2017 Residential Wi-Fi Thermostat DR Evaluation

Prepared for National Grid

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EXECUTIVE SUMMARY

National Grid's Massachusetts and Rhode Island residential customers can contribute toward reducing the system peak demand by participating in the Residential Wi-Fi Thermostat DR program, ConnectedSolutions. The ConnectedSolutions program was first offered to National Grid customers in 2016 and reached over 1,400 customers and more than 2,000 thermostats enrolled. The program has continued to grow in 2017 with over 4,300 customers and more than 5,900 thermostats enrolled and the addition of Nest thermostats in Rhode Island. The demonstration project tests controllable thermostats as a demand reduction (DR) technology (testing various thermostat models from multiple thermostat vendors) and customer acceptance of the DR program offerings (testing two program platforms that offer different incentive structures).

Navigant Consulting, Inc.'s (Navigant's) evaluation of the 2017 DR season found the program was successful both in testing the effectiveness of thermostats as a residential DR technology and in customer acceptance of the program offering. This study confirmed the technical feasibility of using thermostats to reduce household peak demands; however, it has not looked at whether that control will be cost-effective for the electric system, program administrators, and/or customers. Furthermore, there was only one event in the 2016 and 2017 summer seasons when the average outdoor temperature exceeded 90°F.[1] As a result, National Grid has not yet had the opportunity to test program performance under more extreme weather conditions. Nevertheless, National Grid is positioned to leverage the experience of the 2016 and 2017 program years to further test the technology and program offering in 2018 to inform future program design.

Program Summary

The ConnectedSolutions program aims to reduce peak demand of residential customers with Wi-Fi thermostats. The program includes three Wi-Fi thermostat manufacturers: ecobee, Honeywell, and Nest. National Grid can call events between June 1 and September 30 on a non-holiday weekday between 10 a.m. and 8 p.m.; National Grid has standardized the event start time to 2 p.m. with event durations of 3 hours. During events setpoints are increased 3°F for all thermostat types unless the customers choose to opt out of the event or adjust their thermostat setpoint. Aside from these commonalities across the thermostat types, there remain two key program differences:

- Honeywell and Nest have pre-cooling (-2°F), whereas ecobee does not
- ecobee and Honeywell have a participation requirement to receive an annual incentive, whereas Nest does not

Evaluation Objectives and Methods

Navigant completed an impact and process evaluation of National Grid's residential Wi-Fi thermostat DR program in 2016. The 2017 evaluation builds upon the 2016 evaluation by further focusing the evaluation objectives and refining the evaluation approaches.

[1] In 2016, there was one Nest event above 90°F, and no ecobee and Honeywell events. In 2017, there were no events above 90°F for any thermostat type.

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Navigant, in collaboration with National Grid and the Massachusetts Energy Efficiency Advisory Council Consultants, identified several key research questions aimed at assessing the effectiveness of the DR offering, as well as the success of program improvements since 2016; these questions have been placed into four categories:

- Technology and Program Offering
- Program Design and Implementation
- DR Impacts
- Scalability

Navigant's evaluation approach relied on several methods:

1. Post-season survey to gain feedback from 2017 Massachusetts program participants
2. Thermostat usage assessment that combines and analyzes thermostat telemetry data and event participation data
3. Regression analysis to estimate demand and energy impacts

The research questions identified in Table 1 in each category are addressed for the Massachusetts and Rhode Island evaluations, except those answered by a post-season survey of Massachusetts participants.

Table 1. Evaluation Objectives

Research Category	Research Questions	Evaluation Approach
Technology and Program Offering	• How does connectivity of Wi-Fi thermostats vary among models and through the season? • Have actions to improve connectivity been successful?	Thermostat usage assessment
Program Design and Implementation	• Are certain types of residential customers more likely to enroll? *[Massachusetts only]* • What are the opt-out rates during DR events and throughout the DR season? • What is the relationship between opt-out rates and other factors, such as weather or event attributes? • Have opt-out rates increased or decreased compared to 2016? • What are the reasons that led a customer to opt out of an event? *[Massachusetts only]* • How do the different program designs impact participation, customer satisfaction, and savings?	Post-season survey *[Massachusetts only]* Thermostat usage assessment Regression analysis
DR Impacts	• What are the demand impacts before, during, and after the DR event for each DR offering? • Do energy and demand impacts vary if pre-cooling is offered? • What are coincident peak demand savings? • What are the energy impacts from calling a DR event?	Regression analysis

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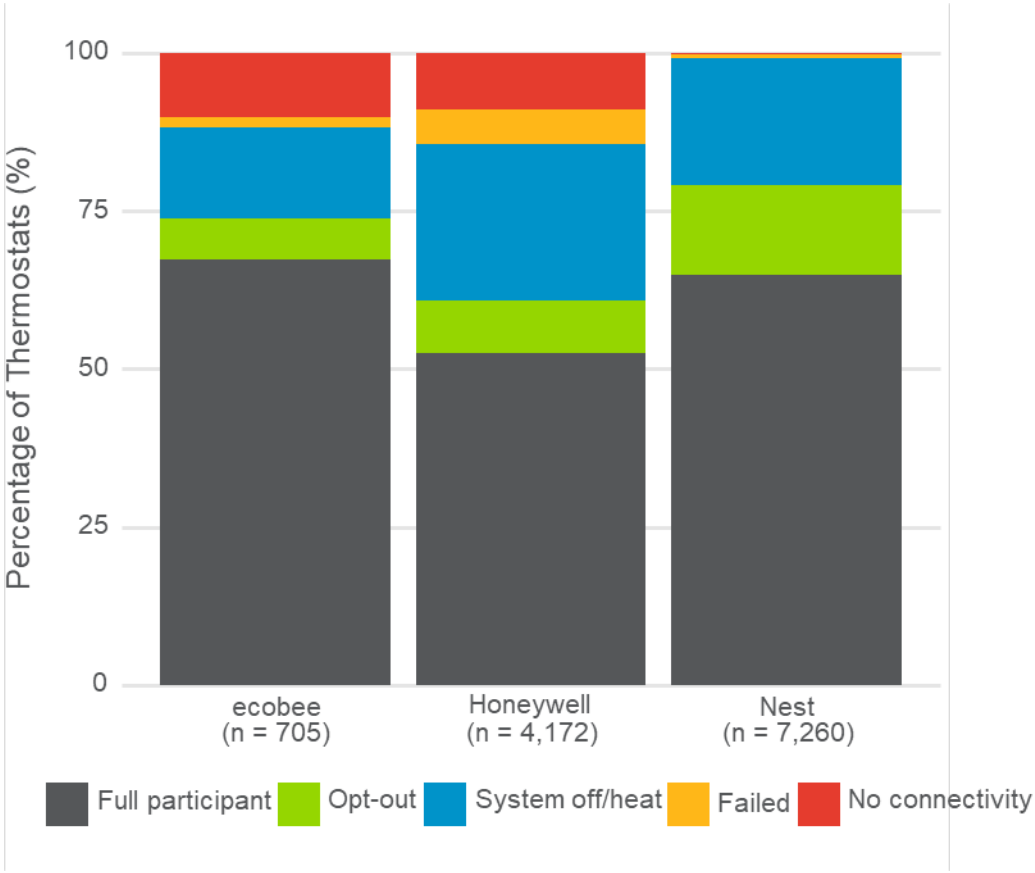
Research Category	Research Questions	Evaluation Approach
Scalability	• After signing up in 2016, have customers returned for 2017? • Have changes to the 2017 program improved customer acceptance/satisfaction at different project stages (e.g., enrollment, event notification)? *[Massachusetts only]*	Post-season survey

Overview of 2017 Program Performance in Massachusetts

Participation Status

Figure 1 displays the average participation for each thermostat type, showing considerable variation by device type. Honeywell devices only averaged 52% full participation in events, while Nest and ecobee averaged 66%. Connectivity issues were most prevalent for ecobee and Honeywell, while opt-out rates were highest for Nest. Due to cooler weather in the days before several DR events, a large percentage of devices (21% on average) were in either off or heat mode at the start of the DR event. While these devices are not contributing to peak demand, these savings are not attributed to the DR program.

Figure 1. Average Participation by Device Type: Massachusetts



Note that *n* represents the total instances of thermostat participation during the DR season for each thermostat type.

Source: Navigant analysis

Event Average Demand Savings

Table 2 displays the average impacts (average treatment effect [ATE]) and the full participation impacts (treatment effect on the treated [TOT]) for each thermostat type. Average impacts ranged from 0.41 kW to 0.53 kW (or 61% to 67% of cooling load). Per device kW impacts are partially a function of the baseline device consumption. Thermostat types with a higher baseline tend to have higher kW impacts.

Table 2. ATE and TOT Summary: Massachusetts

		ecobee	Honeywell	Nest
Enrolled thermostats on September 30		203	1,081	3,435
Average ATE	Savings per thermostat (kW)	0.48	0.53	0.41
	Percent savings	67%	65%	61%
	Baseline per thermostat (kW)	0.72	0.81	0.68
Average TOT	Savings per thermostat (kW)	0.57	0.65	0.58
	Percent savings	75%	70%	81%
	Baseline per thermostat (kW)	0.76	0.93	0.71

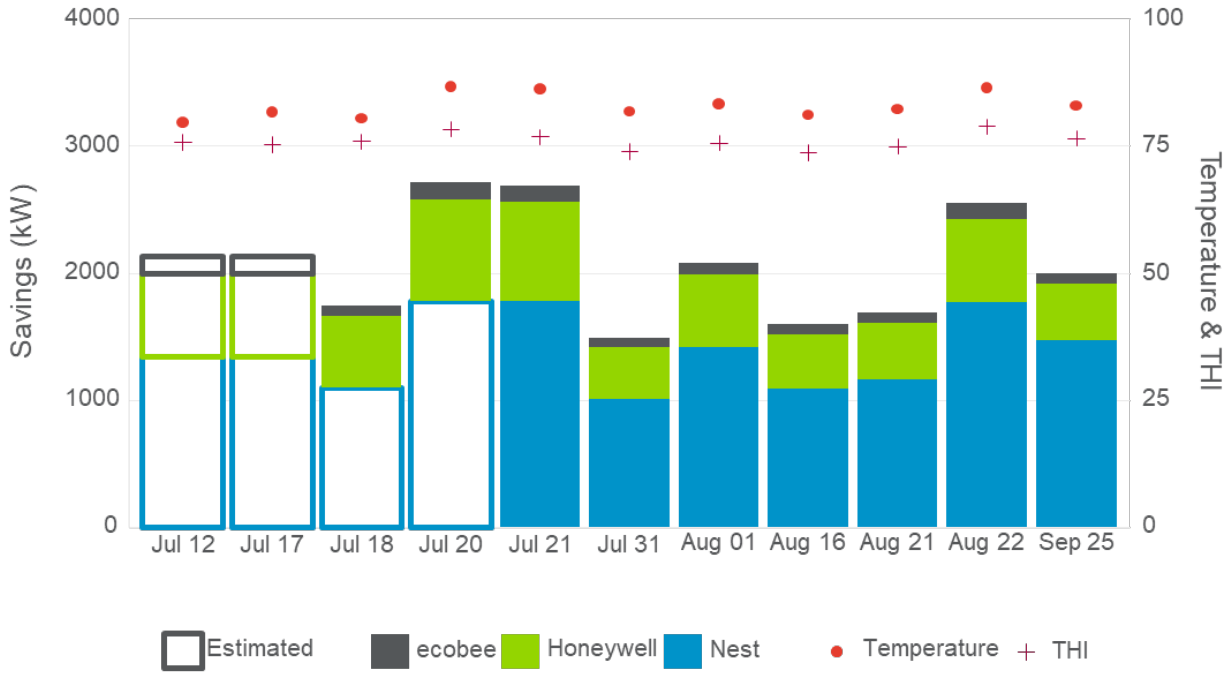
Note: See Appendix A.1 for a list of events included in the summer average. ATE includes thermostats in the full participant, opt-out, and system off/heat categories. TOT includes only full participants.
Source: Navigant analysis

Total Program Demand Savings

Figure 2 presents the total DR for the Residential Wi-Fi Thermostat DR program by event for Massachusetts. The maximum kilowatt (kW) reduction occurred on July 20, 2017, with a total demand savings of 2.7 MW. Higher savings is correlated with higher temperature and the temperature-humidity index (THI). The 2017 Independent System Operator-New England (ISO-NE) system peak was on June 13, 2017. Navigant estimates a demand savings of 2.4 MW could have been achieved had the program called an event that day.[2]

[2] The estimate is calculated as the average demand savings for the most similar event day *x* the number of total enrolled devices at the end of the season.

Figure 2. Total Savings by Event and Thermostat Type: Massachusetts



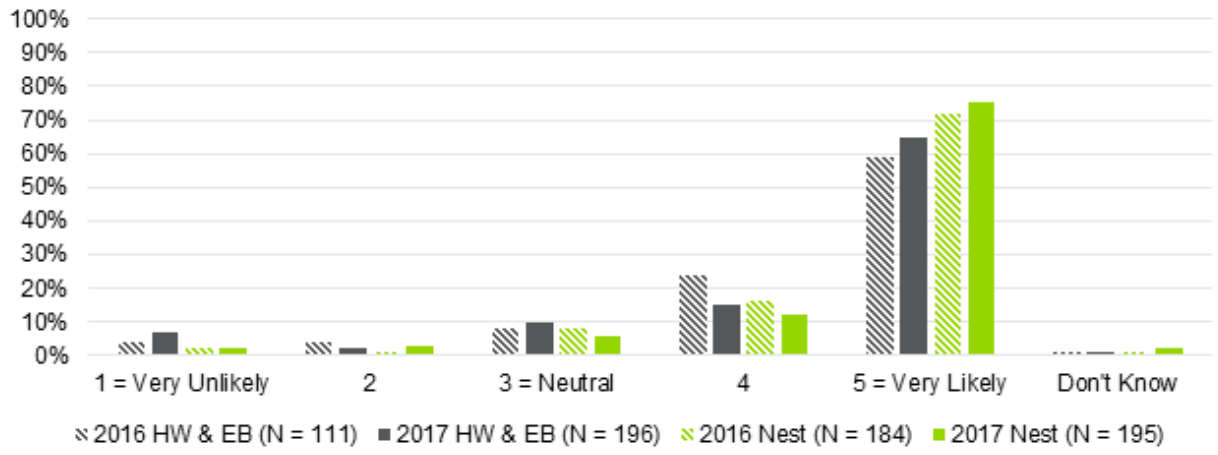
Note: Total savings is the sum of average demand savings by event *x* number of total enrolled devices at the end of the season for each thermostat type. Estimated savings were calculated using similar event day demand savings; paired event days are listed in Appendix B.1.

Source: Navigant analysis

Overall Customer Satisfaction

The majority of survey respondents were satisfied with the 2017 program offerings. Similar to the 2016 post-season survey findings, approximately 85% of all survey respondents reported they are “likely” or “very likely” to participate in the program in future summers.

Figure 3. Based on your experience to date, in future summers, will you continue to participate in the program?



Source: Post-season surveys administered and analyzed by Navigant

Comparison to 2016

Compared to 2016, the number of enrolled thermostats in the ConnectedSolutions program continued to grow and reached 4,719 by September 30, 2017, an increase of 168%. Average demand savings per thermostat increased 22%, likely the result of a combination of factors:

- Setpoint adjustment increased from 2°F to 3°F for ecobee and Honeywell in 2017
- There were no events in 2017 with average outdoor temperatures <80°F, whereas in 2016 12 of 29 ecobee and Honeywell events and 3 of 13 Nest events had average outdoor temperatures <80°F in 2016.
- Customers participated in fewer events due to the change in the DR dispatch protocol and the experimental design
- Events were shorter on average (3.0 hours in 2017 vs. 3.8 hours in 2016)

Meanwhile, customers continue to be highly satisfied with the program and reported the same likelihood that they are “likely” or “highly likely” to continue participating. These key comparisons between 2017 and 2016 performance are provided in Table 3.

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Table 3. Comparing 2017 to 2016 Performance: Massachusetts

	2016	2017	2017 vs. 2016
Enrolled thermostats on September 30	1,761	4,719	168% increase
Average ATE demand savings (kW per thermostat)	0.39	0.44	14% increase
Average TOT demand savings (kW per thermostat)	0.50	0.60	18% increase
Full participant percentage	64%	61%	3% decrease
Opt-out percentage	19%	12%	7% improvement
System off/heat percentage	12%	21%	9% increase
Connectivity percentage	2.4%	3.8%	1.4% increase
Failed percentage	2.7%	2.3%	0.4% decrease

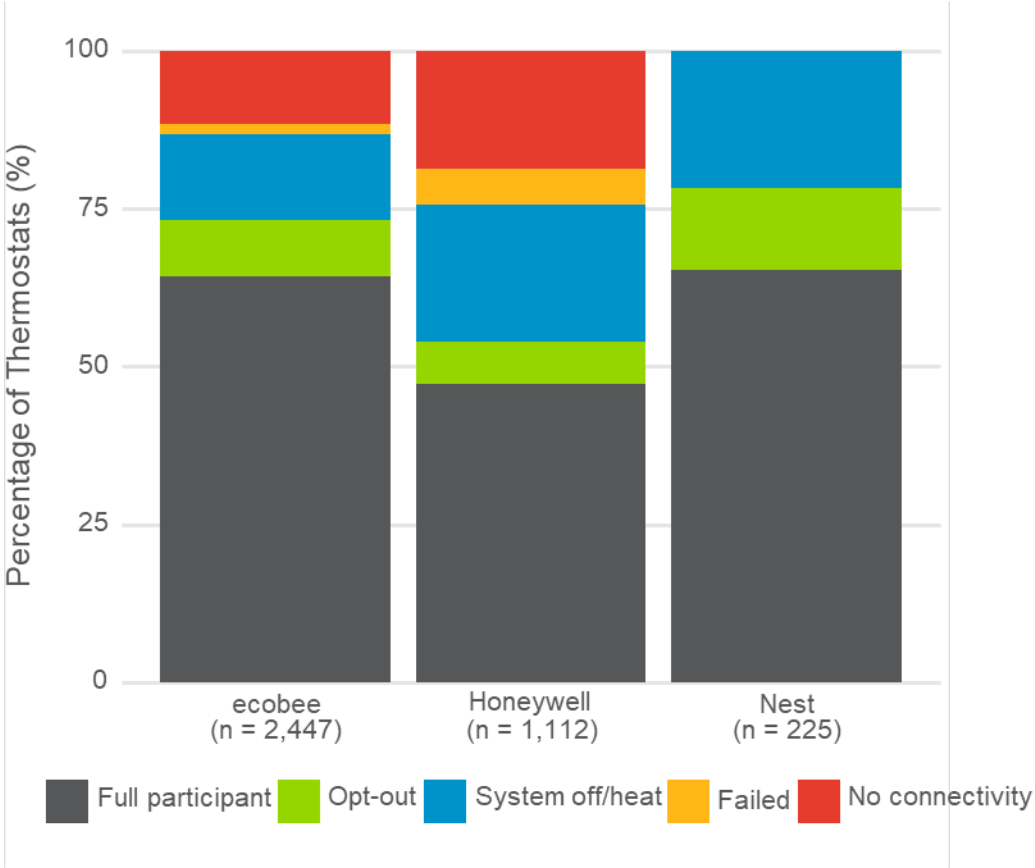
Note: ATE includes thermostats in the full participant, opt-out, and system off/heat categories. TOT includes only full participants.
Source: Navigant analysis

Overview of 2017 Program Performance in Rhode Island

Participation Status

Figure 4 displays the average participation for each thermostat type, showing considerable variation by device type. Honeywell devices only averaged 47% full participation in events, while Nest and ecobee averaged 65%. Due to cooler weather in the days before several DR events, a large percentage of devices (16% on average) were in either off or heat mode at the start of the DR event. While these devices are not contributing to peak demand, these savings are not attributed to the DR program.

Figure 4. Average Participation by Device Type: Rhode Island



Note that *n* represents the total instances of thermostat participation during the DR season for each thermostat type.

Source: Navigant analysis

Event Average Demand Savings

Table 4 displays the average impacts (ATE) and full participation impacts (TOT) for each thermostat type. Average impacts ranged from 0.41 kW to 0.59 kW (or 59% to 61% of cooling load). Per device kW impacts are partially a function of the baseline. Device types with a higher baseline tend to have higher kW impacts.

Table 4. ATE and TOT Summary: Rhode Island

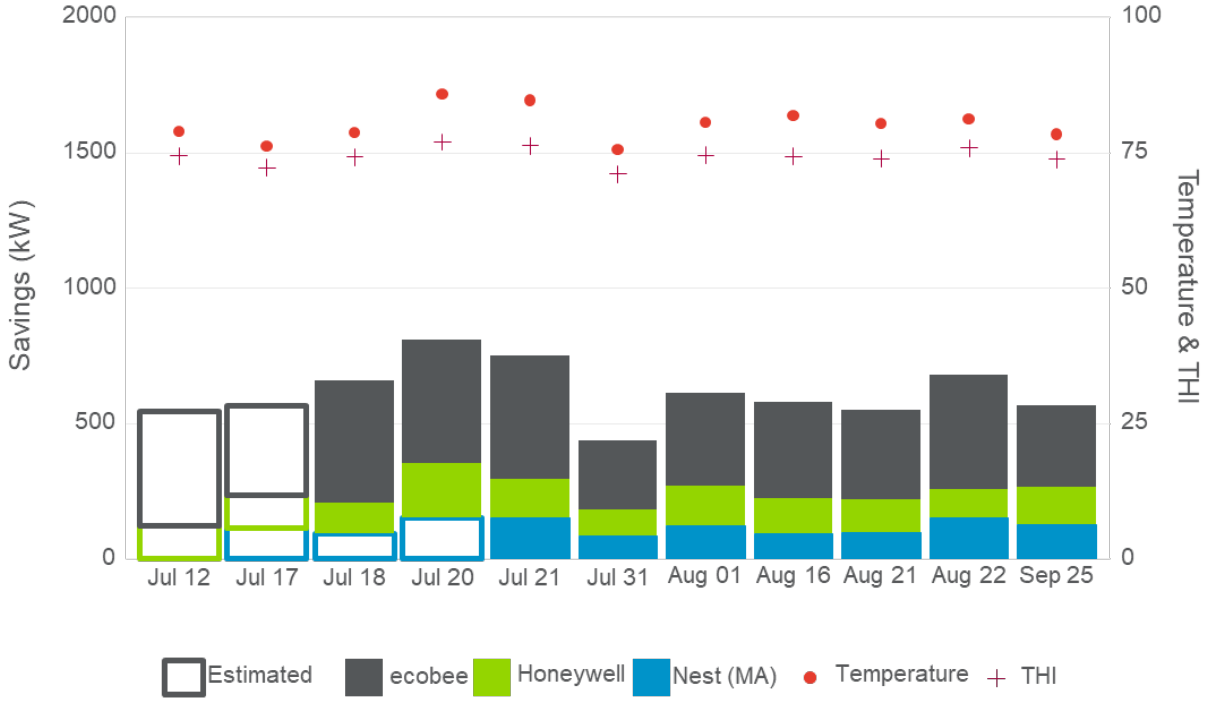
		ecobee	Honeywell	Nest
Enrolled thermostats on September 30		632	275	1,201
Average ATE	Savings per thermostat (kW)	0.59	0.48	0.41*
	Percent savings	61%	59%	61%*
	Baseline per thermostat (kW)	0.97	0.81	0.68*
Average TOT	Savings per thermostat (kW)	0.69	0.59	0.58*
	Percent savings	66%	62%	81%*
	Baseline per thermostat (kW)	1.04	0.95	0.71*

Note: See Appendix A.2 for a list of events included in the summer average. ATE includes thermostats in the full participant, opt-out, and system off/heat categories. TOT includes only full participants.
* Result from Massachusetts
Source: Navigant analysis

Total Program Demand Savings

Figure 5 presents the total DR for the Residential Wi-Fi Thermostat DR program by event for Rhode Island. The maximum kW reduction occurred on July 20, 2017, with a total DR of 809 kW. Higher savings is correlated with higher temperature and the THI. The 2017 ISO-NE system peak was on June 13, 2017. Navigant estimates a DR of 534 kW could have been achieved had the program called an event that day.[3]

Figure 5. Total Savings by Event and Thermostat Type: Rhode Island



[3] The estimate is calculated as the average demand savings for the most similar event day *x* the number of total enrolled devices at the end of the season.

Note: Total savings is the sum of average demand savings by event *x* number of total enrolled devices at the end of the season for each thermostat type. Estimated savings was calculated using similar event day demand savings; paired event days are listed in Appendix B.2.

Source: Navigant analysis

Comparison to 2016

Compared to 2016, the number of enrolled thermostats in the ConnectedSolutions program continued to grow and reached 1,201 by September 30, 2017, an increase of 298%. In addition, the number of thermostat models participating in the RI ConnectedSolutions program grew with the addition of Nest thermostats in 2017. Average demand savings per thermostat increased 37%, likely the result of a combination of factors:

- Setpoint adjustment increased from 2°F to 3°F for ecobee and Honeywell in 2017
- Events were shorter on average (3.0 hours in 2017 vs. 3.7 hours in 2016)

Meanwhile, customers continue to be highly satisfied with the program and reported the same likelihood that they are "likely" or "highly likely" to continue participating. These key comparisons between 2017 and 2016 performance are provided in Table 5.

Table 5. Comparing 2017 to 2016 Performance: Rhode Island

	2016	2017	2017 vs. 2016
Enrolled thermostats on September 30	302	1,201	298% increase
Average ATE demand savings (kW per thermostat)	0.33	0.52	60% increase
Average TOT demand savings (kW per thermostat)	0.37	0.64	72% increase
Full participant percentage	72%	59%	13% decrease
Opt-out percentage	8.4%	7.9%	0.5% decrease
System off/heat percentage	14%	16%	2% increase
Connectivity percentage	4.1%	13%	8.9% increase
Failed percentage	1.6%	2.7%	1.1% increase

Note: ATE includes thermostats in the full participant, opt-out, and system off/heat categories. TOT includes only full participants.
Source: Navigant analysis

Conclusions

Navigant's evaluation of the Massachusetts and Rhode Island ConnectedSolutions program found it was successful in testing the effectiveness of thermostats as a residential DR technology and customer acceptance of the program offering. The evaluation shows promise for thermostats as a residential DR technology, though important differences exist across different thermostat models and customer acceptance has not been adequately tested due to the relatively mild temperatures on event days.[4]

The evaluation of the ConnectedSolutions program in Massachusetts and Rhode Island resulted in several cross-cutting key findings, considerations, and recommendations (described in Table 6, Table 7 and Table 8) that should inform future program planning.

[4] Although called on some of the warmest days during the summer of 2017, average event temperatures did not exceed 87°F in Massachusetts or 86°F in Rhode Island during 2017.

Table 6. Key Findings

Category	Key Findings
Technology and Program Offering	• About 60%-65% of enrolled thermostats fully participated in each event. • Customers opting out, connectivity issues, failing to receive a DR signal, or a thermostat not in "cool" mode are all factors why 100% full participation was not achieved. • More than 75% of connectivity issues were associated with a relatively small number of thermostats (ecobee and Honeywell).
Program Design and Implementation	• About half of survey respondents follow a thermostat temperature schedule and half only turn their air conditioning on when needed. *[Massachusetts only]* • 20% of Honeywell and ecobee and 40% of Nest survey respondents put their thermostats in off or heating mode when no one is at home. *[Massachusetts only]* • Opt-out rates were greater for Nest thermostats than ecobee and Honeywell. • Approximately 25% of opt outs were associated with a relatively small number of thermostats that frequently opt out (serial opt outers – Nest). • Majority of Honeywell and ecobee survey respondents indicated they were influenced not to opt out by the participation incentive. *[Massachusetts only]* • ISO-NE system peak occurred on June 13 between4 p.m. and 5 p.m., before the DR program was operational.
DR Impacts	• Demand savings in 2017 are greater than in 2016, although a high percentage of customers with thermostats in off/heat mode reduced savings for all thermostat types. • There are energy savings when DR events are called, including when impacts from the pre-cool and recovery period are included. • The average demand savings per thermostat is a function of the baseline – thermostats types with a higher baseline tend to have higher demand savings.[5] • Pre-cooling enables less degradation of demand savings during the event and lower demand during the recovery period.
Scalability	• The overwhelming majority of 2016 participants continued to participate in the program in 2017. • From 2016, total device enrollment increased by 168% in Massachusetts and 298% in Rhode Island. • Customer satisfaction remained strong and 85% of post-survey respondents indicated they plan to continue with the program next year. *[Massachusetts only]* • Continue to send advance notification while providing flexibility to customers to tailor event notifications (e.g., text messages or to more than one email address). • Collaborate with thermostat vendors on marketing campaigns for ConnectedSolutions and seek to strengthen the role of ecobee and Honeywell in program marketing.

[5] Differences in the baseline between Massachusetts and Rhode Island drive the difference in the reported kW demand savings.

Table 7. Considerations

Considerations
• Consideration #1: The 2016 and 2017 summer seasons had relatively few hot event days; there was one event day for Nest thermostats above 90°F in 2016 and no event days for any thermostat type above 90°F in 2017. As a result, National Grid has not yet had the opportunity to test program performance under more extreme weather conditions and should conduct another evaluation of the DR program in 2018.

