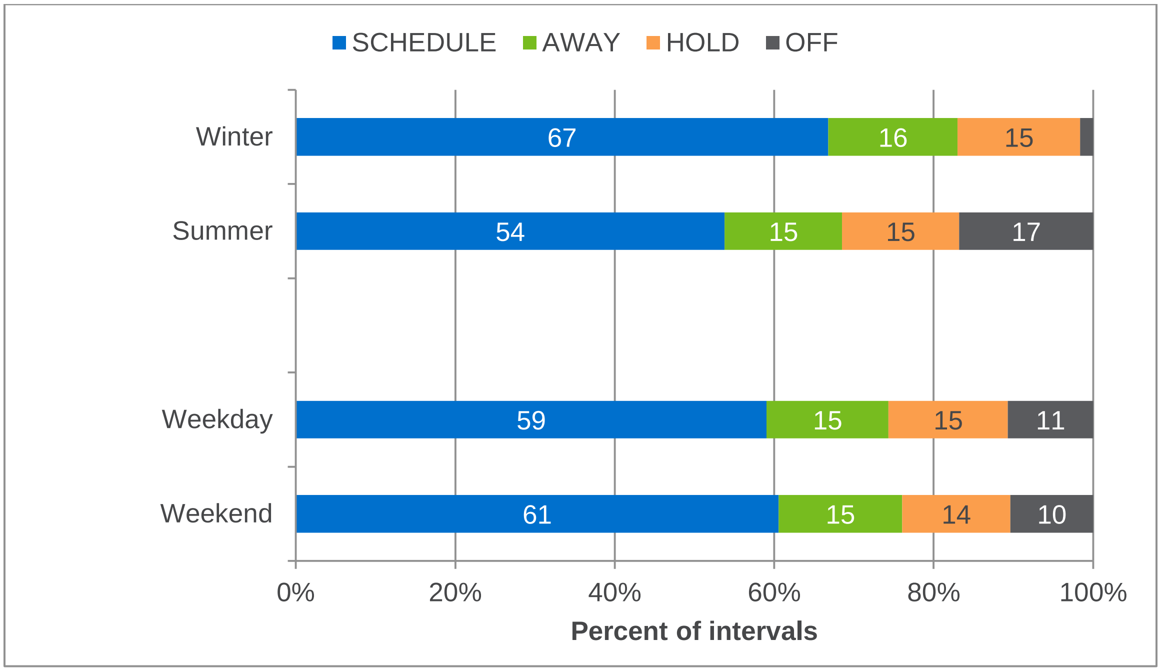
Program setting	Description
SCHEDULE	Dwelling is occupied and default or scheduled temperature settings will be followed
AWAY	Dwelling will be unoccupied for a specified period of time during which temperature is adjusted for efficiency
HOLD	Default or scheduled temperature setting has been overridden and but will automatically return to the schedule at the next scheduled period
OFF	Thermostat is set to off and no heating or cooling occur

During the summer months (June through September), the Vendor 3 devices analyzed spent most of the time in the SCHEDULE setting, as shown in Figure 7-9. About 54% of the time, Vendor 3 devices were in the SCHEDULE setting with the remainder of time split roughly evenly among the AWAY, HOLD, and OFF settings, with no meaningful difference by day of week.

Like Vendor 2 devices, the primary seasonal[94] difference for Vendor 3 thermostats is with the OFF program setting. During winter months (December through March), Vendor 3 devices were set to provide space conditioning about 98% of the time in the winter but only about 83% of the time in the summer (i.e., 17% of the time Vendor 3 devices were set to OFF during the summer).

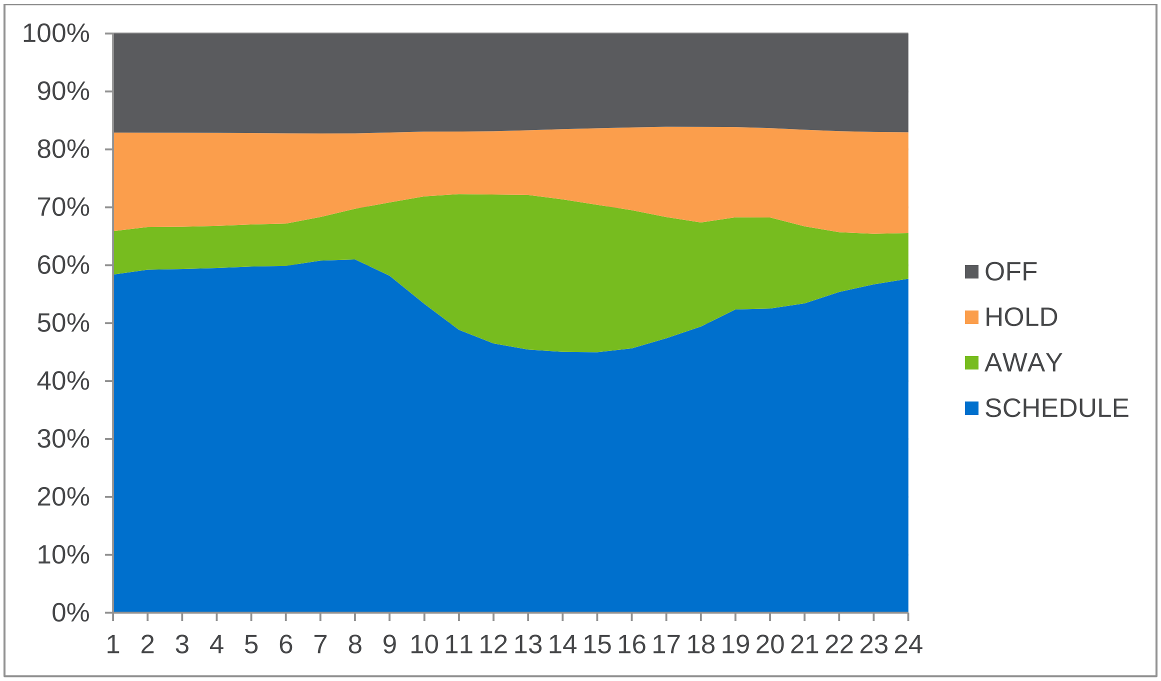
[94] Here summer is defined as June through September, and winter as December through March

Figure 7-9: Percent of Intervals Spent in Each Vendor 3 Program Setting



Assessing the difference in settings by hour of day paints a fuller picture of how Vendor 3 devices are used and how this may differ from other devices. Figure 7-10 shows the hourly variation of time spent in each program setting. The greatest variation is between the SCHEDULE and AWAY modes, with SCHEDULE dropping off between hour 9 and 18. In contrast, the AWAY setting is most likely to be deployed during morning day time hours when residential occupancy is typically lowest.

Figure 7-10: Percent of Thermostats in Vendor 3 Program Settings, Hourly (Summer)



One can observe how a thermostat is used by assessing how long a thermostat typically remains in a given program setting. Figure 7-11 shows the number of days Vendor 3 thermostats typically spend in each setting.[95] For example, Vendor 3 devices analyzed were in the OFF program setting for about 17% of the time during summer months and when devices were off they were typically off for about 23 days at a time. This means that individual thermostats were turned off and on throughout the summer, in contrast to Vendor 1 devices which typically remained off for the whole season when turned off. In contrast to the OFF program setting, AWAY and SCHEDULE settings typically lasted between 3 and 4 days. Most notably, the HOLD mode only lasted on average about half a day, implying that the Vendor 3 HOLD setting is in effect always a temporary hold, with the thermostat returning to the default or scheduled settings in the next schedule period. Vendor 3 devices exhibited very little seasonal variation except in the duration of the OFF setting which was typically much shorter in the winter, though it still lasted almost 13 days on average.

Though Vendor 3 devices were in HOLD settings about half as often as were other devices, the duration of these holds was also many times shorter for Vendor 3 devices (several hours compared to several days for other devices). This means that Vendor 3 owners likely adjusted the temperature more often than did other users, though the Vendor 3 devices remained in HOLD for a much shorter duration each time and hence spent less time in HOLD overall. Survey responses were also consistent with this pattern: as discussed in Section 8.5, Vendor 3 owners reported changing the temperature on their thermostat significantly more frequently than owners of other devices. This has even more importance in the context of the EE savings

95 Only includes intervals when thermostats were in that setting, so NOT weighted for the percent of time spent in each setting.

analysis, discussed in Section 4, which showed that savings were only significant for Vendor 3 devices. This further underscores that the frequency of use of the HOLD setting may not impact energy savings as much as the duration of the HOLD setting. Said another way, allowing a thermostat to remaining in HOLD indefinitely may substantially reduce EE savings potential.

Figure 7-11: Average Consecutive Days When in Each Vendor 3 Program

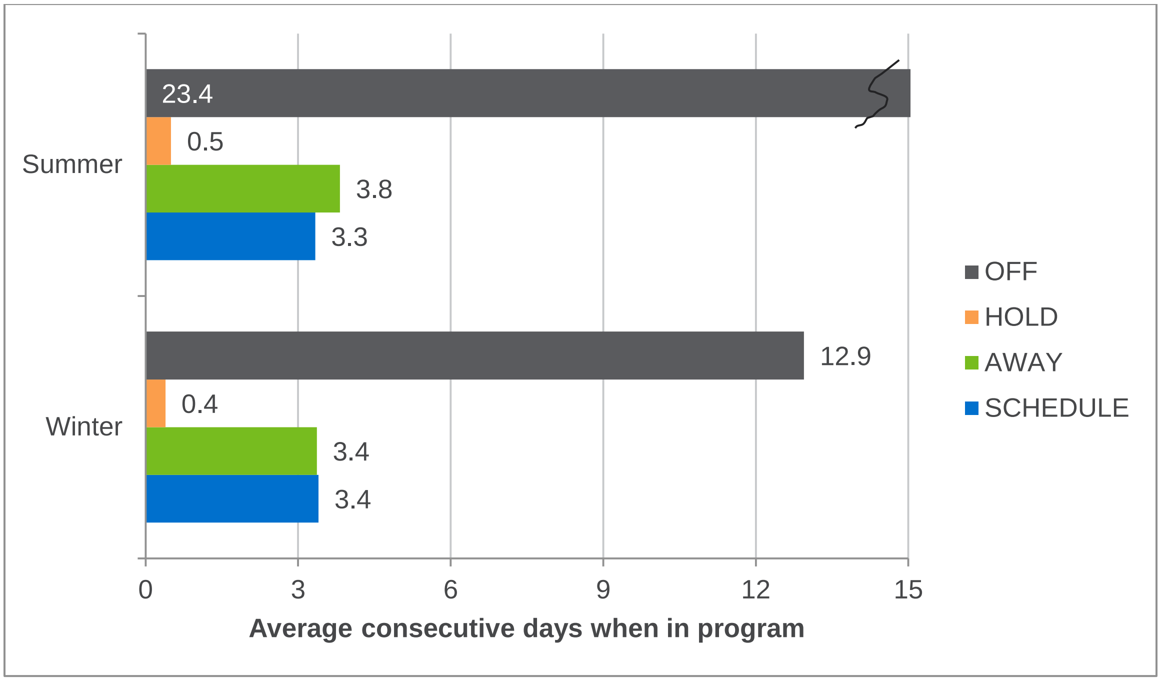
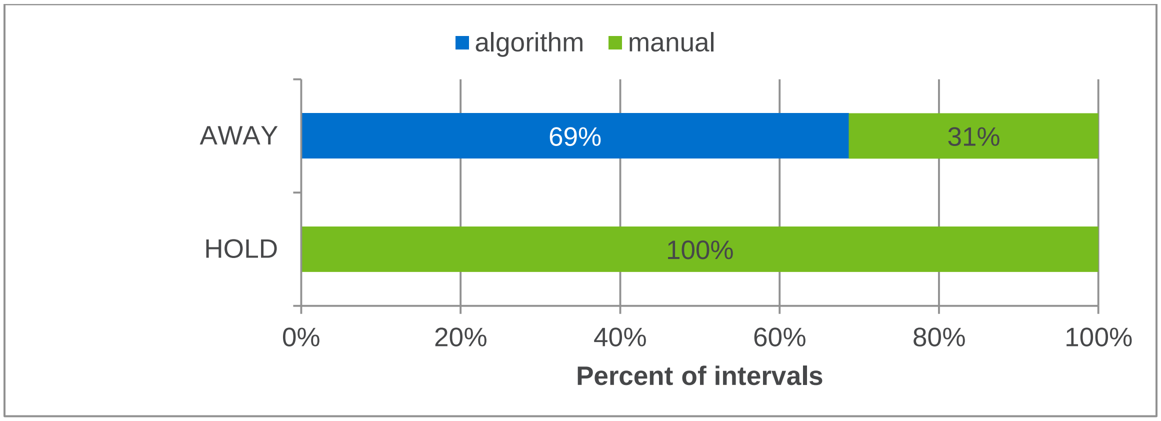


Figure 7-12 shows the source of Vendor 3 hold related settings, demonstrating that the AWAY setting is usually triggered by an algorithm while the HOLD setting is entirely triggered manually by the user.[96] In light of the typical duration for each of these settings, it is likely that the thermostat returns to the SCHEDULE setting automatically from the HOLD settings. In contrast, it appears likely that the thermostat exits the AWAY setting when triggered by the occupancy sensor, which is connected to the algorithm.

96 This data is actually only captured for the away setting. Holds are by definition only triggered manually. Both are shown here for context.

Figure 7-12: Source of Hold Settings-Vendor 3, Summer



7.4 Temperature Setpoints

Scheduled temperature setpoints reflect the temperature preferences of users to the extent that a thermostat has been programmed by the user or that an algorithm has "learned" user preferences and in effect programmed the thermostat accordingly. As such this may reveal at least as much about differences between users as about differences between devices.

Figure 7-13, which summarizes average hourly scheduled summer cooling setpoints for each thermostat manufacturer,[97] shows that there are both similarities and differences. The primary similarity is that scheduled cooling setpoints are higher during midday hours from about hour 7 to hour 18 indicating that on average thermostats were programmed to reduce cooling in the middle of the day when residential occupancy is typically lower.

Despite this key similarity there are some notable differences between the three manufacturers. Vendor 2 schedule setpoints (in green) are one to two degrees higher than Vendor 3 and Vendor 1 setpoints for most of the day. Vendor 2 setpoints also rise about 0.5 degrees in the late evening, unlike Vendor 3 and Vendor 1 which drop by 0.25 to 0.5 degrees during the same time period. This means that scheduled cooling setpoints are lowest in the evening for Vendor 2 but lowest overnight for Vendor 1 and Vendor 3. Also, Vendor 1 setpoints (in blue) are about 0.5 degrees higher than Vendor 3 during the midday schedule period.

[97] Note that scheduled setpoint was not captured in the Vendor 1 data. Scheduled setpoint was inferred by taking the most common (mode) setpoint for each hour when in the schedule program setting.

Figure 7-13: Schedule Setpoint-Summer

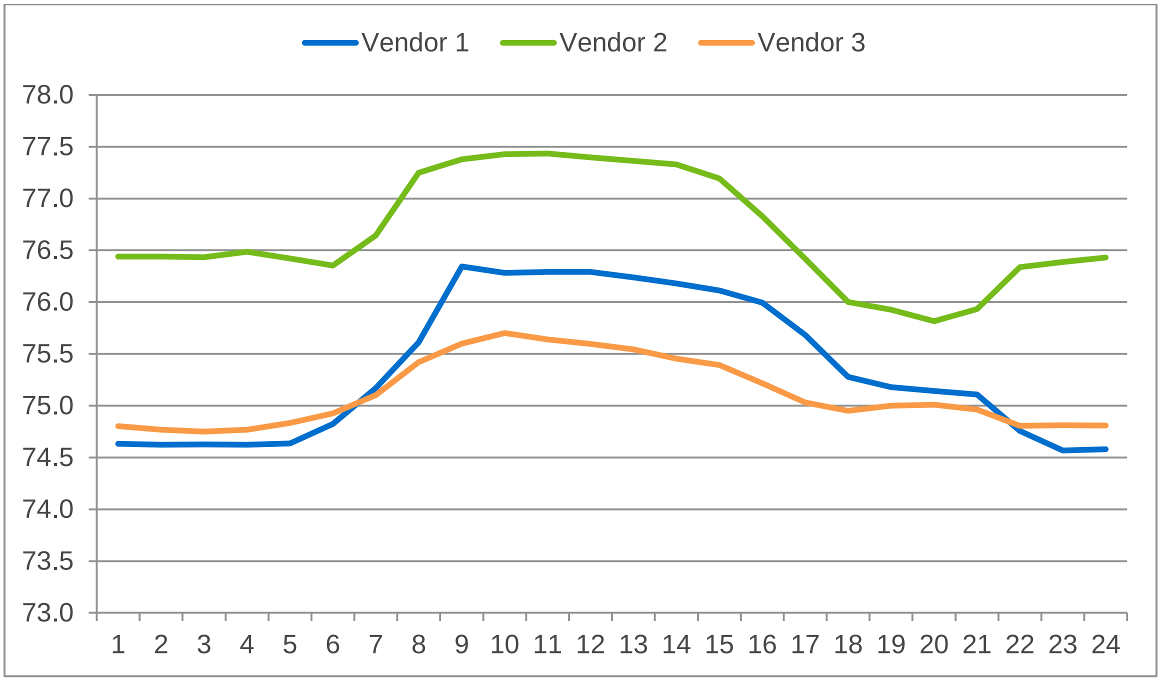
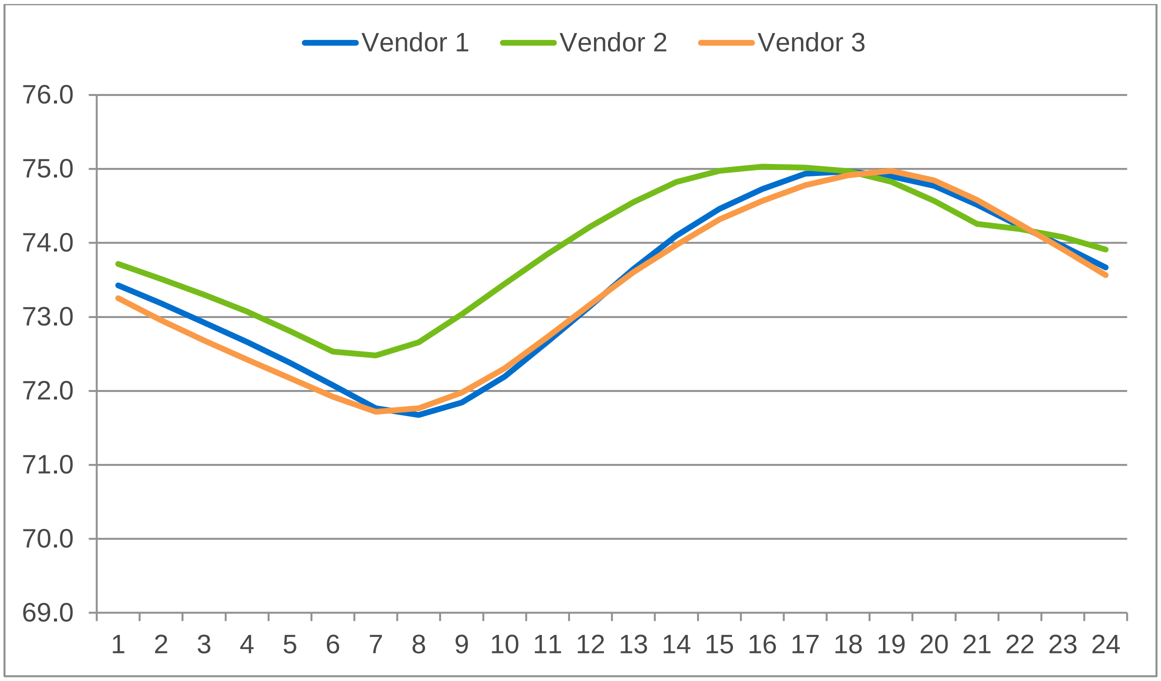


Figure 7-14, which shows mean indoor temperatures during the schedule settings, confirms that these setpoint differences translate into differences in actual indoor temperatures for Vendor 2 devices, though smaller differences than observed for the scheduled cooling setpoints. During night time hours temperatures inside homes with Vendor 2 thermostats are about 0.5 degrees warmer than homes with Vendor 3 or Vendor 1 thermostats and during the day this rises to 1 degree. In the evening, however, temperatures are more or less aligned across all three vendors.

Figure 7-14: Mean Indoor Temperature During Schedule Setting-Summer



While it may not be possible to disaggregate the extent to which user preferences versus thermostat functionality drives these setpoint differences it is clear that each of the three thermostats is operated somewhat differently. For example, Vendor 2 users may simply prefer temperatures somewhat above those preferred by Vendor 3 and Vendor 1 users, at least during the day.

Observing how scheduled temperature setpoints differ from the programmed schedule in other program settings can help reveal the extent to which deviation from the schedule setpoints are driven by comfort versus by efficiency. For example, during the cooling season setpoints which are higher than the scheduled setpoint may help save energy while setpoints below the schedule setpoint may improve comfort.

Figure 7-15, Figure 7-16, and Figure 7-17 provide a summary of how setpoints differ from scheduled setpoints in algorithm and hold related program settings for each manufacturer. Recall from the previous section that the home and away settings for Vendor 1 and the away setting for Vendor 3 appear to be primarily triggered by algorithms. The hold and vacation settings for each manufacturer appear to be manually triggered by the user. Also recall that during summer months Vendor 1 thermostats are in the schedule mode 55% of the time, Vendor 2 39% of the time, and Vendor 3 54% of the time (the schedule setting is called home for Vendor 3 devices). Vendor 1 exhibits very little seasonal variation. The key driver of variation for the other manufacturers is that in the winter very few thermostats are off, compared to 27% of Vendor 2 and 17% of Vendor 3 in the summer. Hold frequencies exhibit no meaningful seasonal variation.

In each figure, the left hand panel (A) shows how much the cooling setpoints in each setting differ from the scheduled cooling setpoint in the summer. The right hand panel (B) shows how much the heating setpoints in each setting differ from the heating schedule in the winter. For each figure, a negative value means the hold setpoint was below the scheduled setpoint—indicating a change made for comfort in the summer—while a positive value means the hold setpoint was above the scheduled setpoint—indicating a change made for efficiency in the summer.

There are three key takeaways from these charts. First, there is mostly directional agreement in temperature variation between device manufacturers within analogous program settings. For example, the cooling setpoints in the efficiency algorithm driven away setting are 4.2 degrees higher than schedule for Vendor 1 devices and 3.0 degrees higher for Vendor 3 devices (there is no algorithm driven energy saving setting for Vendor 2). Only Vendor 1 has a comfort driven setting (home) and cooling setpoints for it are 3.9 degrees lower than scheduled cooling setpoints.

The manual hold setting appears to be used for comfort for both Vendor 2 devices (2.7 lower than cooling schedule in permanent hold and 1.6 lower in temporary hold, this is somewhat less pronounced in the winter) and Vendor 3 devices (1.6 degrees lower than cooling schedule in hold). Interestingly, the hold setting for Vendor 1 devices is on average only slightly lower (0.2F) than the scheduled setpoint, indicating that this setting may be used for both comfort and efficiency.

Finally, the cooling setpoints in the vacation setting are 6.6 degrees higher than schedule mode for Vendor 1 devices but 0.7 degrees lower for Vendor 2 devices (there is no explicit vacation setting for Vendor 3). This is one of two key differences between setpoints in analogous program settings. The other is the Vendor 1 manual hold setting not being different on average from the scheduled setpoint.

Figure 7-15: How Much Setpoints Differ from Schedule in Program Settings—Vendor 1

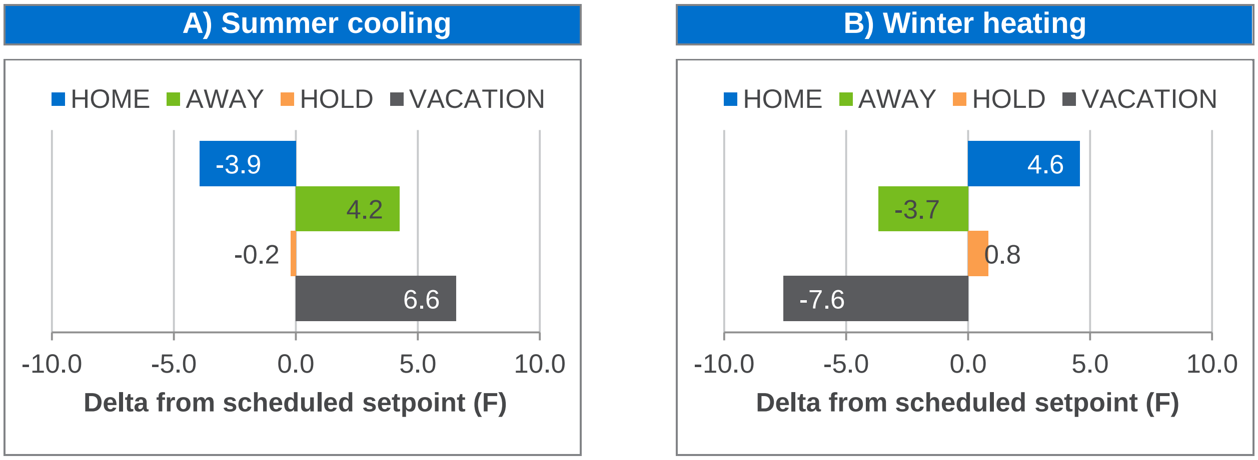


Figure 7-16: How Setpoints Differ from Schedule in Program Settings—Vendor 2

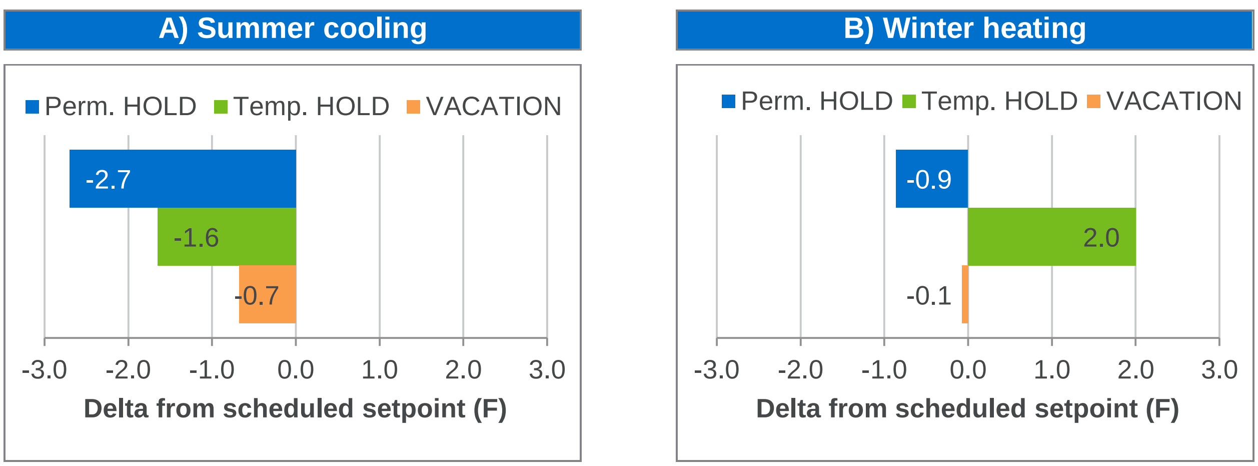
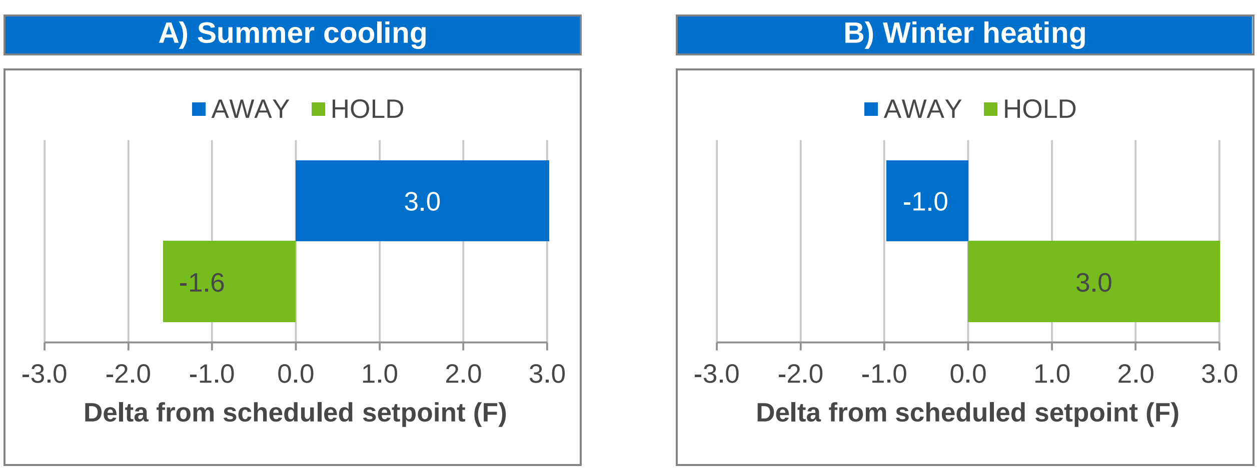


Figure 7-17: How Setpoints Differ from Schedule in Program Settings—Vendor 3



7.5 Potential Link to Energy Efficiency Savings

Differences in thermostat functionality are most interesting to the extent that these differences translate to differences in EE savings. As seen in Section 4, statistically significant EE savings were only observed for Vendor 3 thermostats. Specifically, annual whole house electricity savings of 2.4% and gas savings of 2.5% were found (though this varied by rebate channel). A key question is whether part of the difference in observed EE savings may be explained by the thermostat itself, as opposed to user behavior or other factors.