Table 8. Recommendations

Recommendations
• Recommendation #1: For 2017, National Grid should claim an average demand savings of 0.44 kW per thermostat in Massachusetts and 0.52 kW per thermostat in Rhode Island o Massachusetts: 0.48 kW per ecobee, 0.53 kW per Honeywell, and 0.41 kW per Nest[6] o Rhode Island: 0.59 kW per ecobee, 0.48 kW per Honeywell, and 0.41 kW per Nest[7]
• Recommendation #2: Remove thermostats that persistently opt out (i.e., consider implementing auto-unenroll functionality) or modify the Nest participation incentive structure to include a participation requirement
• Recommendation #3: Proactively monitor connectivity issues; remove thermostats with persistent connectivity issues; consider implementing an auto-unenroll functionality.

[6] Massachusetts: Average percent demand savings during events were 67% for ecobee, 65% for Honeywell, and 61% for Nest.

[7] Rhode Island: Average percent demand savings during events were 61% for ecobee, 59% for Honeywell, and 61% for Nest.

1. INTRODUCTION

National Grid offers a diverse yet complementary set of demonstration projects targeted to reduce peak demand and inform the design of future demand reduction (DR) programs in Massachusetts and Rhode Island. The Residential Wi-Fi Thermostat DR program, ConnectedSolutions, was first offered in Massachusetts and Rhode Island in 2016 and reached over 1,400 customers and enrolled more than 2,000 thermostats. By the end of the 2017 DR season, 4,368 customers and 5,920 thermostats were enrolled in the program across the two states.

The demonstration project tests thermostats as a DR technology (testing various thermostat models from three thermostat vendors) and customer acceptance of the DR program offerings (testing two program platforms that offer different incentive structures and event durations).

Table 1-1. National Grid ConnectedSolutions DR Demonstration Project

Sector	Technology	2017 Devices
Massachusetts	ecobee Wi-Fi Thermostat	203
	Honeywell Wi-Fi Thermostat	1,081
	Nest Wi-Fi Thermostat	3,435
Rhode Island	ecobee Wi-Fi Thermostat	632
	Honeywell Wi-Fi Thermostat	275
	Nest Wi-Fi Thermostat	294

In this evaluation report, Navigant Consulting, Inc. (Navigant) presents findings from process and impact evaluations of the 2017 program year, providing considerations for the 2018 program year.

- Section 2, Evaluation Objectives and Methods, identifies key research questions and describes the evaluation approach.
- Section 3, Massachusetts Program, presents findings from a process and impact evaluation.
- Section 4, Rhode Island Program, presents findings from an impact evaluation.
- Section 5, Conclusions, presents conclusions and future considerations.

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2. EVALUATION OBJECTIVES AND METHODS

The 2017 evaluation identified several key research questions aimed at assessing the effectiveness of the DR offering, as well as the success of program improvements since 2016; these questions have been placed into four categories:

- Technology and Program Offering
- Program Design and Implementation
- DR Impacts
- Scalability

The research questions, identified in Table 2-1 by category, are generally addressed for both the Massachusetts and Rhode Island evaluations, except those answered by a post-season survey of Massachusetts participants. The evaluation approach relied on several methods:

1. Post-season survey of 2017 Massachusetts program participants
2. Thermostat usage assessment
3. Regression analysis to estimate demand and energy impacts

Each of these are described further below.

Table 2-1. Evaluation Objectives

Research Category	Research Questions	Evaluation Approach
Technology and Program Offering	• How does connectivity of Wi-Fi thermostats vary among models and through the season? • Have actions to improve connectivity been successful?	Thermostat usage assessment
Program Design and Implementation	• Are certain types of residential customers more likely to enroll? *[Massachusetts only]* • What are the opt-out rates during DR events and throughout the DR season? • What is the relationship between opt-out rates and other factors, such as weather or event attributes? • Have opt-out rates increased or decreased compared to 2016? • What are the reasons that led a customer to opt out of an event? *[Massachusetts only]* • How do the different program designs impact participation, customer satisfaction, and savings?	Post-season survey *[Massachusetts only]* Thermostat usage assessment Regression analysis
DR Impacts	• What are the demand impacts before, during, and after the DR event for each DR offering? • Do energy and demand impacts vary if pre-cooling is offered? • What are coincident peak demand savings? • What are the energy impacts from calling a DR event?	Regression analysis

Research Category	Research Questions	Evaluation Approach
Scalability	• After signing up in 2016, have customers returned for 2017? • Have changes to the 2017 program improved customer acceptance/satisfaction at different project stages (e.g., enrollment, event notification)? *[Massachusetts only]*	Post-season survey

Post-season survey. Navigant conducted a post-season survey of 2017 Massachusetts program participants to gather feedback related to customer experience with different program elements. The 2017 post-season survey contained key questions that were also asked during the 2016 post-season survey. This allowed the team to analyze the effect of programmatic changes since the 2016 DR season.[8] Further, to ensure a representative sample, the survey sample was stratified to include both those who had participated in both the 2016 and 2017 DR seasons and those who enrolled in the program after the 2016 DR season. Finally, the survey sample was constructed to allow for comparisons in responses between program platforms (i.e., ecobee/Honeywell versus Nest). Table 2-2 provides a summary of survey completes by analysis group. Appendix G and Appendix H include the survey instruments and responses to the multi-choice questions.

Table 2-2. Post-Season Survey Respondent Counts

Enrollment Period	EB and HW[1]	Nest	Total
Pre-September 30, 2016	60	91	**151**
Post-September 30, 2016	140	108	**248**
All Respondents	**200**	**199**	**399**

Note: Five EB and HW respondents and seven Nest respondents did not complete the entire survey.

[1]ecobee (EB) and Honeywell (HW)

Source: Navigant surveys

In 2017, National Grid employed an experimental design for the DR program in which customers were randomly assigned to group A, B, C, or D. On a given event day, two groups were called for the event while the remaining two groups served as the counterfactual or control group.

Thermostat usage assessment. Using thermostat telemetry data and event participation data, Navigant analyzed thermostat participation status on event days for customers assigned to an experimental group that was called for an event, identifying key trends.[9] To analyze the thermostat telemetry data, Navigant first categorized all enrolled devices by event into one of five participation status categories:

- ***Full participant:*** Thermostat used the DR setpoint or a more efficient setpoint for the full event
- ***Opt out:*** Thermostat actively opted out of an event, either before or during the event

[8] At a 90/10 level of confidence and precision.

[9] Refer to 0 for a summary of the population of thermostats analyzed in the thermostat usage assessment.

- ***System off/heat:*** The HVAC system was in off or heat mode before and/or during the event[10]
- ***Failed:*** Thermostat likely did not participate during the event because the event notification was not received or did not correctly initiate the event
- ***No connectivity:*** Thermostat data indicates there was no connectivity during the DR event

Impact analysis. Navigant used a regression-based modeling approach in which customers assigned to an experimental group called for an event were compared to the control group (or the experimental group that was not called for the event). Because advanced metering infrastructure (AMI) data was unavailable, Navigant relied exclusively on thermostat telemetry data to estimate impacts after converting thermostat runtime to power.[11, 12] Formally, the model specification is:[13]

$$\widehat{kW_{it}} = \alpha_i + \lambda_t + \beta_{1i}T_{it} + \beta_{2it}(Precool_t * T_{it}) + \beta_{3t}(Event_t * T_{it}) + \beta_{4t}(Recovery_t * T_{it}) + \gamma Weather_{it} + \varepsilon_{it}$$

Where,

$\widehat{kW_{it}}$	is estimated power draw by device *i* during period *t*
α_i	is a customer-specific fixed effect for device *i*; this picks up all customer-specific characteristics that do not change through time, like household square footage
λ_t	is a time-specific fixed effect for period *t;* this picks up temporal differences, such as occupancy and daylight hours
T_{it}	is a binary variable taking a value of 1 when device *i* is in the treatment group during period *t*
$Precool_t$	is a binary variable taking a value of 1 when *t* is in the 3 hours preceding an event and 0 otherwise
$Event_t$	is a binary variable taking a value of 1 when *t* is in the hours during an event and 0 otherwise
$Recovery_t$	is a binary variable taking a value of 1 when *t* is in the 3 hours following an event and 0 otherwise
$Weather_{it}$	is a series of weather controls specific to device *i* in period *t*
ε_{it}	is the error term for device *i* during period *t*

[10] Whisker Labs and Nest devices that are in off or heat mode before and throughout the DR event are categorized as system off/heat. Devices in cool mode at the event start that switch to off or heat mode during the event are categorized as full participants, since these customers are using a more efficient setpoint. Whisker Labs devices in off or heat mode before the event, that switch to cool mode are categorized as full participants, since the DR algorithm begins when the system turns on. Nest devices, however, cannot participate at all if they are in off or heat mode at the event start, since the DR algorithm will not initiate when the device switches to cool mode. Therefore, these Nest devices are categorized as system off/heat.

[11] Navigant converted thermostat runtime to power based on an analysis of metering data from Phase 2 of the 2017 Massachusetts Baseline Study (n=92) and assumptions regarding average size (3.0 tons) and efficiency (10.7 Energy Efficiency Ratio) of air conditioners based on a field study (n=52) of DR program participants conducted by Navigant in October 2017. For example, for a 15-minute interval with 100% runtime at 80°F, the estimated power is 2.51 kW.

[12] Refer to 0 for a summary of the population of thermostats included in the impact analysis.

[13] Navigant estimated quarter-hourly and hourly impacts for the pre-cooling, event, and recovery periods. In these models, *Pre-cool*, *Event*, and *Recovery* are a set of binary covariates corresponding to each hour or quarter-hour of the period. Navigant estimated event-specific impacts by interacting an event-specific binary variable with the time-specific fixed effect, treatment variable, and treatment interacted with *Pre-cool, Event,* and *Recovery.*

Navigant modeled both the average treatment effect (ATE), in which impacts are modeled for thermostats in the following categories – full participant, opt-out, and system off/hear. The treatment effect of the treated (TOT), in which impacts are modeled for only thermostats in the full participant category.

Due to the delayed implementation of the experimental design[14], savings on event days prior to the deployment of the experimental design were estimated using the modeled results of the closest matching event day based on average temperature and the temperature-humidity index (THI) during the pre-event and event periods, as well as the percentage of devices in cool mode at the beginning of the event for each thermostat type.[15]

[14] The experimental design was implemented on July 18, 2017 for ecobee and Honeywell and July 21, 2017 for Nest.

[15] Refer to Appendix B for the list of paired event days.

3. MASSACHUSETTS PROGRAM

This section presents the findings from Navigant's process and impact evaluations of the ConnectedSolutions program in 2017 in Massachusetts. The remainder of this section is organized as follows:

- Section 3.1. Program Overview
- Section 3.2. Participant Characteristics
- Section 3.3. Program Event Participation
- Section 3.4. Program Impacts
- Section 3.5. Key Findings

3.1 Program Overview

The ConnectedSolutions program—in partnership with Whisker Labs and in coordination with National Grid's Rhode Island and New York programs—aims to reduce the peak demand of residential and small commercial customers in National Grid Massachusetts's service territory using Wi-Fi thermostats. The program launched in 2016 and expanded in 2017, reaching more than 3,500 customers. The program relies primarily on a bring your own thermostat (BYOT) implementation approach in which customers with one of the three thermostat types (ecobee, Honeywell, and Nest) were eligible to participate. The most notable changes in 2017 were (1) a change in the DR dispatch criteria, resulting in a significant reduction in the number of DR events called; and (2) better alignment in program design across thermostat types.

Table 3-1. ConnectedSolutions Customer Incentives: Massachusetts

	ecobee	Honeywell	Nest
Sign-up and annual incentive	Year 1: $25 + $25 Year 2+: $25	Year 1: $25 + $25 Year 2+: $25	Year 1: $40 Year 2+: $25
Participation requirement	75% of events	75% of events	N/A

Source: National Grid

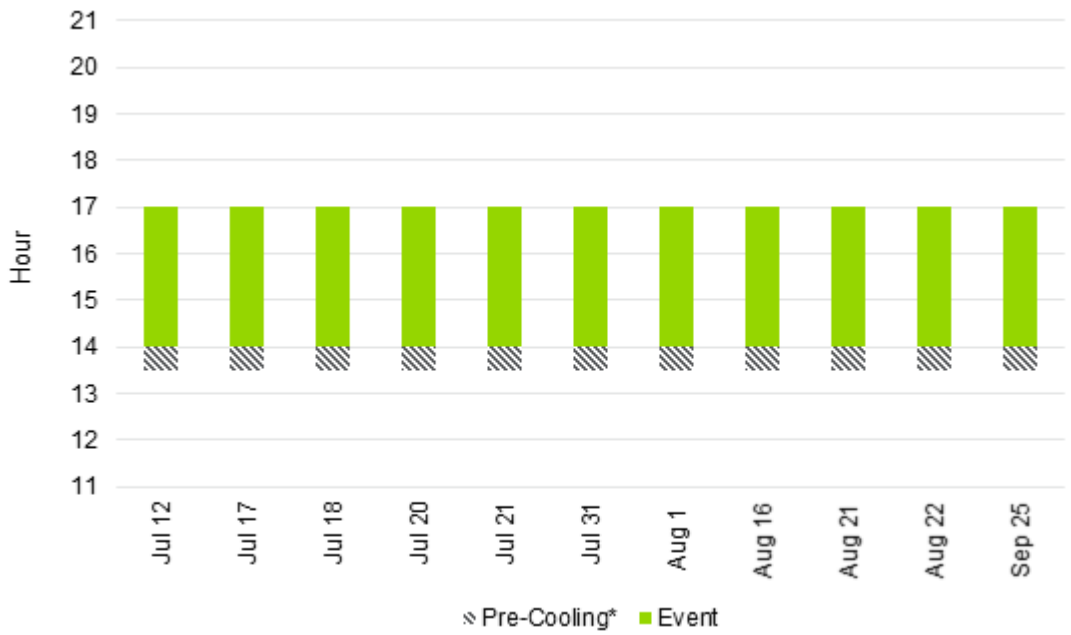
Table 3-2. ConnectedSolutions Event Attributes: Massachusetts

	ecobee	Honeywell	Nest
DR season	Jun 1 to Sept 30	Jun 1 to Sep 30	Jun 1 to Sep 30
Potential event days	Non-Holiday Weekday	Non-Holiday Weekday	Non-Holiday Weekday
Potential event times	10 a.m. to 8 p.m.	10 a.m. to 8 p.m.	10 a.m. to 8 p.m.
Maximum events in season	40	40	15
Maximum events in 1 week	N/A	N/A	3
Maximum events in 1 day	1	1	1
Event duration	3 hours	3 hours	3-4 hours
Pre-cooling setpoint adjustment	N/A	1°F-2°F	Optimized
DR event setpoint adjustment	3°F	3°F	3°F

Source: National Grid

Figure 3-1 and Figure 3-2 show the timing and duration of each of the 11 events. For ecobee and Honeywell, all events began at 2 p.m. and ended at 5 p.m. For Nest, all events began at 2 p.m. but the first five events lasted 4 hours rather than 3 hours.

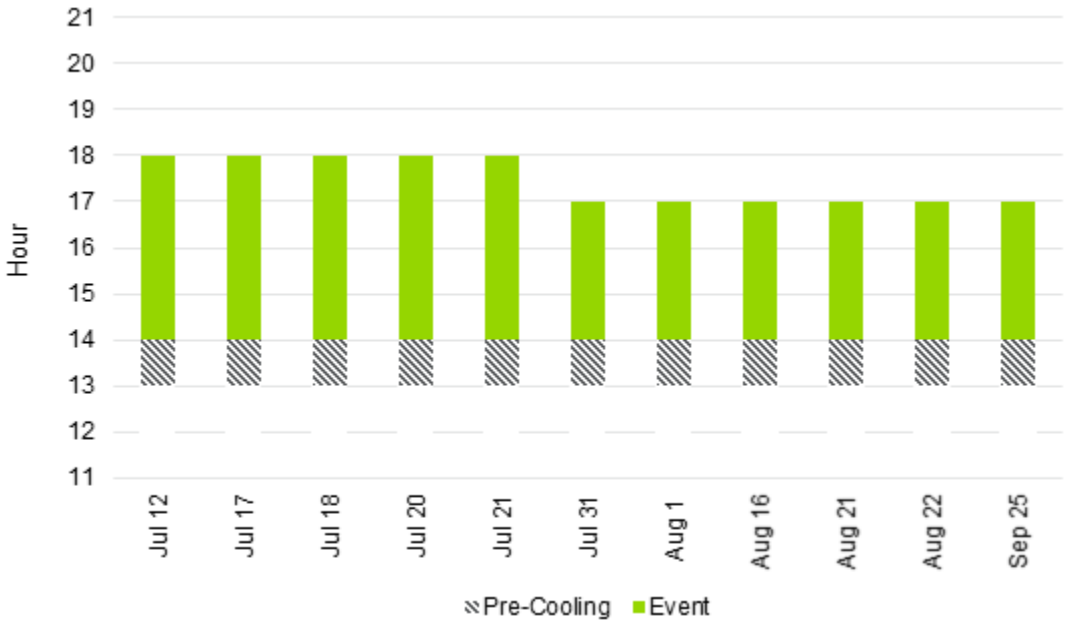
Figure 3-1. Timing of ConnectedSolutions Events in Massachusetts – ecobee and Honeywell



*ecobee thermostats do not have pre-cooling.

Source: Navigant analysis.

Figure 3-2. Timing of ConnectedSolutions Events in Massachusetts – Nest

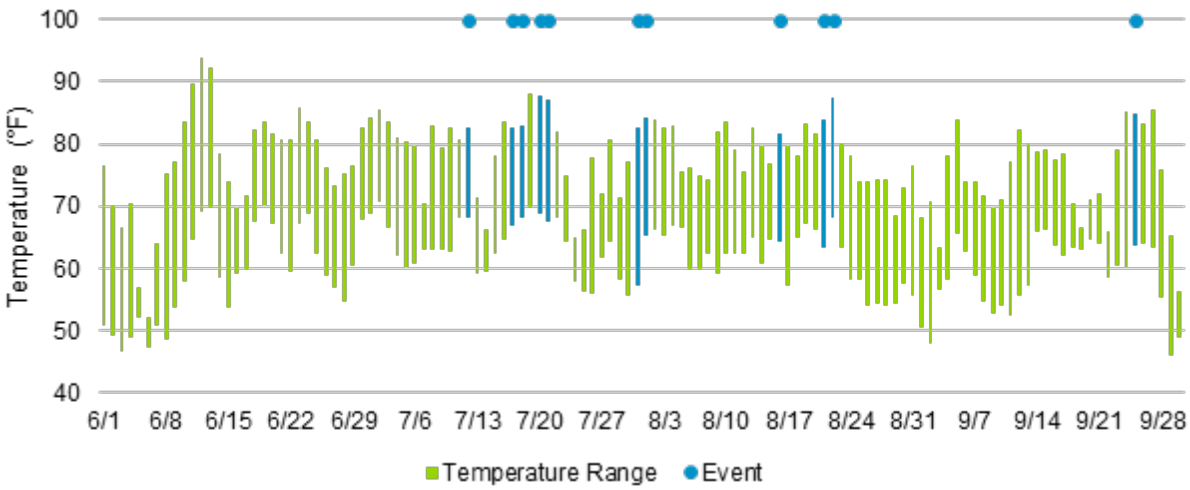


Pre-cooling for Nest thermostats is optimized based on the thermal characteristics of the home.

Source: Navigant analysis.

DR events were called on days when the average high temperature exceeded 80°F, but after mid-June, the average high temperature never exceeded 87°F (Figure 3-3).

Figure 3-3. Average Daily Temperature Range: Massachusetts



Bars represent the daily average high and low outdoor temperature for all devices.

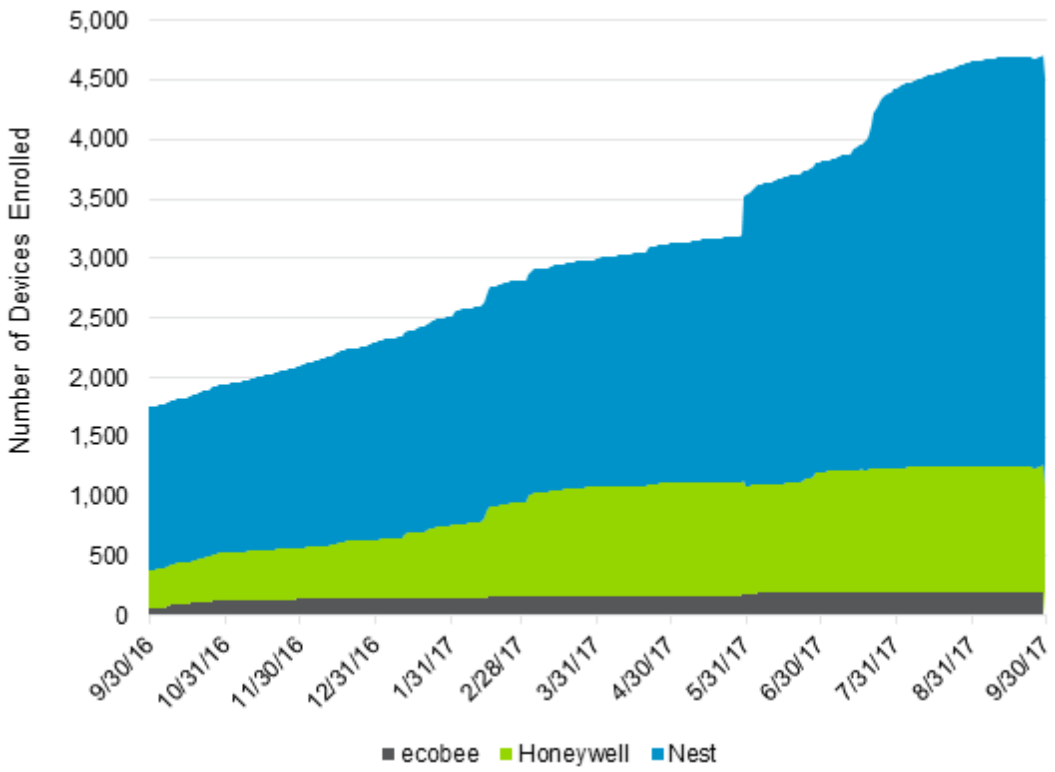
Source: Navigant analysis of NOAA temperature data

The average outdoor temperature for ecobee and Honeywell events in 2016 as 81.2°F and 83.4°F in 2017. In 2016, 12 of 29 events had average outdoor temperatures <80°F, whereas in 2017 no events had average outdoor temperatures <80°F. In both 2016 and 2017 no events occurred for these thermostats when outdoor event temperature averaged ≥90°F.

The average outdoor temperature for Nest events in 2016 as 84.5°F and 83.4°F in 2017. In 2016, 3 of 13 events had average outdoor temperatures <80°F, whereas no events had average outdoor temperatures <80°F in 2017. In 2016 1 of 13 events had average outdoor temperatures ≥90°F, and in 2017 there were no events.

As of September 30, 2016, there were 3,519 customers and 4,719 thermostats enrolled in the ConnectedSolutions demonstration project in Massachusetts. Figure 3-4 shows the number of enrolled thermostats since the end of the 2017 DR season.

Figure 3-4. Number of Enrolled Thermostats: Massachusetts



Source: Navigant analysis of customer enrollment data

Table 3-3 shows the number of thermostats and customers enrolled in the ConnectedSolutions Massachusetts program through September 30, 2017.

Table 3-3. Number of Enrolled Thermostats at End of DR Season: Massachusetts

Thermostat Type	Thermostats	Customers	Thermostats per Customer
ecobee	203	143	1.4
Honeywell	1,081	754	1.4
Nest	3,435	2,622	1.3
Total	**4,719**	**3,519**	**1.3**

Source: Navigant analysis of customer enrollment data

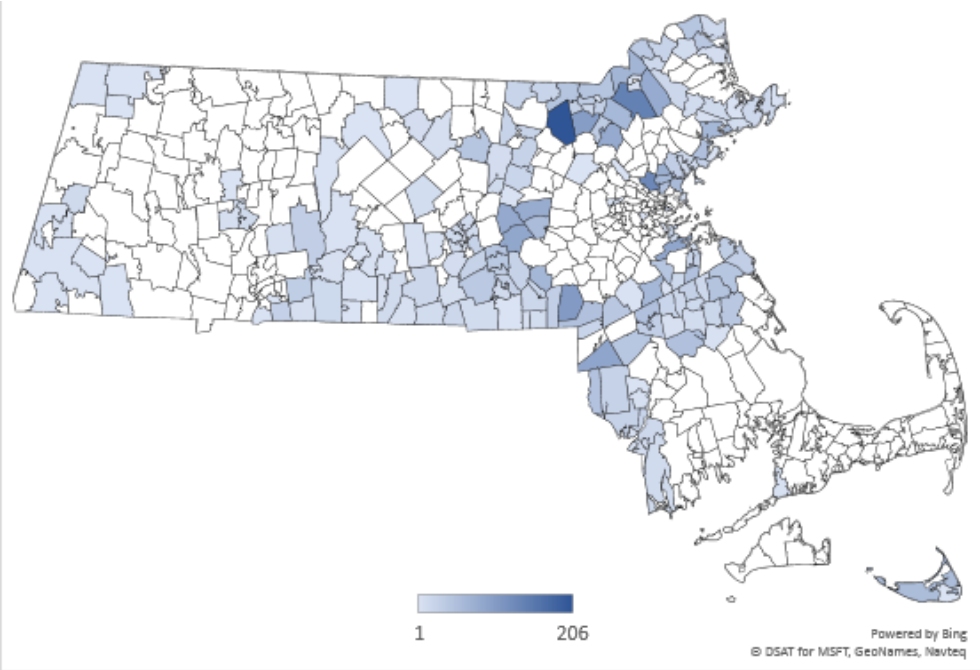
National Grid implemented the ConnectedSolutions demonstration project in 2017 using an experimental design such that the DR algorithm was only initiated on half of the enrolled devices on a given event day. Customers that enrolled in the program were randomly assigned to group A, B, C, or D. For each event, two groups were called for the DR event while the remaining two served as the control group. Table 3-4 presents the DR dispatch protocol. The experimental design was not implemented until July 18 for ecobee and Honeywell, and July 21 for Nest.

Table 3-4. Groups Assigned to Treatment and Control by Event: Massachusetts

DR Event	ecobee and Honeywell		Nest	
	Treatment	Control	Treatment	Control
Jul 12	N/A	N/A	N/A	N/A
Jul 17	N/A	N/A	N/A	N/A
Jul 18	A B	C D	N/A	N/A
Jul 20	B C	D A	N/A	N/A
Jul 21	C D	A B	C D	A B
Jul 31	D A	B C	D A	B C
Aug 1	A C	B D	A C	B D
Aug 16	B D	A C	B D	A C
Aug 21	A B	C D	A B	C D
Aug 22	B C	D A	B C	D A
Sep 25	C D	A B	C D	A B

Figure 3-5 presents the location of thermostats enrolled as of September 30, 2017. The ConnectedSolutions program includes thermostats from most of the communities served by National Grid, with the communities in MetroWest Boston having the most participating thermostats. Westford has the most participating thermostats both in total (206) and by thermostat type (19 ecobee, 54 Honeywell, and 133 Nest).

Figure 3-5. Geographic Distribution of ConnectedSolutions: Massachusetts



Source: Navigant analysis

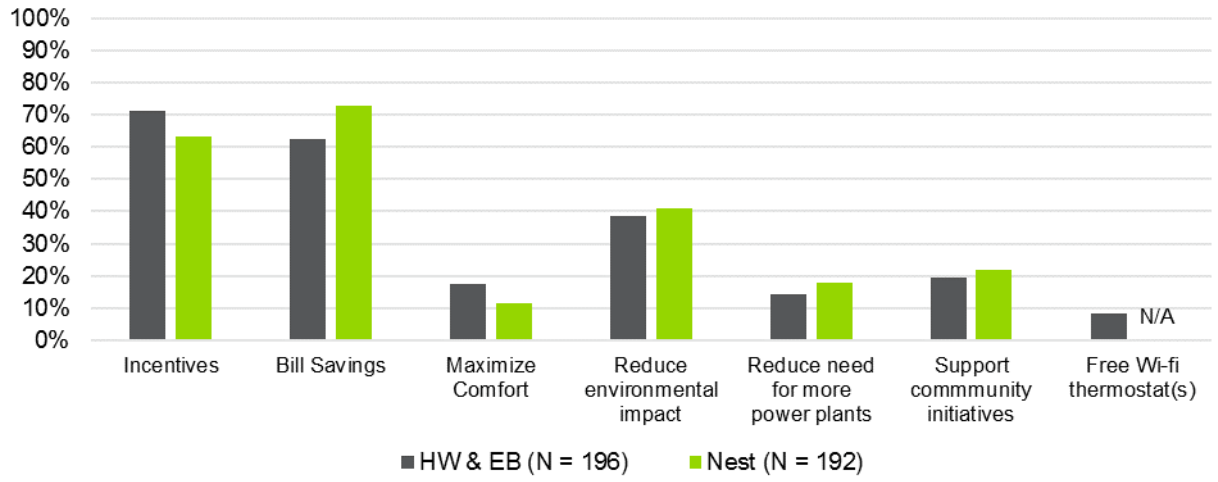
3.2 Participant Characteristics

3.2.1 Motivations and Demographics

During the post-season survey, respondents were asked about their motivations both for getting a Wi-Fi thermostat and for enrolling in the ConnectedSolutions program. Convenience (i.e., remote-control functionality) and potential bill savings were major drivers of respondents' decision to purchase Wi-Fi thermostats. Nest customers were much more interested than ecobee and Honeywell customers in the learning features associated with Wi-Fi thermostats (see Appendix H).

In terms of motivations to enroll in the program, as illustrated in Figure 3-6, most participants (60%-70%) believed the program would help them achieve bill savings. Incentives also played a major role in participants' decision to enroll. Additionally, 40% of respondents were also interested in reducing their environmental impact.