Table 7-6 summarizes the various analyses above to provide answers to the research questions for each thermostat type. Vendor 3 thermostats do appear to exhibit unique functionality that could logically result in more energy savings than the other two manufacturers. The key feature separating Vendor 3 is that the device returns automatically to the scheduled program once the next schedule period is reached, on average after half a day for Vendor 3 customers. Perhaps in part because of this, Vendor 3 thermostats are in the HOLD setting about half as much as the other two thermostats (17% of the time in the summer compared to 30% of the time for Vendor 1 and 34% of the time for Vendor 2). According to device documentation, both Vendor 1 and Vendor 2 provide automatic reset to the scheduled program as an option, but given the multi-day hold durations observed for those devices it is apparent that users usually do not choose this option. This is notable because the manual HOLD setting tends to be used for comfort (e.g., lowering a cooling setpoint) rather than for efficiency.

In addition to this, the Vendor 3 algorithm triggered by occupancy sensors also appears to exhibit more energy efficiency behavior than the Vendor 1 algorithm (this feature was not available for Vendor 2 devices). Specifically, the Vendor 3 algorithm appears to adjust the temperature to favor efficiency when no occupancy is detected. In contrast, Vendor 1 has two occupancy sensor triggered algorithm settings: home and away. Away appears to function like the Vendor 3 away setting, while the Vendor 1 home setting appears to adjust the temperature for comfort if occupants are detected, presumably during daytime low occupancy hours. This automated adjustment for comfort is not present in the Vendor 3 devices and may actually lead to incremental energy usage for the Vendor 1 devices. While this Vendor 1 comfort algorithm is seldom deployed (about 2% of the time in summer, 3% in the winter) the efficiency algorithm is also seldom deployed (3% of the time in the summer and winter). The Vendor 3 efficiency algorithm, however, is deployed 15% of the time in the summer and 16% of the time in the winter. In sum, this means that the Vendor 3 thermostat may feasibly provide more opportunity for EE savings because it deploys an efficiency algorithm much more often than Vendor 1 and never deploys a comfort algorithm.

Table 7-6: Key Takeaways for Thermostat Modeling Questions

Topic	Question	Vendor 1	Vendor 2	Vendor 3
Schedules & Other Program Settings	Are setback schedules typically deployed? How long do customers spend in setback schedules vs. putting thermostats on hold?	Summer & winter: Scheduled 55% of the time, off 7%	Summer: Scheduled 39% of the time, off 27% Winter: Scheduled 62% of the time, off 3%	Summer: Scheduled 54% of the time, off 17% Winter: Scheduled 67% of the time, off 2%
	What are typical hours used for algorithms triggered by occupancy sensors (away, home, etc.)?	Away during the day and evening (hours 9 to 22) Home during the day (hours 9 to 18)	NA	Away during daytime hours (hours 9 to 18)
	Are scheduled setpoints changed often? How often are thermostats put in hold mode?	Hold: 30% of intervals	Hold: 34% of intervals (temporary 6% + permanent 28%)	Hold: 15% of intervals
	How long does a typical "hold" persist?	10.7 days	Permanent hold: 40.4 days Temporary hold: 4 days	0.5 days
	Do smart thermostat owners take action to return to the setback schedule or is that automated?	User option. In practice appears to usually be manual	User option: automated for temporary hold, manual for permanent hold. In practice users usually choose manual	Automated
Setpoints	What are typical setpoints used by customers for setback schedules, by period?	Cooling: 76 daytime 75 evening 74.5 night	Cooling: 77.5 daytime 76 evening 76.5 night	Cooling: 75.5 daytime 75 evening 74.5 night
	What are typical setpoints deployed when thermostats are on hold?	Cooling setpoint 3.9F below schedule in Home, 4.2 above in Away Slightly below (0.2F) in manual hold	Cooling setpoint 1.6F below schedule in temporary hold, 2.7F below in permanent hold	Cooling setpoint 1.6F below schedule in manual hold, 3.0F above in away
	When customers put their	Manual hold	Holds used for	Manual hold

	thermostat on hold, is it typically done to save energy or increase comfort?[98]	used for both efficiency and comfort. Algorithm based hold used far less frequently but also appears to even out between home and away	comfort: in hold cooling setpoints are consistently lower, for heating setpoints just 0.9F lower so may also be used for efficiency. Efficiency used for vacation setting but that setting is used <1% of the time	used for comfort, algorithm (away) used for efficiency
Potential Link to Energy Savings	What is the typical usage and energy savings profile of users for each type of thermostat deployed?	Avg July daily use before thermostat: 36.2kWh Electricity savings directionally negative, nothing significant	Avg July daily use before thermostat: 34.3kWh No significant savings	Avg July daily use before thermostat: 38.9kWh Annual whole house energy savings of 2.5% gas, 2.4% electricity
	If users of a particular thermostat save more, what are the likely causes?	Return from hold is usually not automated Comfort algorithm (home) and infrequent deployment of efficiency algorithm	Return from hold is usually not automated	Return from hold is automated No comfort algorithm (only efficiency)

98 E.g., are holds deployed in a way that consumes more energy (increasing heating setpoint from 68 to 70 on a cold day) or less energy (decreasing heating setpoint from 68 to 62 while occupants are away unexpectedly)?

8 Residential Survey Results

8.1 Residential Survey Methodology

Nexant conducted a mixed-mode (mail and internet) survey among residential pilot participants in the EE and DR pilots. The survey was mailed out to a random sample of 750 total participants across Colorado, stratified into pilot participation groups (EE only, DR only, and both). Nexant expected that this mail-out volume of 750 would produce at least 300 completed surveys (a 40% response rate). With 300 completes, the survey results would be within +/- 5% precision at a 95% confidence level.

Nexant developed and deployed a mixed-mode survey that collected data via online and paper surveys, and used direct mail and email recruitment. Table 8-1 summarizes the implementation timeline for the residential participant survey reflecting a five-step process. The process began just after the end of the 2016 DR event control season in late September by mailing an Xcel Energy-branded invitation letter to all households in the survey sample. The initial letter was followed by email[99] and postcard reminders at 7 to 10 day intervals after the initial contact. For customers who did not respond, the last step was to send a paper version of the survey for the respondent to fill out by hand and mail back. The initial letter contained a simple survey URL with passcode and a new $2 bill thanking the customer in advance for completing the survey. In general, these procedures are designed to drive respondents to the internet first because it is less costly, but then still provide an opportunity to reply by mail for customers who have concerns about replying over the internet. Responses were collected between late September and mid-October using the fielding protocol but a few additional paper surveys were received after the survey close date and were also included.

Table 8-1: Fielding Protocol for Residential Participant Surveys

Date	Communication Sent
September 26, 2016	Initial recruitment letter with $2 bill (unconditional incentive)
September 30, 2016	Initial recruitment email
October 3, 2016	Paper version of survey instrument
October 7, 2016	Email reminder
October 17, 2016	Postcard reminder
October 26, 2016	Online survey close

The surveys contained some common questions across all three participant groups, which included general questions about Xcel Energy services, participants' thermostat usage, as well as demographic questions. Those customers that were enrolled in the demand response Saver's Stat program (DR) were also asked about DR program experience. For those

[99] Sent to customers with an available email address.

customers enrolled in the energy efficiency smart thermostat pilot (EE), they were asked about thermostat purchase and enrollment as well as their rebate experience, in addition to understanding why they did not choose the DR option. As shown in Table 8-2**,** the overall completion rate across Colorado was a robust 65.5%. Note that all subgroups had a response rate above 60% and that it was highest among dually enrolled participants, implying that engagement may be higher among this group.

Table 8-2: Participants Sampled

Program	Participants surveyed	Responses	Responses Rates
DR	125	86	68.8%
EE	500	305	61.0%
both	125	100	80.0%
Total	*750*	*491*	*65.5%*

Nexant combined the survey analysis with data from the other analyses (EE savings, DR impacts, thermostat usage models), which produced further insights because the survey results helped explain what drove the EE impacts, DR impacts, and thermostat usage trends.

Table 8-3 shows how various survey questions were combined with other analyses to enrich insights that could otherwise be gained by only analyzing each separately. Essentially, Nexant sought to identify to what extent participant stated behavior and perceptions around thermostat usage, comfort, EE savings, etc. aligns with observed usage, temperature changes, and EE savings.

Table 8-3: Residential Participant Survey Questions

Topic	Question	EE Savings	DR Impacts	DR Participation	Thermostat Usage
Thermostat purchase	Freeridership intention and influence questions (see Section 3.2.3)	✓	✓	✓	✓
	Rebate experience	✓			
Thermostat usage	Perceived change in comfort	✓	✓	✓	✓
	Impressions about thermostat (ease of use, perceived energy savings)	✓			✓
	Thermostat app usage frequency (for changing temperature, programming thermostat, viewing usage)	✓			✓
	Timing of temperature adjustments (day of week, peak vs off-peak)	✓			✓
Program experience	Reason for not choosing DR option	✓			
	Reenrollment intent		✓	✓	
	Perception of DR events experiences		✓	✓	
	Perceived comfort during DR events		✓	✓	
	Recall of and satisfaction with event incentives		✓	✓	
Demo-graphics	Gender, age, income, home ownership	✓	✓	✓	✓

8.2 Survey Instrument Design

Table 8-4 shows the questions included in the residential Smart Thermostat Pilot participant survey, and indicates which questions were specific to each participation group (DR only, EE only, and both). While there were several DR specific questions, there was one question specific to EE only participants about why they did not choose to enroll in the DR pilot. Note that the online version of the survey contained questions meant to gauge general participant interest in smart devices and Xcel Energy's online Storefront. These questions are of interest to Xcel Energy but are not critical to the evaluation. To limit any impact these questions may have on completion rates, the paper version of the survey excluded these non-critical questions and the online version included them after the demographics questions. For the purposes of analysis, online responses were considered complete if demographics questions were completed, regardless of whether these general questions were completed.

The General questions were included as they were of interest to Xcel Energy program marketing going forward but were not components of the energy efficiency or demand response evaluation. Results for these questions are included in the Appendix.

Table 8-4: Residential Survey Evaluation Questions

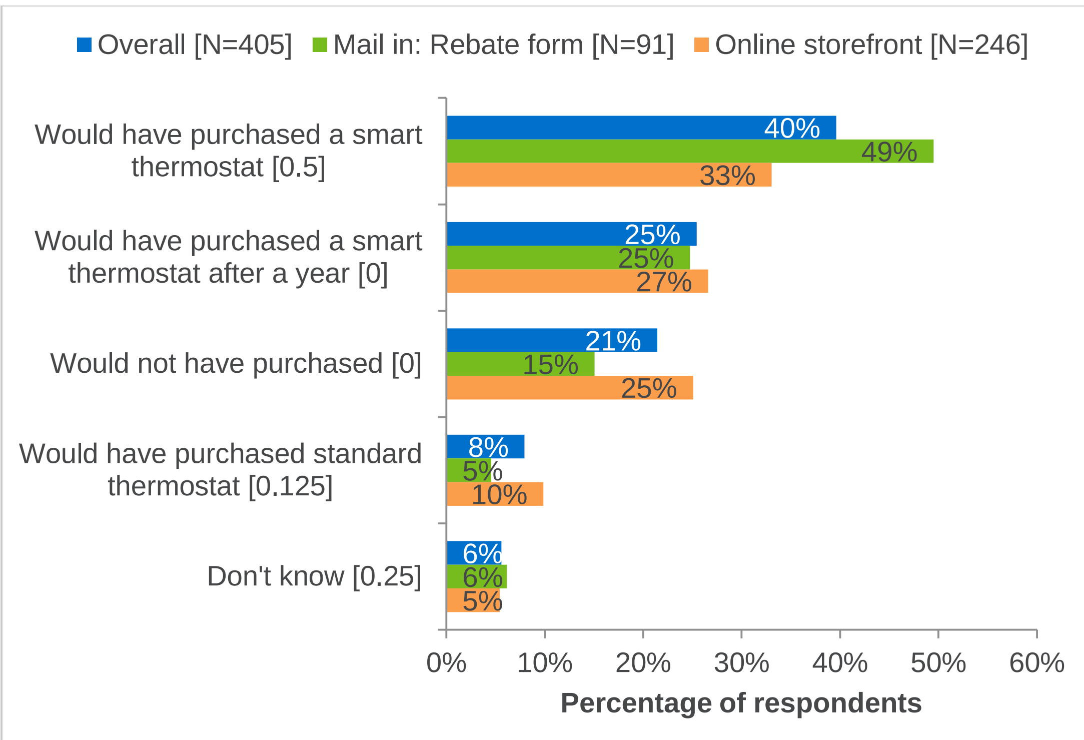
Topic	Question	DR	EE	Both
Energy efficiency rebate experience	Freeridership intention and influence questions (see Section 3.2.3)		✓	✓
	Rebate experience		✓	✓
	Reason for not choosing DR option		✓	
Saver's Stat demand response experience	Reenrollment intent	✓		✓
	Perception of DR events experiences	✓		✓
	Perceived comfort during DR events	✓		✓
	Recall of and satisfaction with event incentives	✓		✓
Thermostat usage	Perceived change in comfort	✓	✓	✓
	Impressions about thermostat (ease of use, perceived energy savings)	✓	✓	✓
	Thermostat app usage frequency (for changing temperature, programming thermostat, viewing usage)	✓	✓	✓
	Timing of temperature adjustments (day of week, peak vs off-peak)	✓	✓	✓
Demo-graphics	Gender, age, income, home ownership	✓	✓	✓
General	Xcel Energy net promoter score	✓	✓	✓
	General questions about interest in smart devices and in Xcel Energy's online Energy Store (online version only)	✓	✓	✓

8.3 Thermostat EE Rebate Questions and Freeridership

Energy efficiency pilot participants were offered a $50 rebate for the purchase and installation of an eligible smart thermostat as part of the pilot. Respondents who participated in the energy efficiency rebate pilot, or energy efficiency respondents, were asked about their smart thermostat rebate experience and purchase including questions designed to assess the level of freeridership in the pilot. Energy efficiency respondents who did not also enroll in the Saver's Stat BYOT DR program were asked to indicate why they did not enroll.

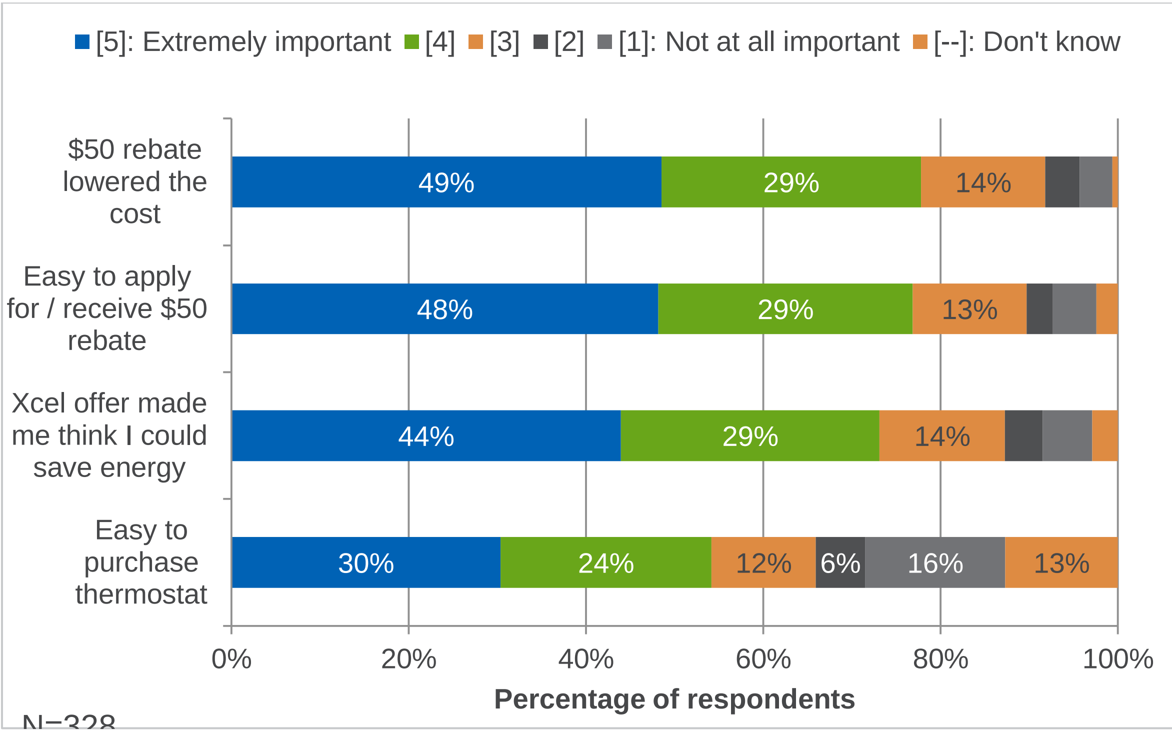
Figure 8-1 shows the responses given for the purchase intention question; numbers in brackets represent the intention scores assigned to each response. Though 40% of respondents overall said they intended to purchase a smart thermostat even without the rebate, there is a marked difference by rebate channel. Nearly half of respondents who used the mail-in form would have purchased without the rebate, compared to one third of respondents who used the online Storefront. As added context, because participants using the online Storefront purchased through Xcel Energy it is certain that the rebate application occurred in conjunction with the thermostat purchase. In contrast, as long as the customer kept the relevant information, such as purchase receipt, it would have been possible to apply for the rebate weeks or even months after the fact and there were many cases where mail-in rebate participants did this. It is possible that the higher level of freeridership reflected for the mail-in rebate group in this question is indicative of the fact that some mail-in participants did indeed purchase their thermostat without knowledge of the rebate. To avoid this potential freeridership it may make sense to discontinue the mail-in rebate option in the future.

Figure 8-1: "You were offered a $50 rebate for purchasing a smart thermostat. Imagine you had never learned that Xcel was offering a rebate for the purchase of a smart thermostat. Which of the following describes what you would have done?" [score applied]



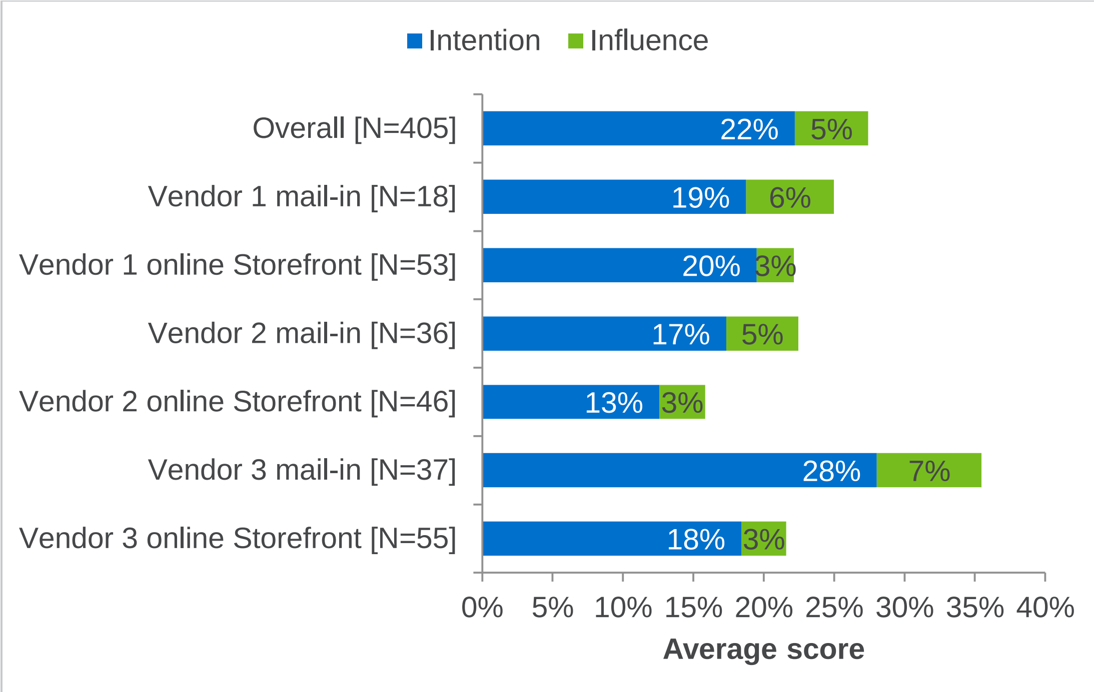
Responses to the influence question, which followed the intention question in the survey, are shown in Figure 8-2. That the rebate lowered the cost of the thermostat and was easy to receive were reported as highly influential for nearly half of respondents. Many respondents (44%) reported also being influenced by the Xcel Energy offer making them think the thermostat would produce energy savings. This question shows that the Xcel Energy rebate pilot and communications were probably effective at influencing participants to purchase a smart thermostat.

Figure 8-2: "Please indicate on a scale of 1-5 how important each of the following was in your decision to purchase a smart thermostat." [rating]



The total freeridership score is a composite of the intention and influence scores, as summarized in Figure 8-3. Overall, freeridership averages 27% for the total pilot population, but is significantly lower for respondents who used the online Storefront and lowest for respondents who purchased a Vendor 2 thermostat. While freeridership scores are generally calculated in aggregate across customer groups they are also typically calculated separately by efficiency measure or approach and different rebate channels can constitute different measures in that they are different program design options. The split by rebate channel and thermostat provider clearly shows that the different measures lead to different levels of freeridership. Figure 8-3 shows the split by thermostat vendor and by rebate channel to highlight the range of values, in particular the difference between vendor 2 devices purchased on the Storefront and vendor 3 devices for which a rebate was submitted via mail. However, only the difference by rebate channel is statistically significant across all participants, so net EE savings were assessed separately for by rebate channel, as discussed in more depth in section 4. In addition, the only participants who exhibited reliably statistically significant EE savings were those who purchased the Vendor 3 on the online Storefront. Thermostat provider and rebate channel represent different measures around which Xcel Energy can design future programs. It appears that Xcel Energy may want to focus on the online Storefront rebate channel to deliver EE savings while minimizing freeridership.

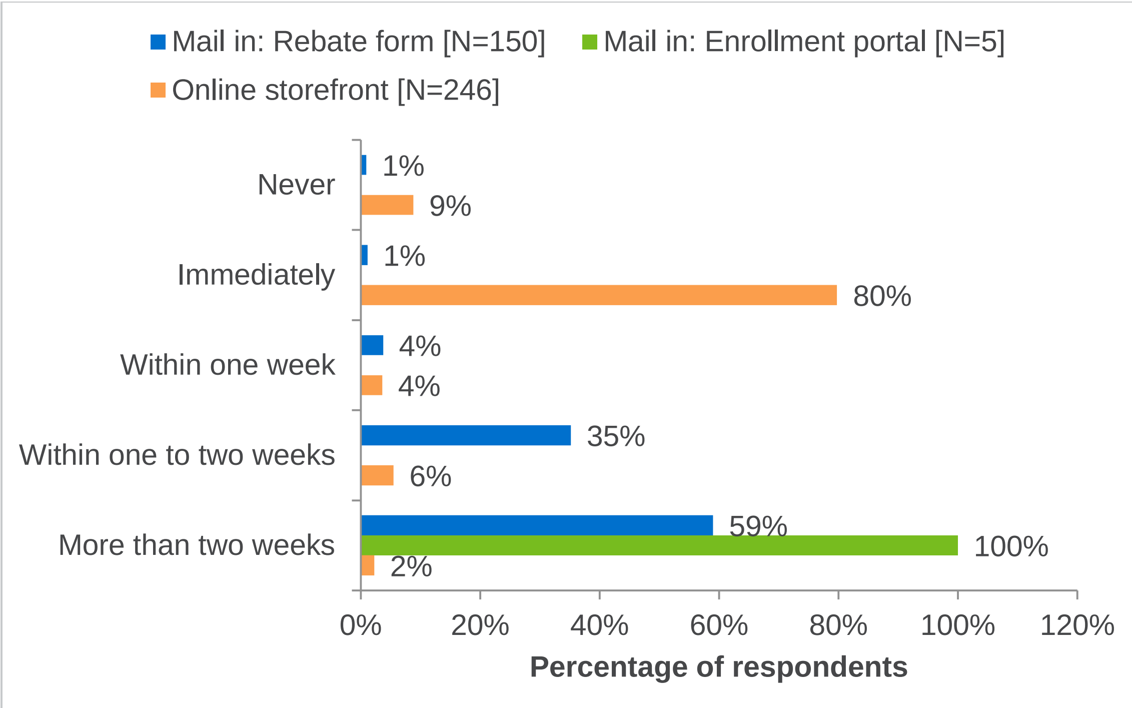
Figure 8-3: Freeridership Score and Components by Rebate Channel and Thermostat Provider



Energy efficiency respondents were also asked roughly when they received the $50 smart thermostat rebate. As shown in Figure 8-4, 80% of respondents using the Storefront reported receiving the EE rebate immediately, while most respondents who used mail-in applications reported waiting more than two weeks to receive the EE rebate.

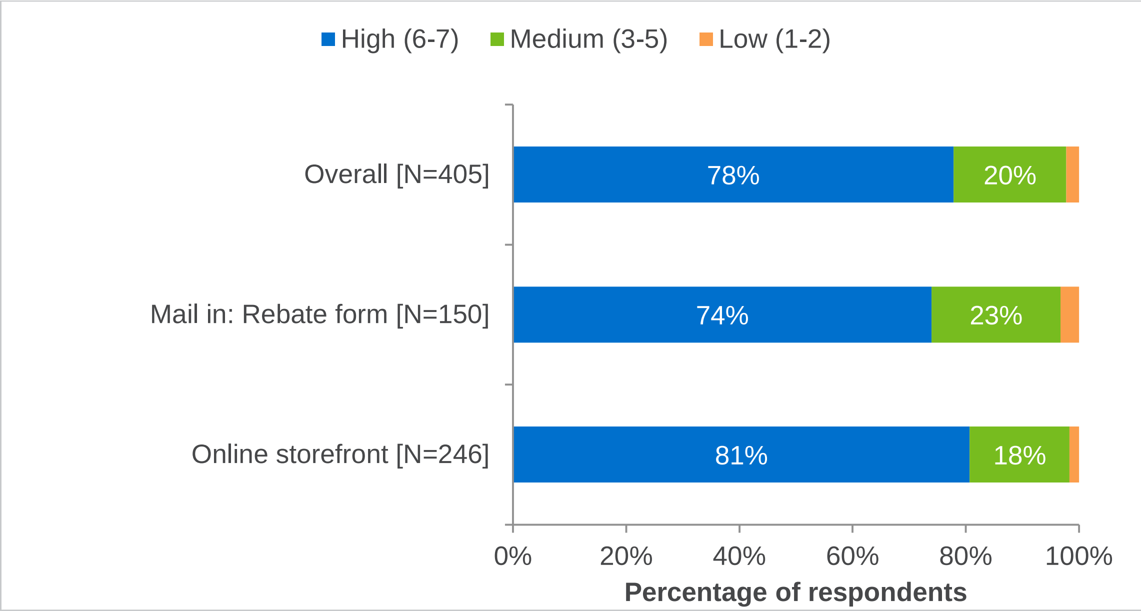
It makes sense that respondents using the online Storefront would report receiving the rebate immediately because the rebate was applied to their purchase during checkout. By definition 100% of participants purchasing their thermostat via the Storefront received the rebate immediately. That only 80% of respondents using the Storefront reported receiving the rebate is an important reminder that data collected in a survey environment reflects the perceptions and recollections of the respondents surveyed. It is quite possible, for example, that many of the 22% of the respondents who did not report experiencing an instant rebate either did not notice the rebate or did not recall it. Regardless, responses from mail-in respondents highlights that the mail-in form may result in a rebate processing delay of typically two weeks or more, in contrast to the immediate processing of the instant rebate made possible on the online Storefront.

Figure 8-4: "Please indicate roughly when you received your $50 thermostat rebate for purchasing a smart thermostat."



As summarized in Figure 8-5, energy efficiency respondents were asked to rate their satisfaction with the rebate experience. Rebate satisfaction was reportedly high overall, with 78% of respondents reporting high satisfaction (6-7), and only 2% of customers reporting low satisfaction (1-2). Satisfaction was highest among those aged 55 years or older and satisfaction was noticeably higher for respondents who used the online Storefront than it was for those who used the mail-in rebate form. This implies that the instant rebate processing may also result in higher participant satisfaction.

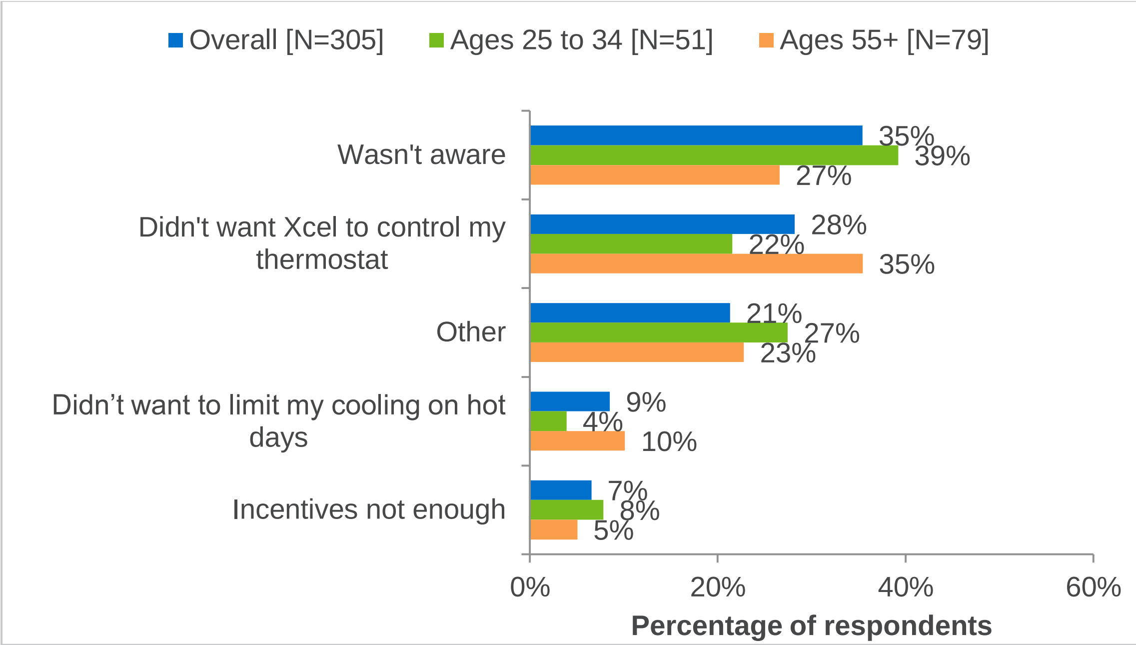
Figure 8-5: "On a scale of 1-7, how satisfied are you with your smart thermostat rebate experience?"



The final question was only asked of energy efficiency respondents who did not enroll in the Saver's Stat DR program. These respondents were asked to indicate their reason for not enrolling in the DR program. As depicted in Figure 8-6, the most commonly reported reasons for not enrolling were lack of awareness (35%) followed by not wanting utility control (28%) and other (21%). As indicated in a free response follow up question, common "other" reasons were not having AC, perceived challenges with enrollment and installation, and believing the account was already enrolled (likely confusion with the existing Saver's Switch program).

Notably, incentive levels were the least frequently selected reason for not enrolling, indicating that increasing current incentive levels may not substantially increase enrollment. Only 7% of respondents reported that the incentives offered were not high enough to inspire enrollment. Certain respondent groups were significantly more likely than others to cite lack of awareness as the reason for not enrolling in Saver's Stat. Specifically, these groups include women, respondents ages 25 to 34, and respondents also enrolled in the Savers Switch program. In contrast, some other groups of respondents were significantly more likely than others to cite not wanting utility control as their reason for not enrolling such as men, mail-in rebate users, and respondents aged 55 to 64.

Figure 8-6: "In addition to offering a smart thermostat rebate, Xcel also offered additional incentives for allowing Xcel to use the smart thermostat to reduce your AC use on some hot days. What was your primary reason for not choosing this option?"



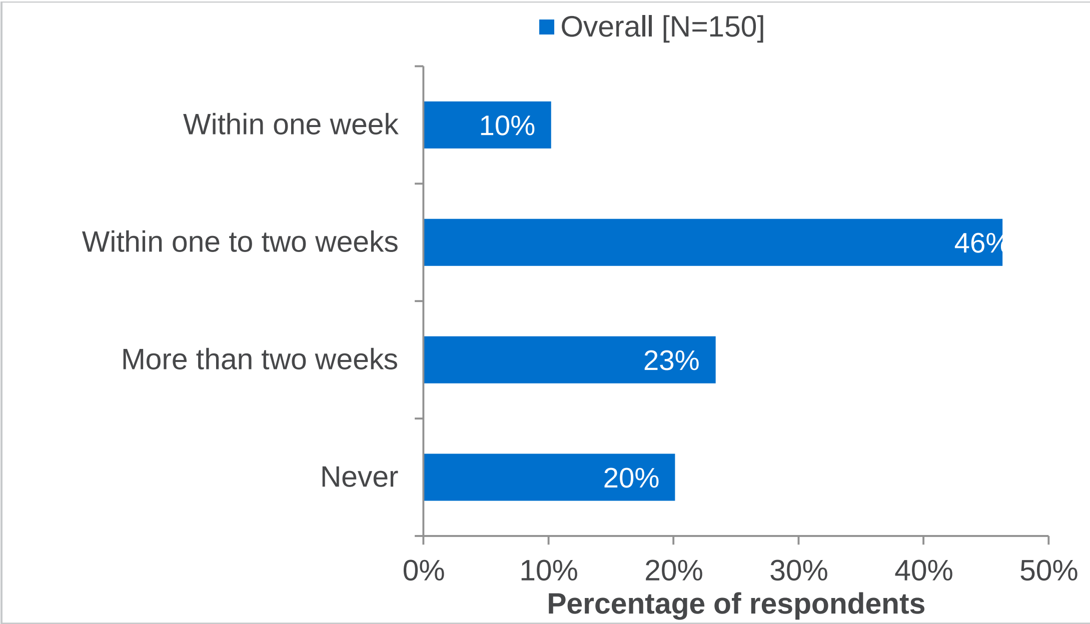
8.4 Saver's Stat Specific Questions

The respondents enrolled in the Saver's Stat BYOT demand response program were asked questions specific to their experience in the DR pilot. While the energy efficiency participants were offered a $50 rebate for the purchase of a smart thermostat, the demand response participants were offered a $25 gift card in exchange for participation in the pilot plus available event performance incentives.

First, DR respondents were asked when they recalled receiving the gift card, as summarized in Figure 8-7.[100] Most respondents (46%) reported receiving the gift card within one to two weeks. While another 20% reported never having received the gift card, it is important to note that the survey captures recollections and not necessarily what occurred. For context, it may be helpful to compare the responses to this question to a similar question asked of energy efficiency respondents about the time it reportedly took to receive a rebate for a smart thermostat purchase. In particular 22% of respondents who received an instant rebate online did not recall the instant rebate, including 9% who did not recall receiving the rebate at all. Therefore, it is quite possible that many of the DR respondents reporting never having received the gift card may have actually received it.

[100] values summarized here exclude participants who reported not knowing when they received their gift card

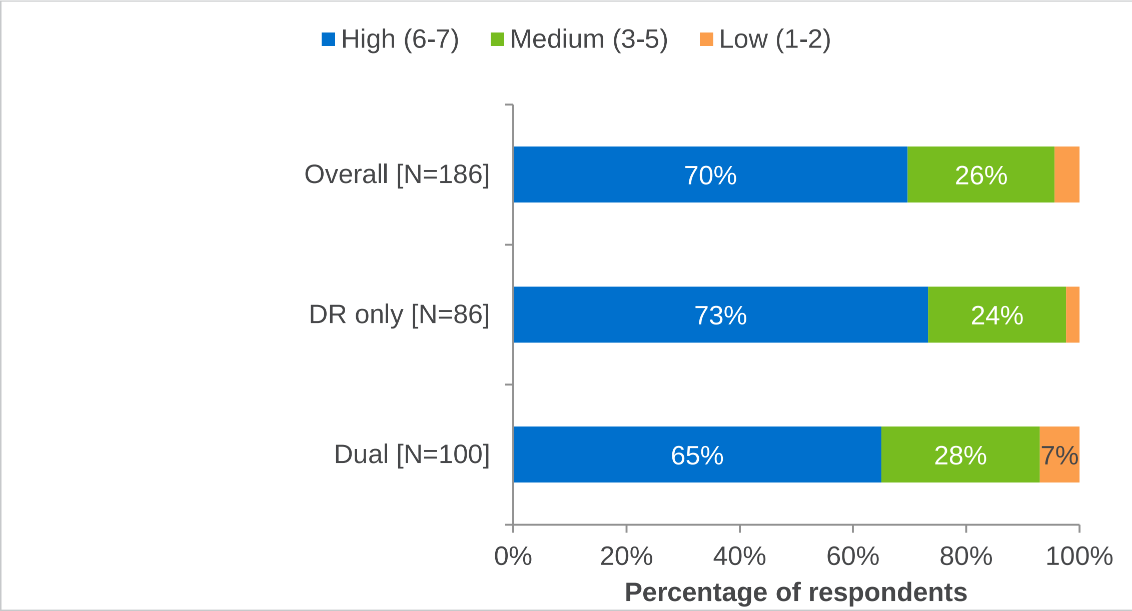
Figure 8-7: "Please indicate roughly when you received your $25 gift card for enrolling in Saver's Stat."[101]



Next, DR respondents were asked to rate their satisfaction with the enrollment process on a 1 to 7 scale as shown in Figure 8-8. Overall, most respondents (70%) reported high satisfaction with the DR enrollment process. In comparison, somewhat more energy efficiency respondents (79%) reported high satisfaction with the smart thermostat rebate process. This is normal given that multiple steps were required in the DR enrollment process, including initial enrollment, thermostat installation (if not already installed) and verification of smart thermostat connectivity to Xcel Energy's DR dispatch system. It is possible to further understand the contrast in satisfaction between the instant rebate and the multi-step DR enrollment process by specifically analyzing dually participating respondents who both applied for the smart thermostat EE rebate and also enrolled in the DR program. Among these respondents, 65% were highly satisfied with the DR enrollment experience while 87% were highly satisfied with the smart thermostat EE rebate experience. For added context, it is important to note that 65% of dual participants in CO used the online Storefront and thus received an instant rebate

[101] The instrument actually used a slightly different name: SmartStat Savings

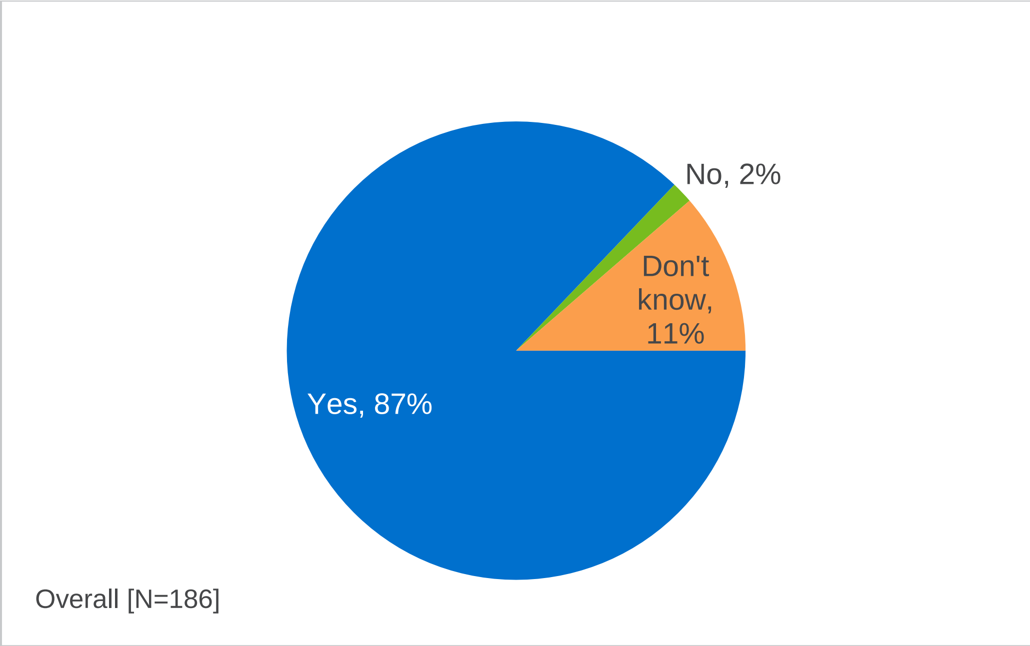
Figure 8-8: "On a scale from 1 to 7, how satisfied are you with your Saver's Stat[102] enrollment experience?"



Following the questions about enrollment experience, the DR respondents were asked about whether they would participate again in Saver's Stat were it to be offered the following year. Figure 8-9 shows that a large majority of respondents (87%) reported that they would participate in a subsequent year. While participants aged 65 and over were the most open to re-enrollment (95% said yes), re-enrollment openness was also quite high (91%) among the respondents aged 45 to 54—the age group with the fewest respondents indicating they would reenroll. That the vast majority of DR respondents reported being open to re-enrolling implies that most respondents likely also had a positive experience with the DR pilot and that a healthy retention rate could be observed in future years, assuming a program similar in structure to the pilot.

102 The instrument actually used a slightly different name: SmartStat Savings

Figure 8-9: "Would you choose to participate in Saver's Stat[103] next year if it were offered?"



While the enrollment satisfaction and re-enrollment questions addressed general Saver's Stat experience, the next two questions asked about respondent experiences and perceptions on DR event days in particular. On these days a control signal was sent to participating smart thermostats to reduce cooling energy usage during event hours. Figure 8-10 shows the percent of respondents who reported recalling a specific number of event days during the DR event season, which ran from June to September 2016. Overall, 73% of respondents reported recalling the number of event days experienced.

Figure 8-11 shows how the number of event days recalled. Because of the varied event dispatch schedule individual participants were not called on all ten event days called in Colorado. To account for the variation Figure 8-11 shows the recollection of event days as a percentage of days on which each respondent was actually called.[104]On average respondents recalled 91% of actual event days. This reasonably high level of recall accuracy implies that respondents were sufficiently engaged in the Saver's Stat program to notice event days and recall them in a survey setting days or weeks after the events occurred. Responses to remembering days is negatively correlated with age, indicating that younger respondents were more likely to recall Saver's Stat days, but not to recall them more accurately.

103 The instrument actually used a slightly different name: SmartStat Savings

104 number of days recalled in the survey divided by the actual number of days each respondent experienced, thus normalizing the responses

Figure 8-10: "How many Saver's Stat days do you remember experiencing?" [showing percent of respondents who recalled a number of days]

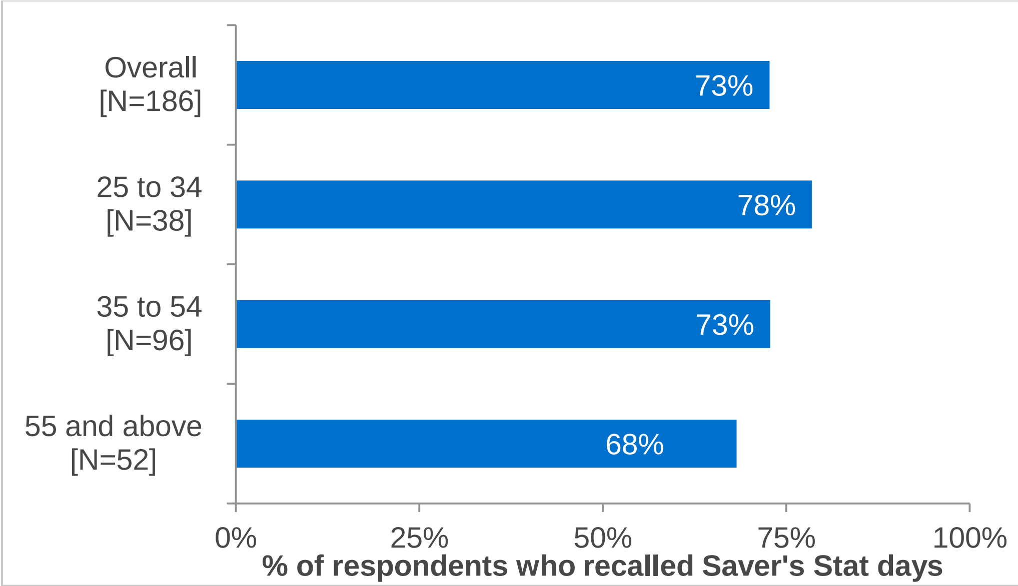
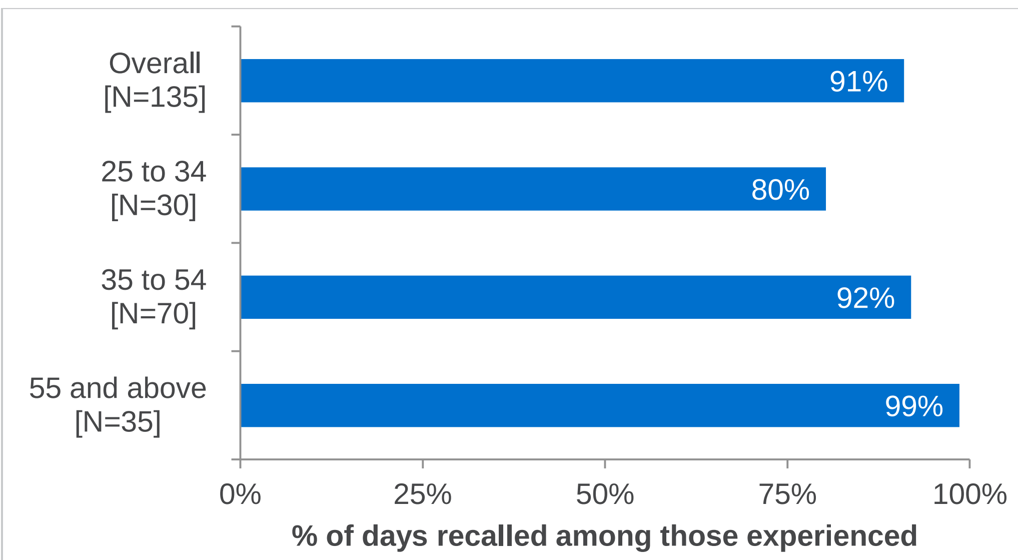


Figure 8-11: "How many Saver's Stat days do you remember experiencing?" [shown as percent of days actually experienced]



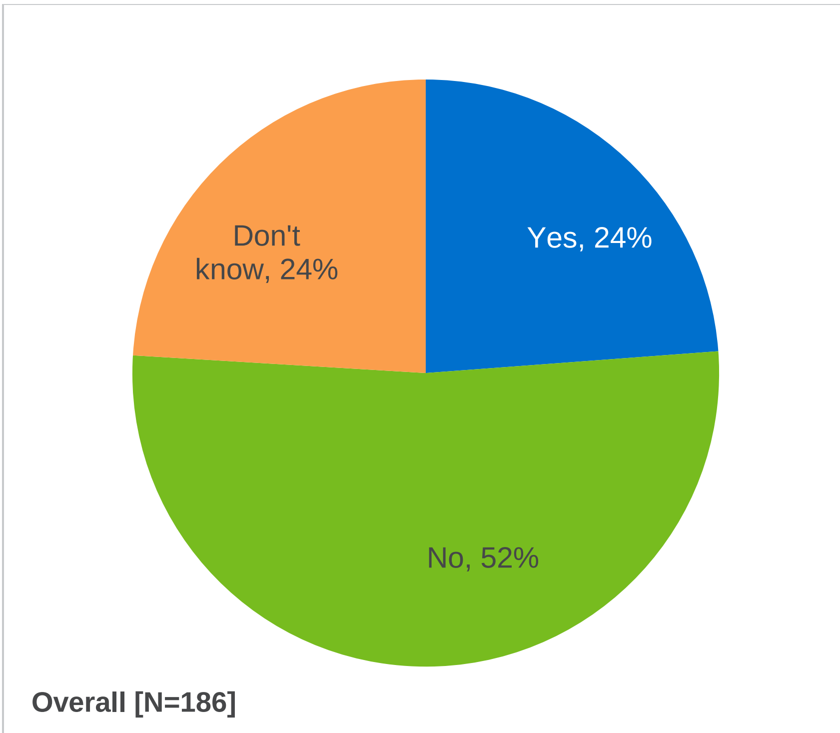
In addition to the $25 gift card received for enrolling Saver's Stat participants received bill credit performance incentives for each event for which participation could be confirmed.[105] Figure 8-12 shows that only about 24% of DR respondents reported noticing the participation incentives on their bill while 52% reported not noticing the on-bill incentives. Some groups of respondents

105 Defined as full participation in the first 30 minutes of an event

were more likely to notice the incentives, including respondents aged 65 and older (33%), and respondents with incomes of less than $100,000 (34%).

As these incentives were delivered via an on-bill credit potentially weeks after an event was called it is possible that some respondents did not recall seeing the incentives or that the incentives had not yet been received at the time the respondent took the survey (respondents took the survey on before October 1 would not yet have received incentives for September).

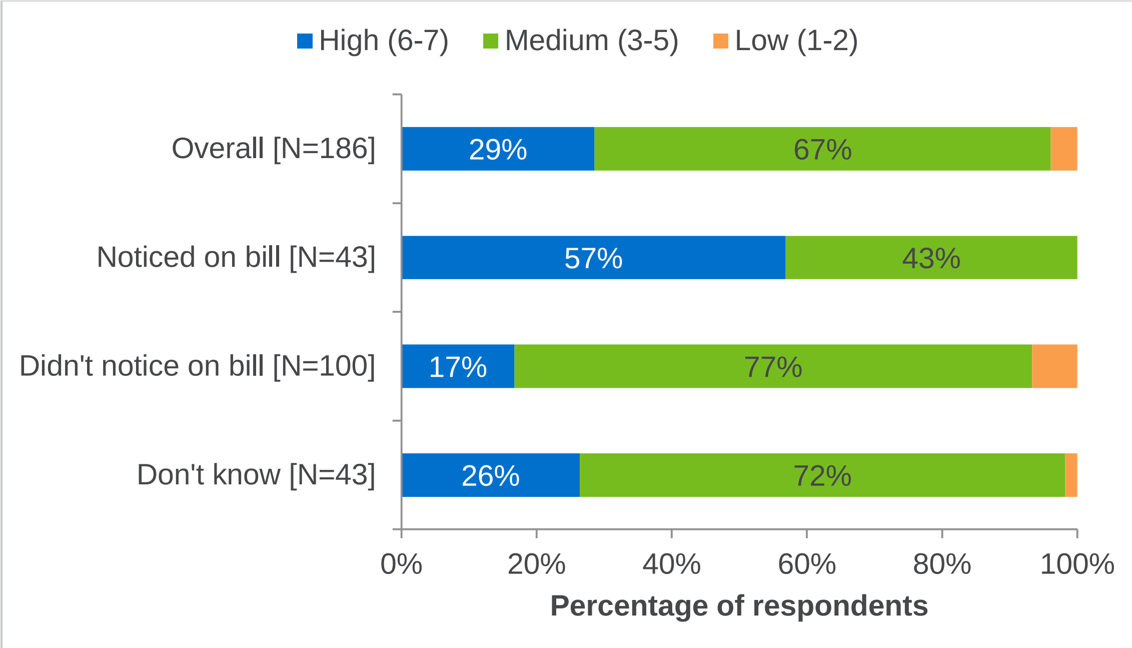
Figure 8-12: "Did you notice Saver's Stat Savings on your bill statement?"