Figure 3-6. What are your main reasons for enrolling in the program? (Select all that apply)



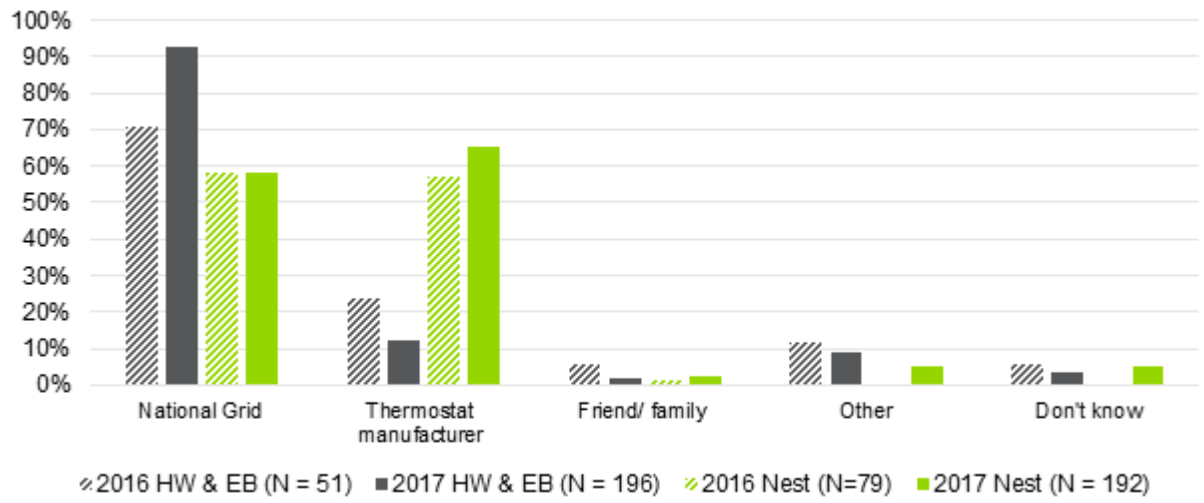
Note: This question allowed each respondent to select multiple responses. The chart denominator is number of respondents, so column percentages do not sum to 100%.

Source: 2017 post-season survey administered and analyzed by Navigant

In terms of program marketing, Figure 3-7 indicates that fewer program enrollees with ecobee and Honeywell thermostats reported being introduced to the program through marketing from their thermostat manufacturer as compared to 2016.[16] Conversely, Nest respondents continued to learn about the program through Nest and/or National Grid.

[16] 2016 and 2017 proportions of ecobee and Honeywell participants citing "Thermostat Manufacturer" are significantly different at the 95% confidence level.

Figure 3-7. How did you hear about the program? (Select all that apply)



Note: For this chart, 2016 enrollees were filtered out of the 2017 survey results. Also, this question allowed each respondent to select multiple responses. The chart denominator is number of respondents, so column percentages do not sum to 100%.

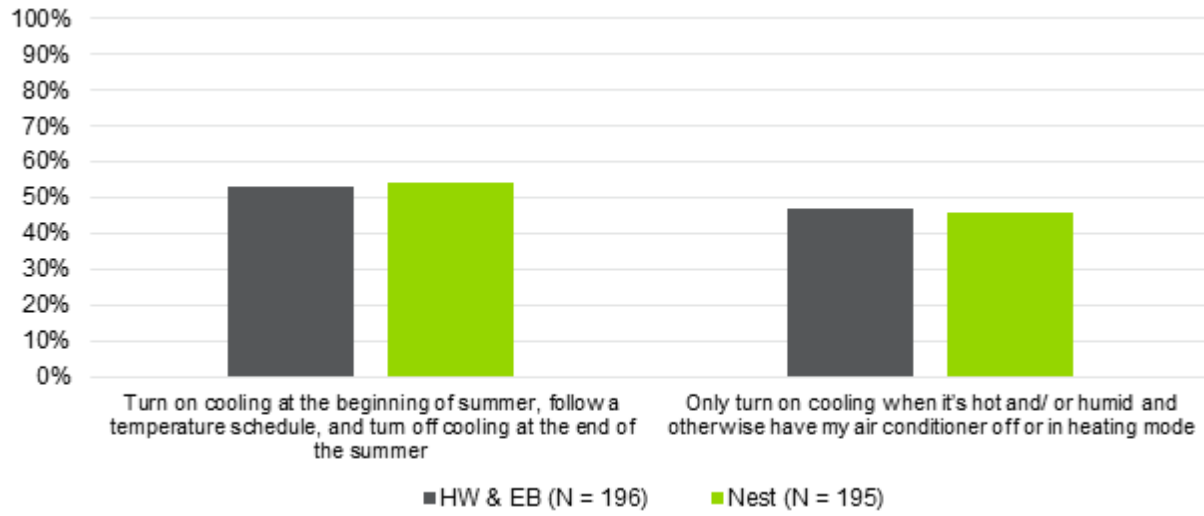
Source: 2016 post-enrollment survey and 2017 post-season survey administered and analyzed by Navigant

3.2.2 Typical AC Usage Behavior

As illustrated in Figure 3-8, approximately 55% of all survey respondents reported keeping their thermostats on a schedule throughout the summer. The remaining respondents reported having their thermostats in off or heating mode, except when cooling was needed.

Additionally, approximately 20% of Honeywell and ecobee respondents and 40% of Nest respondents indicated that when no family member was at home during the summer, their thermostats were in off or heating mode.

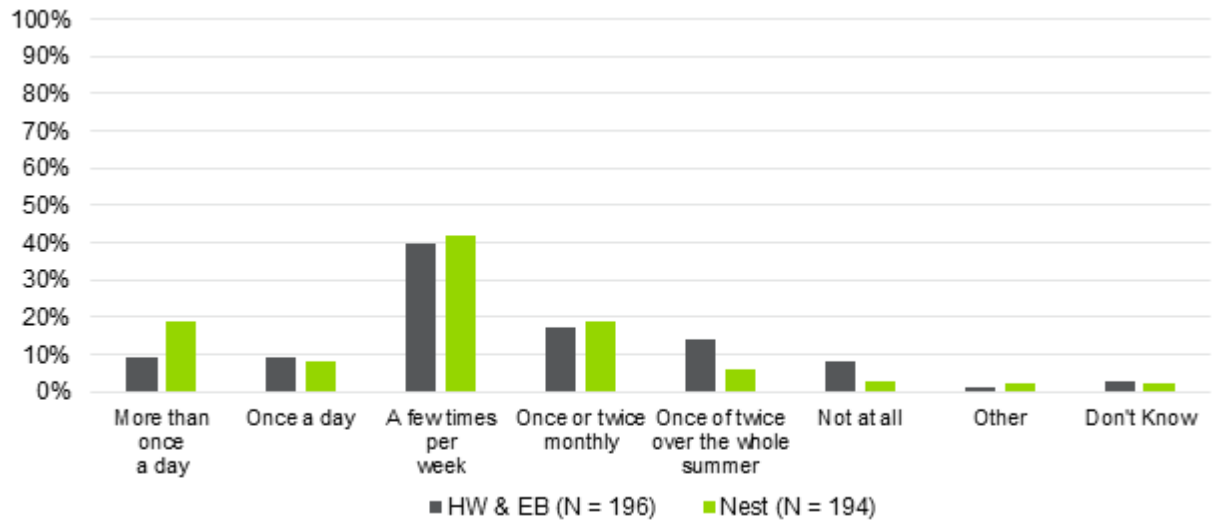
Figure 3-8. Which of the following best describes the way you used your air conditioner this past summer?



Source: 2017 post-season surveys administered and analyzed by Navigant

The frequency with which respondents engaged with their thermostats to adjust setpoint or schedule varied, with over half indicating they adjusted a few times per month to a few times per week (Figure 3-9). Additionally, over half of respondents indicated that their behavior related to the frequency with which they adjusted their thermostat's setting or schedule did not vary based on whether the day was an event day or not.

Figure 3-9. Now we'd like to understand the frequency with which you adjusted your Wi-Fi thermostat's setting or schedule during this summer. Would you say it was…



Source: 2017 post-season surveys administered and analyzed by Navigant

3.3 Program Event Participation

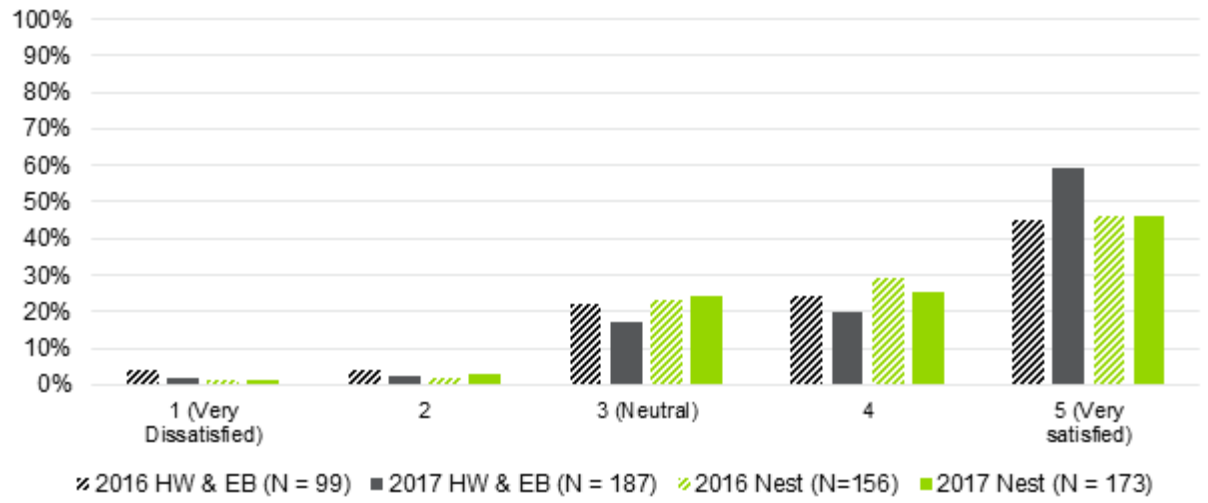
This section summarizes findings from survey questions regarding event notification and awareness, as well as the results of the thermostat usage assessment.

3.3.1 Event Notification and Awareness

Participant recollections of event notification timing varied. The approximate mean hours of advance notification cited by Honeywell and ecobee and by Nest respondents were 3.6 and 2 hours, respectively. Of those who were aware of advance event notification, 80% of Honeywell and ecobee and 20% of Nest respondents cited email notification. Additionally, 70% of Nest participants cited being notified via the Nest app. Of all respondents 40% also cited notification via the thermostat itself.

As indicated in Figure 3-10, of 2017 respondents who recalled being notified about events, most were satisfied with event notification (similar to 2016). Those who were dissatisfied (rated 1 or 2) would have liked to be notified earlier and have the timing of notification be more consistent from event to event.

Figure 3-10. What is your level of satisfaction with the notification you receive about an event that is set to occur?



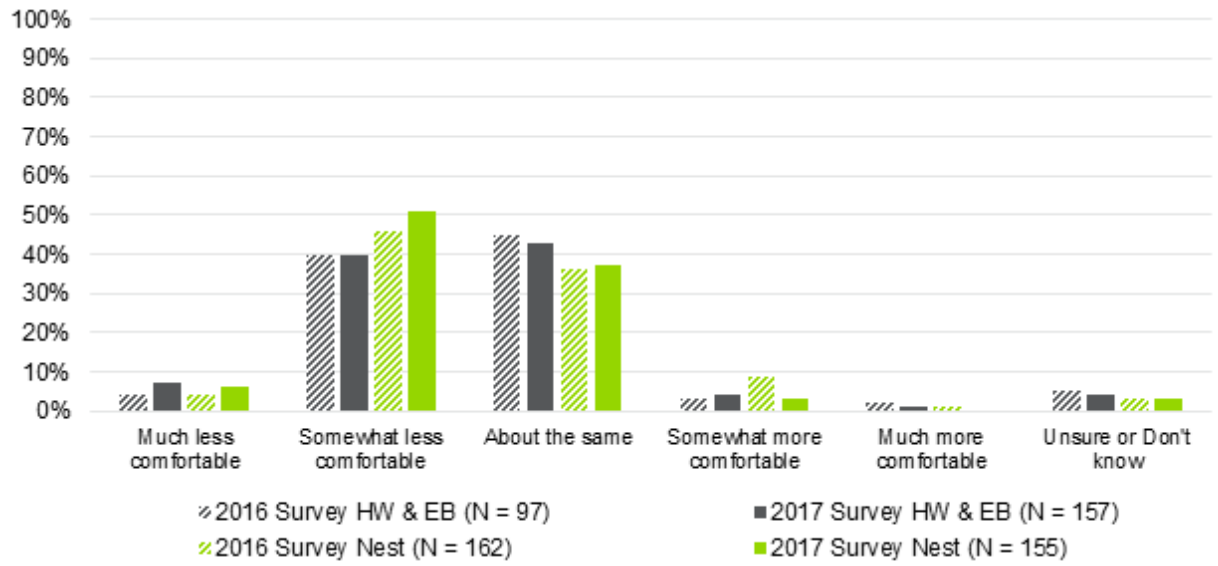
Source: 2016 and 2017 post-season surveys administered and analyzed by Navigant

Although 85% of participants indicated they were "likely" or "very likely" to participate in the program in future summers (refer to Section 3.5), survey results revealed that participants' willingness to participate in the future would drop to approximately 50% overall if no advance notice were provided prior to events.

3.3.2 Event Participation

As shown in Figure 3-11, approximately 40% of Honeywell and ecobee 2017 respondents and approximately 50% of Nest 2017 respondents reported being "somewhat less comfortable" during events relative to other afternoons with similar outdoor temperatures. Only 7% of Honeywell and ecobee respondents and 6% of Nest respondents were "much less comfortable" during events. These results are not statistically different from the 2016 results, despite the 1°F higher setpoint adjustment for Honeywell and ecobee participants in 2017 compared to 2016.

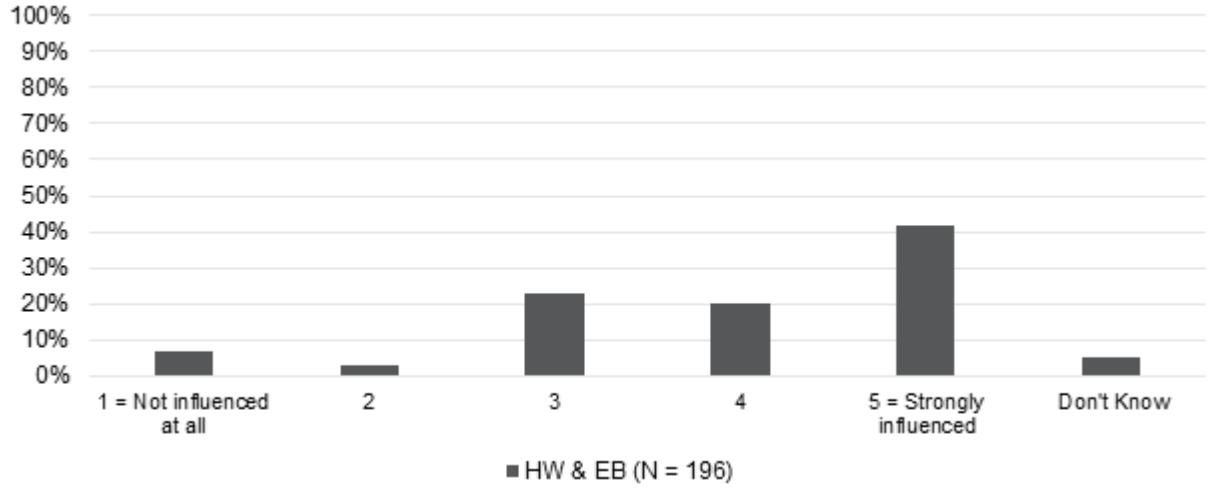
Figure 3-11. During events, how would you generally describe your comfort compared to typical afternoons with similar outdoor temperatures?



Source: 2016 and 2017 post-season surveys administered and analyzed by Navigant

Twenty-six percent of Honeywell and ecobee respondents and 31% of Nest respondents recalled having opted out of an event at least once during the 2017 summer season. The post-season survey investigated two possible causes for differences in opt-out behavior between Honeywell and ecobee participants and Nest participants. First, the survey probed Honeywell and ecobee respondents about the importance of the participation incentive in their decisions of whether or not to override their thermostat's setpoint during events (Nest participants do not receive an annual participation incentive). Over 60% of Honeywell and ecobee respondents indicated that the participation incentive was influential in their decision not to opt out of events (Figure 3-12).

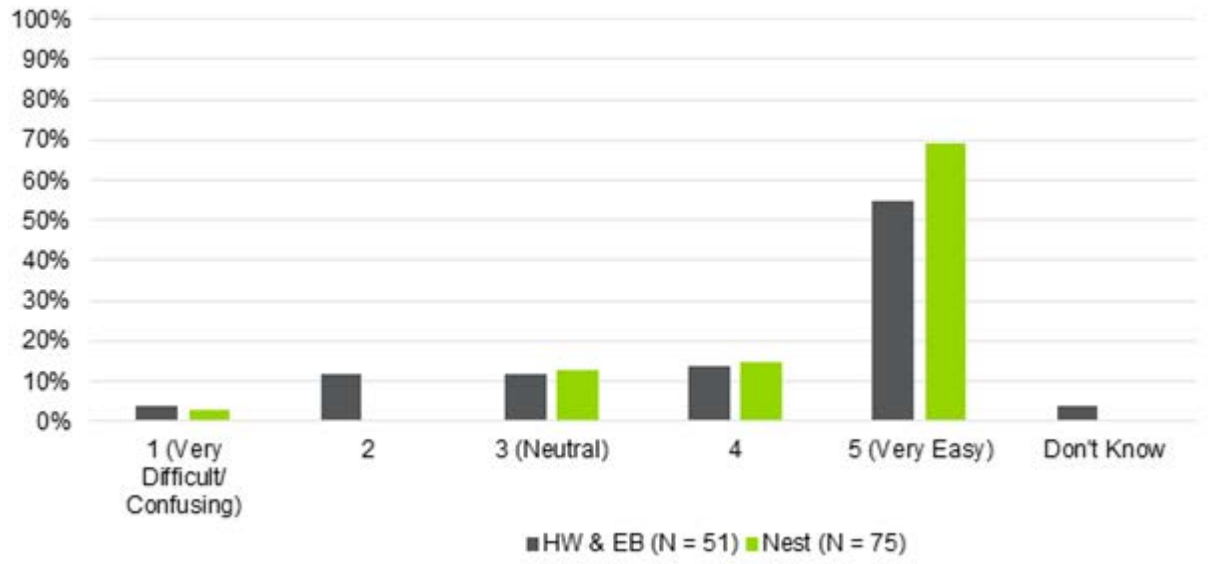
Figure 3-12. On a scale of 1-5, where 1 is "Not influenced at all" and 5 is "Strongly influenced", how much would you say the program's $25 participation incentive influenced you not to opt-out or override the Wi-Fi thermostat setting during events?



Source: 2017 post-season survey administered and analyzed by Navigant

The post-season survey also explored the theory that the (ease of use of) user interfaces of particular thermostat types may play a factor in whether or not participants opt out. As seen in Figure 3-13, 16% of Honeywell and ecobee respondents indicated that they found the process of opting out of an event to be difficult or very difficult. For Nest, only 3% of respondents found opting out to be challenging.[17]

Figure 3-13. Using a scale of 1 to 5, where 1 means "Very Difficult or Confusing" and 5 means "Very Easy", how easy was it to opt-out of or override events?

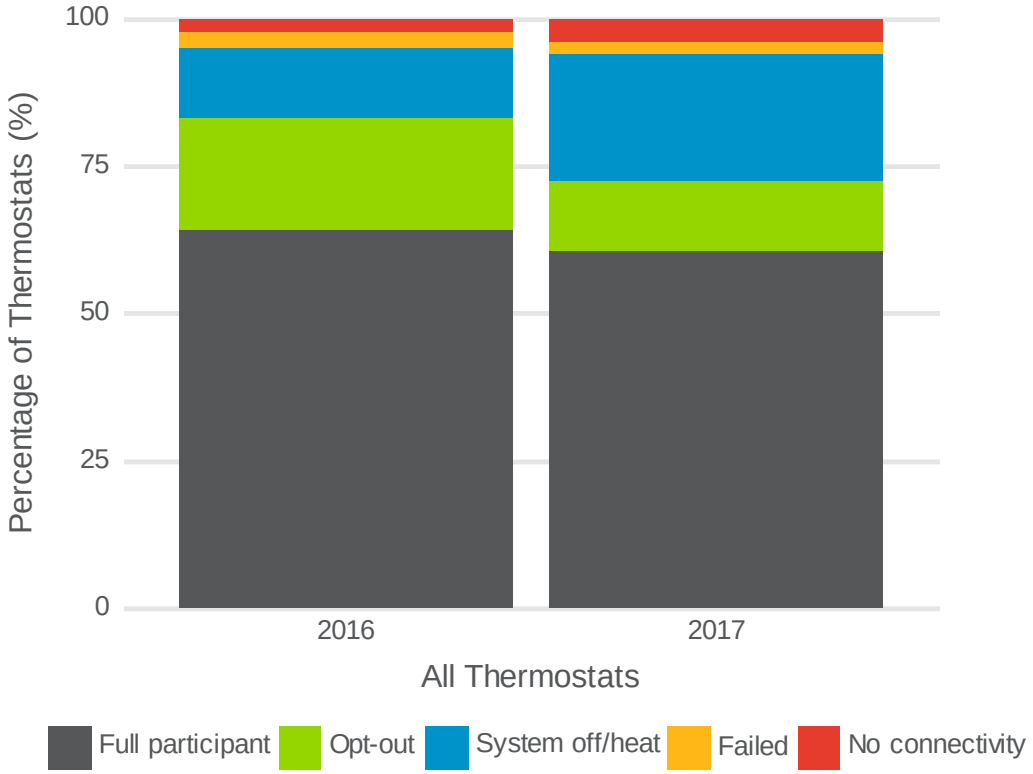


Source: 2017 post-season survey administered and analyzed by Navigant

To further study customer acceptance of DR events, Navigant analyzed thermostat telemetry data on event days to characterize device-level participation status. Figure 3-14 represents the average participation across all events for all devices in the ConnectedSolutions program for the 2016 and 2017 DR seasons. In 2017, 61% of thermostats fully participated in events, on average. As shown, customers have several reasons for not participating in DR events, including opting out of an event, the air conditioning system being in either off or heat mode, the device failing to receive the DR signal, or a connectivity issue. Air conditioning systems in off or heat mode (21%) is the primary reason for devices not participating in events, which is likely due to the cooler weather immediately preceding some events in 2017. Opt-outs (12%), devices that failed to receive the DR signal (2%), and no connectivity (4%) had smaller impacts.

[17] The difference in the percentage of respondents who found opting out to be difficult/very difficult between Honeywell/ecobee and Nest respondents is statistically significant at a 99% confidence level.

Figure 3-14. Average Participation Across all Events in Massachusetts: 2016 vs. 2017

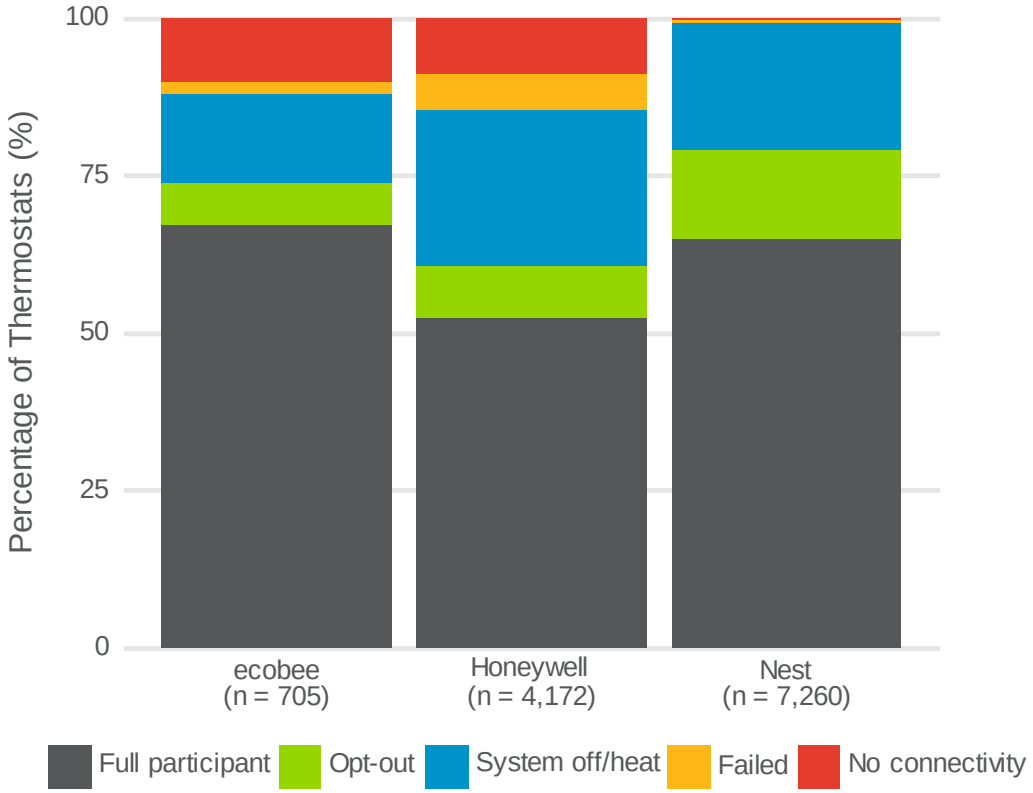


Source: Navigant analysis

Figure 3-15 shows the average participation by thermostat type.[18] On average, 67% of ecobee, 52% of Honeywell, and 65% of Nest thermostats fully participated in the events. As shown, there are considerable differences in the reasons for not participating in an event based on the type of device. Opt-out rates are highest for Nest (14%), double that of ecobee (7%) and Honeywell (8%). Survey responses suggest the higher opt-out rates for Nest may be attributed to the incentive structure and device usability (i.e., the method used to opt out). The rate of air conditioning systems in off or heat mode is high for all three devices types: 14% for ecobee, 20% for Nest, and 25% for Honeywell. Rates of failed devices were low across thermostats, with the highest seen by Honeywell devices (6%). Nest thermostats had few connectivity issues (0.2%) compared to ecobee (10%) and Honeywell (9%).

[18] Refer to Appendix C.1 for participation status by event for each of the three thermostat types.

Figure 3-15. Average Participation Across All Events: Massachusetts



Note that *n* represents the total instances of thermostat participation during the DR season for each thermostat type.

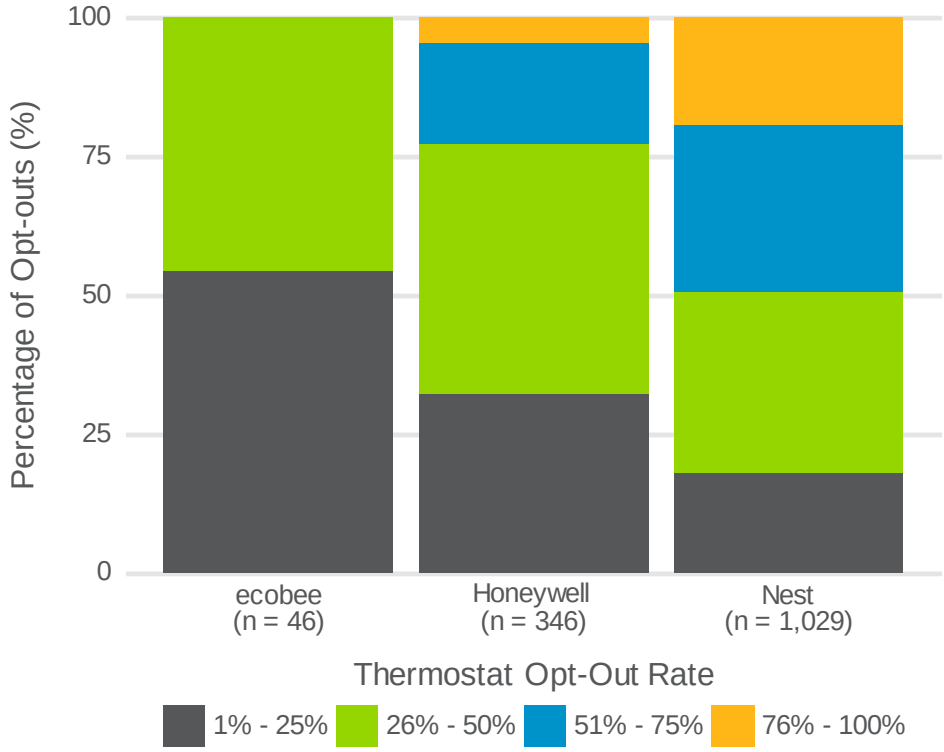
Source: Navigant analysis

To further study whether higher opt-out rates were due to participant fatigue, Navigant investigated the timing of opt outs to determine if a greater percentage occurred toward the end of an event. Participants opted out throughout the events at a relatively constant level, providing no evidence of participation fatigue. Navigant also investigated whether opt-out rates correlated with the frequency of events, day of the week, or temperature and found that both frequency of events and higher temperatures may have contributed to higher opt-out rates during DR events though the sample sizes were small.