As shown below in Figure 8-13, respondents were next asked about their satisfaction with incentives received as Saver's Stat participants. While 29% of respondents overall reported being highly satisfied there was a substantial difference in satisfaction depending on whether on-bill incentives were noticed. Respondents who noticed the on-bill incentives reported much higher satisfaction (57% reported high satisfaction) than those who did not (17% reported high satisfaction). Women and respondents older than 55 years old also reported above average satisfaction (35%). Notably, there was no significant difference in satisfaction with incentives between pilot participants who were completely new to Xcel Energy DR programs and those who were also participants in the longstanding Saver's Switch switch-based DR program.

In addition, virtually no one who noticed the on-bill incentives reported being dissatisfied. This implies that incentives may be high enough to satisfy participants, especially when taken in context with the energy efficiency specific question which showed that incentive levels were not perceived to be an important reason for not enrolling in the BYOT DR.

Figure 8-13: "Indicate on a scale of 1 to 7, how satisfied you were with the Saver's Stat Savings incentive that you received."

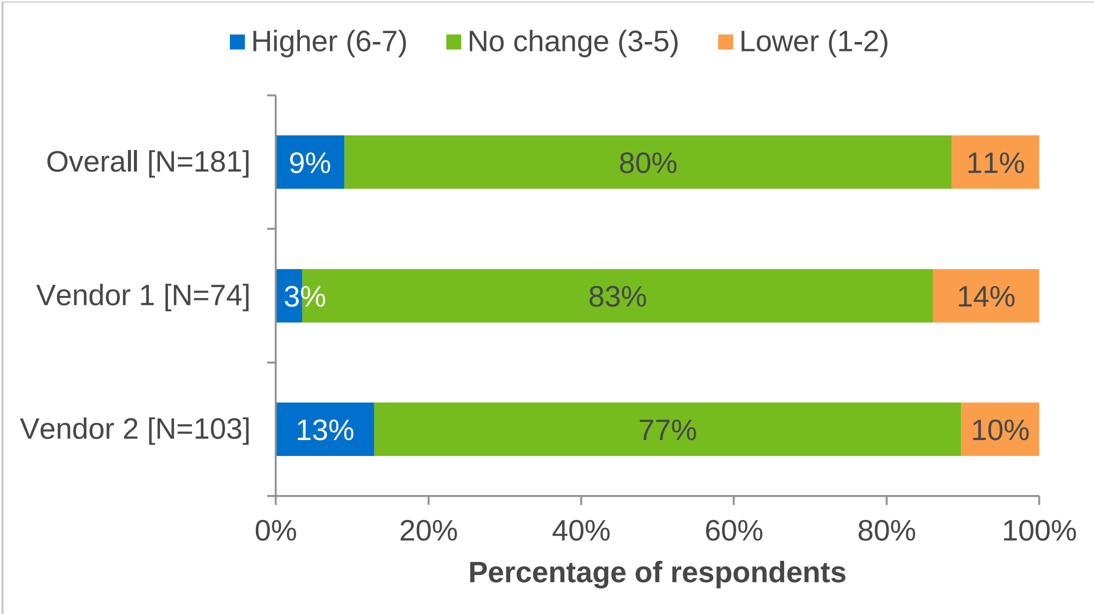


Finally, respondents were asked to report any change in the comfort of their home during event hours. As shown in Figure 8-14, a large majority (80%) of DR respondents reported that the comfort of their home remained the same during Saver's Stat event hours and only 9% reported being less comfortable, though this figure was 3% for Vendor 1 owners compared to 13% for Vendor 2 owners. Though this may suggest that differences in technology functionality may influence comfort, 20% percent of respondents who reported noticing incentives on bill also reported higher comfort. This underscores that awareness and engagement may also be correlated with perceptions of comfort.

As discussed in the sections on DR impacts temperatures did not rise by more than a degree or two on average during events, perhaps in part due to the mild outdoor temperatures during events. It makes sense in this context that most respondents would report no change in comfort at home during events. This may also have influenced respondent perceptions of Saver's Stat in general and event days in particular. For example, participants who experience no change in comfort might logically be more open to participating in subsequent years. This is something to keep in mind for a future program: if events are called on much hotter days than was the case in 2016 metrics such as re-enrollment openness (and hence retention), satisfaction with incentives, and comfort during events may all be lower.

From an engagement perspective it is also notable that most respondents recalled most events even though comfort reportedly remained unchanged for most respondents. This means it is more likely that respondents noticed the event days thanks to notifications rather than due to perceived discomfort.

Figure 8-14: "On a scale of 1-7, how would you rate the comfort of your home during Saver's Stat hours?"



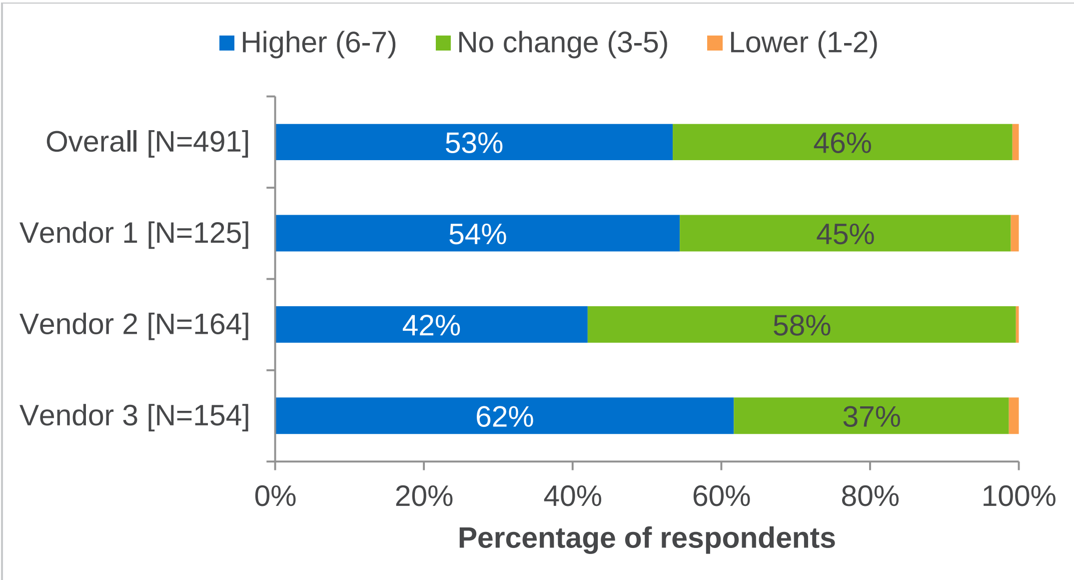
8.5 Thermostat Usage and Perception Questions

Participants in both the energy efficiency rebate pilot and the BYOT DR pilot have an installed smart thermostat[106] and agreed to provide Xcel Energy access to their smart thermostat data for evaluation purposes. Respondents from both pilots were asked a few questions about their perceptions and usage of the smart thermostat which were also compared to actual behaviors observed within the smart thermostat data. The topics covered in these questions included comfort in the home after thermostat installation, thermostat usability and functionality, and thermostat usage tendencies including temperature adjustments and programming.

Figure 8-15 shows that over half of respondents reported higher levels of comfort in the home after the installation of the smart thermostat, and nearly all of the remaining respondents reported no change in comfort. However, there is a significant discrepancy in reported comfort by type of thermostat. While comfort reported by Vendor 1 owners reflects the average across respondents, 10% fewer Vendor 2 owners and 10% more Vendor 3 owners reported an improvement in comfort. When interpreting this difference it is important to remember that there may be fundamental differences between Vendor 2 and Vendor 3 owners because the thermostat brand was self-selected rather than assigned. Therefore, this result is likely to capture, at least in part, differences in brand awareness and perceptions for Vendor 3 and Vendor 2.

[106] Energy efficiency participants purchased and installed anew thermostat, BYOT participant could have used an existing device or purchased and installed a new device

Figure 8-15: "On a scale of 1-7, how would you rate the comfort of your home after installing your thermostat?"



Though Section 7 on thermostat modeling showed that Vendor 3 devices were in HOLD settings about half as often as were other devices, the duration of these holds was also many times shorter for Vendor 3 devices (several hours compared to several days for other devices). This means that Vendor 3 owners likely adjusted the temperature more often than did other users, though the Vendor 3 devices remained in HOLD for a much shorter duration each time and hence spent less time in HOLD overall.. Survey responses were also consistent with this pattern: among survey respondents Vendor 3 owners were about 50% more likely than Vendor 1 owners and twice as likely as Vendor 2 owners to report interacting with their thermostat very frequently (e.g., more than once a week).[107] This has even more importance in the context of the EE savings analysis, discussed in Section 4, which showed that savings were only significant for Vendor 3 devices. This further underscores that the frequency of use of the HOLD setting may not impact energy savings as much as the duration of the HOLD setting. Said another way, allowing a thermostat to remaining in HOLD indefinitely may substantially reduce EE savings potential.

Higher comfort was also reported by energy efficiency respondents, higher amongst females, younger respondents (age 25 to 34), those that have incomes above $100,000, and customers who adjust the temperature at least several times per month (high engagement). However, all of these groups are disproportionately represented among Vendor 3 owners.[108] This underscores that when similar behaviors are observed among different groups or demographics there may be a common thread between each group. Perhaps in this case preexisting brand perceptions and interest in smart thermostats led certain participants to choose the Vendor 3, influenced

[107] See Figure 8-17

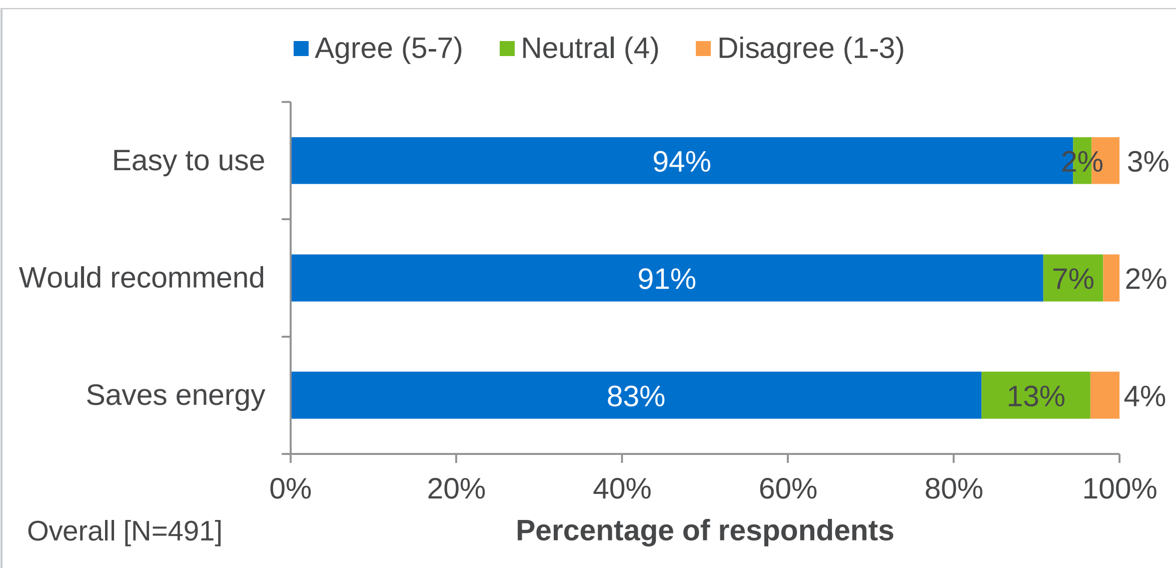
[108] Compared to Vendor 2 owners, among Vendor 3 owners there were 61% more females, 55% fewer respondents ages 55 or above, and 59% more respondents reporting incomes of $150,000 or above

perception of the Vendor 3 once installed in the home, and led to respondents interacting more frequently with the thermostat.

All respondents were also asked about their perception of the smart thermostat by the three distinct thermostat characteristics summarized in Figure 8-16: ease of use, willingness to recommend, and energy saving capability. Collectively, respondents reported very positive perceptions of their thermostat; 94% believe that it is easy to use, 91% would recommend to a friend, and 83% believe that the smart thermostat helps them save energy. Notably, 90% of Vendor 3 owners believe the thermostat saves them energy. While this may also reflect perceptions, the EE savings analysis did show that Vendor 3 owners who purchased online was the only group to exhibit statistically significant energy savings.

However, there were some groups of customers where reported impressions were 3-5% less positive than all respondents on average: females, respondents over the age of 45. Vendor 1 and Vendor 2 device owners, and participants who reported interacting with their thermostat no more than once or twice a day.

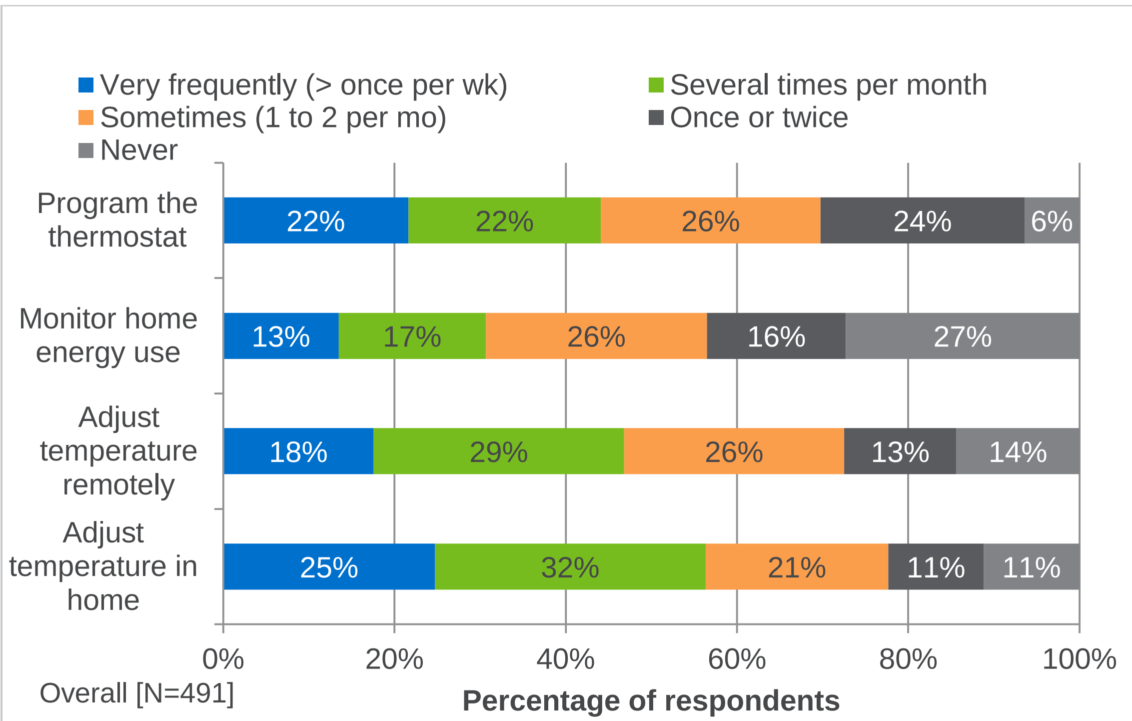
Figure 8-16: "Please indicate on a scale of 1-7 whether you agree with the following statements about your smart thermostat."



Positive thermostat perceptions among respondents were also positively correlated with thermostat engagement, a measured by the next survey question, summarized in Figure 8-17. This question asked respondents to indicate how frequently they interacted with the thermostat for various purposes. Respondents reportedly use their thermostat to adjust the temperature from home most frequently and use the web portal or app to monitor their home's energy use least frequently. Interestingly, 94% of respondents also reported programming their thermostat at least once.

Responses to this question varied the most by age and by type of thermostat, two respondent characteristics that are also correlated.[109] Vendor 3 owners were about twice as likely as Vendor 2 owners to report performing all tasks very frequently (except changing the temperature remotely). Most strikingly, 54% of Vendor 2 owners reported never using the app or web to monitor their home energy use. Vendor 1 owners were about midway between Vendor 3 and Vendor 2 owners on most accounts. Variations by age were also similar, with respondents ages 25 to 44 about twice as likely to report performing these behaviors very frequently as were respondents ages 55 and above. The most notable difference was that 23% of the younger group reported changing the temperature remotely very frequently, compared to 8% of the older group. On the flip side, respondents ages 55 and above were at least twice as likely as their counterparts ages 25 to 44 to report never performing most behaviors. About one quarter of the older group reported never changing the temperature, compared to about 5% of the younger group.

Figure 8-17: "Please indicate on a how often you did the following:"



[109] There were reportedly 55% fewer respondents ages 55 or above and 49% more respondents ages 25 to 44 among Vendor 3 owners than among Vendor 2 owners.

8.6 Intersection of Impacts and Behavior

The results for demand response survey questions discussed here capture perceptions and recollections about the program as reported by the subset of participants who took the survey. However, a richer set of insights can be garnered by combining these perceptions with quantitative, objective assessments of how demand response events impacted actual electricity demand usage. This can be done by combining the survey data and with load data used to assess event impacts.[110] Average event impacts were assessed within various subsets of respondents to identify differences or trends by self-reported perceptions and demographics.[111]

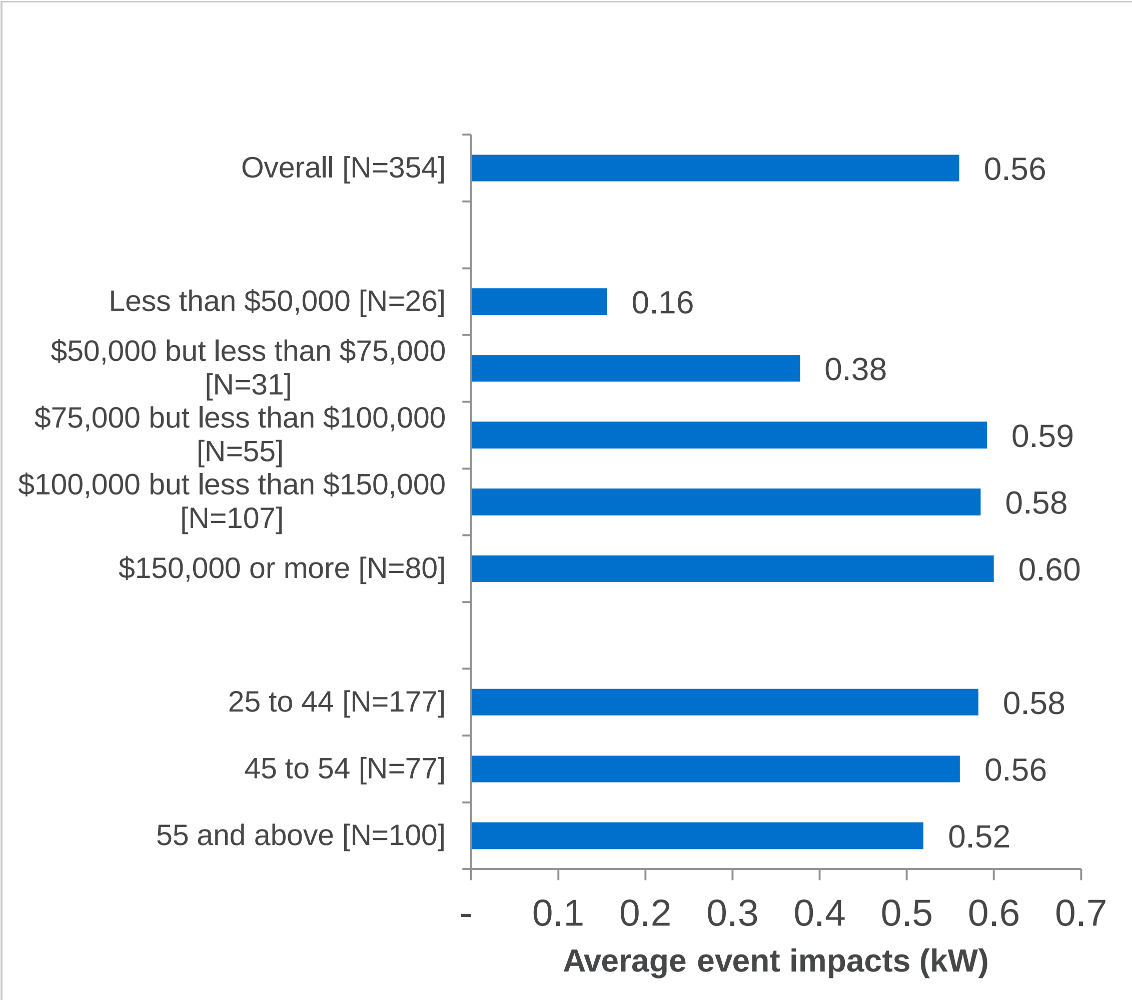
While differences across many survey questions were assessed, the most notable, significant differences found were within income level and age group. Figure 8-18 shows average event impacts (in kW) within income and age groups, showing that impacts appear positively correlated with income and negatively correlated with age. Average load impacts were about 0.55 to 0.60 kW for respondents reporting annual incomes above $75,000 and ages below 55. In contrast, impacts were about 40% to 80% lower (e.g., by 0.2 to 0.4 kW) for respondents reporting incomes below $75,000 or ages 55 and above. Males and respondents who demonstrated or reported higher engagement[112] with their thermostat also exhibited above average impacts.

110 Because impacts for each DR event are evaluated by matching each participant to a control customer with similar loads on similar non-event days it is possible to estimate individual event impacts for each participant. This was done for each event for each respondent then an average impact across events was calculated for each respondent. These average respondent specific impacts could then be aggregated and summarized by responses to various survey questions, both behavioral and demographic.

111 Note that not all DR participants took the survey and about 10% respondents could not be tied to specific device ids so the available respondent pool for this analysis is smaller than for the survey at large. To include the greatest amount of data points the average impact across all events was taken, including the 50% cycling events which were found to produce noticeably smaller impacts than other control strategies. Because of this, impact differences between groups the relatively comparison between groups are more meaningful than the actual impact levels.

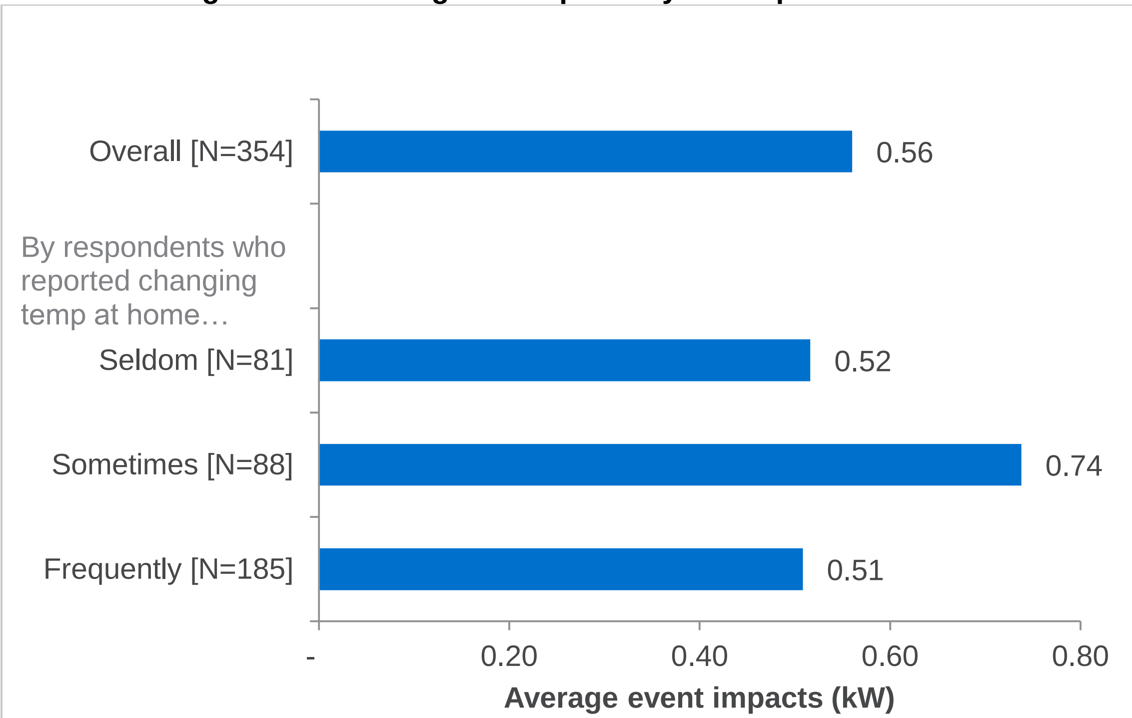
112 Customers who monitor their energy use at least one to two times a month (engagement), and dual-enrollment customers

Figure 8-18: Average BYOT DR Impacts by Income and Age



As with Saver's Stat program-specific behaviors, we are able to establish the correlation between DR impacts and thermostat engagement and usage. DR impacts appear to be highest for respondents who report adjusting the temperature sometimes but not very frequently. More specifically, impacts are approximately 30% lower for participants who report changing the temperature "frequently" or "seldom" (as opposed to changing the temperature "sometimes"). However, impacts are much lower for respondents who report seldom changing the temperature. This is not necessarily a causal relationship but instead may be due to confounding variables such as setpoints. The relationship between participant behavior and average DR impacts is shown below in Figure 8-19.

Figure 8-19: Average DR Impacts by Participant Behavior

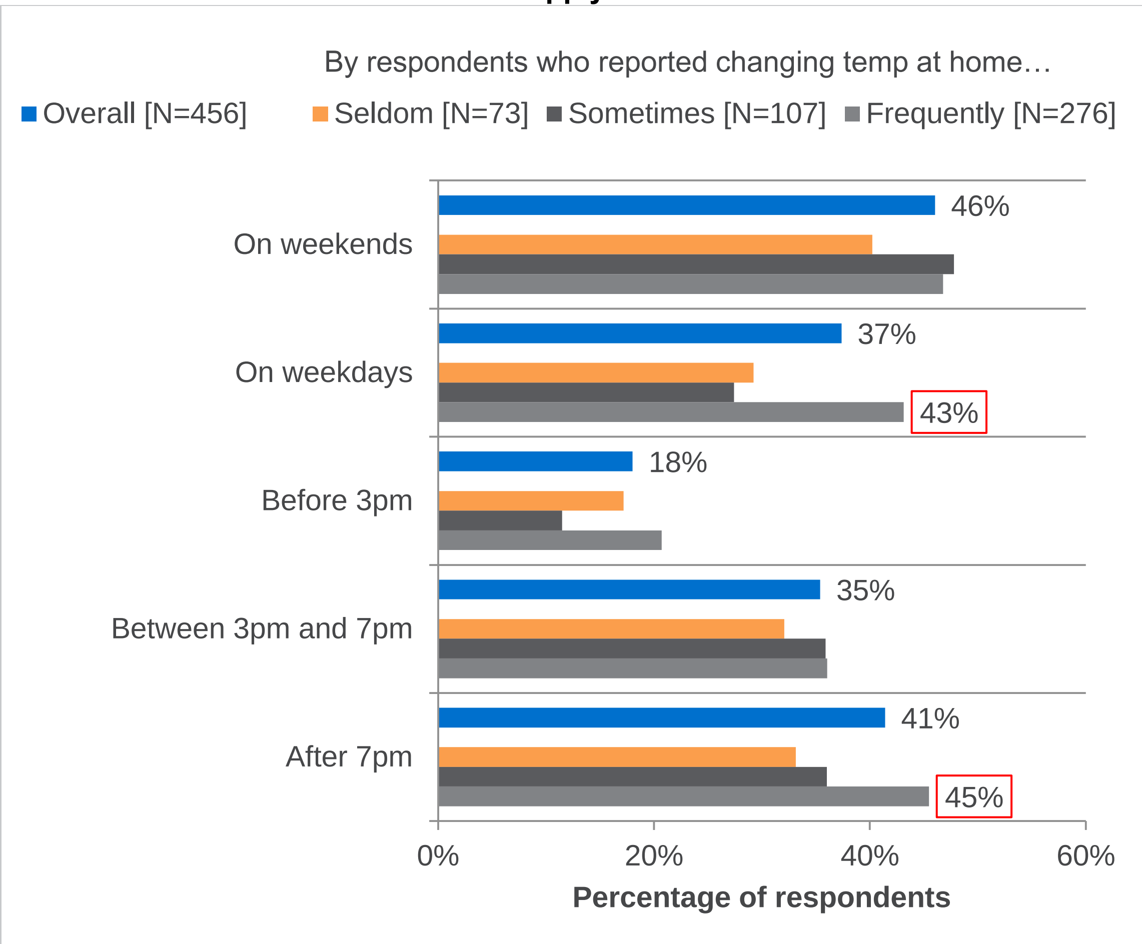


Finally, respondents who indicated changing the temperature at least once[113] were asked when they most typically changed the temperature as summarized in Figure 8-20. Among other things, this question is structured to identify whether respondents typically change their temperature during peak hours, e.g., on weekdays between 3pm and 7pm. However, respondents reported most frequently adjusting the temperature on weekends and after 3pm, times when residential customers are typically at home but not during weekday afternoon peak hours. In contrast, respondents who report frequently changing the temperature at home most typically do so after 7pm and equally frequently on weekdays and weekends.[114] It may be that this group is simply home more often, also enabling them to change the temperature from home more frequently and on weekdays. This also seems like a possibility given that among DR participants in this group, event participation was about 10 percentage points lower and opt-out rates were about ten percentage points higher than for respondents who reportedly changed the temperature less frequently. Average DR load impacts were also about 0.2 kW to 0.3 kW lower for this group than for respondents who reported only changing temperature sometimes.

[113] E.g., all respondents except those in the Seldom group who reported never changing the temperature

[114] only the day of week difference is statistically significant at the 95% confidence level

Figure 8-20: "When did you typically adjust the thermostat temperature? Select all that apply."



8.7 Demographics Questions

All survey participants were asked a variety of demographic questions. These questions provide insights about who took the survey and enable exploration of demographically driven differences in survey responses and other observable data (e.g., load impacts and thermostat use). Participants were asked questions about their gender, age, income, and residence ownership.

With respect to gender, one quarter of all respondents were women but within the EE only group 30% were women as shown in Figure 8-21. This is about twice the female representation in the DR only or dual EE and DR pilot groups. This further reflects that about 69% of EE only respondents owned a Vendor 3 devices and that 60% of women respondents were Vendor 3 owners, compared to 46% of men. Women respondents also reported being less aware of the Saver's Stat BYOT DR pilot, noticing incentives on their bill, and experiencing improved comfort after thermostat installation. Though DR load impacts were lower among women than among men participation rates were comparable. Female respondents also skewed somewhat younger and lower income than male respondents so it may be that the difference in DR load impacts could be explained by other factors such as home size.

Figure 8-21: "Please select your gender."

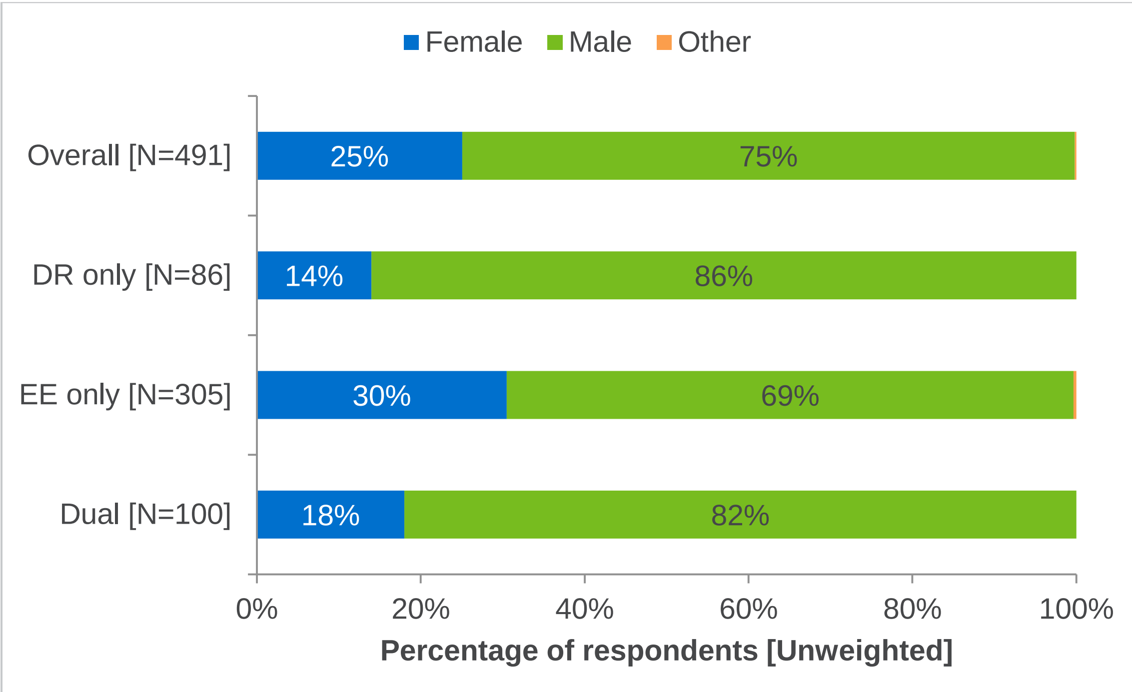
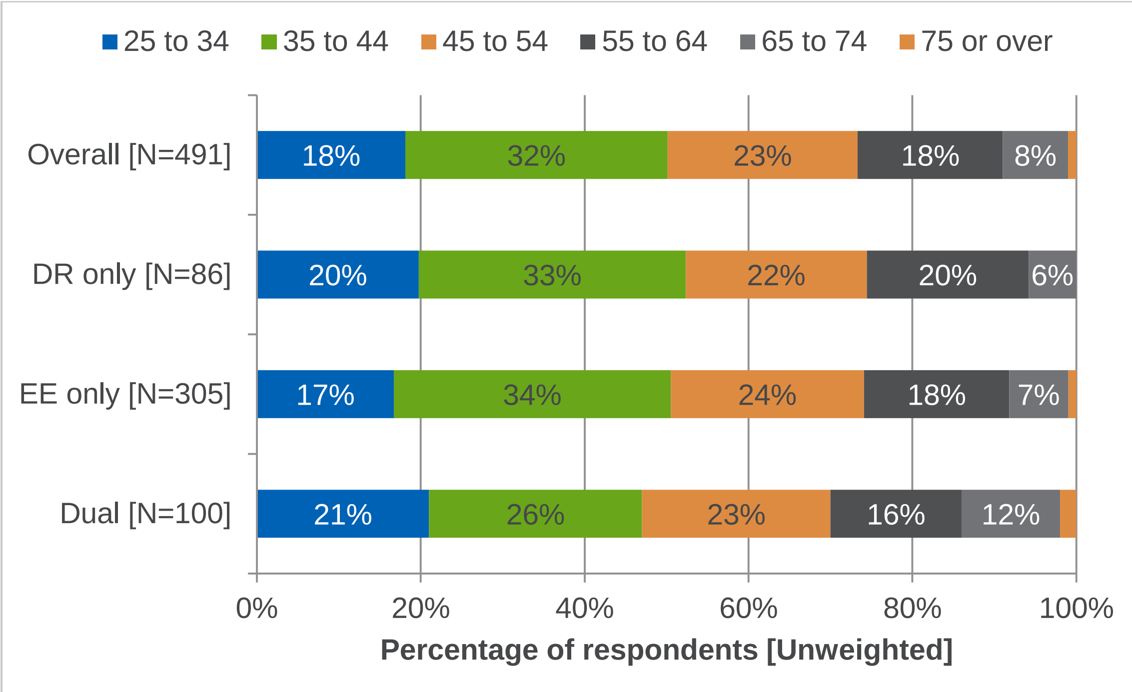


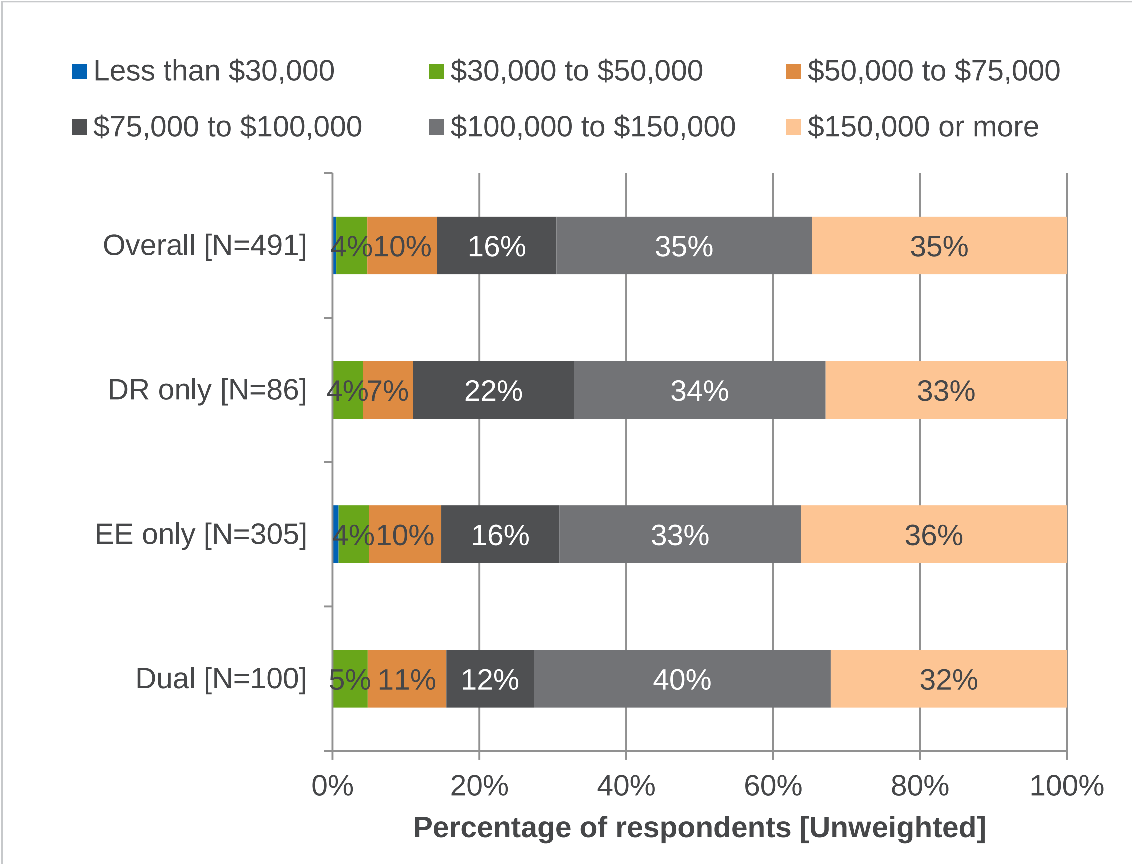
Figure 8-22 shows the respondent breakdown by age. About half of respondents were between ages 25 and 44. When looking at DR impacts, they were highest for those between 25-44 years old, while people over 65 years old reported higher comfort during event hours but had lower impacts. In addition, re-enrollment likelihood was lowest for 55 to 64 years old, but still at a firm 80%. Customers between 25 and 34 years old cite lack of awareness as the main reason for not enrolling in the Saver's Stat demand response program, and also report higher comfort post-installation than other age groups. Older customers (45+) generally had less positive impressions of their thermostats when compared to other age groups.

Figure 8-22: "Please select your age bracket."



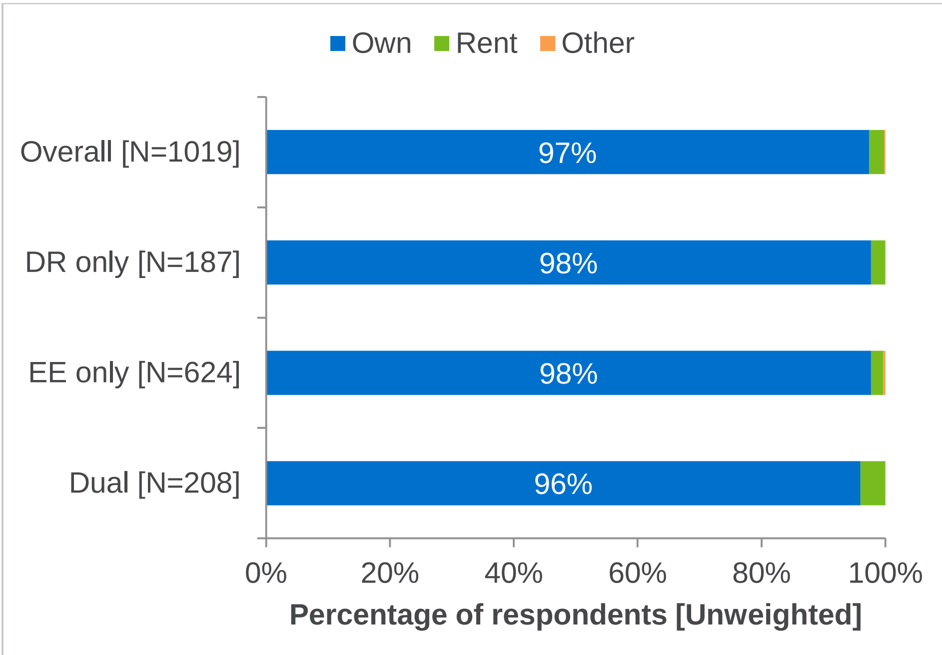
The third demographic question asked to all customers was about income, where 70% of respondents reported income above $100,000. There were no statistically significant differences in income between participant types (Figure 8-23).

Figure 8-23: "Which of the following categories includes the approximate annual income for your household before taxes?"



The final demographic question that was asked of all participants centered around residence ownership, and whether or not the participant owned their home. 97% of respondents reported owning their residences while only 2% reported renting their residence. This likely reflects the ineligibility of condos and multifamily units and the central AC requirement (Figure 8-24).

Figure 8-24: "Do you own or rent your residence."



9 Small Business Survey Results

9.1 SMB Survey Methodology

The challenge within the SMB segment was the small pilot population (61 customer sites) and that small business customers are typically unresponsive to direct mail and email communications. Therefore, Nexant conducted the survey while already on-site with participants during data logger retrievals in October and November 2016, supplemented by phone and internet outreach to all participants. The SMB survey asked similar questions as the residential survey, except the rebate experience questions were replaced with questions related to participants' experience with the direct install approach.

The SMB survey was provided to 61 participating sites[115] including both those that participated in the data logging field study and those that did not. Despite the very small target population, Nexant achieved an overall response rate of 42.6%, including a response rate of 84.0% among field study participants. To achieve this robust response rate, Nexant followed up the initial in person data collection during the data logger retrievals with outbound phone calls (up to five per participant) and with a programmed internet survey link. Responses through the phone mode were counted as either online or paper completes because in the few cases where additional responses were collected this was done so either by resending the survey link or by traveling to the site to provide and collect another survey form. In fact, all but a handful of the 18 paper responses were collected during the logger retrievals. The phone and internet modes were made available to all participants including those who did not participate in the field study.

Table 9-1: Response Rates for SMB Survey

Program	Total sampled	Online responses	Paper responses	Total responses	Response rate
Field Study	25	3	18	21	84.0%
Non-Field Study	36	4	1	5	13.9%
Total	*61*	*7*	*19*	*26*	*42.6%*

9.2 Survey Instrument Design

The participant survey instruments included the following sections:

- Thermostat usage and perception questions (on-site comfort, opinion on thermostat, thermostat usage/engagement)

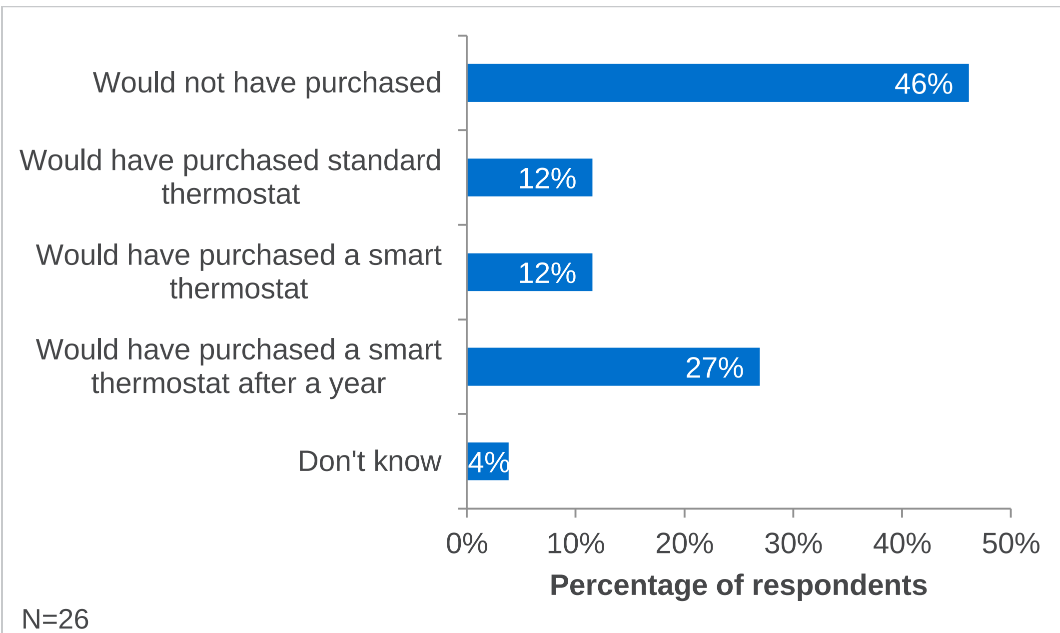
115 Excludes four participants who had already communicated strong dissatisfaction with their installation, and were thus not included in the survey.

- Installation experience – Thermostat rebate questions (purchase intention, direct install influence, timeline to receive thermostats, thermostat satisfaction, reason for not enrolling in demand response);
- Firmographic questions.

9.3 SMB Saver's Stat Experience Questions

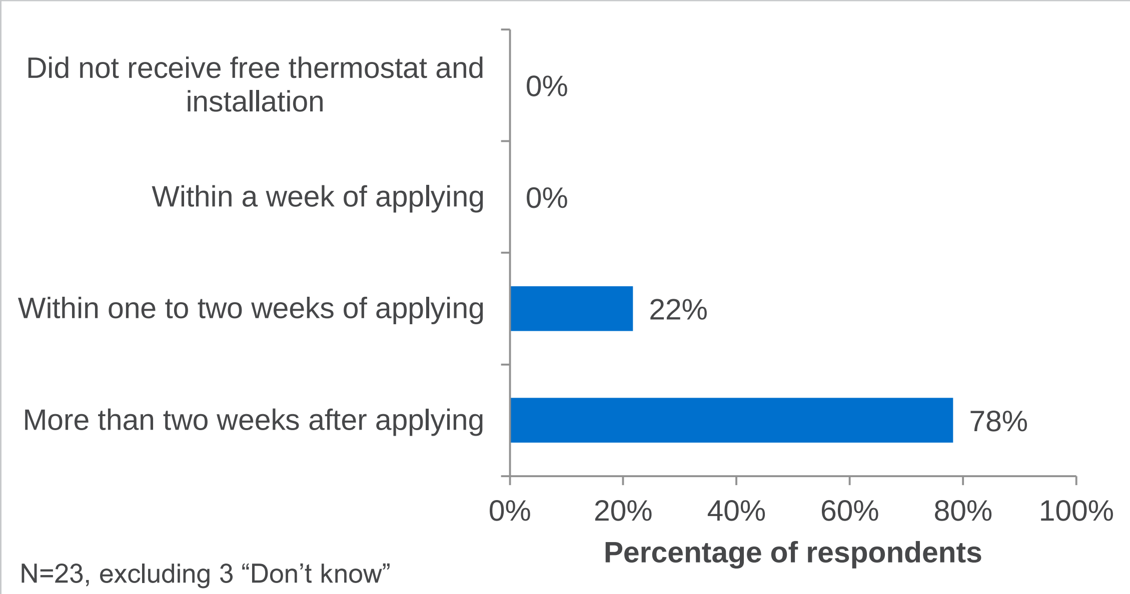
Similarly to the intention question in the residential survey, the SMB survey asked respondents what they would have done had they not received no-cost, installed thermostats. The majority of respondents reported they would not have purchased a smart thermostat absent the pilot offer. As seen below in Figure 9-1, 46% of respondents would not have purchased a smart thermostat at all. Several noted in the accompanying free format question that their current thermostat was working properly, so there was no need to replace it. Additionally, only 12% of SMB respondents would have still purchased a smart thermostat. These results contrast with the results from the residential survey, in which 40% respondents said they would have purchased a smart thermostat within the year and another 35% in more than a year.

Figure 9-1: "You received a free smart thermostat and installation from Xcel as part of the Saver's Stat pilot. Imagine you had never learned that Xcel was offering free smart thermostats and installation."



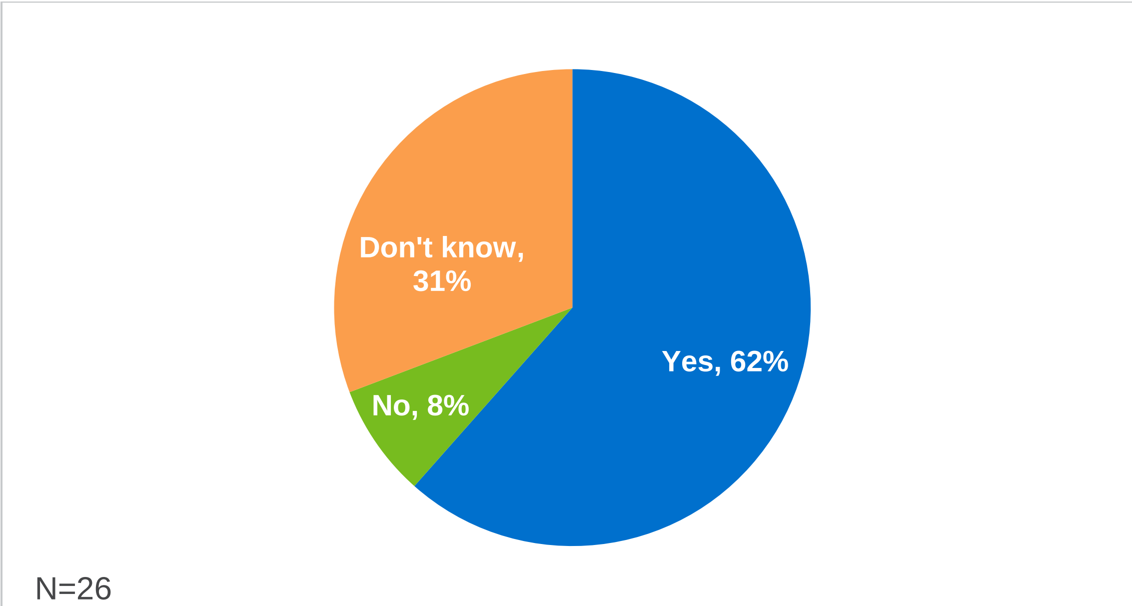
While the residential survey asked the respondents about the time it took to receive their rebate, the SMB survey asked respondents how long it took for their smart thermostats to be installed after applying. Almost all respondents reported receiving their free thermostat and installation more than two weeks after applying (78%), as seen in Figure 9-2 below. All respondents reported receiving their free thermostat and installation, but 16% of respondents reported some sort of technical or equipment issue after the initial installation, as reported in write-in comments.

Figure 9-2: "When was your smart thermostat installed?"