Navigant further analyzed opt-out rates to assess whether they can be attributed to specific customers persistently opting out of every event. The evaluation team classified individual thermostat opt outs into categories based on the number of times each thermostat opted out compared to the total number of events the thermostat was enrolled in. The total number of opt outs for each category was summed and then divided by the total number of opt outs for each thermostat type during the entire DR season.

Figure 3-16 presents the results of this analysis and indicates there were some Honeywell and Nest participants who frequently opted out of events. ecobee devices never opted out of more than 50% of events for which they were eligible. Almost one-quarter of Honeywell's opt outs were accounted for by devices opting out of over half of events (yellow and blue bars), with five devices opting out of every event. Over 75% of Nest opt outs were by devices that opted out of more than one-quarter of events (green, blue, and yellow bars), with 92 devices opting out of every event. As previously noted, survey responses indicated the higher opt-out rates by Nest participants may be attributed to the incentive structure and device usability (i.e., the method used to opt out).

Figure 3-16. Percentage of Total Opt Outs by Thermostat Opt-Out Rates: Massachusetts



Note that *n* represents the total number of thermostat opt outs during the DR season for each thermostat type.

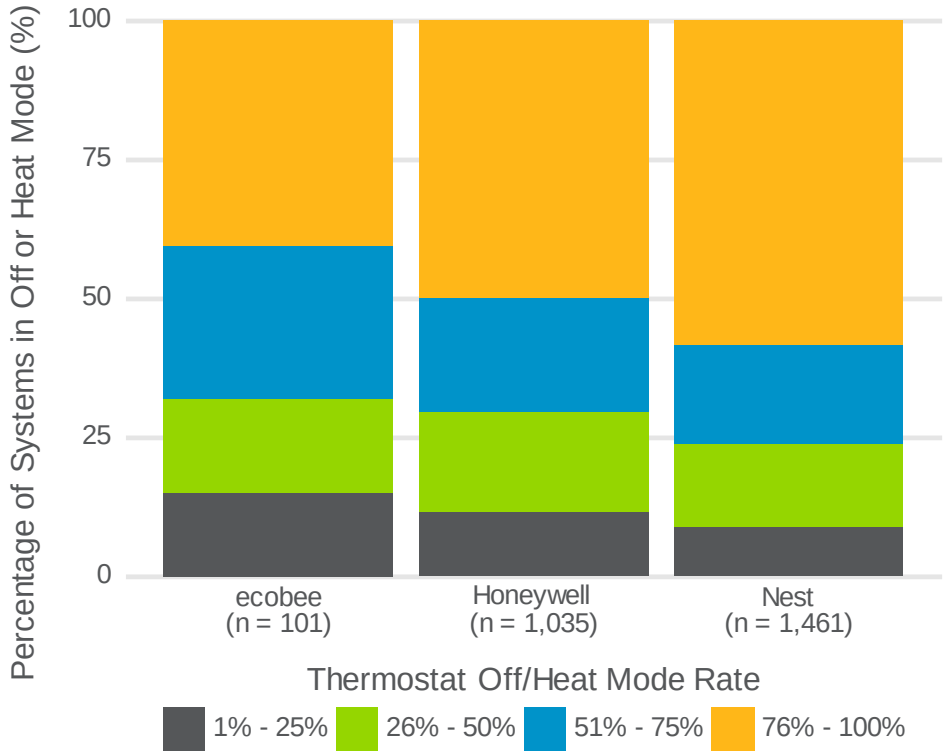
Source: Navigant analysis

Navigant performed a similar analysis to assess whether there were some air conditioning systems that were persistently in off or heat mode, devices that persistently failed to receive the DR signal, or devices that had persistent connectivity issues. Figure 3-17 to Figure 3-19 present these results.

Figure 3-17 shows some participants frequently had their air conditioning systems in off or heat mode, representing most instances when air conditioning systems were in off or heat mode. About 50% of all instances of systems in off or heat mode were caused by devices that were not cooling for at least 75% of events (yellow bar). A total of 10 ecobee devices, 101 Honeywell, and 330 Nest devices were never in cooling mode during an event.[19]

[19] 3 of the 10 ecobee devices, 44 of the 101 Honeywell devices, and 39 of the 330 Nest devices were never in cooling mode during the summer season.

Figure 3-17. Percentage of Thermostats in Off or Heat Mode by Rate of Thermostats in Off or Heat Mode: Massachusetts

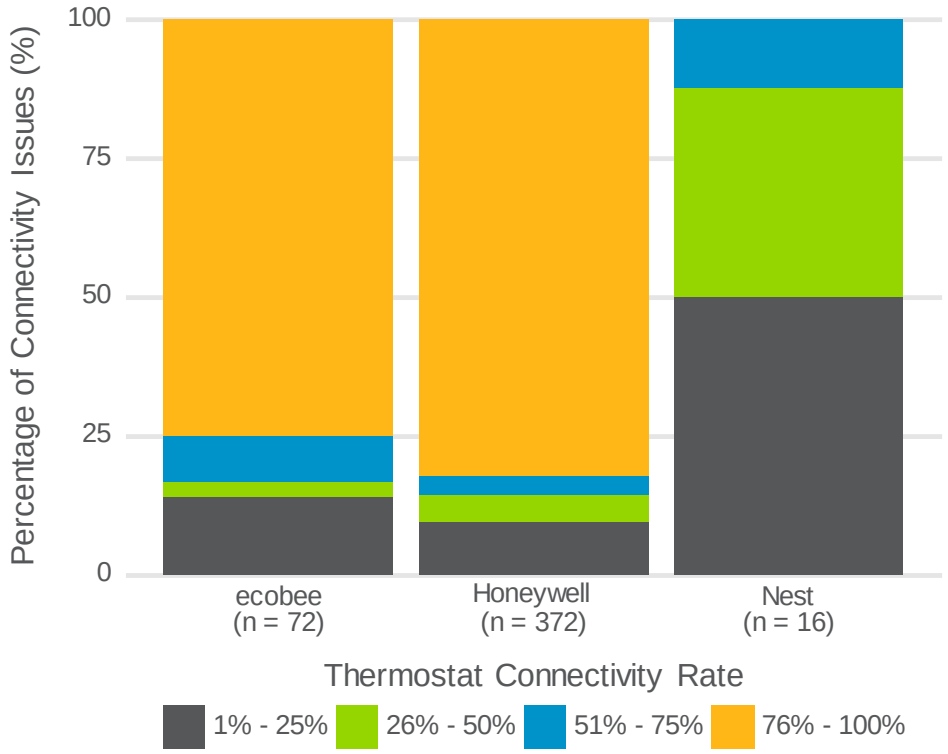


Note that *n* represents the total instances of systems in off/heat mode during the DR season for each thermostat type.

Source: Navigant analysis

Figure 3-18 shows that devices with frequent (or sustained) connectivity issues represent the majority of connectivity issues for ecobee and Honeywell. Over 75% of ecobee and Honeywell connectivity issues were accounted for by devices with issues for at least three-quarters of events (yellow bar). A total of 13 ecobee devices and 74 Honeywell devices experienced connectivity issues for all events. There were only 14 Nest devices that experienced connectivity issues.

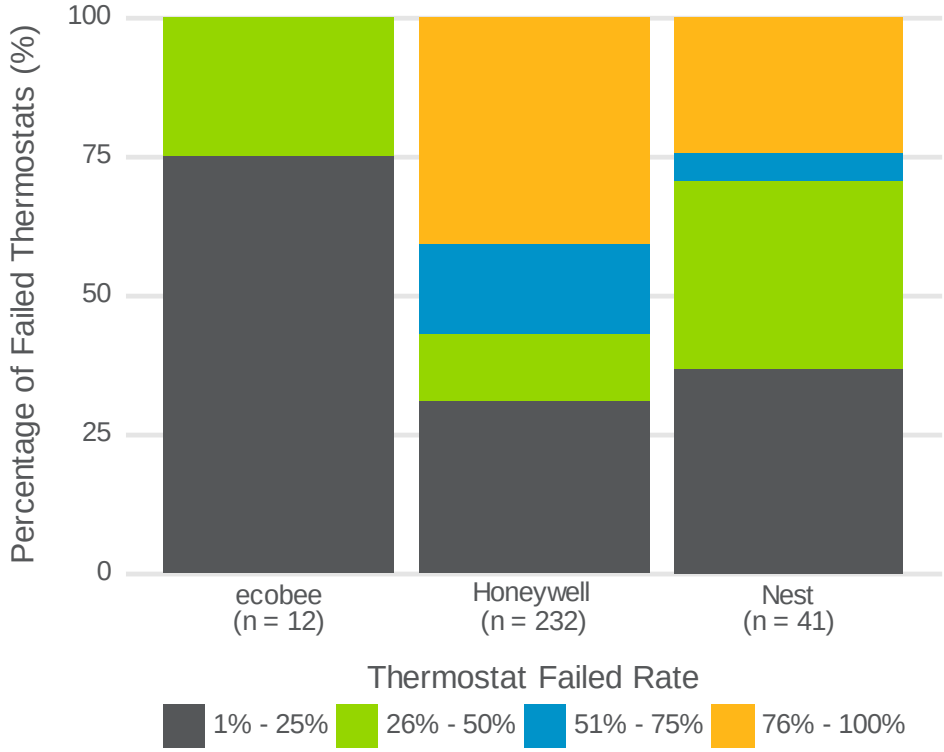
Figure 3-18. Percentage of Total Connectivity Issues by Thermostat Connectivity Rate: Massachusetts



Note that *n* represents the total instances of no connectivity during the DR season for each thermostat type.
Source: Navigant analysis

Figure 3-19 shows devices failing to receive the event notification during most events represent the minority of DR message failures, especially for ecobee and Nest. For Honeywell, about half of all notification failures were caused by devices that failed during at least half of all events. A total of zero ecobee devices, 14 Honeywell, and six Nest devices failed during every event.

Figure 3-19. Percentage of Failed Thermostats by Thermostat Failed Rate: Massachusetts



Note that *n* represents the total number of event notification failures during the DR season for each thermostat type.

Source: Navigant analysis

3.4 Program Impacts

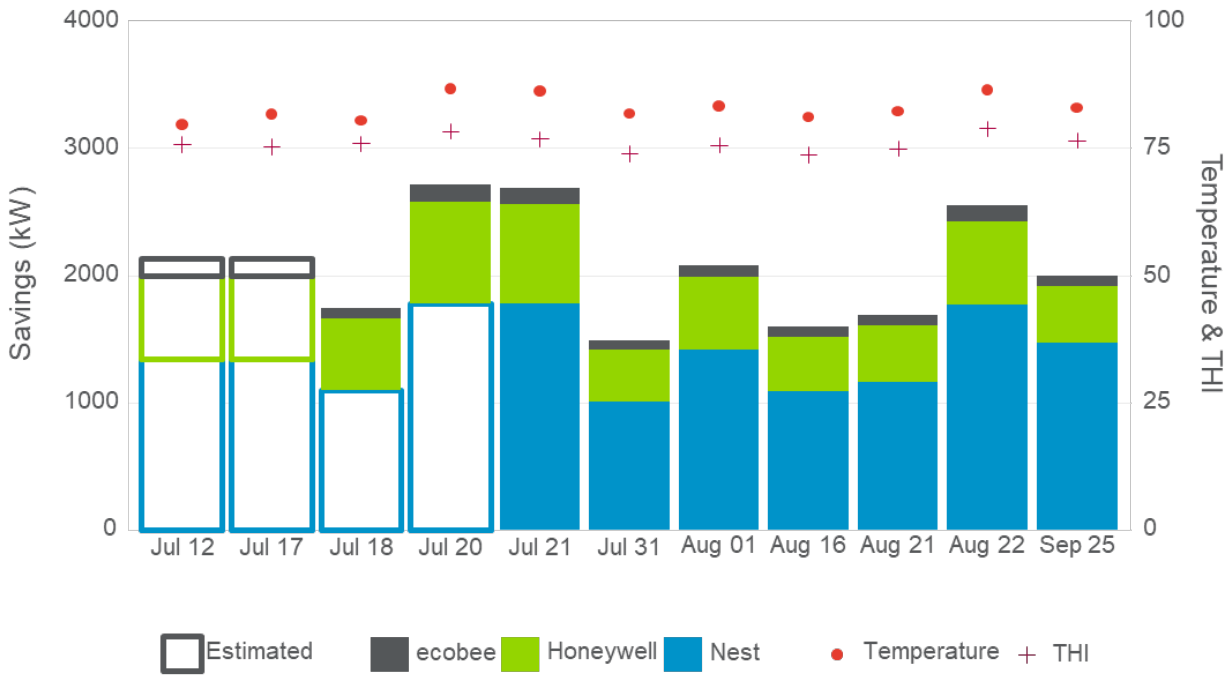
This section presents the results of Navigant's impact analysis.

3.4.1 2017 Program Savings

Figure 3-20 presents the total demand reduction for the ConnectedSolutions program by event. The maximum kilowatt (kW) reduction occurred on July 20, 2017, with a total DR of 2.7 MW. Higher savings is correlated with higher temperature and the temperature-humidity index (THI). The 2017 Independent System Operator-New England (ISO-NE) system peak was on June 13, 2017. Navigant estimates demand savings of 2.4 MW could have been achieved had the program called an event that day.[20]

[20] The estimate is calculated as the average demand savings for the most similar event day x the number of total enrolled devices at the end of the season.

Figure 3-20. Total Savings by Event and Thermostat Type: Massachusetts



Note: *n* represents the total number of event notification failures during the DR season for each thermostat type. Total savings is the sum of average demand savings by event *x* number of total enrolled devices at the end of the season for each thermostat type. Estimated savings were calculated using similar event day demand savings; paired event days are listed in Appendix B.1.

Source: Navigant analysis

Table 3-5 shows the summary of program impacts for the 2017 DR season, assuming end-of-season enrollment. The table contains average and maximum impacts for the entire season, as well as energy savings.

Table 3-5. Summary of 2017 Program Savings: Massachusetts

	Total
Average demand reduction per event	2,074 kW
Maximum demand reduction per event	2,714 kW
Average energy savings per event	3,512 kWh

Source: Navigant analysis

3.4.2 Average Impacts

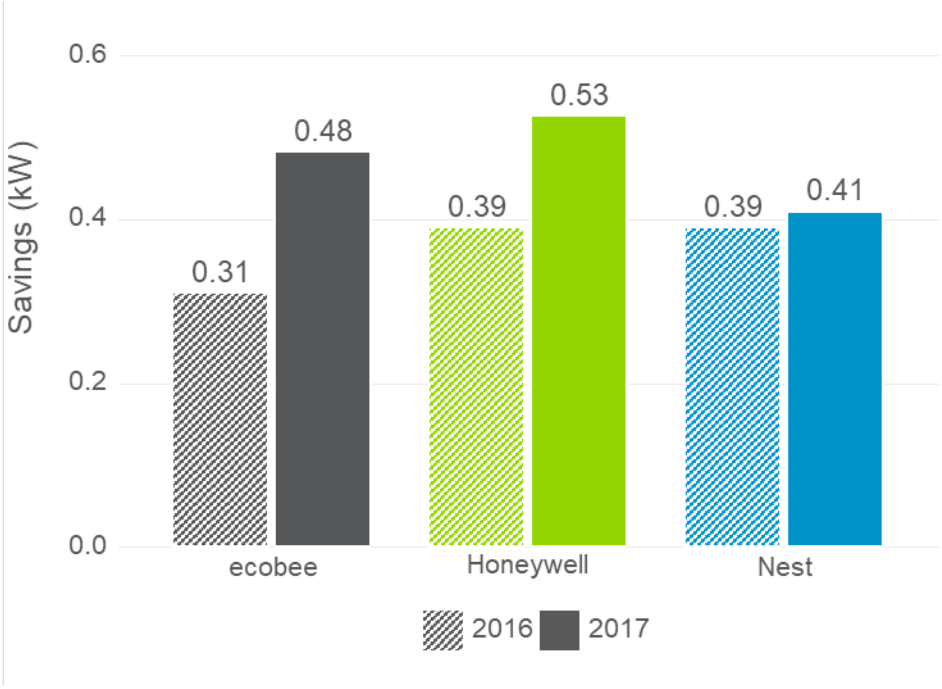
Navigant estimated the ATE per device, which included all enrolled devices regardless of participation status. This estimate reflects actual impacts, acknowledging a portion of devices will opt out, or have their air conditioning systems in off or heat mode. Average demand impacts varied by thermostat model, with the ecobee model achieving an average DR of 0.48 kW per event, the Honeywell model achieving 0.53 kW per event, and the Nest model achieving 0.41 kW per event (Figure 3-21).

The average demand savings per thermostat increased by 22% from 0.38 kW to 0.44 kW from 2016 to 2017. This was likely the result of a combination of factors:

- Setpoint adjustment increased from 2°F to 3°F for ecobee and Honeywell in 2017
- There were no events in 2017 with average outdoor temperatures <80°F, whereas in 2016 12 of 29 ecobee and Honeywell events and 3 of 13 Nest events had average outdoor temperatures <80°F in 2016.
- Customers participated in fewer events due to the change in the DR dispatch protocol and the experimental design
- Events were shorter on average (3.0 hours in 2017 vs. 3.8 hours in 2016)

Nest thermostats may have experienced a smaller change since they already had 3°F setbacks, were more frequently called on warmer days in 2016, and a portion of Nest customers participated in Seasonal Savings in 2017,[21] which also increases scheduled setpoints.

Figure 3-21. ATE per Device for All Events: Massachusetts

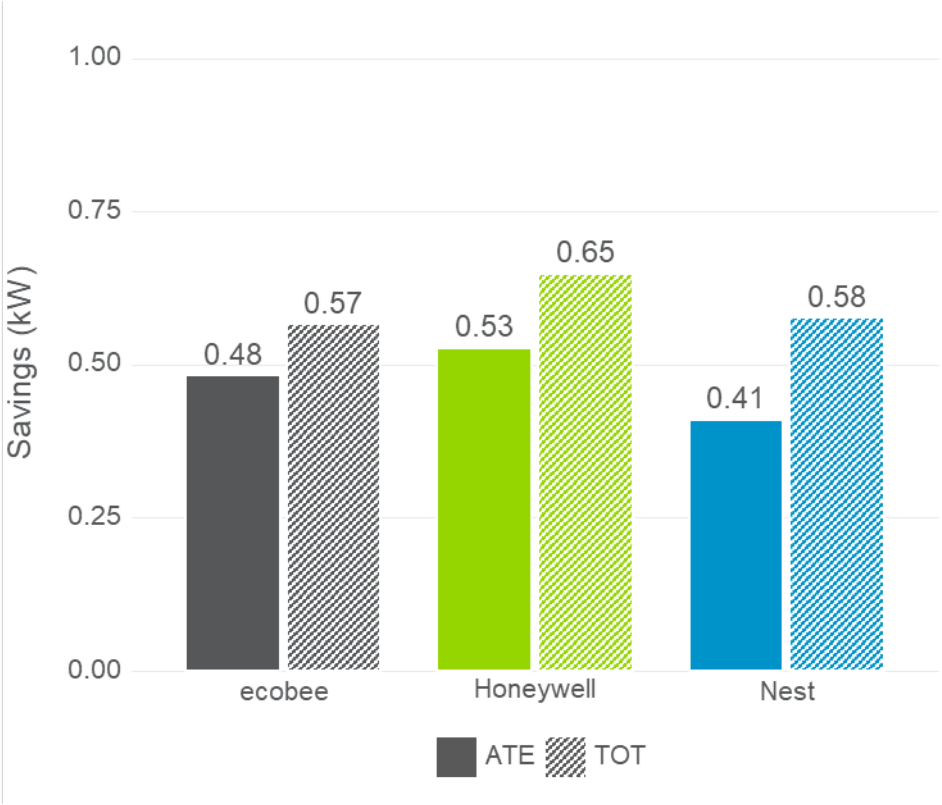


Source: Navigant analysis

Since the ATE included opt-outs and systems in off/heat, which vary by thermostat type, Navigant also estimated the TOT per device, which only includes thermostats in the full participant category. Figure 3-22 displays both the ATE and TOT by thermostat type, revealing higher TOT average impacts. The variance in average TOT impacts was likely due to differences in pre-cooling, geographic location, or customer attributes. Both the Honeywell and Nest thermostats pre-cooled prior to DR events, which was not a feature of the ecobee thermostat. Pre-cooling can increase DR impacts by lengthening the time it takes for a home to reach the elevated setpoint temperature, reducing overall air conditioning runtime.

[21] https://nest.com/support/article/What-is-Seasonal-Savings.

Figure 3-22. ATE vs. TOT by Device for All Events: Massachusetts



Note: See Appendix A.1 for a list of modeled events included in the summer average.
Source: Navigant analysis

Table 3-6 displays a summary of the average impacts (ATE) and full participation impacts (TOT) by kW and as a percent of cooling load for each thermostat type. Impacts ranged from 61% to 67% of cooling load. Per device kW impacts are partially a function of the baseline. Device types with a higher baseline tend to have higher kW impacts.[22]

[22] Impacts within device types can differ between Massachusetts and Rhode Island due to differences in baseline usage. For example, baseline kW for ecobee devices is 0.72 kW in Massachusetts and 0.97 kW in Rhode Island. Thus, the average impact per ecobee device is higher in Rhode Island.

Table 3-6. ATE and TOT Summary: Massachusetts

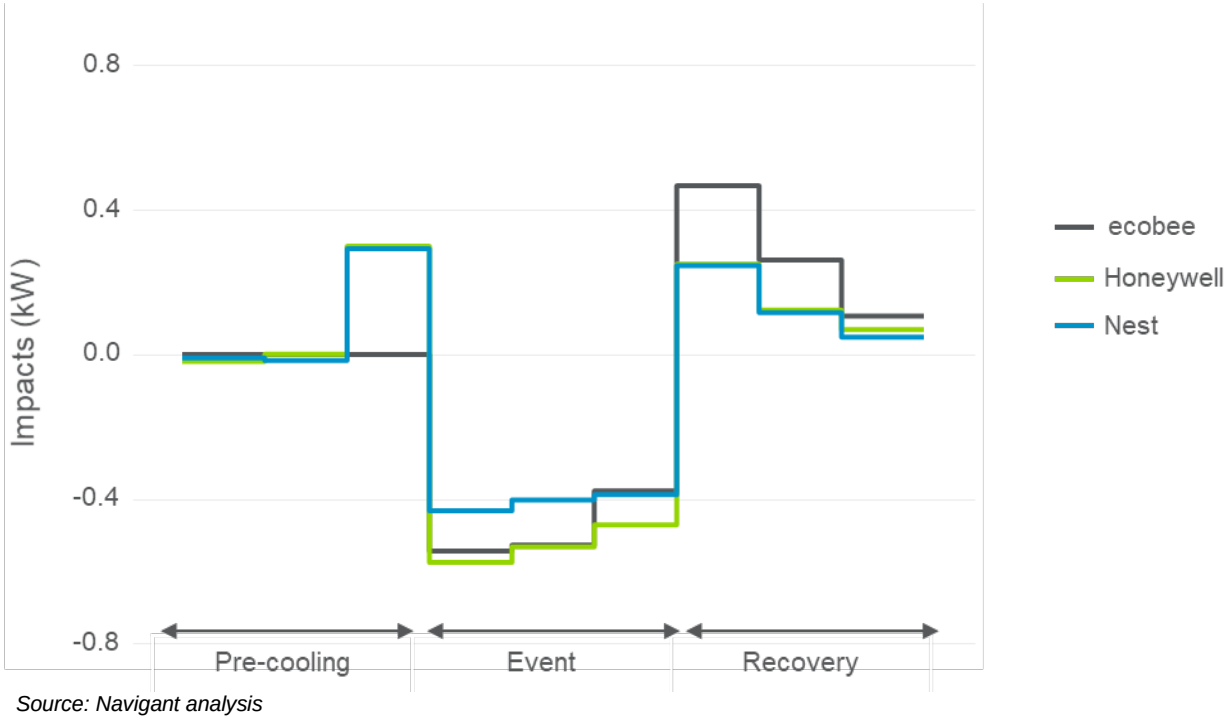
		ecobee	Honeywell	Nest
Enrolled thermostats on September 30		203	1,081	3,435
Average ATE	Savings per thermostat (kW)	0.48	0.53	0.41
	Percent savings	67%	65%	61%
	Baseline per thermostat (kW)	0.72	0.81	0.68
Average TOT	Savings per thermostat (kW)	0.57	0.65	0.58
	Percent savings	75%	70%	81%
	Baseline per thermostat (kW)	0.76	0.93	0.71

Note: See Appendix A.1 for a list of events included in the summer average. ATE includes thermostats in the full participant, opt-out, and system off/heat categories. TOT includes only full participants.
Source: Navigant analysis

3.4.2.1 Average Hourly Impacts

The previous section presented average impacts—i.e., the average of hourly impacts over the duration of the event. In this section, Navigant presents the hourly impacts for both the event period and for the pre-cooling and recovery periods. The pre-cooling period included the 3 hours preceding an event, while the recovery period covered the 3 hours immediately following an event. Figure 3-23 displays average hourly impacts. Of note, the largest impacts were observed during the final pre-cooling interval (for the Honeywell and Nest devices, which have pre-cooling) and the first intervals during the event and recovery periods. Impacts during the event were largest during the first hour and steadily degrade. This is a common feature of thermostat DR programs where indoor air temperatures increase throughout the duration of the event, resulting in increased cooling loads. Relative to Honeywell and Nest, the ecobee thermostat's impacts degrade at a faster rate and experience a larger recovery peak as a result of not offering pre-cooling.

Figure 3-23. Average Hourly Impacts for All Events, ATE: Massachusetts



Source: Navigant analysis

Table 3-7 summarizes the average impact (ATE) during the pre-cooling, event, and recovery periods by thermostat type, as well as the maximum hourly impact. One thing to note is the increase in (maximum) demand during the pre-cooling period for the Honeywell and Nest thermostats (the ecobee does not pre-cool). Average impacts match the 2017 impacts presented in Figure 3-21, and the maximum hourly impact across thermostat models exhibits similar differences (Nest with the smallest impact and Honeywell with the largest). Finally, an increase in demand during the recovery period was observed for all thermostat models, with slightly lower maximum hourly impacts for the Honeywell and Nest thermostats due to pre-cooling. Navigant also reports energy impacts, which show a reduction in energy usage during the pre-cooling, event, and recovery periods across all thermostat models. This energy reduction is smallest for the Nest thermostat.

Table 3-7. Summary of Seasonal Impacts by Device and Period: Massachusetts

	Pre-cooling (kW)	Event (kW)	Recovery (kW)	Energy (kWh)
Ecobee				
Average hourly impact*	-	-0.48	0.28	-0.61
Maximum hourly impact (average)	-	-0.57	0.47	N/A
Maximum hourly impact (maximum)	-	-0.83	0.73	
Honeywell				
Average hourly impact*	0.09	-0.53	0.15	-0.85
Maximum hourly impact (average)	0.30	-0.58	0.25	N/A
Maximum hourly impact (maximum)	0.43	-0.87	0.39	
Nest				
Average hourly impact*	0.09	-0.41	0.14	-0.60
Maximum hourly impact (average)	0.30	-0.45	0.25	N/A
Maximum hourly impact (maximum)	0.53	-0.65	0.41	

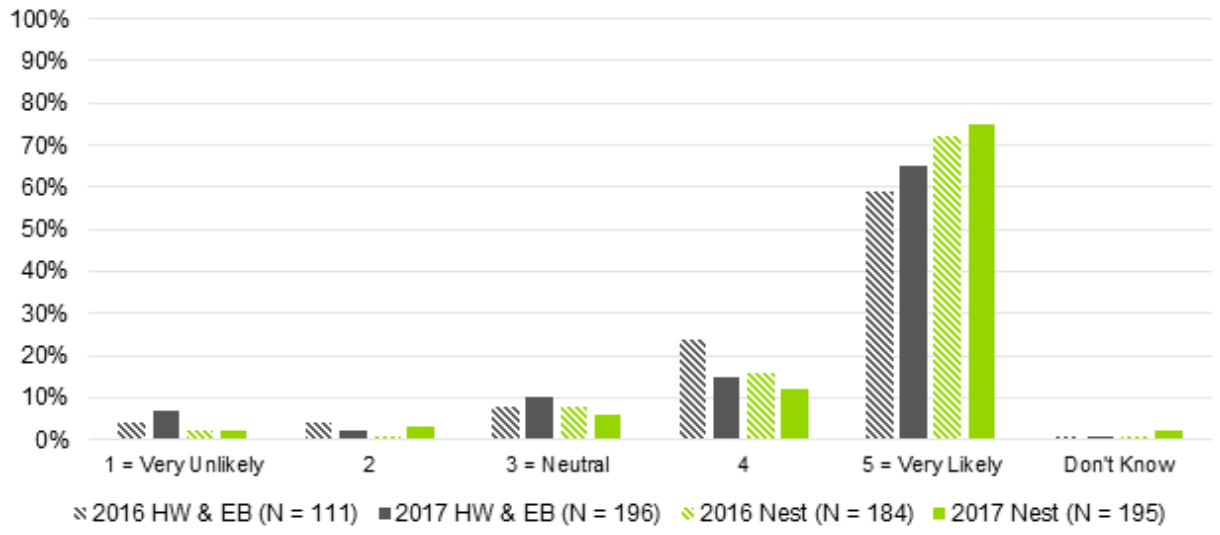
* Pre-cooling and recovery periods are calculated using 3 hours.

Source: Navigant analysis

3.5 Program Satisfaction

As with the 2016 program offering, the majority of survey respondents were satisfied with the 2017 program offering. Of survey respondents, 85% in both programs reported they were “likely” or “very likely” to participate in the program in future summers.

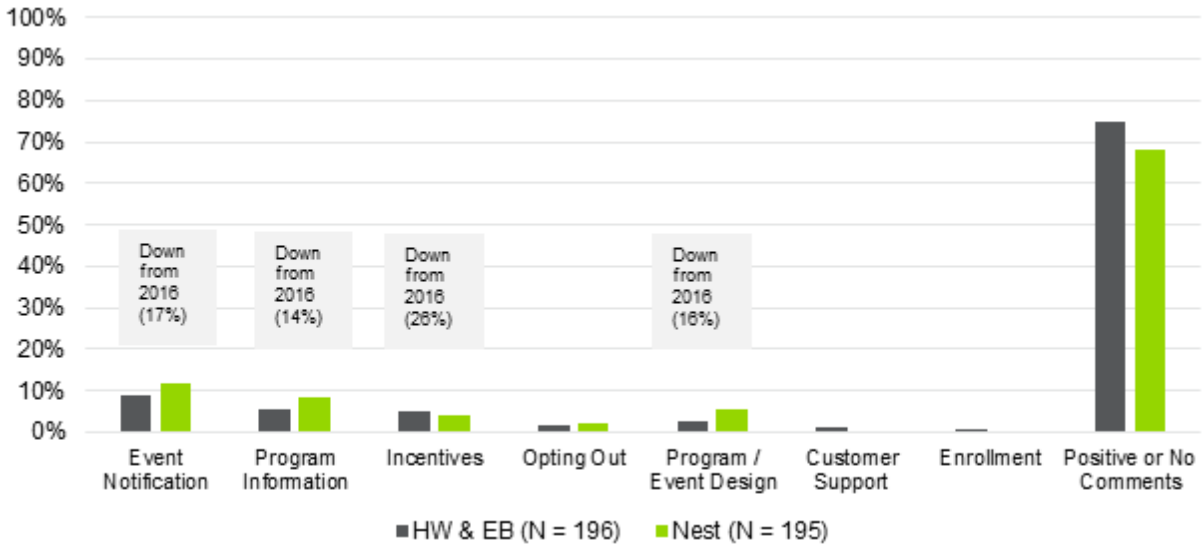
Figure 3-24. Based on your experience to date, in future summer, will you continue to participate in the program?



Source: 2016 and 2017 post-season surveys administered and analyzed by Navigant

Among respondents who offered direct customer feedback, event notification, program information, incentives, and program and/or event design were the most commonly cited areas for improvement.

Figure 3-25. ConnectedSolutions Program Improvement Categories: Massachusetts



Source: 2017 post-season surveys administered and analyzed by Navigant

3.6 Key Findings

National Grid Massachusetts' ConnectedSolutions program was successful in testing the effectiveness of three Wi-Fi thermostats as a DR-enabling technology and the customer acceptance of program offerings. Navigant's evaluation resulted in several key findings (described in Table 3-8) that should inform future program planning.

Table 3-8. Key Findings: Massachusetts

Category	Key Findings
Technology and Program Offering	• On average, 61% of thermostats fully participated during DR events, which is down from 64% in 2016. • Customers opting out, connectivity issues, failing to receive a DR signal, or a thermostat not in "cool" mode are all factors why 100% full participation was not achieved. • Participation status varied by thermostat manufacturer—67% of ecobee, 52% of Honeywell, and 65% of Nest thermostats fully participated.
Program Design and Implementation	• ecobee and Honeywell thermostats had a large percentage with connectivity issues (10% and 9% per event), and Nest thermostats had a large percentage of opt outs (14% per event). • The percentage of Honeywell connectivity issues increased from 3% in 2016 to 9% in 2017. • The percentage of Nest opt outs decreased from 24% in 2016 to 14% in 2017. • The percentage of ecobee connectivity issues decreased from 15% in 2016 to 10% in 2017. • The number of air conditioning systems in off/heat mode averaged 21% across thermostat types, compared to about 12% in 2016. • About half of survey respondents follow a thermostat temperature schedule and half only turn their air conditioning on when needed. • 20% of Honeywell and ecobee and 40% of Nest survey respondents put their thermostats in off or heating mode when no one is at home. • Majority of Honeywell and ecobee survey respondents indicated they were influenced not to opt out by the participation incentive.
DR Impacts	• Average demand savings per thermostat were 0.48 kW (67% savings) for ecobee, 0.53 kW (65% savings) for Honeywell, and 0.41 kW (61% savings) for Nest. These kW impacts are slightly higher than in 2016. • Average demand savings per event was 2,074 kW, with maximum event savings of 2,714 kW. • Average energy savings per thermostat were 0.61 kWh for ecobee, 0.85 kWh for Honeywell, and 0.60 kWh for Nest.

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Category	Key Findings
Scalability	• The overwhelming majority of 2016 participants continued to participate in the program 2017. • From 2016, total device enrollment increased by 168%. • Fewer customers were introduced to the program through their thermostat vendors. • Customer satisfaction remained strong, and 85% of post-survey respondents indicated they plan to continue with the program next year.

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4. RHODE ISLAND PROGRAM

This section presents the findings from Navigant's process and impact evaluations of the ConnectedSolutions program in 2017 in Rhode Island. The remainder of this section is organized as follows:

- Section 4.1. Program Overview
- Section 4.2. Program Event Participation
- Section 4.3. Program Impacts
- Section 4.4. Key Findings

4.1 Program Overview

The ConnectedSolutions program—in partnership with Whisker Labs and in coordination with National Grid's Massachusetts and New York programs—aims to reduce the peak demand of residential and small commercial customers in National Grid Rhode Island's service territory using Wi-Fi thermostats. The program launched in 2016 and expanded in 2017 to include Nest thermostats, reaching nearly 850 customers. The program relies primarily on a BYOT implementation approach in which customers with one of the three thermostat types (ecobee, Honeywell, or Nest) were eligible to participate. The most notable change in 2017, beyond the inclusion of Nest thermostats, was a change in the DR dispatch criteria, resulting in a significant reduction in the number of DR events called.

Table 4-1. ConnectedSolutions Customer Incentives: Rhode Island

	ecobee	Honeywell	Nest
Sign-up and annual incentive	Year 1: $25 + $25 Year 2+: $25	Year 1: $25 + $25 Year 2+: $25	Year 1: $40 Year 2+: $25
Participation requirement	75% of events	75% of events	N/A

Source: National Grid

Table 4-2. ConnectedSolutions Event Attributes: Rhode Island

	ecobee	Honeywell	Nest
DR season	Jun 1 to Sept 30	Jun 1 to Sep 30	Jul 13 to Sep 30
Potential event days	Weekday Non-Holidays	Weekday Non-Holidays	Weekday Non-Holidays
Potential event times	10 a.m. to 8 p.m.	10 a.m. to 8 p.m.	10 a.m. to 8 p.m.
Maximum events in season	40	40	15
Maximum events in 1 week	N/A	N/A	3
Maximum events in 1 day	1	1	1
Event duration	3 hours	3 hours	3-4 hours
Pre-cooling setpoint adjustment	N/A	1°F to 2°F	Optimized
DR event setpoint adjustment	3°F	3°F	3°F

Source: National Grid

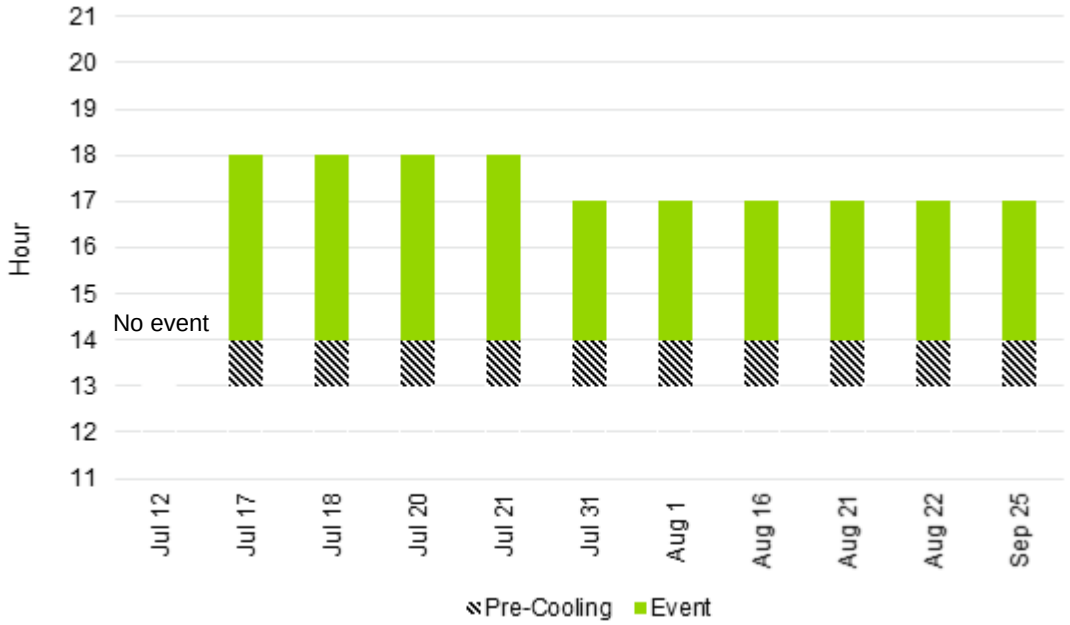
Figure 4-1 and Figure 4-2 show the timing and duration of each of the events. For ecobee and Honeywell, all 11 events began at 2 p.m. and ended at 5 p.m. For Nest, all 10 events began at 2 p.m., but the first four events lasted 4 hours rather than 3 hours.

Figure 4-1. Timing of ConnectedSolutions Events in Rhode Island – ecobee and Honeywell

*ecobee thermostats do not have pre-cooling

Source: Navigant analysis

Figure 4-2. Timing of ConnectedSolutions Events in Rhode Island – Nest

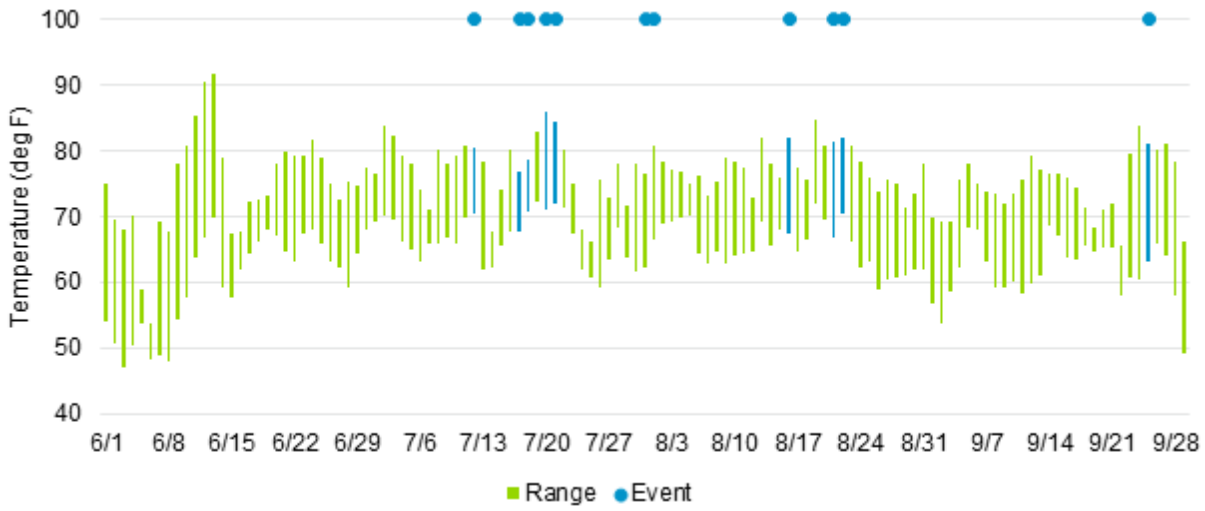


Pre-cooling for Nest thermostats is optimized based on the thermal characteristics of the home.

Source: Navigant analysis.

DR events were called on days when the average high temperature exceeded 77°F but after mid-June, the average high temperature never exceeded 86°F (Figure 4-3).

Figure 4-3. Average Daily Temperature Range: Rhode Island



Bars represent the daily average high and low outdoor temperature for all devices.
Source: Navigant analysis NOAA temperature data

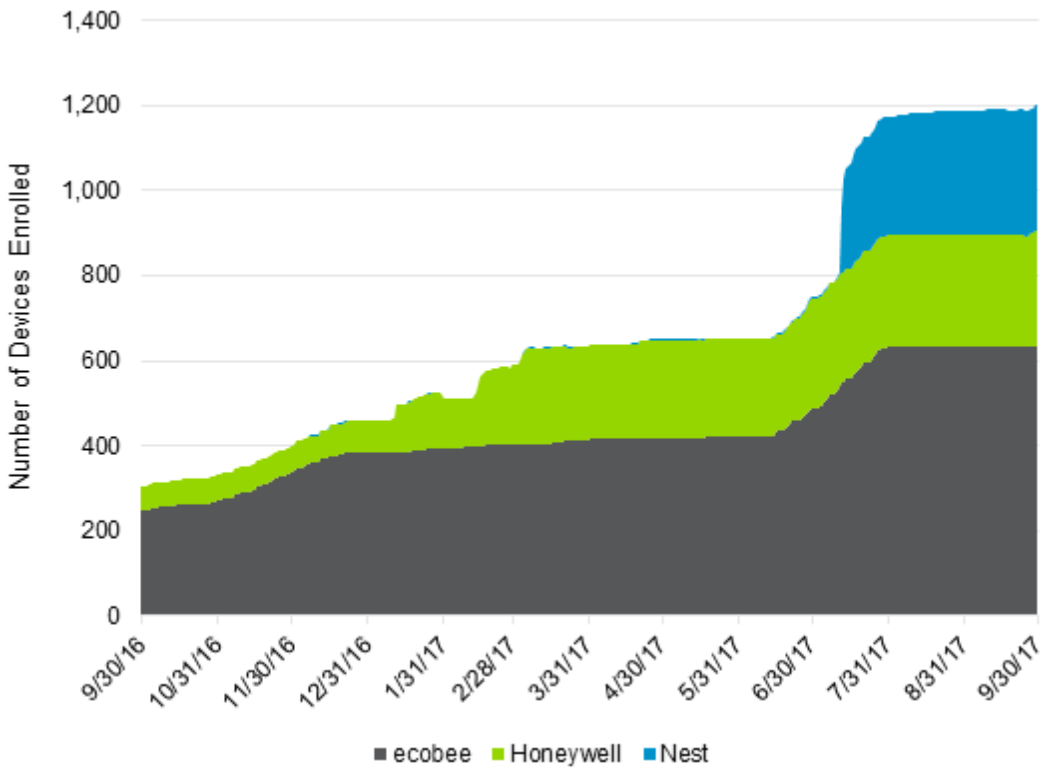
The average outdoor temperature for ecobee and Honeywell events in 2016 as 81.2°F and 80.5°F in 2017. In 2016, 12 of 29 events had average outdoor temperatures <80°F, whereas in 2017 3 of the modeled events had average outdoor temperatures <80°F. In both 2016 and 2017 no events occurred for these thermostats when outdoor event temperature averaged ≥90°F.

The average outdoor temperature for Nest events in 2016 as 84.5°F and 83.4°F in 2017.[23] In 2016, 3 of 13 events had average outdoor temperatures <80°F, whereas no events had average outdoor temperatures <80°F in 2017. In 2016 1 of 13 events had average outdoor temperatures ≥90°F, and in 2017 there were no events.

As of September 30, 2016, there were 849 customers and 1,201 thermostats enrolled in the ConnectedSolutions demonstration project in Rhode Island. Figure 4-4 shows the number of enrolled thermostats since the end of the 2017 DR season.

[23] The Nest statistics are for Massachusetts due to the late deployment of the experimental design and insufficient Rhode Island data.

Figure 4-4. Number of Enrolled Thermostats: Rhode Island



Source: Navigant analysis of customer enrollment data

Table 4-3 shows the number of thermostats and customers enrolled in the ConnectedSolutions Rhode Island program through September 30, 2017.

Table 4-3. Number of Enrolled Thermostats at End of DR Season: Rhode Island

Thermostat Type	Thermostats	Customers	Thermostats per Customer
ecobee	632	545	1.2
Honeywell	275	181	1.5
Nest	294	214	1.4
Total	**1,201**	**849**	**1.4**

Source: Navigant analysis of customer enrollment data

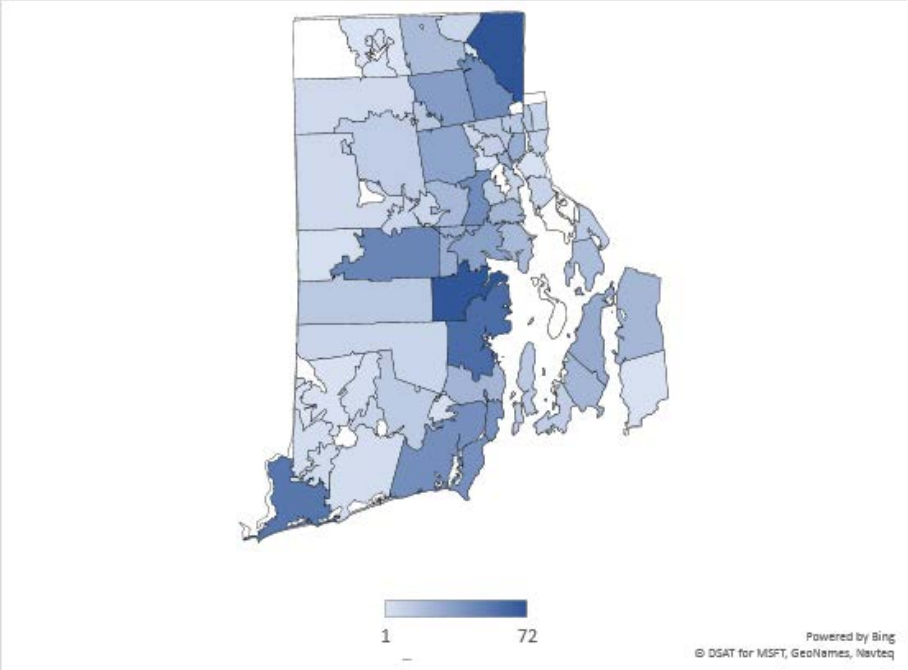
National Grid implemented the ConnectedSolutions demonstration project in 2017 using experimental design such that the DR algorithm was only initiated on half of the enrolled devices on a given event day. Customers that enrolled in the program were randomly assigned to group A, B, C, or D. For each event, two groups were called for the DR event while the remaining two served as the control group. Table 4-4 presents the DR dispatch protocol. The experimental design was not implemented for events until July 18 for ecobee and Honeywell and August 16 for Nest.

Table 4-4. Groups Assigned to Treatment and Control by Event: Rhode Island

DR Event	ecobee and Honeywell		Nest	
	Treatment	Control	Treatment	Control
Jul 12	N/A	N/A	N/A	N/A
Jul 17	N/A	N/A	N/A	N/A
Jul 18	A B	C D	N/A	N/A
Jul 20	B C	D A	N/A	N/A
Jul 21	C D	A B	N/A	N/A
Jul 31	D A	B C	N/A	N/A
Aug 1	A C	B D	N/A	N/A
Aug 16	B D	A C	B D	A C
Aug 21	A B	C D	A B	C D
Aug 22	B C	D A	B C	D A
Sep 25	C D	A B	C D	A B

Figure 4-5 presents the location of thermostats enrolled as of September 30, 2017. The ConnectedSolutions program includes thermostats from nearly every community served by National Grid.

Figure 4-5. Geographic Distribution of ConnectedSolutions: Rhode Island

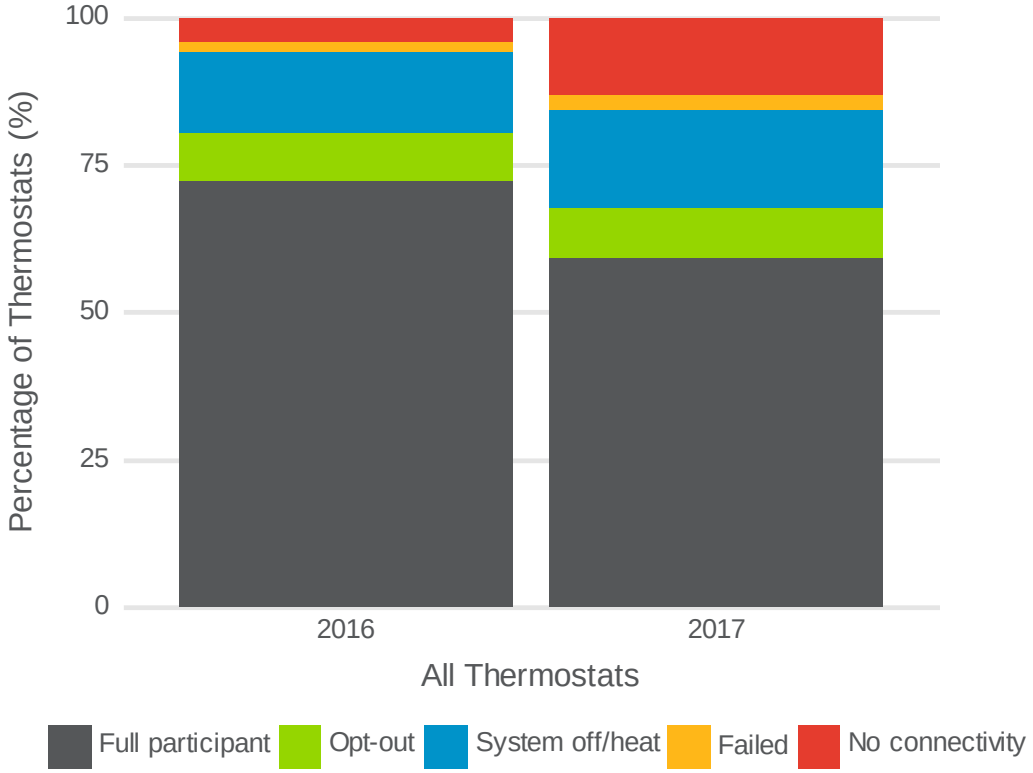


Source: Navigant analysis

4.2 Program Event Participation

To study customer acceptance of DR events, Navigant analyzed thermostat telemetry data on event days to characterize the device-level participation status. Figure 4-6 represents the average participation across all events for all devices in the ConnectedSolutions program for the 2016 and 2017 DR seasons. In 2017, 59% of thermostats fully participated in events, on average. As shown, customers have several reasons for not participating in DR events, including opting out of an event, the air conditioning system being in either off or heat mode, the device failing to receive the DR signal, or a connectivity issue. Air conditioning systems in off or heat mode (16%) are the primary reason for devices not participating in events, which is likely due to the cooler weather immediately preceding some events in 2017. There were also many devices with no connectivity (13%). Opt outs (8%) and devices that failed to receive the DR signal (3%) had smaller impacts.

Figure 4-6. Average Participation Across all Events in Rhode Island: 2016 vs. 2017



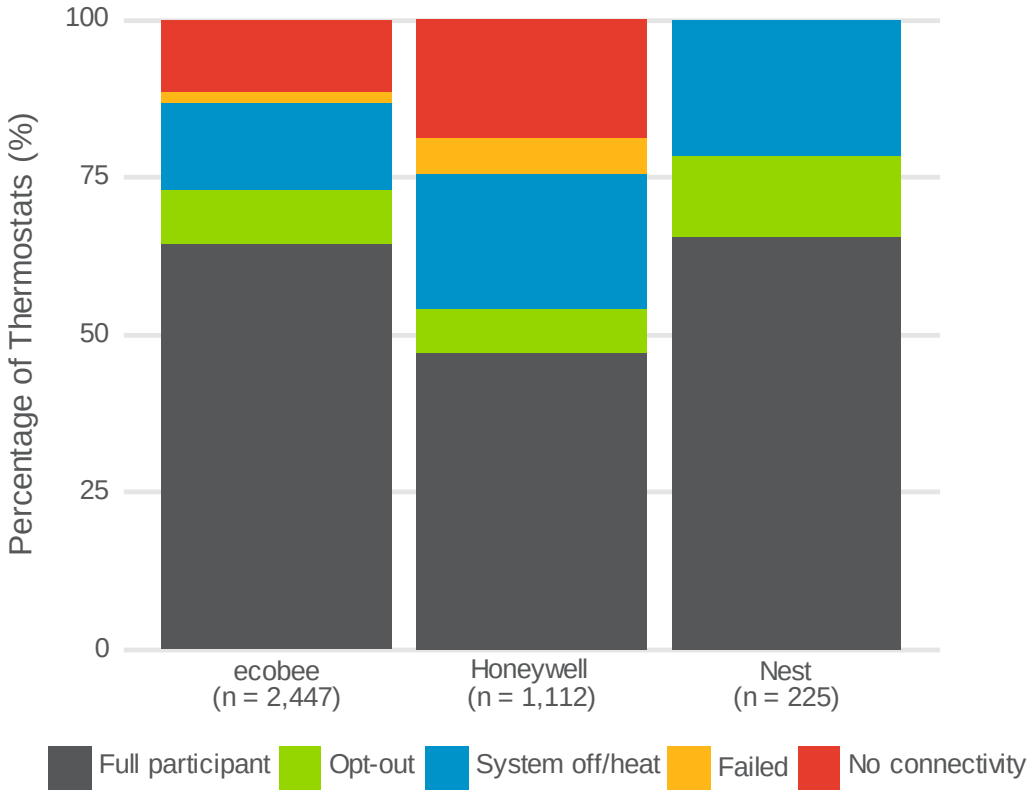
Source: Navigant analysis

Figure 4-7 shows average participation by thermostat type.[24] On average, 64% of ecobee, 47% of Honeywell, and 65% of Nest thermostats fully participated in the events. As shown, there are considerable differences in the reasons for not participating in an event based on the type of device. Opt-out rates are highest for Nest (13%), followed by ecobee (9%) and Honeywell (7%). Process evaluation results suggest the higher opt-out rates for Nest may be attributed to the incentive structure and device usability (i.e., the method used to opt out). The rate of air conditioning systems in off or heat mode is high for all three devices types: 14% for ecobee, 22% for Nest, and 22% for Honeywell. Rates of failed devices

[24] Refer to Appendix C.2 for participation status by event for each of the three thermostat types.

were low across thermostats, with the highest seen by Honeywell devices (6%). Nest thermostats had no connectivity issues, while ecobee and Honeywell had high rates (12% and 19%, respectively).

Figure 4-7. Average Participation Across All Events: Rhode Island



Note that *n* represents the total instances of thermostat participation during the DR season for each thermostat type.

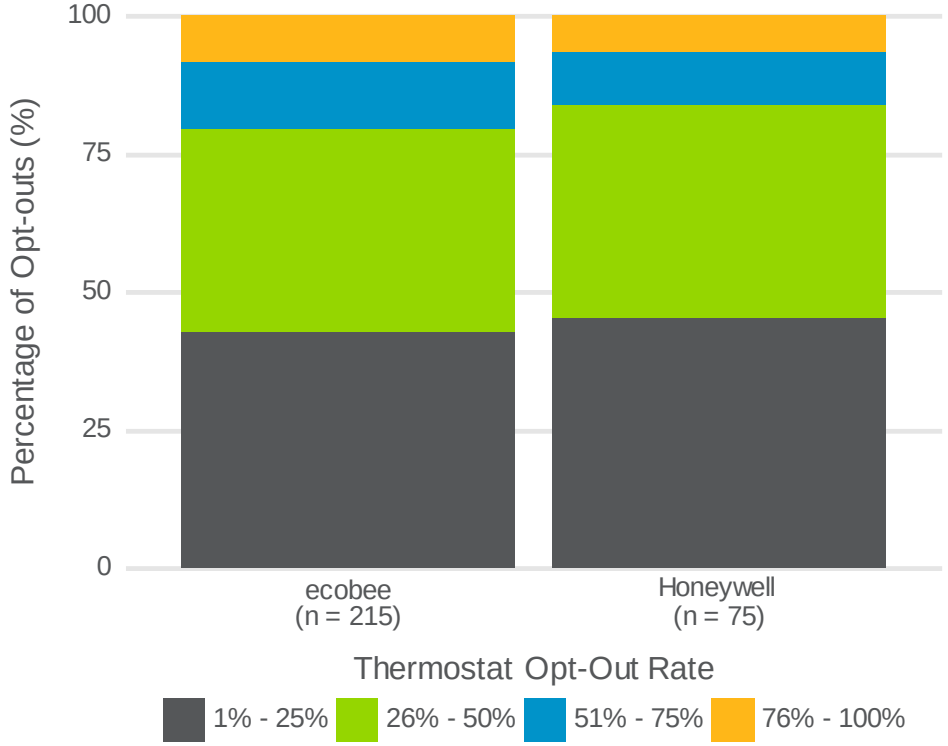
Source: Navigant analysis

To further study whether higher opt-out rates were due to participant fatigue, Navigant investigated the timing of opt outs to determine if a greater percentage occurred toward the end of an event. The average percentage of opt outs was higher in hours 2 and 3 (2.9% and 2.5%) compared to hour 1 (1.8%), providing some evidence of participation fatigue. Navigant also investigated whether opt-out rates correlated with the frequency of events, day of the week, or temperature and found that both frequency of events and higher temperatures may have contributed to higher opt-out rates during DR events though the sample sizes were small.

Navigant further analyzed opt-out rates to assess whether they can be attributed to specific customers persistently opting out of every event. The evaluation team classified individual thermostat opt outs into categories based on the number of times each thermostat opted out compared to the total number of events the thermostat was enrolled in. The total number of opt outs for each category was summed and then divided by the total number of opt outs for each thermostat type during the entire DR season.