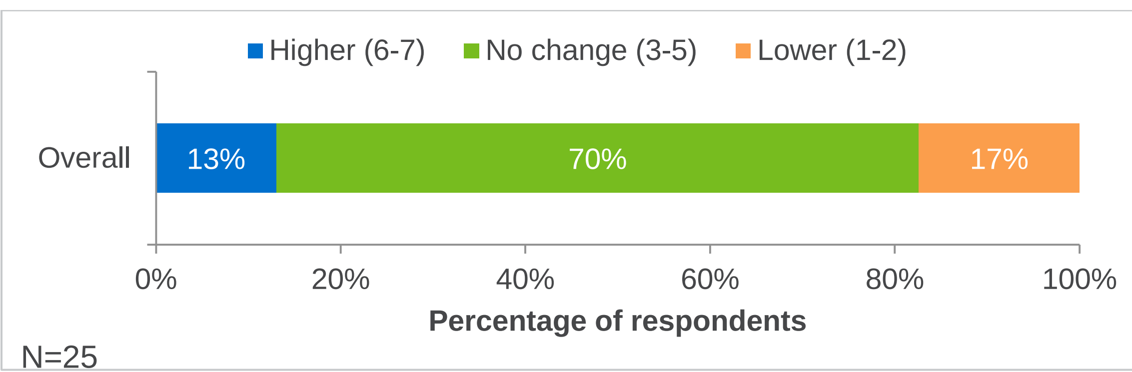
As shown in Figure 9-3, 62% of respondents said they would participate again in Saver's Stat for Small Business next year. Most of the remainder were unsure about whether to participate in Saver's Stat next year. Among those that would re-enroll the most common reason for participation was "the ability to save money" as noted in an open-ended question. The 39% of respondents that responded "No" or "Don't know" to participating next year were asked if incentives might influence their decision. Of these ten people, five declined to give a value and another four gave values ranging from $20-$50 per event. The last person gave an outlier value due to being highly dissatisfied.

Figure 9-3: "Would you choose to participate in Saver's Stat next year if it were offered? This would mean allowing your smart thermostat, which you received at no cost, to automatically reduce power use during the hottest days of summer."



Like the residential survey, the SMB survey also asked respondents about the comfort of their facilities during Saver's Stat event hours, shown in Figure 9-4. A large majority (70%) of respondents reported no changed in comfort during events, though this was somewhat lower than the 80% of residential respondents who reported no change in comfort, though more SMB respondents also reported higher and lower comfort, so this variation is likely explained by the small sample size.

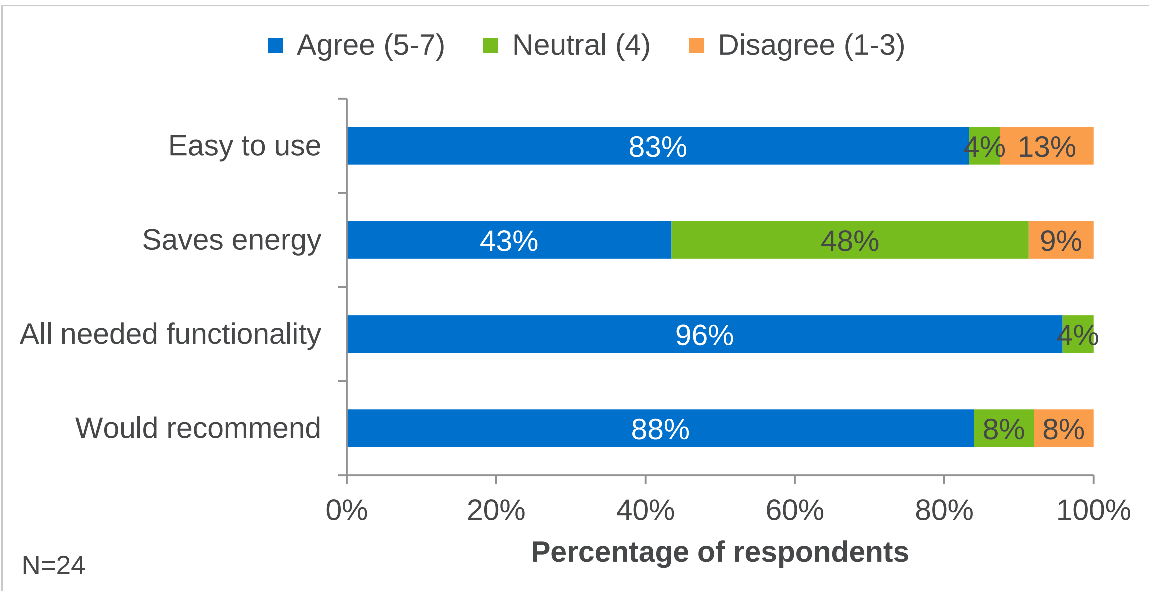
Figure 9-4: "On a scale of 1-7, how would you rate the comfort of your business during Saver's Stat hours?"



9.4 Thermostat Perceptions and Usage

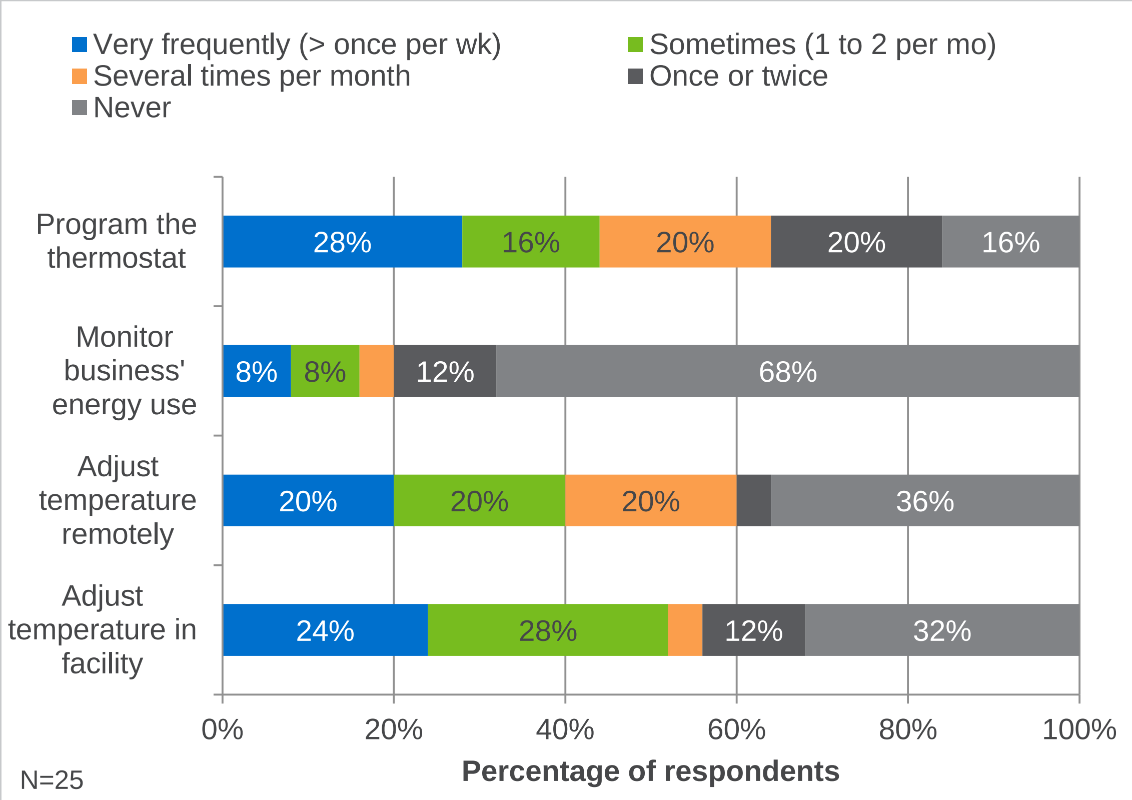
Figure 9-5 shows the perceptions of smart thermostats reported by SMB respondents. Reported perceptions were positive overall with 83% to 96% of respondents agreeing with statements about functionality, ease of use, and recommendation potential. While, only 43% of respondents reported believing that the smart thermostat saves energy and another 48% were neutral on this question the focus of the SMB pilot and accompanying marketing was DR impacts not EE savings. Further, many participants would not have had the thermostat for a substantial portion of the cooling season or any of the heating season, during which EE savings potential could have been highest.

Figure 9-5: "Please indicate on a scale of 1-7 whether you agree with the following statements about your smart thermostat."



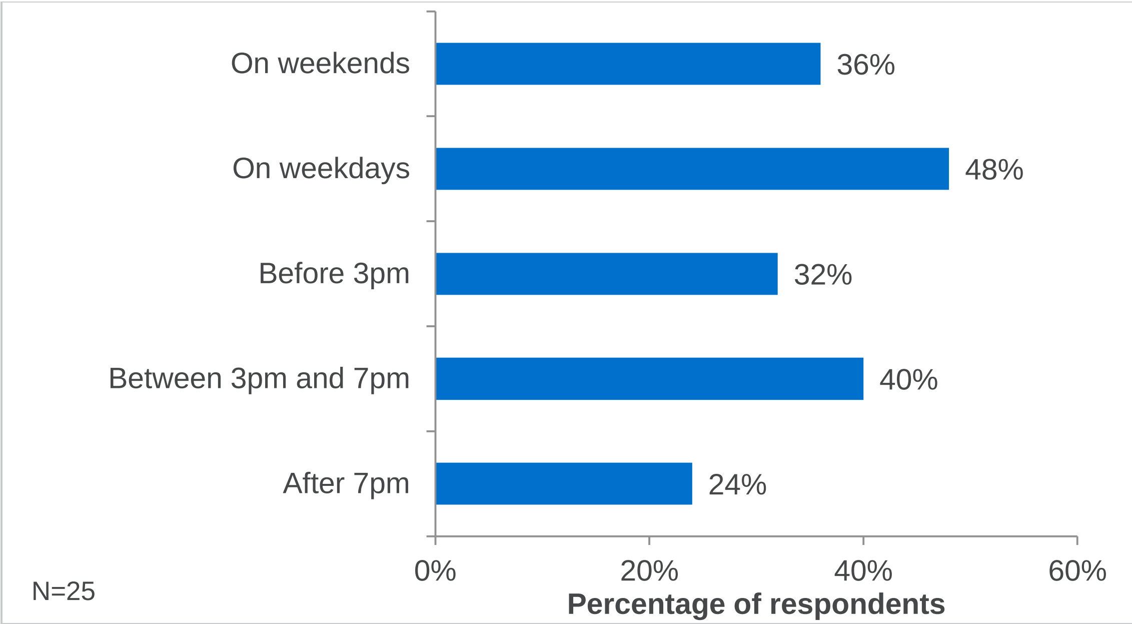
Understanding how SMB respondents interact with their thermostat can help gauge which features are most valued. Figure 9-6 shows that most respondents reported programming their thermostats and changing the temperature but never monitoring their energy use. Eighty-four percent of respondents reported programming their thermostats at least once and about 60% reported changing the temperature both remotely and while in the facility at least several times a month. Lastly, 68% report never monitoring their energy use at all.

Figure 9-6: "Please indicate on a how often you did the following:"



The last thermostat related question, summarized in Figure 9-7, asked respondents when they typically adjust temperatures via their thermostat. SMB respondents reported adjusting the temperature most often on weekdays and between 3pm and 7pm, in line with business hours but also in line with typical peak hours and DR events. This contrasts residential survey respondents who reported changing the temperature most typically on weekends and after 7pm, which is also when homes are most typically occupied.

Figure 9-7: "When did you typically adjust the thermostat temperature? Select all that apply."



9.5 Firmographics Questions

All SMB respondents were asked firmographics questions to better understand what types of industries, people, and facilities participated in the pilot. Figure 9-8 shows that 63% of respondents were female while 37% were male. This contrasts notably with the residential survey in which only 24% of respondents were female. Figure 9-9 shows that 63% of respondents reported working in rented spaces.

Figure 9-8: "Please select your gender."

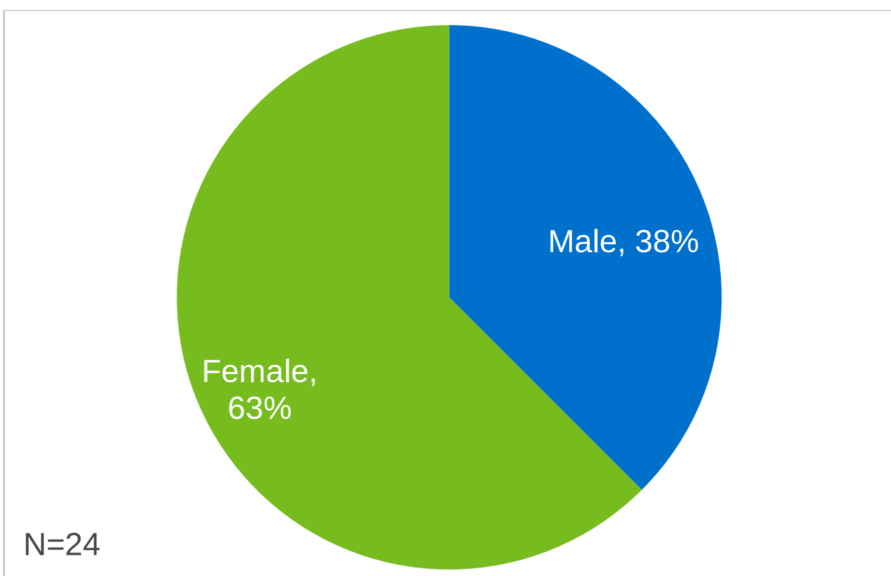
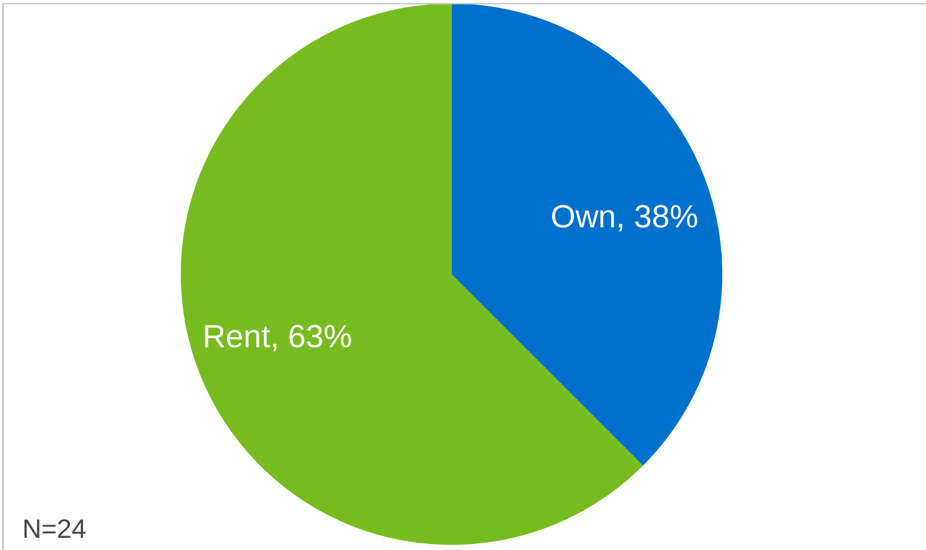
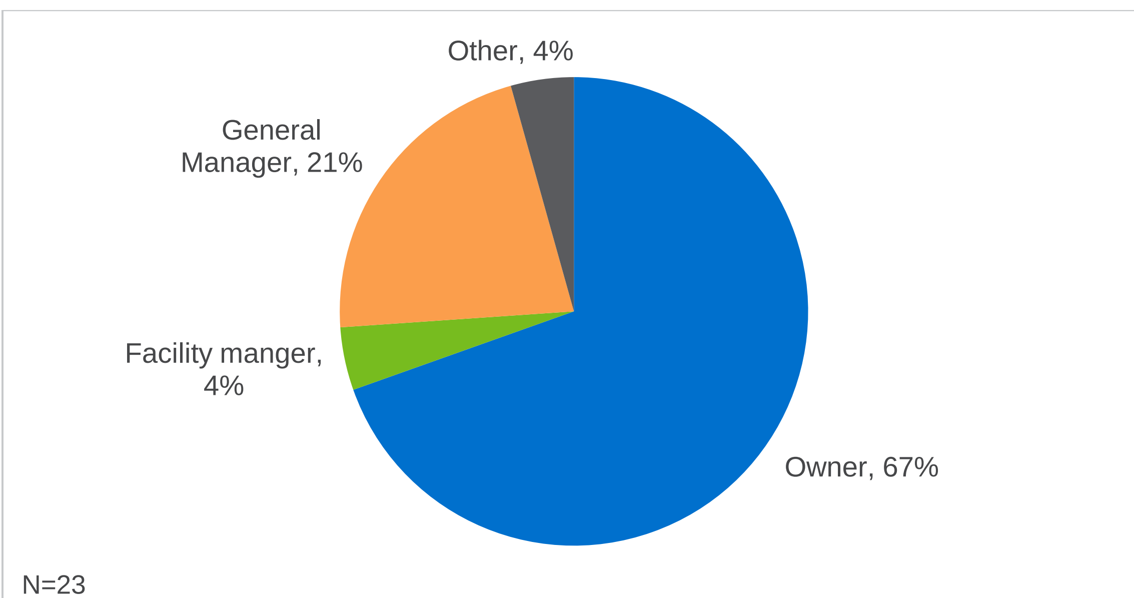


Figure 9-9: "Do you own or rent your facility?"



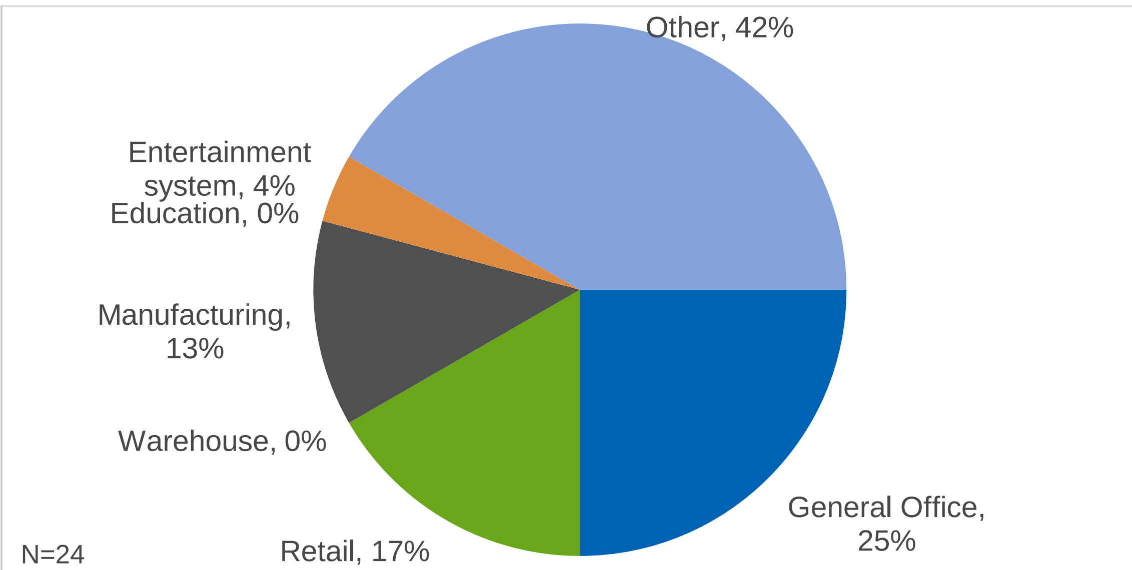
Respondents were also asked their business title, in order to gauge if key decision makers were completing the survey. Figure 9-10 shows that 88% of respondents reported being the business owner or general manager, indicating that respondents were typically in decision-making roles.

Figure 9-10: "Which of the following best describes your business title?"



The final firmographics question asked about the respondents' industry. As shown in Figure 9-11, a plurality of respondents chose the "other' option, though nearly a third of these respondents specified that they were restaurants. Overall, respondents came from a diverse number of industries, with most representing general offices and retail. Though self-reported industry does not align perfectly with industry data in Xcel Energy's customer database, there are similarities. In particular, participant industry captured in the database shows that 18% of participant premises were classified as retail establishments. Another 12% were classified as "Other" and 52% were missing an industry designation. The industry coding system used in the database is grouped by economic activity (healthcare, finance, media, etc.) rather than work environment (e.g., office) so no "General Office" category is present.

Figure 9-11: "Which of the following best describes the industry in which your business operates?"



Appendix A Methodology Supplement for Energy Savings Analysis

A.1 Definition of Pre- and Post-treatment Periods

The matching analysis was performed on pre-treatment billing. Given the long enrollment period for the EE pilot, the pre-treatment period was not the same for all participants. The post-treatment period was restricted to all months in 2016 for purposes of the analysis. Table A - 1 shows (in green**)** the period during which customers could participate in the pilot by applying for a smart thermostat rebate**.** Table A - 2 shows two conceptual examples (A and B) to illustrate that pre-treatment (orange) and post-treatment (blue) periods differed by participant based on enrollment date and data availability. The identification of months as the period when the treatment occurred, e.g., when the thermostat purchase and installation took place, was key to designating usage as pre-treatment and post-treatment. By design, the rebate pilot collected the date on which the customer applied for the rebate but not when the thermostat was installed. To increase the likelihood that the energy usage impacts were assessed for months where the thermostat was indeed installed, Nexant excluded from the impact assessment both the month in which the thermostat application was filed and the following month**.**[116]

In example A, a participant was “treated” in September 2015 by applying for the rebate (R) and getting a smart thermostat installed (I). The post-treatment period is the 12 month period directly following, October 2015 to September 2016. To the extent possible, pre- and post-treatment month pairs are 12 months apart. However, because the months during enrollment and installation were excluded, there are some cases where the pre- and post-treatment periods are 24 months apart. For example, in the case of post-treatment months September through December 2016, September through December 2014 were used as the pre-treatment months instead of September through December 2015.

In example B, a participant was “treated” in June through May 2016. The post-treatment period extends from June 2016 through December 2016, the end of the pilot evaluation period. The pre-treatment period used for the energy savings calculation is June 2015 through December 2015, and all pre and post month pairs are 12 months apart. However, the pre-treatment period for the matching analysis was the full 12 month period leading up to enrollment, May 2015 through March 2016 (indicated in light orange). Using a full 12 months of pre-treatment data to develop matches for all participants, regardless of the number of post-treatment months, ensures the same matching approach is applied to all participants.

[116] In the absence of information about when the thermostat was installed, it may be reasonable to assume that thermostat installation often took place in the month following the rebate application and thermostat purchase. After verifying that treatment effects negligible in the first month after rebate application, it was assumed that for many participants the thermostat may have been installed during this first month.

Table A - 1: Smart Thermostat Rebate Availability Period

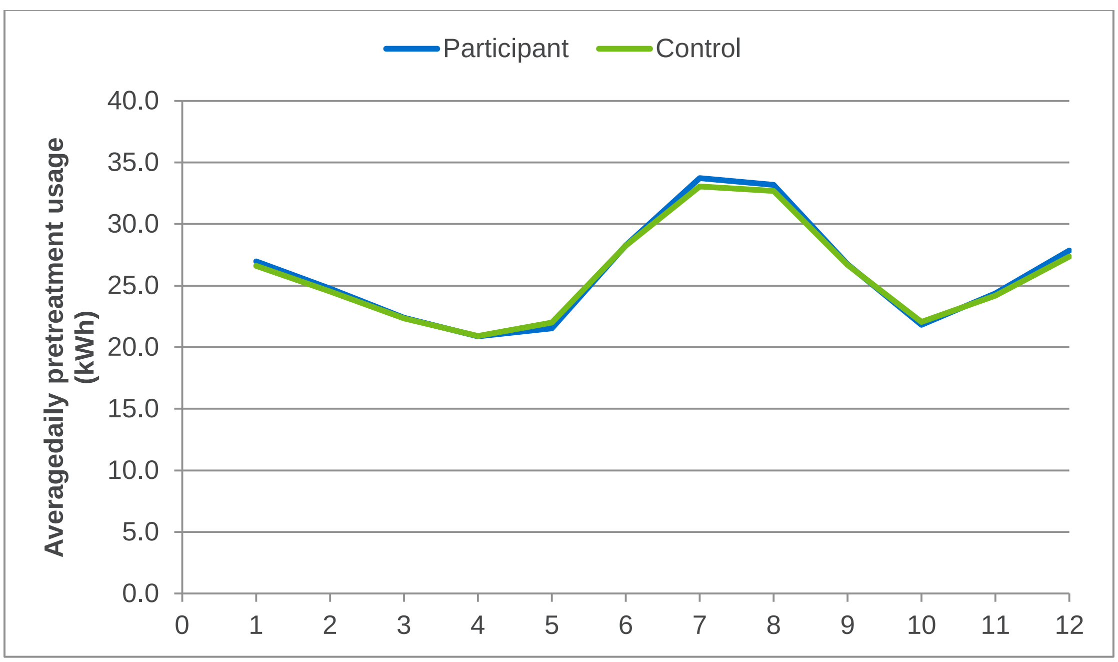
2014												2015												2016												2017											
J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
																	Smart thermostat rebate availability: June 2015 to Sept 2016																														

Table A - 2: EE Pre- & Post-treatment Examples

2014												2015												2016												2017											
J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
									Ex A: Pre-treatment Oct 2014 to Sept 2015												R	I		Ex A: Post-treatment Nov 2015 to Oct 2016																											
																	Ex B: Pre-treat Jun-Dec 2015										R	I	Ex B: Post-treat Jun-Dec 2016																			

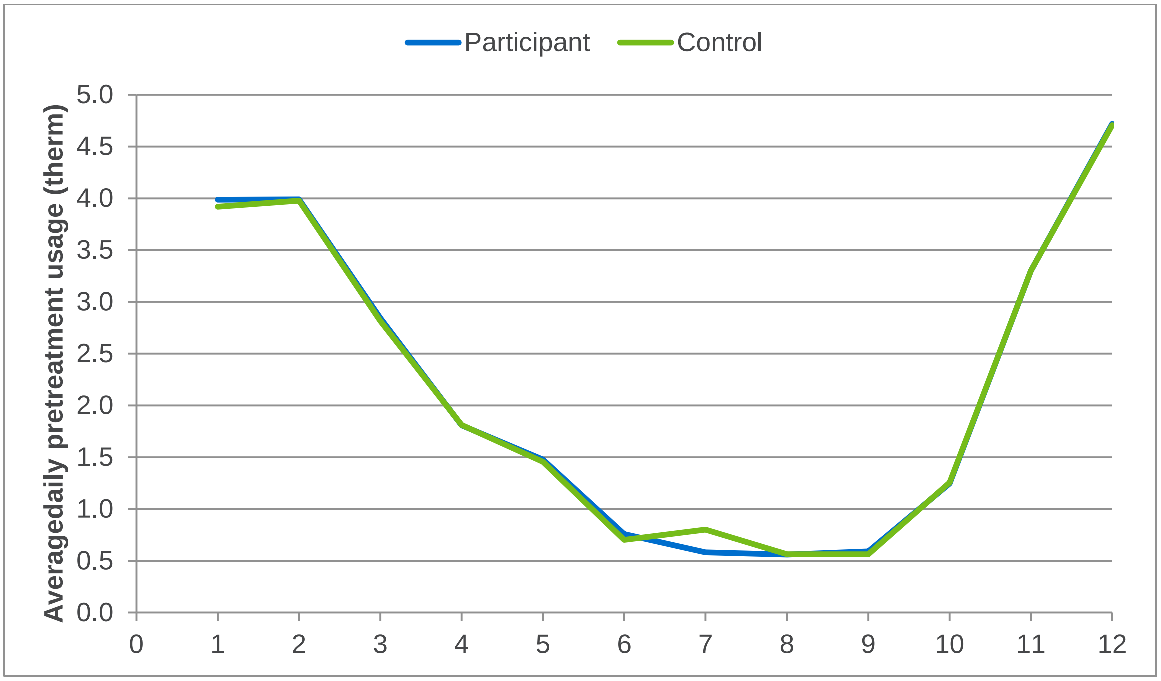
Figure A - 1 and Figure A - 2 provide a comparison of EE participant and matched control group monthly usage averaged across the pre-treatment period for each participant. As shown in the figure, the matched control group usage closely aligns with participant usage in the pre-treatment period (the difference in usage is 0.6% on average for electricity and 0.4% for gas).