Figure 4-8 presents the results of this analysis and indicates there were some ecobee and Honeywell participants who frequently opted out of events. However, most ecobee and Honeywell opt outs are accounted for by devices that opt out of less than 50% of events (green and grey bars). A total of eight ecobee and two Honeywell devices opted out of every event.

Figure 4-8. Percentage of Total Opt-Outs by Thermostat Opt-Out Rates: Rhode Island



Nest is excluded because they had few events and variable participation, with about 30 devices called on August 16, 21, and 22, and about 120 devices called on September 25, 2017.

Note that *n* represents the total number of thermostat opt outs during the DR season for each thermostat type.

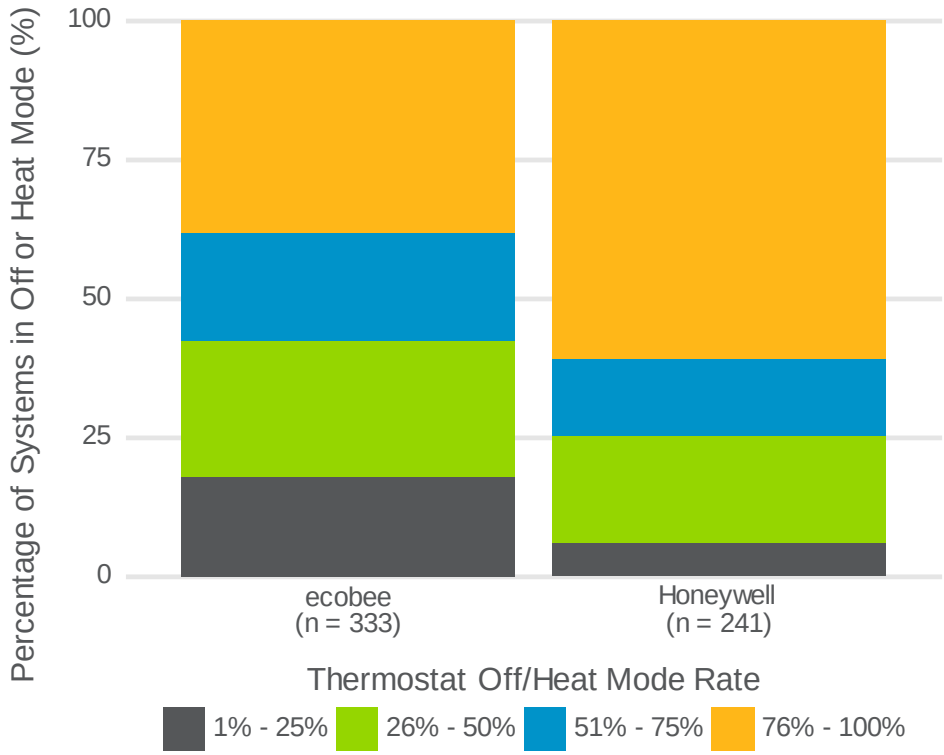
Source: Navigant analysis

Navigant performed a similar analysis to assess whether there were some air conditioning systems that were persistently in off or heat mode, devices that persistently failed to receive the DR signal, or devices that had persistent connectivity issues. Figure 4-9 through Figure 4-11 present these results.

Figure 4-9 shows some participants frequently had their air conditioning systems in off or heat mode and represent most instances when air conditioning systems were in off or heat mode. For ecobee and Honeywell, between 38% and 61% of all instances of systems in off or heat mode were caused by devices that were not cooling for at least 75% of events (yellow bar). A total of 31 ecobee devices and 29 Honeywell devices were never in cooling mode during an event.[25]

[25] 8 of the 31 ecobee devices and 15 of the 29 Honeywell devices were never in cooling mode during the summer season.

Figure 4-9. Percentage of Thermostats in Off or Heat Mode by Rate of Thermostats in Off or Heat Mode: Rhode Island



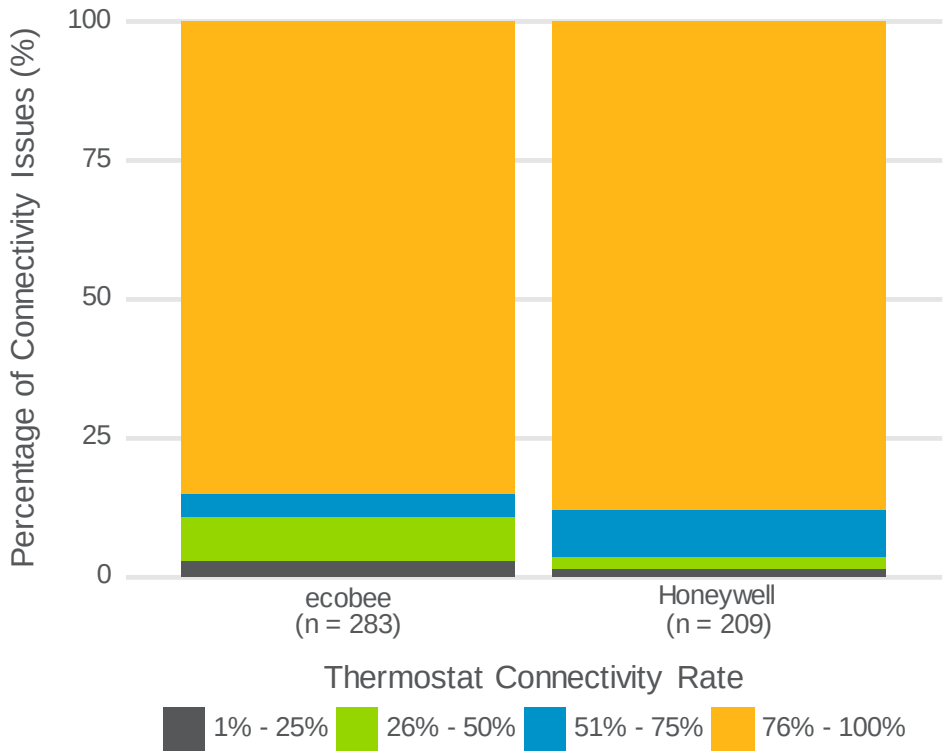
Nest is excluded because they had few events and variable participation, with about 30 devices called on August 16, 21, and 22, and about 120 devices called on September 25, 2017.

Note that *n* represents the total instances of systems in off/heat mode during the DR season for each thermostat type.

Source: Navigant analysis

Figure 4-10 shows that devices that experienced connectivity issues during most events account for nearly all of the connectivity issues for ecobee and Honeywell. Nearly 90% of ecobee and Honeywell connectivity issues were accounted for by devices with issues for at least three-quarters of events (yellow bar). A total of 54 ecobee devices and 44 Honeywell devices experienced connectivity issues for all events.

Figure 4-10. Percentage of Total Connectivity Issues by Thermostat Connectivity Rate: Rhode Island



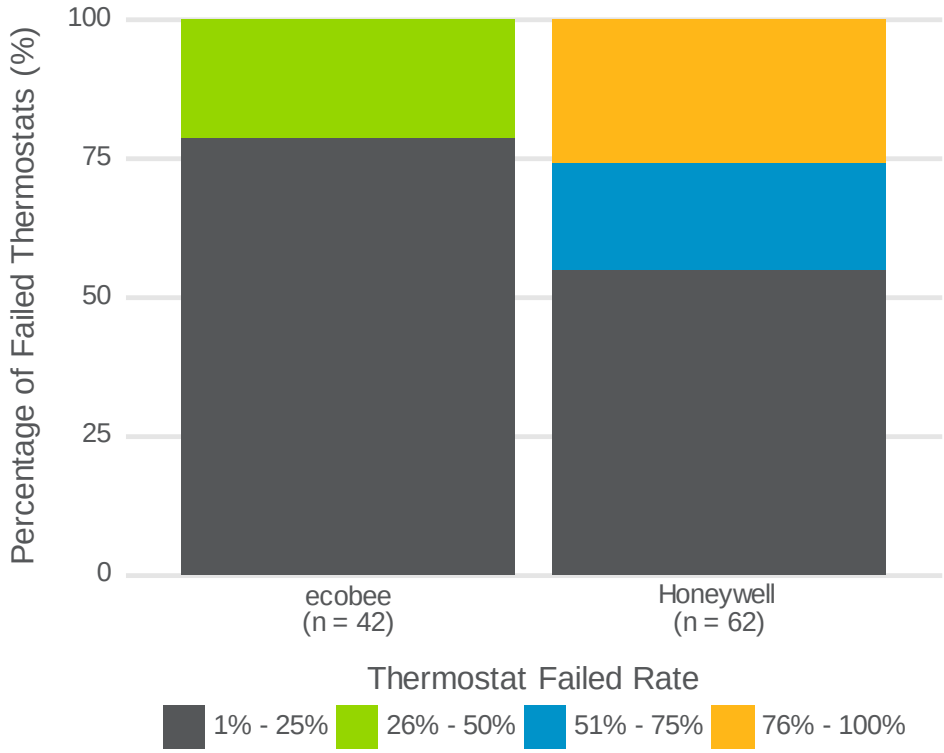
Nest is excluded because they had few devices participate in 2017. Of the events evaluated, there were zero Nest devices with connectivity issues.

Note that *n* represents the total instances of no connectivity during the DR season for each thermostat type.

Source: Navigant analysis

Figure 4-11 shows devices failing to receive the event notification during most events represent the minority of DR message failures, especially for ecobee. For Honeywell, almost half of all notification failures were caused by devices that failed during at least half of all events. A total of zero ecobee devices and only two Honeywell devices failed during every event.

Figure 4-11. Percentage of Failed Thermostats by Thermostat Failed Rate: Rhode Island



Nest is excluded because they had few devices participate in 2017. Of the events evaluated, there were zero Nest devices that failed.

Note that *n* represents the total number of event notification failures during the DR season for each thermostat type.

Source: Navigant analysis

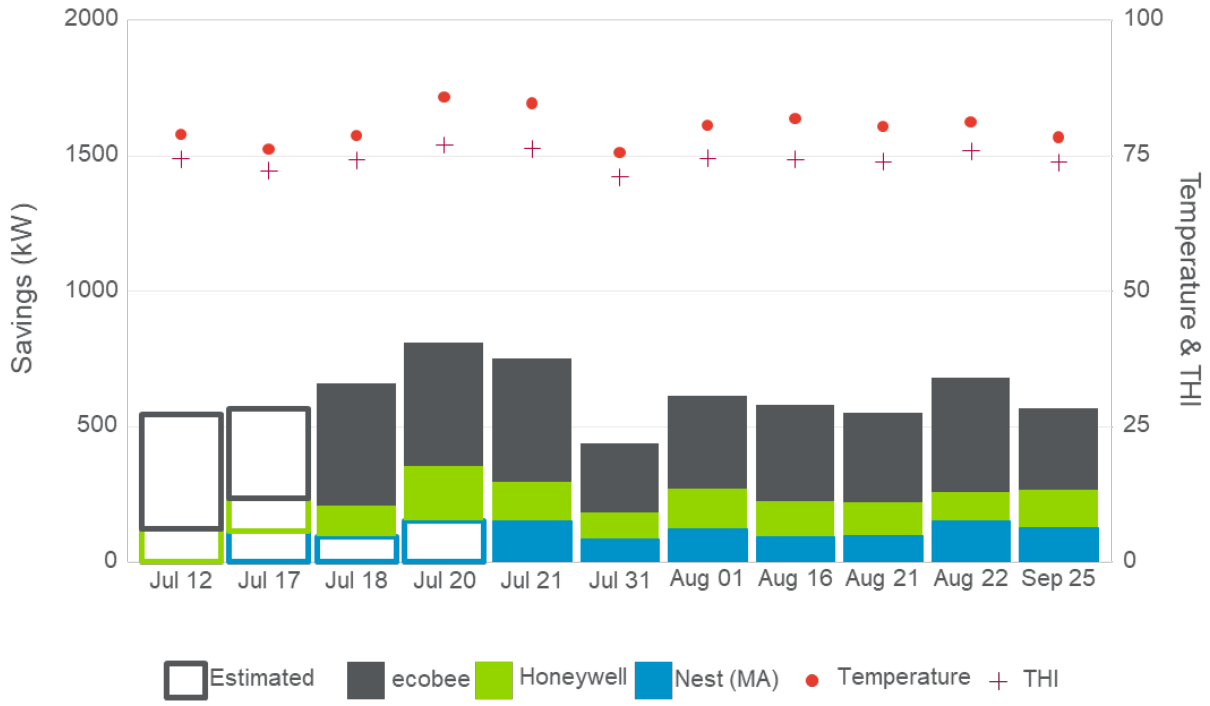
4.3 Program Impacts

4.3.1 2017 Program Savings

Figure 4-12 presents the total demand reduction for the ConnectedSolutions program by event. The maximum kW reduction occurred on July 20, 2017, with a total DR of 809 kW. Higher savings is correlated with higher temperature and the THI. The 2017 ISO-NE system peak was on June 13, 2017. Navigant estimates demand savings of 534 kW could have been achieved had the program called an event that day.[26]

[26] The estimate is calculated as the average demand savings for the most similar event day *x* the number of total enrolled devices at the end of the season.

Figure 4-12. Total Savings by Event and Thermostat Type: Rhode Island



Note: Total savings is the sum of average demand savings by event *x* number of total enrolled devices at the end of the season for each thermostat type. Estimated savings were calculated using similar event day demand savings; paired event days are listed in Appendix B.2.

Source: Navigant analysis

Table 4-5 shows the summary of program impacts for the 2017 DR season, assuming end-of-season enrollment. The table contains the average and maximum impact for the entire season, as well as energy savings.

Table 4-5. Summary of 2017 Program Savings: Rhode Island

	Total
Average demand reduction per event	616 kW
Maximum demand reduction per event	809 kW
Average energy savings per event	873 kWh

Source: Navigant analysis

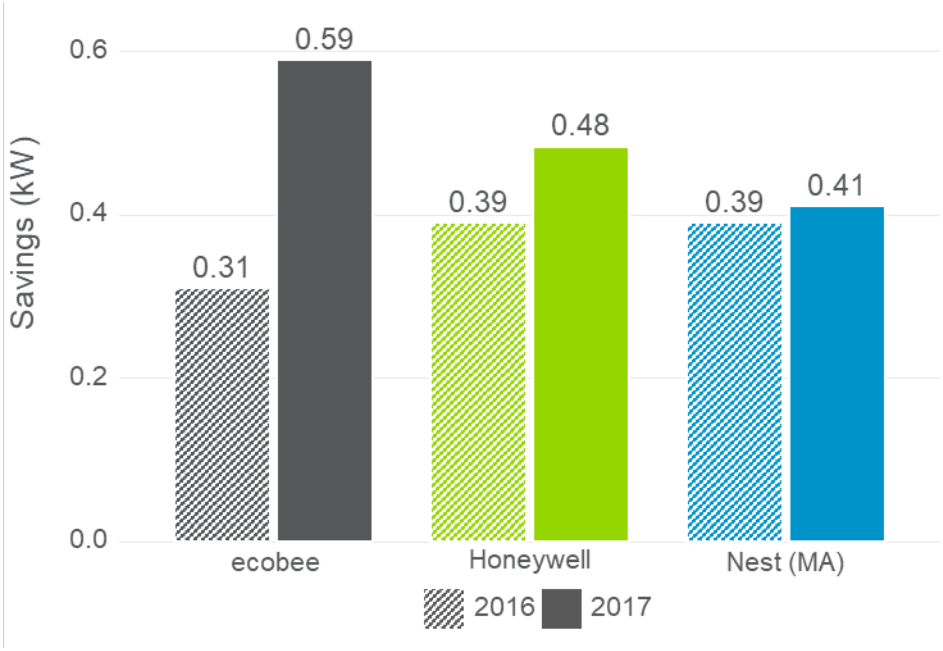
4.3.2 Average Impacts

Navigant estimated the ATE per device, which included all enrolled devices regardless of participation status. This estimate reflects actual impacts, acknowledging a portion of devices will opt out, or have their air conditioning systems in off or heat mode. Average demand impacts varied by thermostat model, with the ecobee model achieving an average DR of 0.59 kW per event, the Honeywell model achieving 0.48 kW per event, and the Nest model achieving 0.41 kW per event (Figure 4-13).

The average demand savings per thermostat increased from 0.33 kW to 0.52 kW per thermostat, an increase of 60%, likely the result of a combination of factors:

- Setpoint adjustment increased from 2°F to 3°F for ecobee and Honeywell in 2017
- Events were shorter on average (3.0 hours in 2017 vs. 3.7 hours in 2016)

Figure 4-13. Average ATE per Device for All Events: Rhode Island

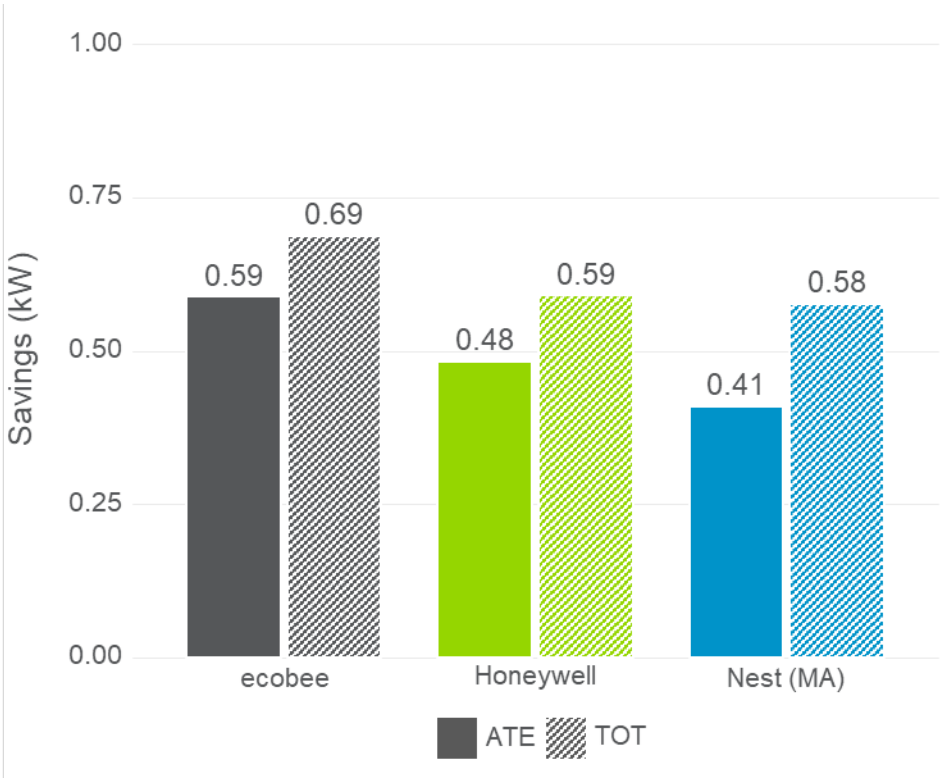


Note: Nest was not offered in Rhode Island in 2016, and Nest impacts were estimated using Massachusetts data due to late deployment of the experimental design and insufficient Rhode Island data.

Source: Navigant analysis

Since the ATE included opt-outs and systems in off/heat, which vary by thermostat type, Navigant also estimated the TOT per device, which only includes thermostats in the full participant category. Figure 4-14 displays both the ATE and TOT by thermostat type, revealing higher TOT average impacts. The variance in average TOT impacts was likely due to differences in pre-cooling or customer attributes. Both the Honeywell and Nest thermostats pre-cooled prior to DR events, which was not a feature of the ecobee thermostat. Pre-cooling can increase DR impacts by lengthening the time it takes for a home to reach the elevated setpoint temperature, reducing overall air conditioning runtime. However, despite the lack of pre-cooling, ecobee achieved the highest average TOT impacts.

Figure 4-14. Average ATE vs. TOT per Device for All Events: Rhode Island



Note: See Appendix A.2 for a list of modeled events included in the summer average. Nest impacts are estimated using Massachusetts data due to late deployment of the experimental design and insufficient Rhode Island data.
Source: Navigant analysis

Table 4-6 displays a summary of the average impacts (ATE) and full participation impacts (TOT) by kW and as a percent of cooling load for each thermostat type. Impacts ranged from 59% to 61% of cooling load. Per device kW impacts are partially a function of the baseline. Device types with a higher baseline tend to have higher kW impacts.[27]

[27] Impacts within device types can differ between Massachusetts and Rhode Island due to differences in baseline usage. For example, baseline kW for ecobee devices is 0.72 kW in Massachusetts and 0.97 kW in Rhode Island. Thus, the average impact per ecobee device is higher in Rhode Island.

Table 4-6. ATE and TOT Summary: Rhode Island

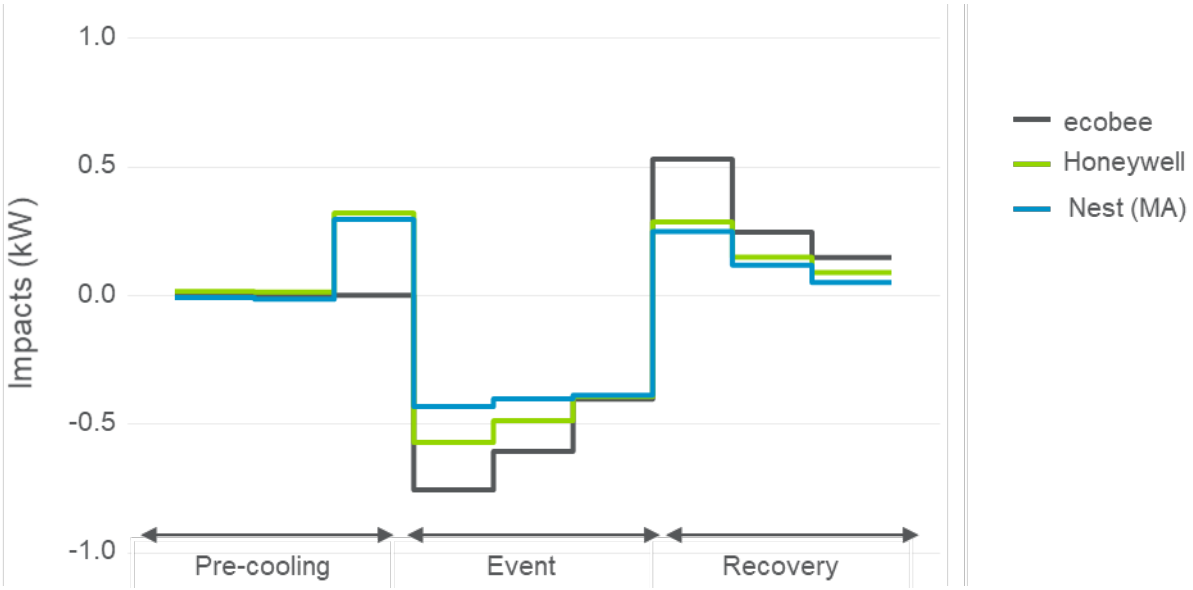
		ecobee	Honeywell	Nest
Enrolled thermostats on September 30		632	275	1,201
Average ATE	Savings per thermostat (kW)	0.59	0.48	0.41*
	Percent savings	61%	59%	61%*
	Baseline per thermostat (kW)	0.97	0.81	0.68*
Average TOT	Savings per thermostat (kW)	0.69	0.59	0.58*
	Percent savings	66%	62%	81%*
	Baseline per thermostat (kW)	1.04	0.95	0.71*

Note: See Appendix A.2 for a list of events included in the summer average. ATE includes thermostats in the full participant, opt-out, and system off/heat categories. TOT includes only full participants.
* Result from Massachusetts
Source: Navigant analysis

4.3.2.1 Average Hourly Impacts

The previous section presented average impacts—i.e., the average of hourly impacts over the duration of the event. In this section, Navigant presents the hourly impacts for both the event period and for the pre-cooling and recovery periods. The pre-cooling period included the 3 hours preceding an event, while the recovery period covered the 3 hours immediately following an event. Figure 4-15 displays average hourly impacts. Of note, the largest impacts were observed during the final pre-cooling interval (for the Honeywell and Nest devices, which have pre-cooling) and the first intervals during the event and recovery periods. Impacts during the event were largest during the first hour and steadily degrade. This is a common feature of thermostat DR programs where indoor air temperatures increase throughout the duration of the event, resulting in increased cooling loads. Relative to Honeywell and Nest, the ecobee thermostat's impacts degrade at a faster rate and experience a larger recovery peak as a result of not offering pre-cooling.

Figure 4-15. Average Hourly Impacts for All Events, ATE: Rhode Island



Note: Nest impacts are estimated using Massachusetts data due to late deployment of the experimental design and insufficient Rhode Island data.
Source: Navigant analysis

Table 4-7 summarizes the average impact (ATE) during the pre-cooling, event, and recovery periods by thermostat type, as well as the maximum hourly impact. One thing to note is the increase in (maximum) demand during the pre-cooling period for the Honeywell and Nest thermostats (the ecobee does not pre-cool). Average impacts match those presented in Figure 4-15, and the maximum hourly impact across thermostat models exhibits similar differences (Nest with the smallest impact and ecobee with the largest). Finally, an increase in demand during the recovery period was observed for all thermostat models, with lower maximum hourly impacts for the Honeywell and Nest thermostats due to pre-cooling. Navigant also reports energy impacts, which show a reduction in energy usage during the pre-cooling, event, and recovery periods across all thermostat models. This energy reduction is smallest for the Honeywell thermostat.

Table 4-7. Summary of Seasonal Impacts (ATE) by Period: Rhode Island

	Pre-cooling (kW)	Event (kW)	Recovery (kW)	Energy (kWh)
ecobee				
Average impact	-	-0.59	0.31	-0.85
Maximum hourly impact (average)	-	-0.76	0.53	N/A
Maximum hourly impact (maximum)	-	-1.02	0.68	
Honeywell				
Average impact	0.12	-0.48	0.18	-0.58
Maximum hourly impact (average)	0.32	-0.58	0.28	N/A
Maximum hourly impact (maximum)	0.56	-1.01	0.52	
Nest (Massachusetts)				
Average impact	0.09	-0.41	0.14	-0.60
Maximum hourly impact (average)	0.30	-0.45	0.25	N/A
Maximum hourly impact (maximum)	0.53	-0.65	0.41	

* Pre-cooling and recovery periods are calculated using 3 hours.

Note: Nest impacts are estimated using Massachusetts data due to late deployment of the experimental design and insufficient Rhode Island data.

Source: Navigant analysis

4.4 Key Findings

National Grid Rhode Island's ConnectedSolutions program was successful in testing the effectiveness of three Wi-Fi thermostats as a DR-enabling technology. Navigant's evaluation resulted in several key findings and recommendations (described in Table 4-8) that should inform future program planning.

Table 4-8. Key Findings: Rhode Island

Category	Key Findings
Technology and Program Offering	• On average, 59% of thermostats fully participated during DR events, down from 72% in 2016. • Customers opting out, connectivity issues, failing to receive a DR signal, or a thermostat not in "cool" mode are all factors why 100% full participation was not achieved. • The participation status varied by thermostat manufacturer – ~64% of ecobee, ~47% of Honeywell, and ~65% of Nest thermostats fully participated.
Program Design and Implementation	• ecobee and Honeywell thermostats had a large percentage of thermostats with connectivity issues (12% and 19% per event), and Nest thermostats had a large percentage of opt outs (13% per event). • The percentage of Honeywell connectivity issues increased from 7% in 2016 to 19% in 2017. • The percentage of ecobee connectivity issues increased from 3% in 2016 to 12% in 2017. • The number of air conditioning systems in off/heat mode averaged 16% across thermostat types, compared to about 14% in 2016.
DR Impacts	• Average demand savings per thermostat were 0.59 kW (61% savings) for ecobee, 0.48 kW (59% savings) for Honeywell, and 0.41 kW (61% savings) for Nest. These kW impacts are slightly higher than in 2016. • Average demand savings per event was 616 kW, with maximum event savings of 809 kW. • Average energy savings per thermostat were 0.85 kWh for ecobee, 0.58 kWh for Honeywell, and 0.60 kWh for Nest.
Scalability	• The overwhelming majority of 2016 participants continued to participate in the program 2017. • Customer enrollment continued to grow during 2017 with the addition of Nest thermostats. • From 2016, total device enrollment increased by 298%.

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5. CONCLUSIONS

Navigant's evaluation of the Massachusetts and Rhode Island ConnectedSolutions program found it was successful in testing the effectiveness of thermostats as a residential DR technology and customer acceptance of the program offering. The evaluation shows promise for thermostats as a residential DR technology, though important differences exist across different thermostat models and customer acceptance has not been adequately tested due to the relatively mild temperatures on event days.[28]

The evaluation of the ConnectedSolutions program in Massachusetts and Rhode Island resulted in several cross-cutting key findings, considerations, and recommendations (described in Table 5-1, Table 5-2 and Table 5-3) that should inform future program planning.

Table 5-1. Key Findings

Category	Key Findings
Technology and Program Offering	• About 60%-65% of enrolled thermostats fully participated in each event. • Customers opting out, connectivity issues, failing to receive a DR signal, or a thermostat not in "cool" mode are all factors why 100% full participation was not achieved. • More than 75% of connectivity issues were associated with a relatively small number of thermostats (ecobee and Honeywell).
Program Design and Implementation	• About half of survey respondents follow a thermostat temperature schedule and half only turn their air conditioning on when needed. *[Massachusetts only]* • 20% of Honeywell and ecobee and 40% of Nest survey respondents put their thermostats in off or heating mode when no one is at home. *[Massachusetts only]* • Opt-out rates were greater for Nest thermostats than ecobee and Honeywell. • Approximately 25% of opt outs were associated with a relatively small number of thermostats that frequently opt out (serial opt outers – Nest). • Majority of Honeywell and ecobee survey respondents indicated they were influenced not to opt out by the participation incentive. *[Massachusetts only]* • ISO-NE system peak occurred on June 13 between4 p.m. and 5 p.m., before the DR program was operational.

[28] Although called on some of the warmest days during the summer of 2017, average event temperatures did not exceed 87°F in Massachusetts or 86°F in Rhode Island during 2017.

Category	Key Findings
DR Impacts	• Demand savings in 2017 are greater than in 2016, although a high percentage of customers with thermostats in off/heat mode reduced savings for all thermostat types. • There are energy savings when DR events are called, including when impacts from the pre-cool and recovery period are included. • The average demand savings per thermostat is a function of the baseline – thermostats types with a higher baseline tend to have higher demand savings.[29] • Pre-cooling enables less degradation of demand savings during the event and lower demand during the recovery period.
Scalability	• The overwhelming majority of 2016 participants continued to participate in the program in 2017. • From 2016, total device enrollment increased by 168% in Massachusetts and 298% in Rhode Island. • Customer satisfaction remained strong and 85% of post-survey respondents indicated they plan to continue with the program next year. *[Massachusetts only]* • Continue to send advance notification while providing flexibility to customers to tailor event notifications (e.g., text messages or to more than one email address). • Collaborate with thermostat vendors on marketing campaigns for ConnectedSolutions and seek to strengthen the role of ecobee and Honeywell in program marketing.

Table 5-2. Considerations

Recommendations
• Consideration #1: The 2016 and 2017 summer seasons had relatively few hot event days; there was one event day for Nest thermostats above 90°F in 2016 and no event days for any thermostat type above 90°F in 2017. As a result, National Grid has not yet had the opportunity to test program performance under more extreme weather conditions and should conduct another evaluation of the DR program in 2018.

[29] Differences in the baseline between Massachusetts and Rhode Island drive the difference in the reported kW demand savings.

Table 5-3. Recommendations

Recommendations
• Recommendation #1: For 2017, National Grid should claim an average demand savings of 0.44 kW per thermostat in Massachusetts and 0.52 kW per thermostat in Rhode Island o Massachusetts: 0.48 kW per ecobee, 0.53 kW per Honeywell, and 0.41 kW per Nest[30] o Rhode Island: 0.59 kW per ecobee, 0.48 kW per Honeywell, and 0.41 kW per Nest[31]
• Recommendation #2: Remove thermostats that persistently opt out (i.e., consider implementing auto-unenroll functionality) and modify the Nest participation incentive structure to include a participation requirement
• Recommendation #3: Proactively monitor connectivity issues; remove thermostats with persistent connectivity issues; consider implementing an auto-unenroll functionality.

[30] Massachusetts: Average percent demand savings during events were 67% for ecobee, 65% for Honeywell, and 61% for Nest.

[31] Rhode Island: Average percent demand savings during events were 61% for ecobee, 59% for Honeywell, and 61% for Nest.

APPENDIX A. POPULATION OF THERMOSTATS ANALYZED

The National Grid ConnectedSolutions program included three thermostat types. Navigant received lists of enrolled devices and corresponding telemetry data. Before including thermostats in the thermostat usage assessment or impact analysis, Navigant excluded devices for specific reasons:

- **Commercial accounts:** The analysis only included residential customers
- **Multiple structure IDs or missing:** The thermostat could be not assigned to one property
- **Group assignment issue:** Either thermostat was not assigned to a group or two thermostats for the same customer were in different groups
- **Setpoint issues:** Identified significant number of instances for the same thermostat where there the observed run-time was not readily explained by the telemetry data
- **ZIP code issues:** An out-of-state ZIP was assigned to thermostat
- **Missing runtime data:** Telemetry data was missing for more than 10% of the event period

The count of enrolled thermostats and corresponding thermostats included in the impact analysis are provided for Massachusetts and Rhode Island in the sections that follow.

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A.1 Massachusetts

ecobee: Navigant's impact analysis included ~70% of the ecobee thermostats enrolled in the National Grid ConnectedSolutions program in Massachusetts.

Table A-1. ecobee Population and Thermostats Dropped: Massachusetts

	Jul 12	Jul 17	Jul 18	Jul 20	Jul 21	Jul 31	Aug 1	Aug 16	Aug 21	Aug 22	Sep 25
Enrolled devices	201	202	202	202	202	204	203	203	203	203	203
Total devices in data	201	201	201	201	201	201	201	201	201	201	201
Not yet enrolled or unknown enrollment status	5	4	4	4	4	2	2	2	2	1	0
Enrolled devices with telemetry data	196	197	197	197	197	199	199	199	199	200	201
Commercial accounts	10	10	10	10	10	10	10	10	10	10	10
Multiple structure IDs or missing	0	0	0	0	0	0	0	0	0	0	0
Group assignment issue	186	187	1	0	2	3	0	0	0	0	1
Setpoint issues	0	0	27	27	27	27	28	28	28	28	28
ZIP code issues	0	0	0	0	0	0	0	0	0	0	0
Missing runtime data	0	0	22	21	21	19	20	18	16	15	20
Total remaining	0	0	137	139	137	140	141	143	145	147	142
Not called (control)	0	0	73	69	64	69	63	77	76	76	77
Called	0	0	64	70	73	71	78	66	69	71	65

Source: Navigant analysis

Honeywell: Navigant's impact analysis included ~68% of the Honeywell thermostats enrolled in the National Grid ConnectedSolutions program in Massachusetts.

Table A-2. Honeywell Population and Thermostats Dropped: Massachusetts

	Jul 12	Jul 17	Jul 18	Jul 20	Jul 21	Jul 31	Aug 1	Aug 16	Aug 21	Aug 22	Sep 25
Enrolled devices	1026	1030	1028	1032	1038	1041	1042	1044	1048	1048	1040
Total devices in data	1007	1007	1007	1007	1007	1007	1007	1007	1007	1007	1007
Not yet enrolled or unknown enrollment status	25	22	22	20	19	17	16	15	12	12	0
Enrolled devices with telemetry data	982	985	985	987	988	990	991	992	995	995	1007
Commercial accounts	43	43	43	43	43	43	43	43	43	43	43
Multiple structure IDs or missing	0	0	0	0	0	0	0	0	0	0	0
Group assignment issue	939	942	14	6	5	5	8	0	1	2	2
Setpoint issues	0	0	21	21	21	21	21	21	21	21	22
ZIP code issues	0	0	0	0	0	0	0	0	0	0	0
Missing runtime data	0	0	215	184	189	261	229	216	216	214	245
Total remaining	0	0	692	733	730	660	690	712	714	715	695
Not called (control)	0	0	314	362	387	347	358	334	330	351	333
Called	0	0	378	371	343	313	332	378	384	364	362

Source: Navigant analysis

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Nest: Navigant's impact analysis included ~66% of the Nest thermostats enrolled in the National Grid ConnectedSolutions program in Massachusetts.

Table A-3. Nest Population and Thermostats Dropped: Massachusetts

	Jul 12	Jul 17	Jul 18	Jul 20	Jul 21	Jul 31	Aug 1	Aug 16	Aug 21	Aug 22	Sep 25
Enrolled devices	2612	2655	2655	2655	2655	2655	2655	3245	3330	3330	3435
Total devices in data	3085	3140	3145	3161	3172	3209	3209	3221	3228	3231	3242
Not yet enrolled or unknown enrollment status	640	682	690	705	718	756	758	611	532	453	467
Enrolled devices with telemetry data	2445	2458	2455	2456	2454	2453	2451	2610	2696	2778	2775
Commercial accounts	29	29	29	29	29	29	29	32	34	34	34
Multiple structure IDs or missing	14	13	12	11	12	13	13	18	18	21	29
Group assignment issue	2402	2416	2414	546	547	549	549	557	562	562	319
Setpoint issues	0	0	0	0	0	0	0	0	0	0	0
ZIP code issues	0	0	0	22	22	24	24	22	22	24	25
Missing runtime data	0	0	0	18	11	10	7	28	7	10	7
Total remaining	0	0	0	1830	1833	1828	1829	1953	2053	2127	2361
Not called (control)	0	0	0	2	933	916	912	911	972	1057	1068
Called	0	0	0	1828	900	912	917	1042	1081	1070	1293

Source: Navigant analysis

The thermostat usage assessment was limited to event days for which the experimental design was deployed as indicated in Table A-4.

Table A-4. Events Included in the Thermostat Usage Assessment: Massachusetts

DR Event	ecobee	Honeywell	Nest
Jul 12	Not Included	Not Included	Not Included
Jul 17	Not Included	Not Included	Not Included
Jul 18	Included	Included	Not Included
Jul 20	Included	Included	Not Included
Jul 21	Included	Included	Included
Jul 31	Included	Included	Included
Aug 1	Included	Included	Included
Aug 16	Included	Included	Included
Aug 21	Included	Included	Included
Aug 22	Included	Included	Included
Sep 25	Included	Included	Included

Source: Navigant analysis

Navigant modeled impacts for event days in which the experimental design was deployed. Summer average impacts only include modeled event days. For all other event days, impacts were estimated by selecting the most similar modeled event day. The list of similar event days is included in Appendix B.1.

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Table A-5. Events Modeled vs. Estimated for the Impact Analysis: Massachusetts

DR Event	ecobee	Honeywell	Nest
Jul 12	Estimated	Estimated	Estimated
Jul 17	Estimated	Estimated	Estimated
Jul 18	Modeled	Modeled	Estimated
Jul 20	Modeled	Modeled	Estimated
Jul 21	Modeled	Modeled	Modeled
Jul 31	Modeled	Modeled	Modeled
Aug 1	Modeled	Modeled	Modeled
Aug 16	Modeled	Modeled	Modeled
Aug 21	Modeled	Modeled	Modeled
Aug 22	Modeled	Modeled	Modeled
Sep 25	Modeled	Modeled	Modeled

Source: Navigant analysis

A.2 Rhode Island

ecobee: Navigant's impact analysis included ~81% of the ecobee thermostats enrolled in the National Grid ConnectedSolutions program in Rhode Island.

Table A-6. ecobee Population and Thermostats Dropped: Rhode Island

	Jul 12	Jul 17	Jul 18	Jul 20	Jul 21	Jul 31	Aug 1	Aug 16	Aug 21	Aug 22	Sep 25
Enrolled devices	547	565	575	588	597	632	632	633	634	634	633
Total devices in data	632	632	632	632	632	632	632	632	632	632	632
Not yet enrolled or unknown enrollment status	90	72	63	48	39	4	4	3	2	2	0
Enrolled devices with telemetry data	542	560	569	584	593	628	628	629	630	630	632
Commercial accounts	0	0	0	0	0	0	0	0	0	0	0
Multiple structure IDs or missing	0	0	0	0	0	0	0	0	0	0	0
Group assignment issue	542	560	31	36	39	58	60	2	2	2	4
Setpoint issues	0	0	17	17	17	17	17	17	17	17	17
ZIP code issues	0	0	0	0	0	0	0	0	0	0	0
Missing runtime data	0	0	68	74	73	71	76	69	70	71	79
Total remaining	0	0	453	457	464	482	475	541	541	540	532
Not called (control)	0	0	246	245	240	266	259	273	278	269	265
Called	0	0	207	212	224	216	216	268	263	271	267

Source: Navigant analysis

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Honeywell: Navigant analyzed ~62% of the Honeywell thermostats enrolled in the National Grid ConnectedSolutions program in Rhode Island.

Table A-7. Honeywell Population and Thermostats Dropped: Rhode Island

	Jul 12	Jul 17	Jul 18	Jul 20	Jul 21	Jul 31	Aug 1	Aug 16	Aug 21	Aug 22	Sep 25
Enrolled devices	261	261	261	264	264	264	264	266	266	266	262
Total devices in data	252	252	252	252	252	252	252	252	252	252	252
Not yet enrolled or unknown enrollment status	7	7	7	5	5	4	4	2	2	2	0
Enrolled devices with telemetry data	245	245	245	247	247	248	248	250	250	250	252
Commercial accounts	0	0	0	0	0	0	0	0	0	0	0
Multiple structure IDs or missing	0	0	0	0	0	0	0	0	0	0	0
Group assignment issue	245	245	0	2	2	1	2	0	0	0	2
Setpoint issues	0	0	1	1	1	1	1	1	1	1	1
ZIP code issues	0	0	0	0	0	0	0	0	0	0	0
Missing runtime data	0	0	76	81	79	103	84	72	77	77	89
Total remaining	0	0	168	163	165	143	161	177	172	172	160
Not called (control)	0	0	67	77	92	72	82	87	65	89	77
Called	0	0	101	86	73	71	79	90	107	83	83

Source: Navigant analysis

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Nest: Navigant analyzed the Massachusetts Nest thermostats as a proxy for the Rhode Island Nest thermostats because of the limited number of thermostats that were part of the experimental design.

Table A-8. Nest Population and Thermostats Dropped: Rhode Island

	Jul 12	Jul 17	Jul 18	Jul 20	Jul 21	Jul 31	Aug 1	Aug 16	Aug 21	Aug 22	Sep 25
Enrolled devices	0	208	208	208	208	208	208	284	289	289	294
Total devices in data	274	273	273	275	275	277	277	277	281	280	276
Not yet enrolled or unknown enrollment status	272	83	83	84	84	85	85	51	35	19	20
Enrolled devices with telemetry data	2	190	190	191	191	192	192	226	246	261	256
Commercial accounts	0	2	2	2	2	2	2	2	3	3	3
Multiple structure IDs or missing	0	0	0	0	0	1	0	0	0	0	0
Group assignment issue	2	188	188	189	189	189	190	188	188	188	95
Setpoint issues	0	0	0	0	0	0	0	0	0	0	0
ZIP code issues	0	0	0	0	0	0	0	0	0	0	0
Missing runtime data	0	0	0	0	0	0	0	0	0	0	0
Total remaining	0	0	0	0	0	0	0	36	55	70	158
Not called (control)	0	0	0	0	0	0	0	0	21	40	33

Source: Navigant analysis

The thermostat usage assessment was limited to event days for which the experimental design was deployed as indicated in Table A-9.

Table A-9. Events Included in the Thermostat Usage Assessment: Rhode Island

DR Event	ecobee	Honeywell	Nest
Jul 12	Not Included	Not Included	No Event
Jul 17	Not Included	Not Included	Not Included
Jul 18	Included	Included	Not Included
Jul 20	Included	Included	Not Included
Jul 21	Included	Included	Not Included
Jul 31	Included	Included	Not Included
Aug 1	Included	Included	Not Included
Aug 16	Included	Included	Included
Aug 21	Included	Included	Included
Aug 22	Included	Included	Included
Sep 25	Included	Included	Included

Source: Navigant analysis

Navigant modeled impacts for event days in which the experimental design was deployed. Summer average impacts only include modeled event days. For all other event days, impacts were estimated by selecting the most similar modeled event day. The list of similar event days is included in Appendix B.2.

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Table A-10. Events Modeled vs. Estimated for the Impact Analysis: Rhode Island

DR Event	ecobee	Honeywell	Nest
Jul 12	Estimated	Estimated	No Event
Jul 17	Estimated	Estimated	Estimated (Massachusetts)
Jul 18	Modeled	Modeled	Estimated (Massachusetts)
Jul 20	Modeled	Modeled	Estimated (Massachusetts)
Jul 21	Modeled	Modeled	Estimated (Massachusetts)
Jul 31	Modeled	Modeled	Estimated (Massachusetts)
Aug 1	Modeled	Modeled	Estimated (Massachusetts)
Aug 16	Modeled	Modeled	Estimated (Massachusetts)
Aug 21	Modeled	Modeled	Estimated (Massachusetts)
Aug 22	Modeled	Modeled	Estimated (Massachusetts)
Sep 25	Modeled	Modeled	Estimated (Massachusetts)

Source: Navigant analysis

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APPENDIX B. LIST OF PAIRED EVENT DAYS

Estimated days were paired to modeled event days based on average temperature and THI during the pre-event and event periods, as well as percent of devices in cool mode at the beginning of the event for each thermostat type.

B.1 Massachusetts

Table B-1. Estimate and Paired Event Days by Thermostat Type, Massachusetts

Estimated Day	Day Type	Paired Event Day	Event Temperature (Est | Pair)	Event THI (Est | Pair)	% Cool Mode (Est | Pair)
Ecobee					
6/13/2017	Peak Day	8/22/2017	90.5 | 84.4	80.2 | 78.1	88 | 86
7/12/2017	Event	8/22/2017	80.6 | 84.4	76.2 | 78.1	88 | 86
7/17/2017	Event	7/21/2017	82.2 | 85.1	75.8 | 76.2	87 | 86
7/19/2017	Peak Day	8/22/2017	85.9 | 84.4	78.4 | 78.1	87 | 86
9/27/2017	Peak Day	9/25/2017	82.9 | 82.6	77.3 | 76.6	82 | 80
Honeywell					
6/13/2017	Peak Day	8/22/2017	89.6 | 83.2	79.7 | 77.1	74 | 72
7/12/2017	Event	8/22/2017	80 | 83.2	75.5 | 77.1	73 | 72
7/17/2017	Event	8/22/2017	80.8 | 83.2	74.7 | 77.1	74 | 72
7/19/2017	Peak Day	7/21/2017	84.4 | 83.7	77.3 | 75.4	79 | 80
9/27/2017	Peak Day	9/25/2017	82.1 | 81.7	76.9 | 76	64 | 62
Nest					
6/13/2017	Peak Day	8/22/2017	90.6 | 83.9	80.4 | 77.9	87 | 84
7/12/2017	Event	8/1/2017	80.4 | 81.8	76.1 | 75.1	84 | 81
7/17/2017	Event	8/1/2017	81.5 | 81.8	75.4 | 75.1	83 | 81
7/18/2017	Event	8/21/2017	79.6 | 81.5	75.5 | 74.6	84 | 81
7/19/2017	Peak Day	8/22/2017	85.2 | 83.9	78.2 | 77.9	86 | 84
7/20/2017	Event	7/21/2017	85.8 | 84.4	78.0 | 75.8	87 | 86
9/27/2017	Peak Day	9/25/2017	82.8 | 82.4	77.7 | 76.6	79 | 77

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B.2 Rhode Island

Table B-2. Estimate and Paired Event Days by Thermostat Type, Rhode Island

Estimated Day	Day Type	Paired Event Day	Event Temperature (Est | Pair)	Event THI (Est | Pair)	% Cool Mode (Est | Pair)
Ecobee					
6/13/2017	Peak Day	8/22/2017	90.3 | 79.7	79.3 | 74.1	83 | 86
7/12/2017	Event	8/22/2017	78.1 | 79.7	73.4 | 74.1	88 | 86
7/17/2017	Event	8/21/2017	75.5 | 79.3	71.4 | 72.9	84 | 83
7/19/2017	Peak Day	8/22/2017	81 | 79.7	74.8 | 74.1	88 | 86
9/27/2017	Peak Day	8/1/2017	78.8 | 78.9	75 | 73	77 | 78
Honeywell					
6/13/2017	Peak Day	8/1/2017	89 | 79.2	78.6 | 73.4	65 | 69
7/12/2017	Event	8/21/2017	78.4 | 79.6	73.8 | 73.2	75 | 74
7/17/2017	Event	8/21/2017	75.7 | 79.6	71.7 | 73.2	74 | 74
7/19/2017	Peak Day	7/21/2017	81.4 | 82.5	75.2 | 74.8	77 | 79
9/27/2017	Peak Day	8/1/2017	78.7 | 79.2	74.9 | 73.4	67 | 69
Nest same as Massachusetts					

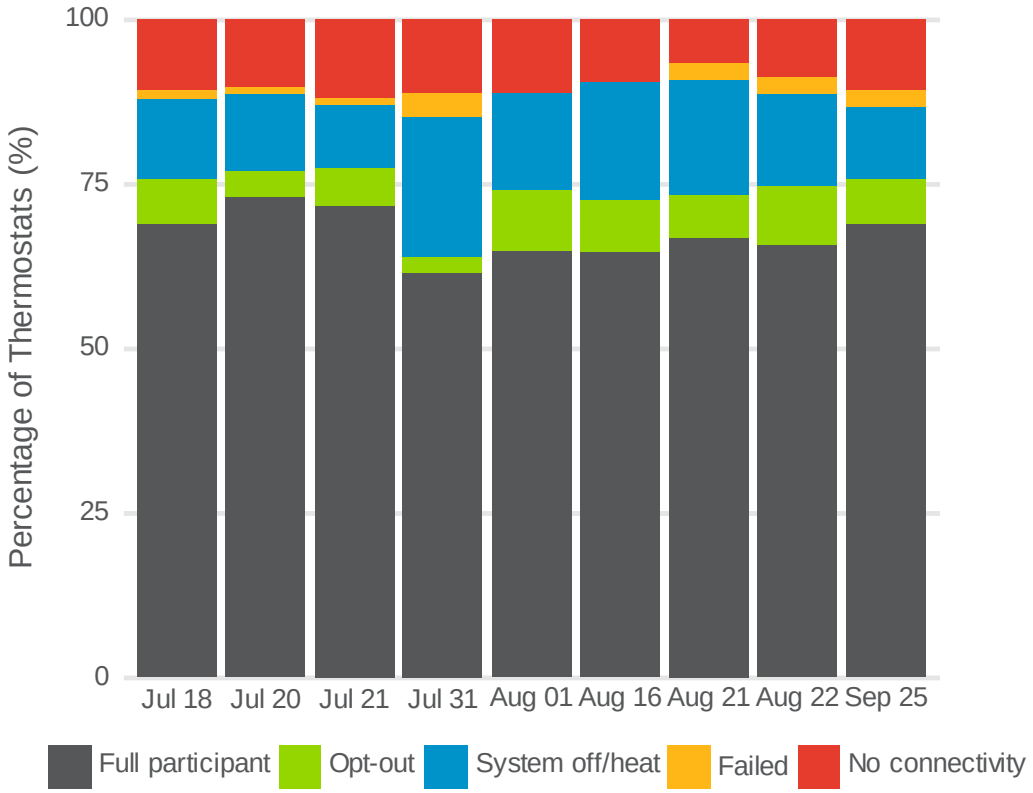
APPENDIX C. PARTICIPATION PER EVENT

Earlier, we provided the participation across the DR season by thermostat type for Massachusetts and Rhode Island. This section provides the participation by event by thermostat type for thermostats in Massachusetts and Rhode Island.

C.1 Massachusetts

ecobee: Figure C-1 displays participation by event for ecobee thermostats in Massachusetts. Ecobee generally had few devices fail, but had rates of devices opt out, in off or heat mode, and with no connectivity. The highest opt-out rates occurred on August 1. August 1 was immediately preceded by an event, indicating event fatigue may have contributed to higher opt-outs. Rates of systems in off or heat mode were highest on July 31 (21% in Massachusetts). Cool nights leading up to both events likely resulted in more thermostats that were not set to cooling mode (see Appendix D.1). Event notification failures were low throughout the season (maximum of 4% in Massachusetts), but no connectivity rates were consistently high (7%-11% for Massachusetts).

Figure C-1. Average Participation by Event, ecobee: Massachusetts



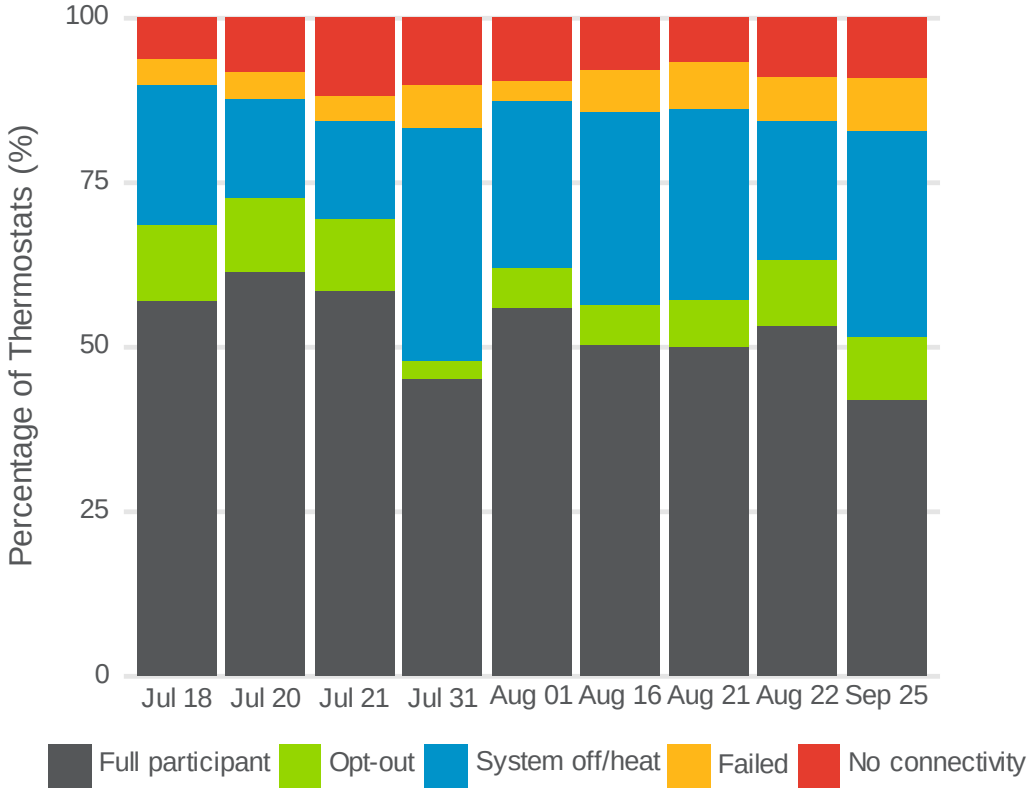
Source: Navigant analysis

Honeywell: Figure C-2 displays participation by event for Honeywell thermostats in Massachusetts In Massachusetts, Honeywell had high rates of systems in off or heat mode (25%), but lower rates of opt-outs (8%), failed devices (6%), and no connectivity (9%). Opt-outs rates were highest on July 18, 20, and

21 in Massachusetts. There were four DR events held during this week (July 17, 18, 20, and 21) with some devices participating in as many as three events. This indicates event fatigue may have contributed to the higher opt-out rates on these event days.

Rates of systems in off or heat mode were highest on July 31 in both states (35% in Massachusetts). Cool weather leading up to both events likely resulted in more thermostats that were not set to cooling mode. The percentage of event notification failures was generally consistent and fairly low. Massachusetts had consistently low rates of devices with connectivity (maximum of 12% on July 21), whereas no connectivity issues.

Figure C-2. Average Participation by Event, Honeywell: Massachusetts



Source: Navigant analysis

Nest: Figure C-3 display participation by event for Nest thermostats in Massachusetts. Nest had high rates of thermostats that opt out or were in off or heat mode, but few devices ever failed or had no connectivity. The opt-out rate was highest on July 21 (22%). It is interesting to note that this was the only four-hour event that was analyzed, and that there were events held previously during the same week on July 17, 18, and 20, with some thermostats participating in all four events called that week. This indicates that participation fatigue may have occurred over both the week and the event timeframes.

Rates of systems in off or heat mode were highest on July 31 (29% in Massachusetts). Cool nights leading up to the event likely resulted in more thermostats that were not set to cooling mode (see Appendix D.1). Event notification failures and devices with no connectivity were extremely low in Massachusetts (maximum combined rate of 1.1%).

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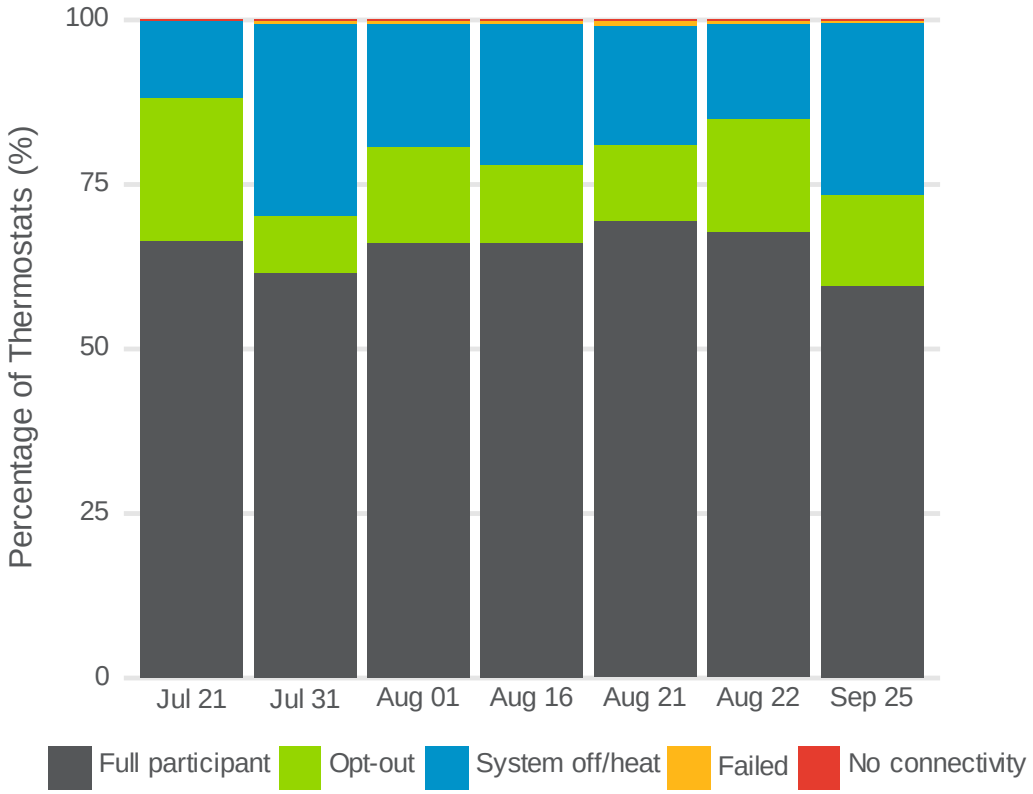
Figure C-3. Average Participation by Event, Nest: Massachusetts



Source: Navigant analysis

C.2 Rhode Island

ecobee: Figure C-4 display participation by event for ecobee thermostats in Rhode Island. Ecobee generally had few devices fail, but had rates of devices opt out, in off or heat mode, and with no connectivity. The highest opt-out rates occurred on July 21. July 21 was immediately preceded by events, indicating event fatigue may have contributed to opt-outs. Rates of systems in off or heat mode were highest on September 25 (26% in Rhode Island). Cool nights leading up to the event likely resulted in more thermostats that were not set to cooling mode (see Appendix D.2). Event notification failures were low throughout the season (maximum of 3% in Rhode Island), but no connectivity rates were consistently high (9%-13% in Rhode Island).