Figure A - 1: Matched Control Group Results: Electricity Usage[117]



117 Matched on average daily usage in December through February and July through August.

Figure A - 2: Matched Control Group Results: Gas Usage[118]



A.2 Difference-in-differences Assessment of Energy Savings

A difference-in-differences analysis was used to estimate the electricity and gas savings that were attributed to smart thermostats. This approach further increased precision by controlling for any small residual discrepancies in pre-treatment usage between the participant and matched control groups. This approach is transparent and eliminates the need to specify an overly complex regression model that relates customer usage to several temperature variables. Instead, if the treatment and matched control customers have nearly identical pre-treatment usage and experience the same weather (by virtue of being in the same geographic area), then it is defensible to assume that any difference during the treatment period is attributable to the smart thermostat pilot.

The difference-in-differences regression defined in Table A - 1 and Equation A - 1 was used to estimate energy savings while adjusting for any remaining pre-existing differences between the participants and their matched controls. Since the pre-existing differences may vary by month and participation also varies, the difference-in-differences regression were first run on a monthly basis including only customers who participated in that month and their matched control customers, using the most recent pre-treatment month, as discussed above. It was also necessary to estimate an average annual impact estimate, weighted by the number of participants with treatment data for each month. Extending this difference-in-differences approach for derivation of an average annual value was straightforward because it was structured as a fixed effects panel regression with errors clustered within each calendar month and account.

118 Matched on average daily usage in October through May.

Equation A - 1: Specification of Difference-in-differences Regression

$$kWh_{i,t} = a * treat_i * post_t + \sum_{cust=1}^{customers} b_{cust} * customer_{cust\ i} + c * post_t + e_{it}$$

Table A - 2: Variables Used for Difference-in-differences Regression

Variable	Description
kWh	Average daily usage
treat	Indicates whether a customer is a participant (treat=1) or a control group member (treat =0)
post	Indicates whether a given month was after installation (post=1) or not (post=0)
customer	A set of indicator variables that equal one if cust=i
month	A set of indicator variables that equal one if month=t
a	Estimated energy savings
b, c	Estimated fixed effects
i	Indexes customers
t	Indexes the months
e	Error term

This estimate of gross electricity (kWh) and gas (therms) energy savings in each treatment month was segmented by rate class, thermostat manufacturer, and relevant program data such as rebate application channel to determine if savings were statistically significant within segments and whether any differences detected between segments were statistically significant. This segmentation analysis was conducted by running the difference-in-differences regression above separately by each segment, therefore allowing definition of the range of likely impacts across different customer types and devices.

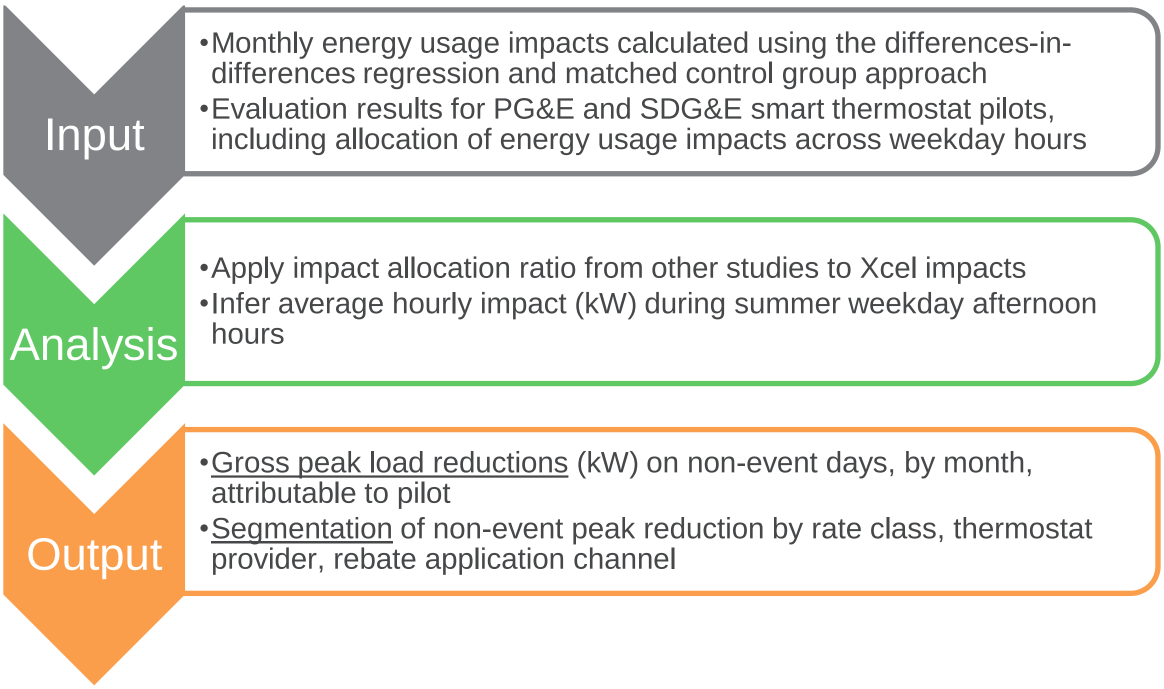
A.3 Estimating Residential Peak Reductions on Nonevent Days

If smart thermostats reduce energy use it is logical that some of these savings also result in load reductions. The degree to which daily peak loads are reduced depends on the allocation of savings between daily peak and nonpeak periods. A typical, robust approach for measuring such savings is a matched control group based difference-in-differences approach similar to what was used for the energy savings analysis. Whereas monthly usage data is sufficient for estimating energy savings, hourly interval data was necessary to estimate peak load reductions using this approach.

However, while interval treatment data was collected, pre-treatment interval data was not available and was not collected after the fact. Because of this, Nexant combined data from two complementary approaches to triangulate a peak load reduction estimate as laid out in Figure A - 3. A key input was post-treatment interval loads constructed by combining smart thermostat runtime data with measurements of participant AC connected loads. This constructed interval data was used for both nonevent peak reduction approach as well as for assessing DR event day impacts.

The approach consisted of allocating energy savings between daily peak and nonpeak periods based on load impacts found in other similar smart thermostat studies in jurisdictions that have smart meter data. The result was monthly estimates of peak load reductions on nonevent days.

Figure A - 3: Estimation Approach for Nonevent Peak Reduction



Studies show that savings are not distributed evenly between peak and nonpeak periods. The approach to calculating peak load reductions on nonevent days allocated energy savings between daily peak and nonpeak periods based on load impacts found in other similar smart thermostat studies in jurisdictions that have smart meter data. If other smart thermostat pilots produce indications that 50% of energy savings are concentrated between hours 14 to 18 in the summer, for example, the savings can be allocated to these hours to deduce an average kW load reduction in those hours due to energy efficiency.

Two relevant smart thermostat studies are known to Nexant. The first is a large residential pilot currently being conducted by Pacific Gas & Electric Company (PG&E) that involves Vendor 3 and Vendor 1. This pilot followed a randomized control trial design and found evidence of annual whole house electricity savings of 4-5%.[119] However, the report did not breakdown results by hour, so while it is a relevant data point indicating a case where smart thermostats were found to result in energy savings, it cannot be used to develop a nonevent load impact for Xcel Energy.

Another smart thermostat evaluation was recently completed as part of the SDG&E Small Customer Technology Deployment (SCTD) program. Figure A - 4 shows the average summer weekday hourly impacts reported for the 2014–2015 program year. Note that no substantial savings were found on weekends.

Figure A - 4: Average Hourly Energy Savings on Weekdays for Summer Months from Smart Thermostats in SDG&E's SCTD Program (2015–2016 Evaluation)[120]

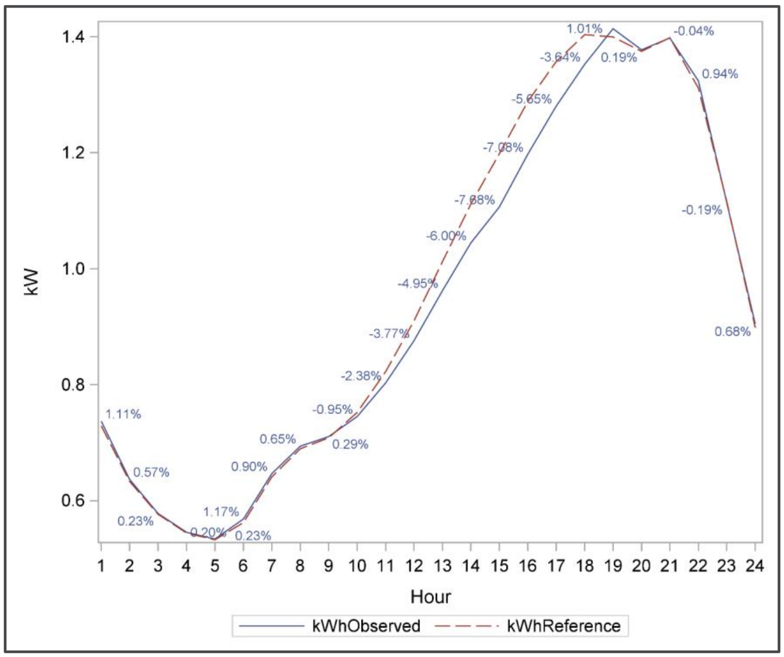


Table A - 3 shows the distribution of electricity savings across hours of the days that can be inferred from the information in Figure A - 4. Note that the sum of the percentages adds up to 100% and the value in each hour is meant as a multiplier to convert from average daily savings to savings in each hour. These impacts indicate that 73% of the savings in summer months were concentrated in hours 15 through 18 and 40% in the two peak hours of 16 and 17 which Xcel Energy used for its BYOT demand response program.

[119] PG&E Smart Thermostat Study: First Year Findings. ET Project Number ET13PGE1462. For more information see http://www.etcc-ca.com/reports/smart-thermostat-study

[120] Source: SCTD Supplementary Analysis to Section 5 of SCTD Evaluation Report, Figure 5-6

Table A - 3: Inferred Distribution of Daily Electricity Usage Savings by Across Hours of the Day

Variable	Percent of daily usage savings in each hour
1	-2%
2	-1%
3	0%
4	0%
5	0%
6	-2%
7	-1%
8	-1%
9	-1%
10	2%
11	5%
12	8%
13	12%
14	16%
15	21%
16	21%
17	18%
18	12%
19	-3%
20	-1%
21	0%
22	-3%
23	1%
24	-2%

In the absence of hourly interval data, this same analysis would not be possible for Xcel Energy. However, it is reasonable to assume that whole house energy savings may be similarly distributed across hours for Xcel Energy customers as was observed for SDG&E customers. Thus, to estimate nonevent load impacts due to smart thermostat energy efficiency, it was assumed the 70% of daily kWh savings were concentrated in summer weekdays between hours 15 to 19 (typical peak hours for Xcel Energy that also align with DR event windows).

Equation A - 2 and Table A - 4 summarize the straightforward calculation used to apply the hourly savings allocation observed for SDG&E to energy savings observed for Xcel Energy in order to derive a peak load impact estimate. Essentially, total summer savings was allocated to peak hours by applying energy savings percentage observed for SDG&E (ratio of savings in peak hours to total daily savings) to savings observed for Xcel Energy, divided by the number of peak hours in question to arrive at average kW impacts across those peak hours.

Equation A - 2: Method for Allocation of Energy Savings to Peak Hours

$$kW_{Xcel,s,p} = \frac{kWh_{s,Xcel} * \frac{kWh_{U,s,p}}{kWh_{U,s}}}{total\ hours_{Xcel,s,p}}$$

Table A - 4: Variables Used for Hourly Energy Savings Allocation

Variable	Description
kW	Average nonevent peak load reduction
kWh	Total energy saved
p	Indicates peak period
s	Indicates summer period
$Xcel$	Indicates Xcel Energy (e.g., savings found for Xcel Energy)
U	Indicates utility example from the literature (e.g., savings found for another utility)

Appendix B Methodology Supplement for Estimating SMB DR Load Impacts

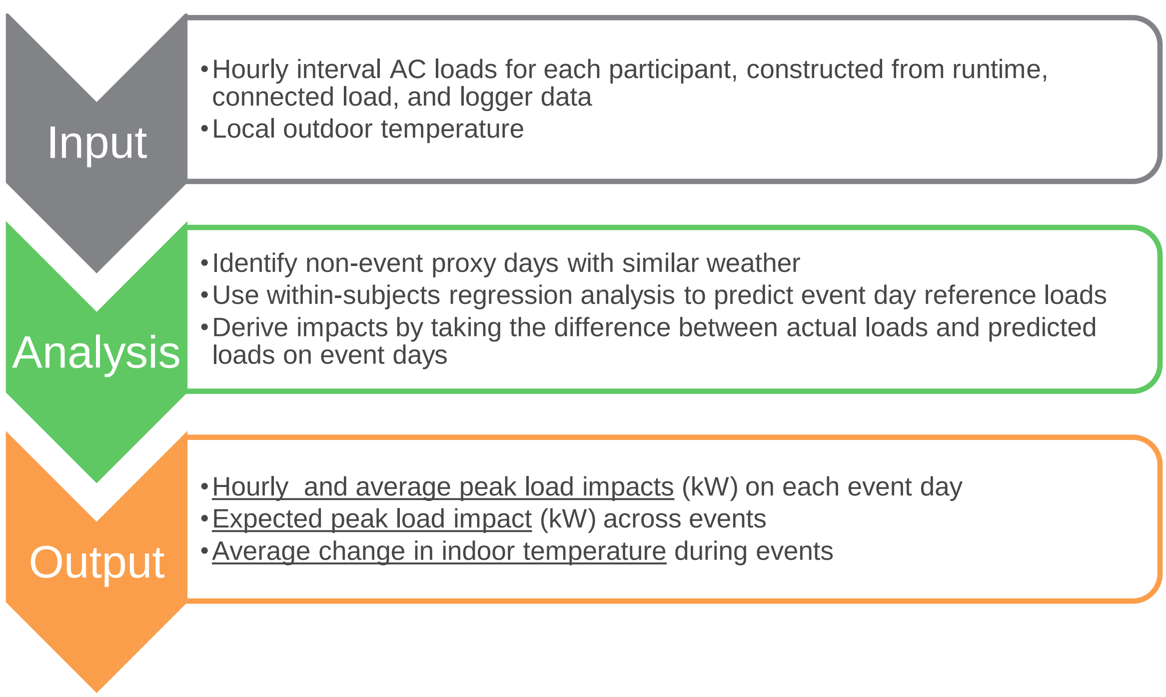
B.1 Estimating SMB Load Impacts Using Regressions

In contrast to the BYOT pilot, there was no pool of non-participants with thermostat or other interval data that could be used to carry out a difference-in-differences approach. Instead, SMB demand response event impacts were estimated. Like the BYOT analysis, the SMB impacts evaluated were also the load impacts on demand response event days.

As described above, a critical component in evaluation design is determination of the counterfactual—what would have happened in the absence of the pilot. In the case of a demand response event, the counterfactual, or reference load, is what loads would have been had the event not been called. Fortunately, to the extent that there were warm non-event days during the same event season, loads on these event proxy days can be used to estimate reference loads.

The data inputs, analysis, and outputs for Nexant's approach are summarized in Figure B - 1. Nexant conducted a within-subjects regression analysis on each participant's load patterns on proxy days to predict reference loads, what loads would have been for that participant on event days. Impacts were estimated by simply subtracting observed loads from estimated reference loads. The key input to these regressions was post-treatment AC interval loads constructed from thermostat runtime data and data collected in the field, including data logger and spot measurement approaches.

Figure B - 1: Estimation Approach for DR Event Impacts



The SMB DR impact analysis consisted of using data from warm non-event weekdays between August and October to estimate reference loads for each participant on individual event days. A straightforward regression model was used to obtain accurate and precise estimates for these individual participant reference loads as a function of conditions on event-like days that influence usage—e.g., weather conditions, month, day of week, hour of day.

The regression equation for these individual customer level regressions took the form of Equation B - 1, which was estimated using an analysis dataset made up of hourly interval AC loads constructed for each customer and local weather from the nearest weather station. This equation represents a within-subjects approach in which participant loads on non-event days are used to predict the reference load for participants on event days. The dependent variable in the regression model will be the kW load in each interval for each participant. The regression contains the x variables in Table B - 1—including weather variables, time variables (designed to track variation in load across days of the week and time of day), and interaction terms. In order to enable estimation of impacts for individual intervals, binary variables specific to each event day and interval (j, t) are included rather than a variable specific only to the event day (j).[121]

Equation B - 1: Calculation of Event Reference Loads

$$kW_t = \sum_{n=1}^{N} \beta_{n,t} x_{n,t} + \sum_{j=1}^{J} \delta_j \text{event}_{j,t} + \varepsilon_t$$

[121] To improve precision, same-day loads for the hour before each event can be included as *x* variables to capture any differences between event and non-event days that are not reflected in the model.

Table B - 1: Variables Used for Calculation of Event Reference Loads

Variable	Description
kW	Participant AC load
β	Parameter estimates for variables related to AC usage (e.g., temperature[122], hourly dummies, day of week, month)
x	Variables related to AC usage (e.g., temperature[123], hourly dummies, day of week, month)
$event$	binary variables that equal 1 for the event intervals associated with event j and zero otherwise
σ	Parameters of interest that estimate the average hourly impact for each event
n	Indexes variables related to AC usage
t	Indexes intervals
j	Indexes events
J	Total number of events
ε	Error term

Event day loads were estimated using loads on the closest 10 to 15 proxy days by device between August 16 and October 31 (few devices have data before the very last days of Aug). Only participants with data for at least 10 of the proxy days were included.

122 The temperature variable used was the average hourly temperature through hour 17, a measure of heat accumulation which Nexant has found in many evaluations to be strongly predictive of AC use especially on warmer days

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Appendix C Data Sources

Table C - 1 summarizes the six primary data sources that will be used to conduct the evaluation of Xcel Energy's smart thermostat pilots, the types of data collected for each, and their direct applicability to each analysis. While data from multiple analyses will be combined to enrich insights, this table summary is intended to capture the primary data needed for each analysis.

Section C.1 describes the plan and progress for collecting field data. Section C.2 describes how field data will be combined with thermostat runtime data to construct participant AC load interval data, a critical input to the DR impact analysis and the evaluation of non-event peak reductions (a component of energy savings). Collection of the thermostat data needed for these analyses and several others, including the thermostat usage modeling, has already begun. Finally, Section C.3 discusses sourcing of weather data. Survey data collection approaches were already discussed in Section 8.

Table C - 1: Data Sources and Use in Analyses

Source	Type of data	Energy Savings (kWh)	Energy Savings (kW)	DR impacts	DR Participation	Thermostat usage	Participant surveys
Xcel Energy	Billing data	✓	✓			✓	
	Customer characteristics	✓	✓	✓	✓	✓	
Field data	AC logger data		✓	✓			
	Connected load measurements		✓	✓			
Thermostat manufacturers	AC Runtime		✓	✓			
	Setpoints		✓	✓	✓	✓	
	Thermostat schedules & mode					✓	
DR provider	Event Participation data			✓	✓		
NOAA	Weather	✓	✓	✓	✓	✓	
Participant surveys	Freeridership	✓	✓				
	Satisfaction						✓
	Perceived / stated behavior						✓

C.1 Field Data Collection

DR event load impacts were estimated using an AC load interval data set as a critical input. In the case of residential participants, this data set was constructed by combining smart thermostat runtime data with spot measurements[124] of AC connected loads for 123 residential BYOT participants[125], in turn validated and calibrated by deploying data loggers[126] to a smaller sample of 28 of these participants. However, there were data corruption issues with 10 of these sites and data quality issues with another 4 so reliable logger data was available for 14 devices. This was too few data points to be used directly in the analysis but was sufficient to confirm that there was no systematic bias between logged loads and loads derived by applying spot measurements to runtime intervals.

In the case of the CO SMB pilot, data loggers were deployed to 26 of the 61 participants.[127,128] Loggers were deployed to 54 AC units and reliable logged data samples were collected for 49 of these devices across these 24 of these sites. Similar connected load measurements[129] were taken for 21 devices. Data was logged for varying periods between September when loggers were deployed through early November when they were retrieved. For intervals where logged loads were available it was used for the analysis in lieu of the value derived from spot load measurements and runtime data.

124 Spot measurements taken of amp, volt, power factor, and kW for all 200 residential sites including those where amp loggers were deployed.

125 To recruit residential customers, Nexant sent a letter to the DR pilot participants, offering a $25 incentive to participate in a study related to their smart thermostat. The first 50 customers who called the phone number in the letter were scheduled for a logger installation by Nexant. These appointments were dispatched to the Louisville, CO office, which conducted the logger installations in both Colorado and Minnesota before the beginning of the DR event season. After the first 50 residential customers were scheduled for a logger installation, Nexant signed up the remaining customers for a site visit. The Louisville, CO office then scheduled and conducted the site visits between May and August. The participants received a $25 gift card for each visit, whether it is for a logger installation, spot measurement of connected load, or logger retrieval.

126 Data loggers measure amperage of connected AC units at 1 minute intervals (one logger per AC unit). The logged amperage will be converted to kW using the spot volt and power factor measurements. Engineers were instructed to perform multiple sets of spot measurements when encountering a multi-stage compressor (one set for each mode of operation).

127 Note that many SMB participants have multiple AC units at their site. Each AC unit will have its own data logger and thermostat runtime data streams.

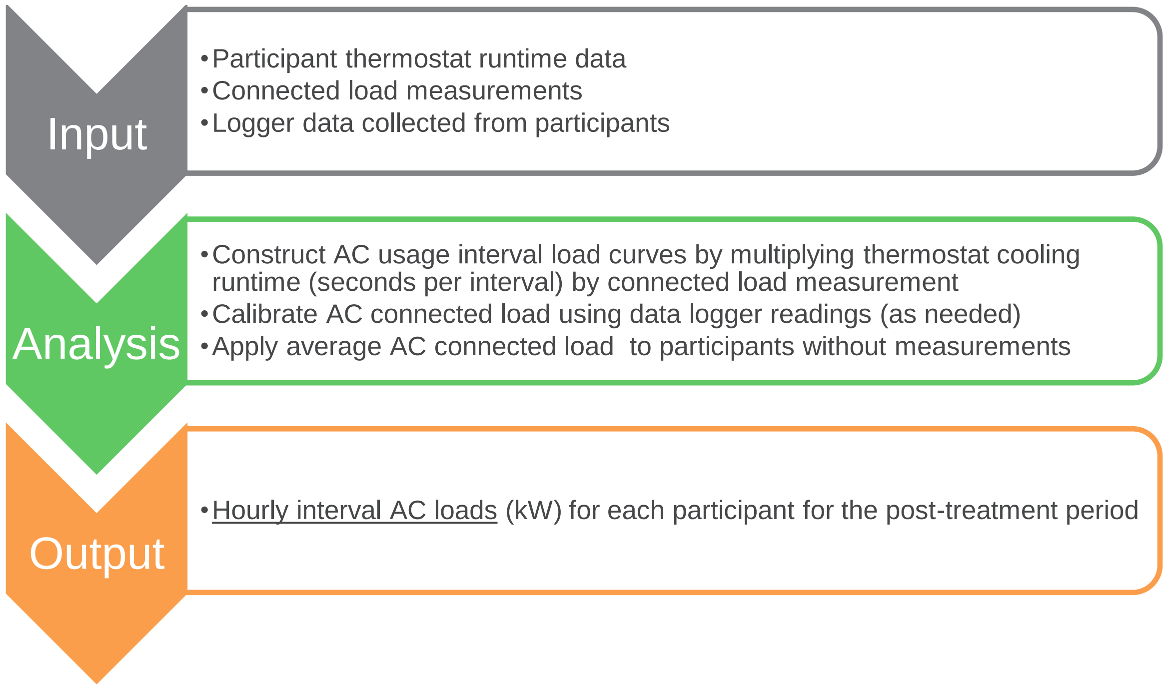
128 Participants were contacted to via phone by Nexant to recruit and schedule the installations

129 Similar connected load measurements will also for all selected SMB sites in addition to deploying kWh meters. In contrast to the measurements for residential participants, measurements for SMB will measure kW directly (so there will be no need to derive kW from other measurements).

C.2 Constructing Post-treatment Interval Load Data

Figure C - 1 summarizes how thermostat runtime data, connected load measurements, and logger data were combined to construct calibrated post-treatment hourly interval load data.

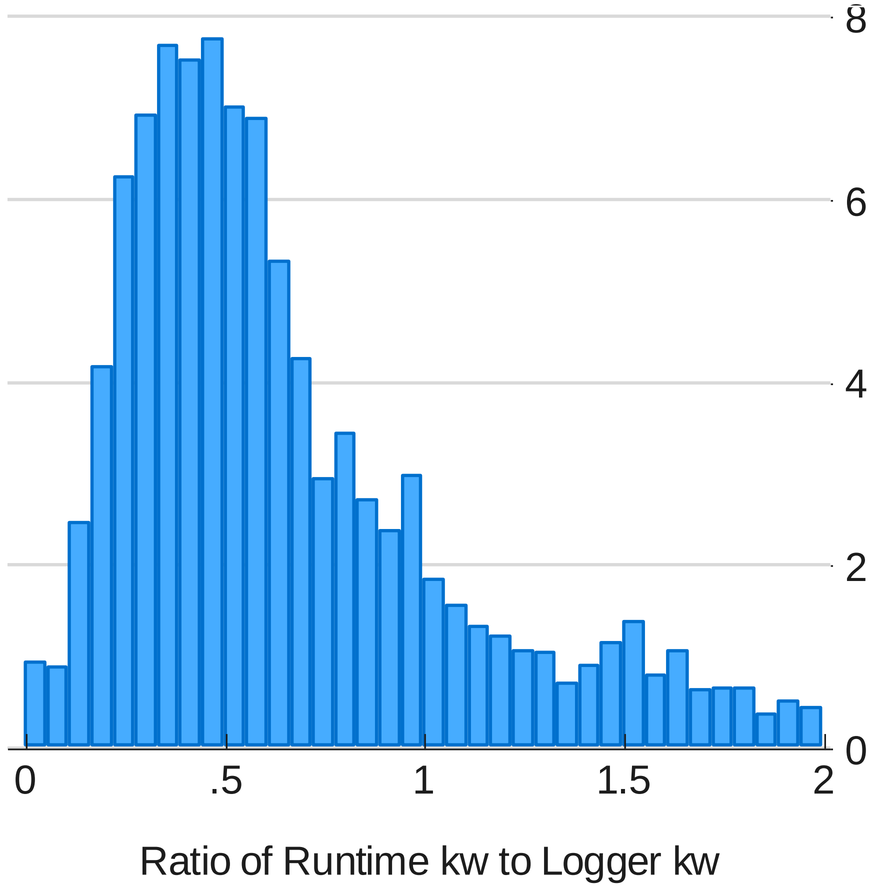
Figure C - 1: Approach for Constructing Post-treatment Interval Load Data



Note that loads were calibrated by taking max average proxy day load for corresponding logger and runtime data and applying to runtime. This adjustment was based on the observed difference between spot load measurements and logger measurements. This was done to help get loads closest to what they should be on proxy and event days during event hours.

Figure C - 2 demonstrates the validity of this adjustment. It shows the distribution of the ratio of runtime loads to logger loads, calculated for individual devices using corresponding 15 minute interval data for each. While one should not expect for data collected using the two methods (logger data and the product of thermostat runtime and spot measurement) to be identical, an adjustment should only be applied to correct a systematic bias. If there were no systematic bias between the two methods, the ratio of the two should be centered around 1, at unity. However, the histogram in Figure C - 2 clearly shows that the ratio is in fact centered around 0.5, meaning that loads derived from runtime data and spot loads is systematically about half the magnitude of logger loads. Figure C - 3 shows the same analysis performed using the spot load and logger data collected for the residential BYOT pilot. Note that same asymmetric pattern was not found, rather the ratio of logger and runtime estimate loads were more or less centered around one.

Figure C - 2: Comparison of AC Load from Logger Data Versus Derived from Runtime and Connected Load Measurements-SMB Devices[130]



130 Excludes a handful of outliers beyond values of 2 for a display purposes, derived by calculating the ratio of logged and derived loads within each interval for devices and intervals for which both were available. Includes 36 Vendor 2 devices.

Figure C - 3: Comparison of AC Load from Logger Data Versus Derived from Runtime and Connected Load Measurements-Residential Devices[131]

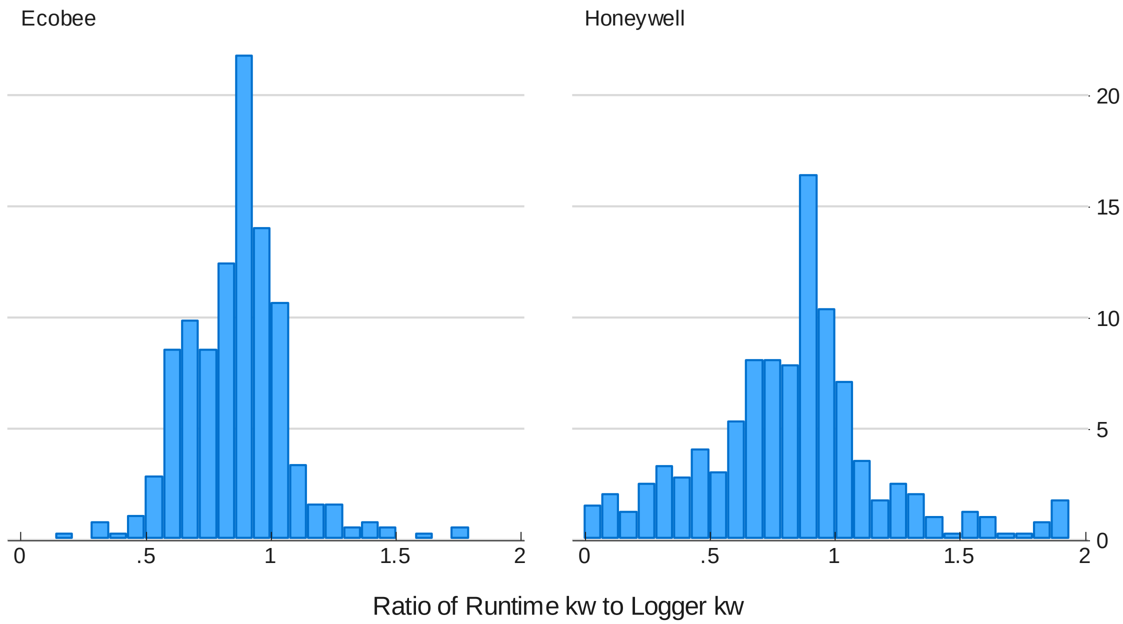
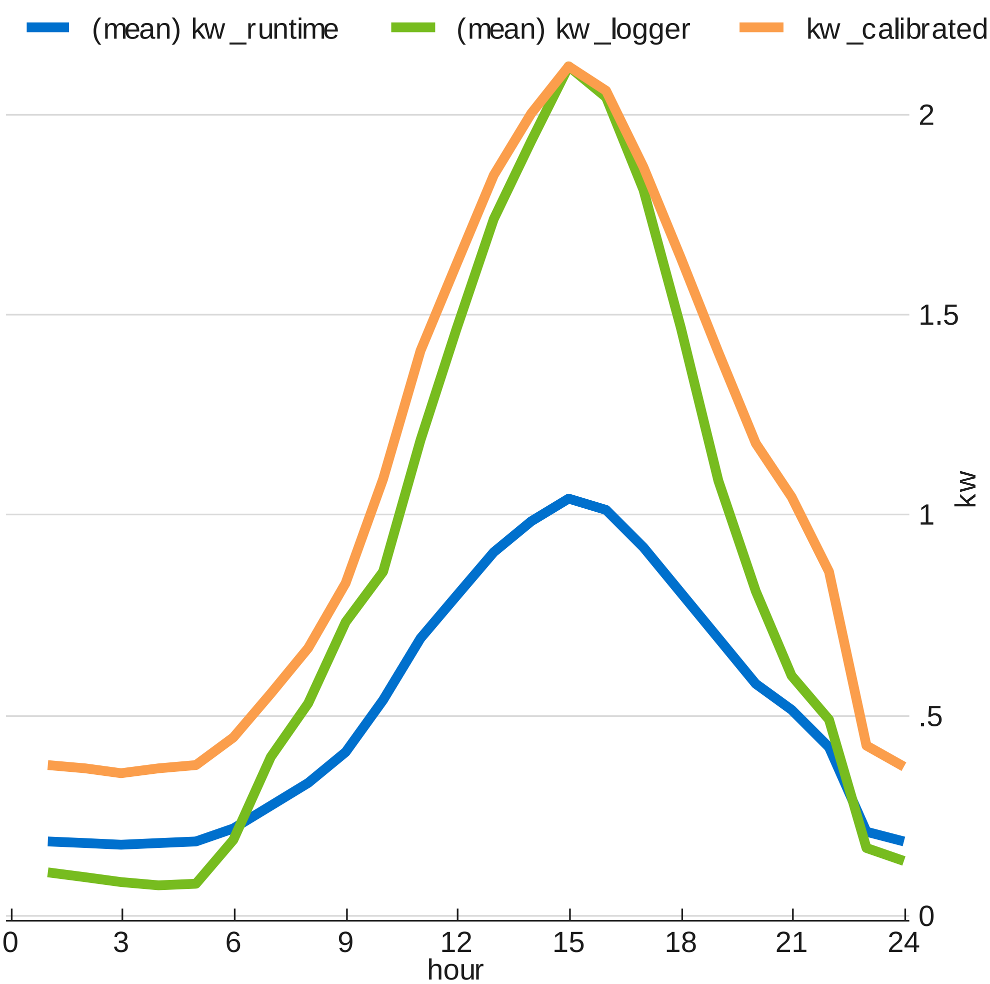


Figure C - 4 shows the approach and results for the calibration. The blue and green lines shows the average load shapes for runtime based loads and logger loads on proxy days for devices with both data streams on the same days and intervals. At the daily peak, the runtime based load is clearly about half of the logger load, consistent with the histogram in Figure C - 3. To calibrate the runtime based load, the ratio of the average daily maximum load using the logger and using the runtime was applied to runtime based loads in all hours, resulting in the calibrated load represented by the orange line.

131 Includes 8 Vendor 2 devices and 6 Vendor 1 devices

Figure C - 4: AC Load Shapes on Proxy Days Before and After Calibration-SMB Devices



C.3 Weather Data

The weather data used was publicly available Local Climatological Data available from NOAA[132], specifically hourly temperature readings at weather stations across Colorado. The data was used for demand response event impact and participation analyses. Thermostat and DR event data sources include estimates of outdoor temperature. For each customer included in the analysis weather from the closest weather station was used. For devices which geographic coordinates were unknown, a participant weighted average derived from mapped participants was applied. Mean event temperatures reflect the average local temperature across participants to best convey local conditions for participants during the event.

132 https://www.ncdc.noaa.gov/cdo-web/datasets#LCD

Appendix D Survey Instruments

D.1 Residential Survey Instrument

Questionnaire

Customer Segment: Residential, all fuel types, CO & MN, smart thermostat participants

Welcome! Thank you very much for agreeing to complete this survey.

You may have completed other surveys for Xcel Energy in the past about your preferences and opinions as an Xcel customer. The questions we have for you today are different.

We'd like to ask you about your participation in the smart thermostat pilot. Your answers are very important because they will help Xcel Energy evaluate the pilot and help improve how we offer energy savings programs to our customers. We sincerely appreciate your time.

This survey will take about 5 minutes.

-The Xcel Energy Team

INTRODUCTION: NPS AND REBATE EXPERIENCE

[TRANSITION SCREEN]

First we have a few questions about Xcel in general and your experience purchasing the smart thermostat.

Q1. **[SINGLE-CHOICE]**
On a scale from 0 to 10, where 0 means Not at all likely and 10 means Extremely likely, how likely are you to recommend Xcel Energy to a friend, relative or colleague for their residential electric service?

0. Not at all likely

1.

2.

3.

4.

5.

6.

7.

8.

9.

10. Extremely likely

Q2. **[OPEN ENDED]**
What is the primary reason for your rating?

Q3. **[SINGLE -CHOICE: EE ONLY AND BOTH]**
You were offered a $50 rebate for purchasing a smart thermostat. **Imagine you had never learned that Xcel was offering a rebate** for the purchase of a smart thermostat.

[NUMBERS IN BRACKETS REPRESENT INTENTION SCORES AND ARE NOT MEANT TO BE PROGRAMMED OR DISPLAYED]

Which of the following best describes what you **would have done**?

I would **not have purchased** a thermostat at all [0]
I would have purchased a **standard thermostat** (e.g. without smart capabilities) [0.125]
I would have purchased a **smart thermostat** without the $50 rebate [0.5]
I would have purchased a **smart thermostat** without the $50 rebate a year or more later [0]
Don't know [0.25]

Q4. **[GRID: SINGLE-CHOICE PER ROW: EE ONLY AND BOTH]**
Please indicate on a scale of 1-5 how important each of the following was in **your decision to purchase a smart thermostat**.

I purchased my smart thermostat because…

[ROW 1] …the $50 rebate lowered the cost of the thermostat.

[ROW 2] …it was easy for me to purchase the thermostat through Xcel.

[ROW 2] …it was easy for me to apply for / receive the $50 rebate through Xcel.

[ROW 3] …the Xcel offer made me think this smart thermostat could help me save energy.

[NUMBERS IN BRACKETS REPRESENT INFLUENCE SCORES AND ARE NOT MEANT TO BE PROGRAMMED OR DISPLAYED]

1 – Not at all important [0.5]
2 – [0.375]
3 – [0.25]
4 – [0.125]
5 – Extremely important [0]
Don't know [0.25]

Q5. **[SINGLE-CHOICE: EE ONLY AND BOTH]**
Please indicate roughly when you received your $50 rebate for purchasing a smart thermostat:

I did not receive the $50 rebate

Immediately upon purchasing my thermostat (instant rebate)

Within a week of purchasing my thermostat

Within one to two weeks of purchasing my thermostat

More than two weeks after purchasing my thermostat

Don't know

Q6. **[SINGLE-CHOICE: EE ONLY AND BOTH]**
On a scale of 1-7, how satisfied are you with your smart thermostat rebate experience?

1 – Very dissatisfied

2

3

4 – Neutral

5

6

7 – Very satisfied

THERMOSTAT EXPERIENCE [TRANSITION SCREEN]

Next we would like to learn about your experience with the smart thermostat [**DR ONLY AND BOTH**: and your experience as a SmartStat Savings participant. Remember that as a SmartStat Savings participant you are rewarded for allowing your thermostat to automatically reduce power use during the hottest days of summer.].

Q5a. **[SINGLE-CHOICE: DR ONLY AND BOTH]**
Please indicate roughly when you received your $25 gift card for enrolling in SmartStat Savings:

I did not receive the $25 gift card

Within a week of enrolling in SmartStat Savings

Within one to two weeks of enrolling in SmartStat Savings

More than two weeks after enrolling in SmartStat Savings

Don't know

Q6a. **[SINGLE-CHOICE: DR ONLY AND BOTH]**
On a scale of 1-7, how satisfied are you with your SmartStat Savings enrollment experience?

1 – Very dissatisfied

2

3

4 – Neutral

5

6

7 – Very satisfied

Q7. **[SINGLE-CHOICE]**

On a scale of 1-7, how would you rate the comfort of your home **after** installing your thermostat?

1 – Much less comfortable

2

3

4 – About the same

5

6

7 – Much more comfortable

Q8.**[GRID: SINGLE-CHOICE PER ROW]**
Please indicate on a scale of 1-7 whether you agree with the following statements about your smart thermostat.

[ROW 1] My thermostat was easy to use

[ROW 2] My thermostat helped me save energy

[ROW 3] I would recommend my thermostat to a friend or colleague

1 – Strongly disagree

2 – Disagree

3 – Disagree somewhat

4 – Undecided

5 – Agree somewhat

6 – Agree

7 – Strongly agree

Q9.**[GRID: SINGLE-CHOICE PER ROW]**

Please indicate on a **how often** you did the following:

[ROW 1] Used the app, website, or thermostat to **program** the thermostat

[ROW 2] Used the app or website to **view my home's energy use**

[ROW 3] Used the app or website to **adjust** the thermostat temperature **while away from home**

[ROW 4] Used the app, website, or thermostat to **adjust** the temperature **from home**

1 – Never

2 – Once or twice

3 – Sometimes (1 to 2 times per month)

4 – Several times per month

5 – Very frequently (more than once per week)

Q10. **[MULTI-CHOICE: SKIP IF ROWS 3 AND 4 IN Q12 BOTH = 1]**
When did you **typically** adjust the thermostat temperature?

Select all that apply.

On weekends

On weekdays

Before 3pm

Between 3pm and 7pm

After 7pm

Q11. **[OPEN ENDED]**
What was your primary reason for adjusting the temperature?

PROGRAM EXPERIENCE

Q12. **[SINGLE-CHOICE QUESTION EE ONLY]**

In addition to offering a smart thermostat rebate, Xcel also offered **additional** incentives for allowing Xcel to use the smart thermostat to reduce your AC use on some hot days. What was your **primary reason** for not choosing this option?

I was not aware of this option
I didn't think the incentives offered were high enough
I didn't want Xcel to control my thermostat
I didn't want to limit my cooling on hot days
Other (please specify _______________)

Q13. **[SINGLE-CHOICE DR ONLY AND BOTH]**
Would you choose to participate in SmartStat Savings next year if it were offered?

Yes

No

Don't know

Q14. **[OPEN ENDED INTEGER, from 1 to 100 DR ONLY AND BOTH]**
How many SmartStat Savings days do you remember experiencing?

____ days

I don't remember how many SmartStat Savings days I experienced

Q15. **[SINGLE-CHOICE DR ONLY AND BOTH]**
On a scale of 1-7, how would you rate the comfort of your home **during** SmartStat Savings hours?

1 – Much less comfortable

2

3

4 – No change

5

6

7 – Much more comfortable

I don't remember experiencing any SmartStat Savings days

Q16. **[SINGLE-CHOICE DR ONLY AND BOTH]**

Did you notice the SmartStat Savings incentives on your bill statement?

Yes

No

Don't know

Q17. **[SINGLE-CHOICE DR ONLY AND BOTH]**
Please indicate on a scale of 1-7 how satisfied you were with the SmartStat Savings incentives you received.

1 – Very dissatisfied

2

3

4 – Neutral

5

6

7 – Very satisfied

DEMOGRAPHICS

Q18. **[SINGLE-CHOICE]**
Please select your gender.

Female

Male

Other

Q19. **[SINGLE-CHOICE]**
Please select your age bracket

18 to 24

25 to 34

35 to 44

45 to 54

55 to 64

65 to 74

75 or over

Q20. **[SINGLE-CHOICE]**
Which of the following categories includes the approximate annual income for your household before taxes?

Less than $30,000

$30,000 but less than $50,000

$50,000 but less than $75,000

$75,000 but less than $100,000

$100,000 but less than $150,000

$150,000 or more

Don’t know / Prefer not to answer

Q21. **[SINGLE-CHOICE]**
Do you own or rent your residence?

Own

Rent

Other

[TRANSITION FOR PAPER SURVEY ONLY]

You’ve reached the end of the survey. Thank you for your participation!

[END OF PAPER SURVEY]

GENERAL SMART DEVICE PURCHASING QUESTIONS FOR ONLINE SURVEY ONLY [TRANSITION SCREEN]

You’re almost done! We have just a few more questions for you about smart devices.

Q22. **[SINGLE-CHOICE QUESTION]**

What aspect of your smart thermostat is most appealing to you?

I like the ability to control equipment in my home remotely

I like that it may be able to save energy in my home

I like that it can monitor or report on energy use in my home

I like that it can alert me to scheduled or unexpected events

Other (please specify ______________)

Q23. **[MULTI-CHOICE QUESTION]**

There are many home products that are similar to smart thermostats that are able to be controlled remotely and allow for the automation of settings. These are called "smart devices."

Which, if any, of the following smart devices do you currently have in your home? Select all that apply.

Lighting

Security and cameras

Appliances (Please specify _________)

Garage doors

Entertainment system (TVs and stereos)

Smart plugs (How many? ____)

Sprinkler/irrigation system

Other (please specify _________)

None, I don't know any of these devices in my home

Q24. **[SINGLE-CHOICE GRID]**
[ASK FOR EACH ITEM NOT SELECTED IN Q23]

How interested are you in obtaining each of the following connected or smart devices for your home?

[ROWS]

[RANDOMIZE]

Lighting

Security and cameras

Appliances (please specify _________)

Garage doors

Entertainment system (TVs and stereos)

Smart plugs (How many? ____)

Sprinkler/irrigation system

[ANCHOR AT BOTTOM]

I am not interested in getting any of these smart devices for my home **[IF SELECTED SKIP TO FINAL SCREEN]**

[COLUMNS]

1. Not at all interested
2.
3.
4.
5.
6.
7.
8.
9.
10. Very interested

Don't know

Q25. **[SINGLE-CHOICE QUESTION]**
Where would you typically go to purchase electronic devices or appliances for your home?

I would go to a physical store to make the purchase

I would make the purchase on the Internet

Other (please specify ____________)

Q26. **[SINGLE-CHOICE QUESTION]**
Xcel Energy is considering expanding their new online store that would make it easier for customers to purchase additional products that Xcel Energy offers rebates on. This store would potentially provide "instant rebates" for some products and obviate the need for rebate applications and paperwork. Would you be willing to purchase products from Xcel Energy's new online store?

Yes

No

Don't know

Q27. **[MULTI-CHOICE QUESTION]**
[ASK IF Q26=No or Don't Know]

Why would you not be interested in purchasing products through Xcel Energy's online store? Please select all that apply.

[RANDOMIZE]

I don't trust my utility to sell me home products

I don't have Internet access

I prefer to see and handle a product in-person before purchasing it

I don't want to wait for the product to be delivered

I don't want to deal with the hassles that may be involved if I need to return the product

Other (please specify _____

FINAL SCREEN

You've reached the end of the survey. Thank you for your participation! **[CLICK ON BUTTON AND REDIRECT TO XCEL ENERGY'S WEBSITE: https://www.xcelenergy.com/]**

D.2 Small Business survey instruments

Questionnaire

Customer Segment: SMB, all fuel types, CO smart thermostat participants

Welcome! Thank you very much for agreeing to complete this survey.

We'd like to ask you about your participation in Xcel Energy Saver's Stat Pilot Program for Businesses. Your answers are very important because they will help Xcel Energy evaluate the pilot and help improve how we offer energy savings programs to our customers. We sincerely appreciate your time.

This survey will take about 5 minutes.

-The Xcel Energy Team

INTRODUCTION: NPS AND REBATE EXPERIENCE

[TRANSITION SCREEN]

First we have a few questions about Xcel in general and your experience with the smart thermostat(s) you received as a Saver's Stat participant.

Q1.**[SINGLE-CHOICE]**
On a scale from 0 to 10, where 0 means Not at all likely and 10 means Extremely likely, how likely are you to recommend Xcel Energy to a friend, relative or colleague for their residential electric service?

0. Not at all likely

1.

2.

3.

4.

5.

6.

7.

8.

9.

10. Extremely likely

Q2. **[OPEN ENDED]**
What is the primary reason for your rating?

Q3. **[SINGLE -CHOICE]**
You received a free smart thermostat and installation from Xcel as part of the Saver's Stat pilot. **Imagine you had never learned that Xcel was offering free smart thermostats and installation**.

Which of the following best describes what you **would have done**?

I would **not have purchased** a thermostat at all
I would have purchased a **standard thermostat** (e.g. without smart capabilities)
I would have purchased a **smart thermostat**
I would have purchased a **smart thermostat** a year or more later
Don't know

Q4. **[SINGLE -CHOICE]**
Please indicate roughly when your smart thermostat was installed:

I did not receive a free thermostat and installation

Within a week of applying for my thermostat

Within one to two weeks of applying for my thermostat

More than two weeks after applying for my thermostat

Don't know

THERMOSTAT EXPERIENCE [TRANSITION SCREEN]

Next we would like to learn about your experience with the smart thermostat and your experience as a Saver's Stat participant. Remember that as a Saver's Stat participant you agreed to allow your thermostat to automatically reduce power use during the hottest days of summer.

Q5. **[SINGLE-CHOICE]**
On a scale of 1-7, how satisfied are you with your smart thermostat installation experience?

1 – Very dissatisfied

2

3

4 – Neutral

5

6

7 – Very satisfied

Q6.[**OPEN ENDED]**

Please provide any details you would like to share about your smart thermostat installation experience.

Q7.**[SINGLE-CHOICE: SMB]**
On a scale of 1-7, how satisfied are you with your experience with Xcel Energy's customer service as a Saver's Stat pilot participant?

1 – Very dissatisfied

2

3

4 – Neutral

5

6

7 – Very satisfied

Q8.[**OPEN ENDED]**
Please provide any details you would like to share about your experience with Xcel Energy's customer service as a Saver's Stat pilot participant.

Q9. **[SINGLE-CHOICE]**
On a scale of 1-7, how would you rate the comfort of your facility or space **after** installing your thermostat(s)?

1 – Much less comfortable

2

3

4 – About the same

5

6

7 – Much more comfortable

Q10. **[GRID: SINGLE-CHOICE PER ROW]**
Please indicate on a scale of 1-7 whether you agree with the following statements about your smart thermostat.

[ROW 1] My thermostat was easy to use

[ROW 2] My thermostat helped me save energy

[ROW 3] My thermostat had all the functionality I needed

[ROW 4] I would recommend my thermostat to a friend or colleague

1 – Strongly disagree

2 – Disagree

3 – Disagree somewhat

4 – Undecided

5 – Agree somewhat

6 – Agree

7 – Strongly agree

Q11. [**OPEN ENDED]**
Please provide any details you would like to share about you smart thermostat.

Q12. **[GRID: SINGLE-CHOICE PER ROW]**
Please indicate on a **how often** you did the following:

[ROW 1] Used the app, website, or thermostat to **program** the thermostat

[ROW 2] Used the app or website to **view my business' energy use**

[ROW 3] Used the app or website to **adjust** the thermostat temperature **remotely**

[ROW 4] Used the app, website, or thermostat to **adjust** the temperature **while at your facility or in your space**

1 – Never

2 – Once or twice

3 – Sometimes (1 to 2 times per month)

4 – Several times per month

5 – Very frequently (more than once per week)

Q13. **[MULTI-CHOICE: SKIP IF ROWS 3 AND 4 IN Q12 BOTH = 1]**
When did you **typically** adjust the thermostat temperature?

Select all that apply.

On weekends

On weekdays

Before 3pm

Between 3pm and 7pm

After 7pm

Q14. **[OPEN ENDED]**

What was your primary reason for adjusting the temperature?

PROGRAM EXPERIENCE

Q15. **[SINGLE-CHOICE]**
Would you choose to participate in Saver's Stat next year if it were offered? This would mean allowing your smart thermostat, which you received at no cost, to automatically reduce power use during the hottest days of summer.

Yes

No

Don't know

Q16. **[OPEN ENDED INTEGER, from 1 to 1000, ASK ONLY IF Q15 NOT "Yes"]**
Imagine you were rewarded with a bill credit incentive for each Saver's Stat event in which you participated next year.

For what incentive amount per event would you choose to participate in Saver's Stat next year?

$____ per event

I would not participate in Saver's Stat events for any incentive amount

Q17. [**OPEN ENDED]**
Please explain why you would or would not participate in Saver's Stat next year.

Q18. **[OPEN ENDED INTEGER, from 1 to 100]**
How many Saver's Stat days do you remember experiencing?

____ days

I don't remember how many Saver's Stat days I experienced

Q19. **[SINGLE-CHOICE]**
On a scale of 1-7, how would you rate the comfort of your business **during** Saver's Stat hours?

1 – Much less comfortable

2

3

4 – No change

5

6

7 – Much more comfortable

I don’t remember experiencing any Saver’s Stat days

FIRMOGRAPHICS

Q20. **[SINGLE-CHOICE]**
Please select your gender.

Female

Male

Other

Q21. **[SINGLE-CHOICE]**
Do you own or rent your facility / space?

Own

Rent

Other

Q22. **[SINGLE-CHOICE]**
Which of the following best describes your business title?

Owner

Facility manager

General Manager

Other (please specify)

Q23. **[SINGLE-CHOICE]**
Which of the following best describes the industry in which your business operates?

General office

Retail

Warehouse

Manufacturing

Education

Entertainment

Other (please specify)

FINAL SCREEN

You've reached the end of the survey. Thank you for your participation! **[CLICK ON BUTTON AND REDIRECT TO XCEL ENERGY'S WEBSITE: https://www.xcelenergy.com/]**