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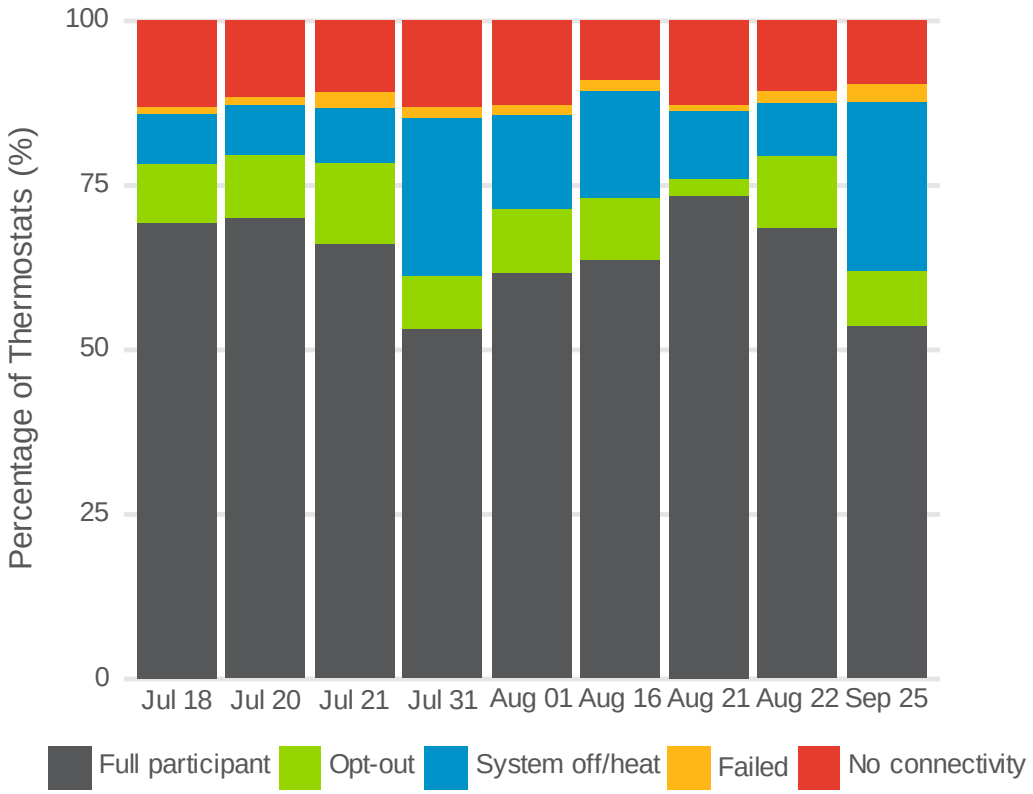
Figure C-4. Average Participation by Event, ecobee: Rhode Island



Source: Navigant analysis

Honeywell: Figure C-5 display participation by event for Honeywell thermostats in Rhode Island. In Rhode Island, there were high rates of systems in off or heat mode (22%) and no connectivity (19%), and lower rates of opt-outs (7%) and failed devices (6%). Opt-outs rates were highest on July 21 in Rhode Island. There were four DR events held during this week (July 17, 18, 20, and 21) with some devices participating in as many as three events. This indicates event fatigue may have contributed to the higher opt-out rates on these event days.

Rates of systems in off or heat mode were highest on July 31 (33% in Rhode Island). Cool weather leading up to both events likely resulted in more thermostats that were not set to cooling mode. The percentage of event notification failures was generally consistent and fairly low. However, rates of no connectivity were more common for Honeywell devices in Rhode Island (maximum of 32% on July 21).

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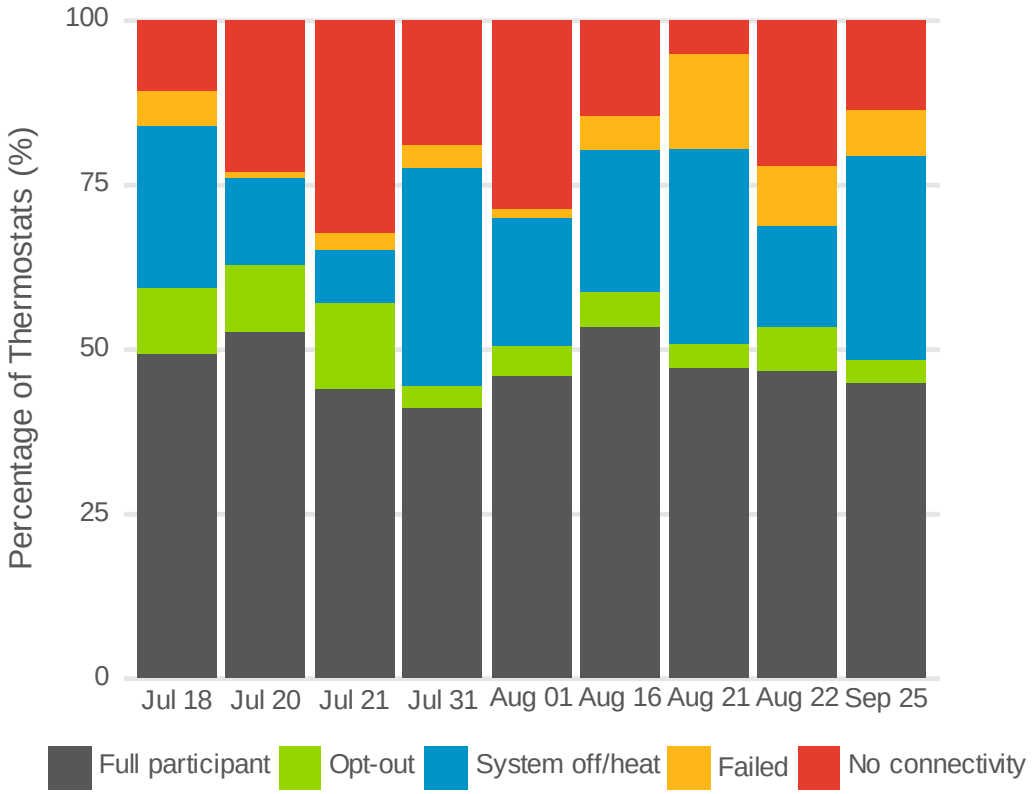
Figure C-5. Average Participation by Event, Honeywell: Rhode Island

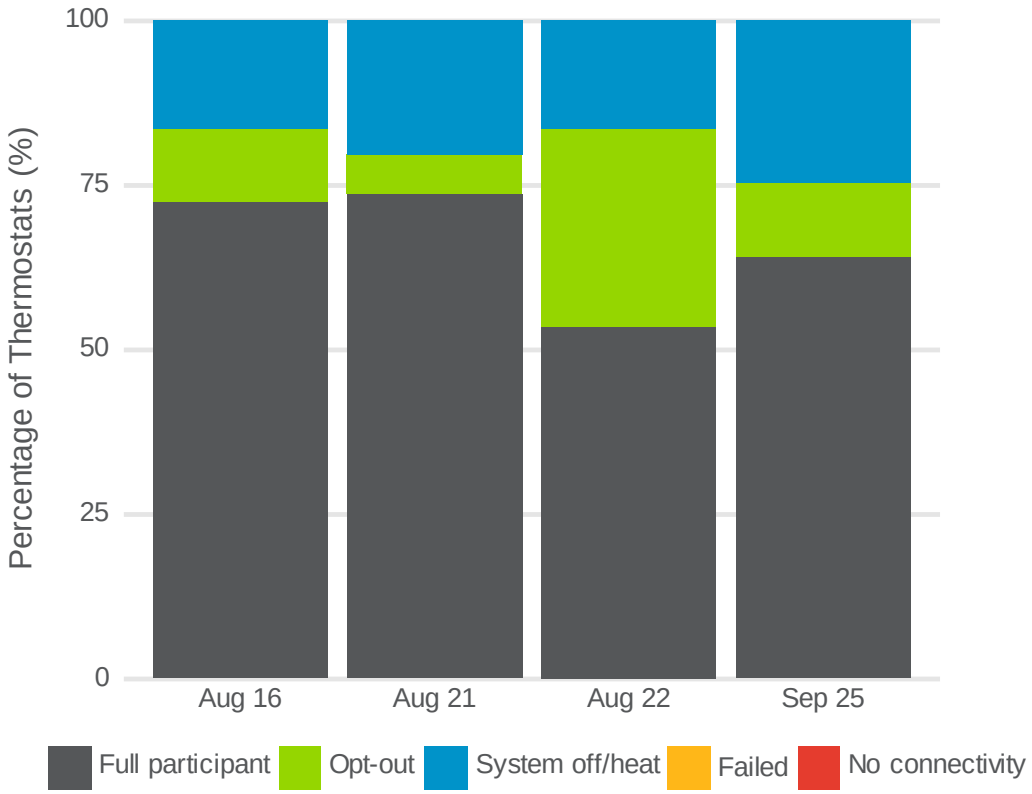


Source: Navigant analysis

Nest: Figure C-6 displays participation by event for Nest thermostats in Rhode Island. Nest devices had high rates of thermostats that opt out or were in off or heat mode, but few devices ever failed or had no connectivity. Rates of systems in off or heat mode were highest on September 25 (25% in Rhode Island)[32]. Cool weather leading up to both events likely resulted in more thermostats that were not set to cooling mode. Event notification failures and devices with no connectivity were extremely low in Massachusetts (maximum combined rate of 1.1%) and never occurred in Rhode Island.

[32] July 31 had the most thermostats in system off/heat mode for the ecobee and Honeywell thermostats. July 31 was not analyzed for the Nest thermostats in Rhode Island because the experimental design had not been implemented.

Figure C-6. Average Participation by Event, Nest: Rhode Island



Source: Navigant analysis

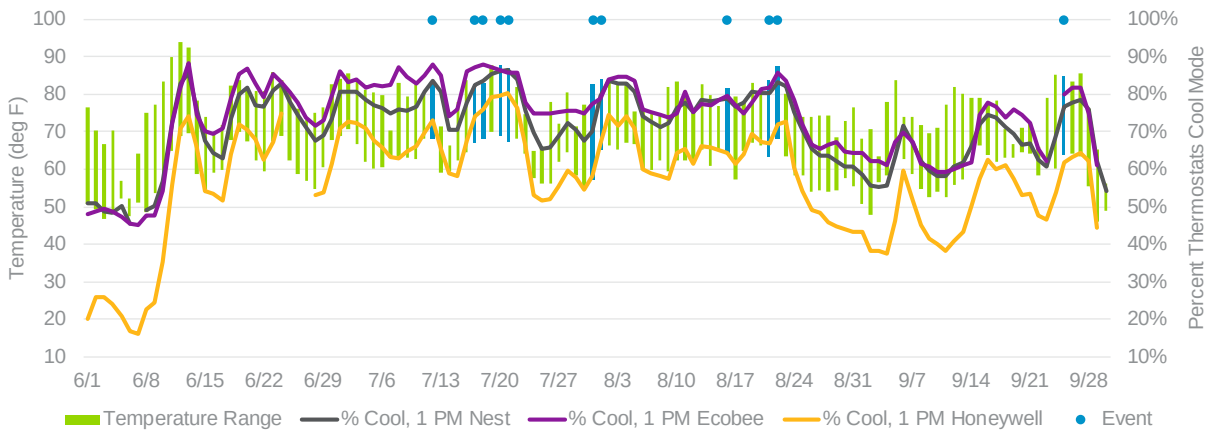
APPENDIX D. COOL MODE OVER DR SEASON

Some events had a greater frequency of thermostats in system off or heat mode than others. This was likely the result customers switching their thermostat mode to “off” or “heat” during cool nights and changing it back to “cool” mode on warm or hot days.

D.1 Massachusetts

A cool week prior to July 31 resulted in 23% of ecobee, 30% of Nest, and 42% of Honeywell devices in off or heat mode at 1 p.m. when the DR event was initiated. Similarly, cooler temperatures in September led to 20-38% of thermostats in off or heat mode for the September 25 event.

Figure D-1. Daily Temperature Range and Percent of Thermostats in Cool Mode: Massachusetts



Note: Daily average high and low outdoor temperature for all devices. Cooling mode is inferred from the Nest telemetry data (it is not currently a provided field) and may be an overestimate.
Source: Navigant analysis of Nest thermostat telemetry data and NOAA temperature data

D.2 Rhode Island

A cool week prior to July 31 resulted in 32% of ecobee and 37% of Honeywell devices in off or heat mode at 1 p.m. when the DR event was initiated. Similarly, cooler temperatures in September led to 27% of ecobee and 36% of Honeywell thermostats in off or heat mode for the September 25 event.

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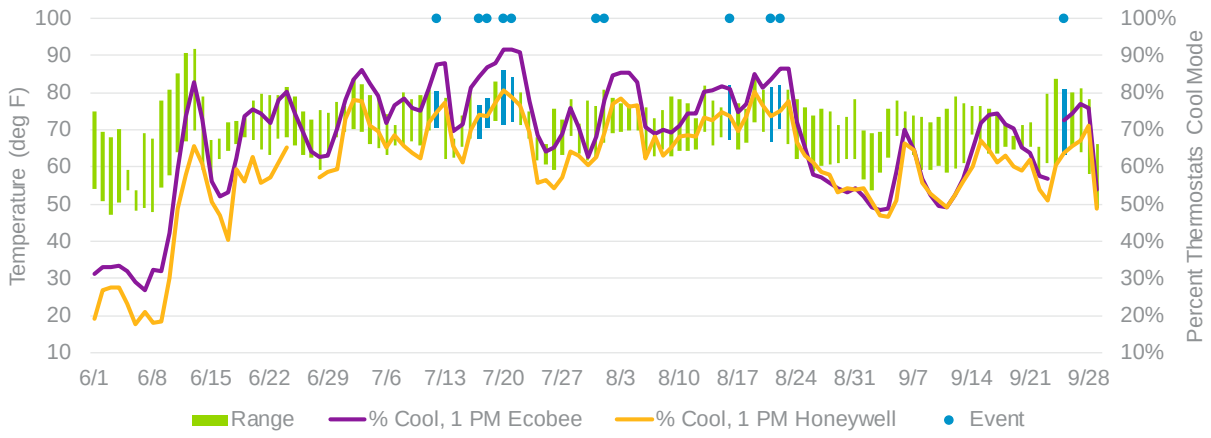
Figure D-2. Daily Temperature Range and Percent of Thermostats in Cool Mode: Rhode Island



Note: Daily average high and low outdoor temperature for all devices. Cooling mode is inferred from the Nest telemetry data (it is not currently a provided field) and may be an overestimate.

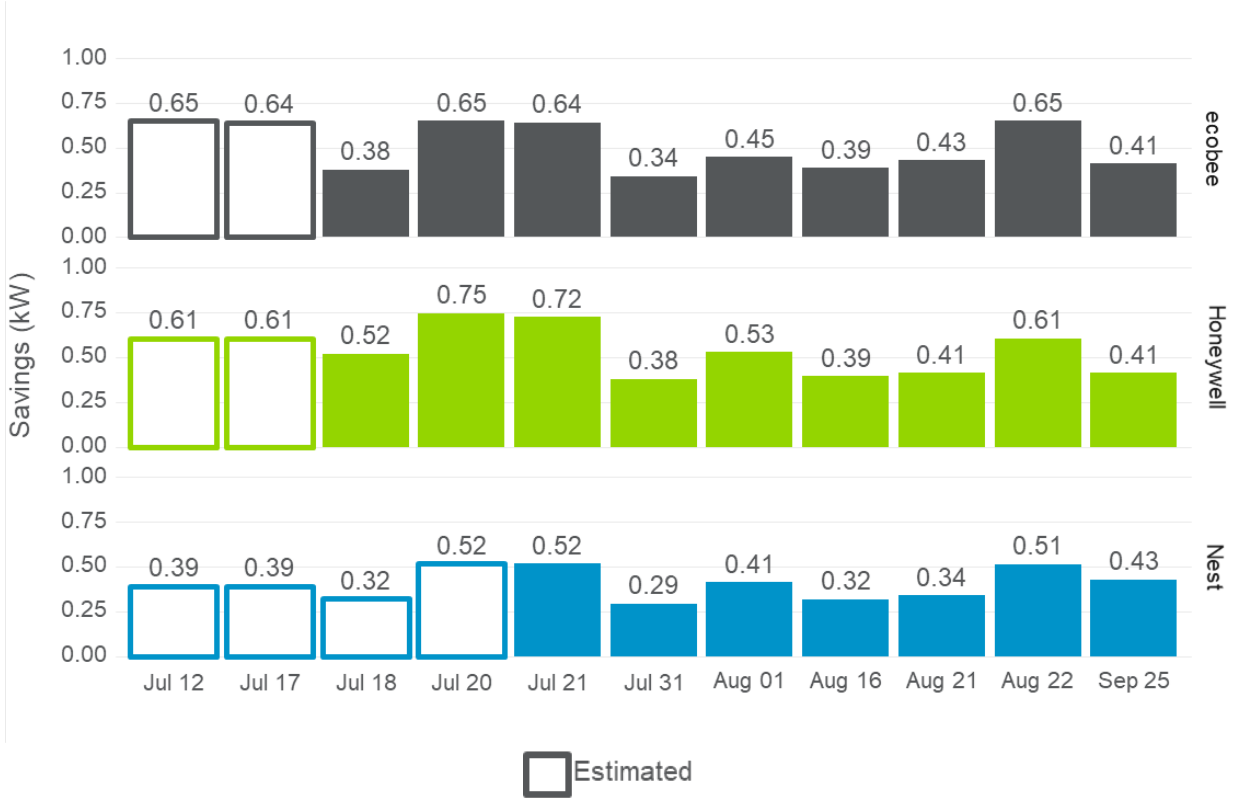
Source: Navigant analysis of Nest thermostat telemetry data and NOAA temperature data

APPENDIX E. EVENT-SPECIFIC IMPACTS

E.1 Massachusetts

Figure E-1 displays the average impacts (ATE) by event for each thermostat type. Bars with no fill represent estimated impacts while bars with fill represent modeled impacts. Average impacts (ATE) ranged from 0.29 kW to 0.75 kW. July 31 resulted in the lowest average impacts (ATE). This event day followed a cool period resulting in a high percentage (approximately one-third) of AC systems being in off or heat mode. July 20 and August 22 resulted in the highest average impacts (ATE). These event days were among the hottest, preceded by similarly hot days.

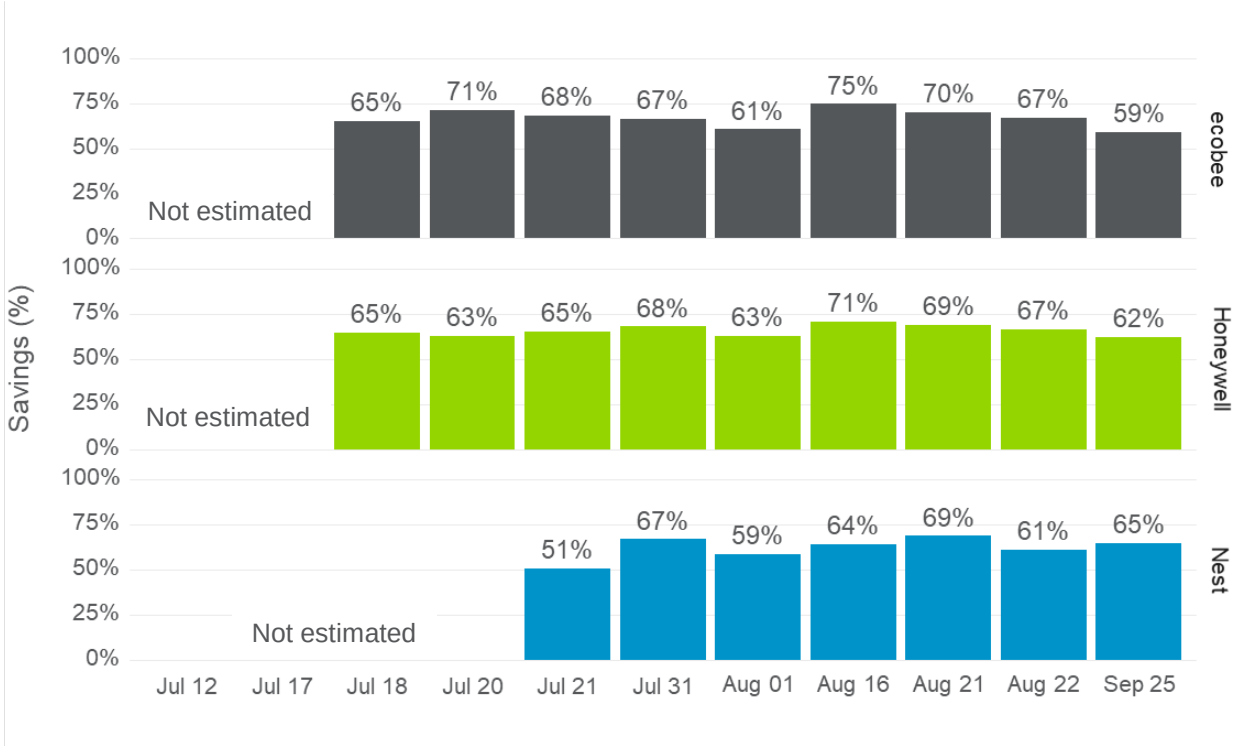
Figure E-1. Average ATE Event Impacts by Device: Massachusetts



Note: Estimated days were paired to modeled event days based on average temperature and THI during the pre-event and event periods, as well as percent of devices in cool mode at the beginning of the event for each thermostat type. Refer to Appendix B for a list of the paired event days.
Source: Navigant analysis

Figure E-2 displays the average impacts (ATE) as a percent of cooling load by event for each thermostat type. Average impacts (ATE) ranged from 51% to 75%.

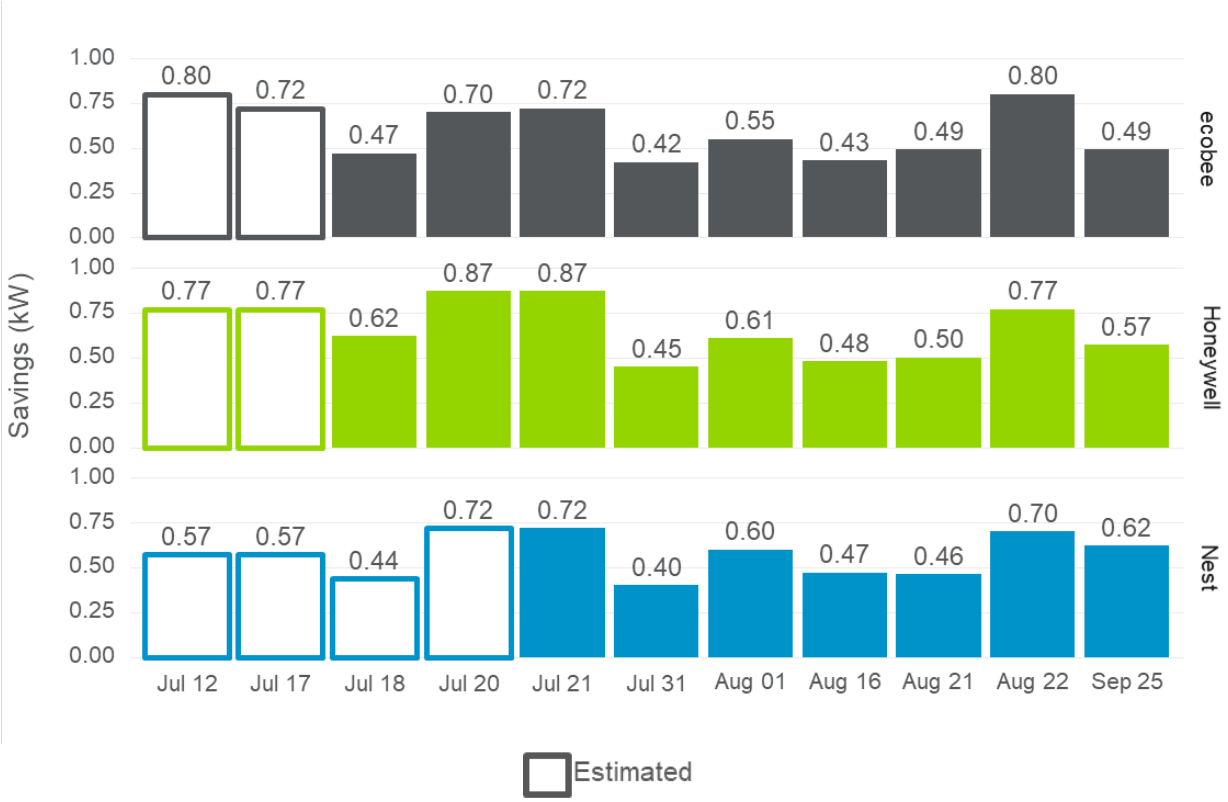
Figure E-2. Average Percent ATE Event Impacts by Device: Massachusetts



Note: Percent savings is shown for events included in the regression analysis.
Source: Navigant analysis

Figure E-3 presents the TOT impacts by event representing the impacts of full participants only (i.e., excluding devices that opt out, where the AC system is in off or heat mode, and devices with connectivity or failure issues). These ranged from 0.40 kW to 0.87 kW. Similar trends are observed as with ATE, impacts track temperature. The largest impacts are estimated on hotter event days when more cooling is occurring.

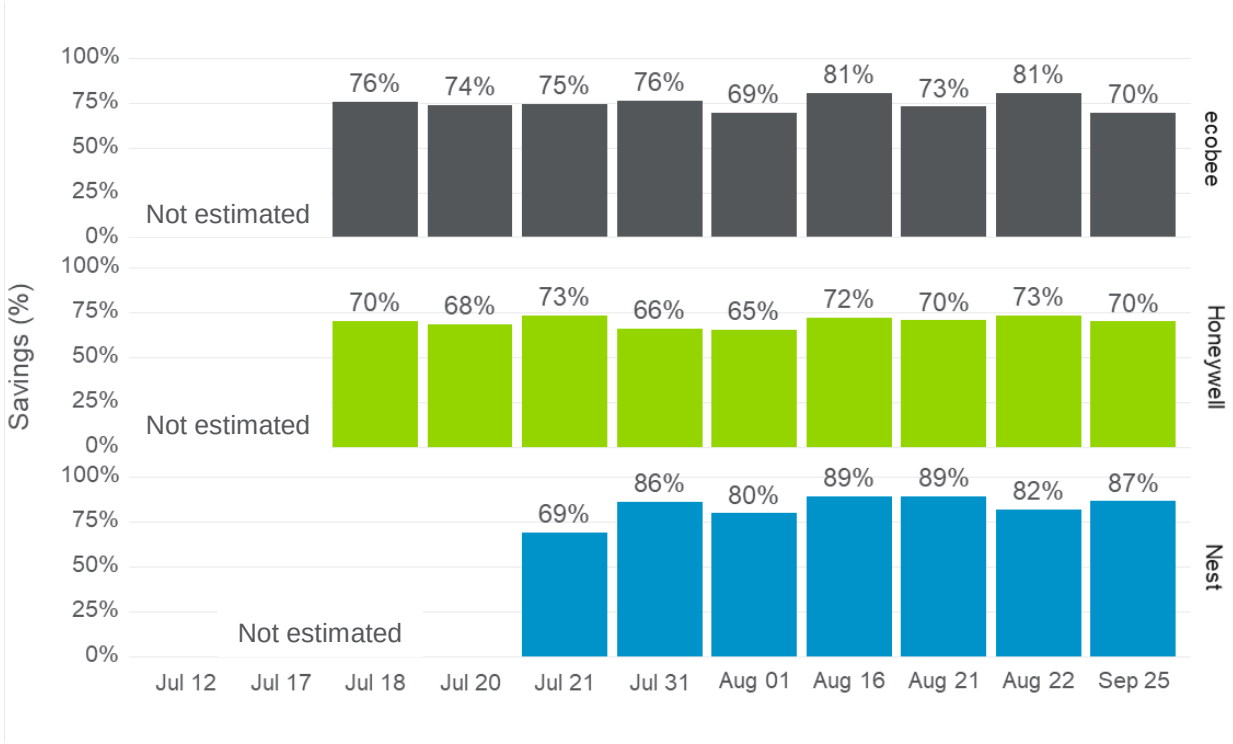
Figure E-3. Average TOT Event Impacts by Device: Massachusetts



Note: Estimated days were paired to modeled event days based on average temperature and THI during the pre-event and event periods, as well as percent of devices in cool mode at the beginning of the event for each thermostat type. Refer to Appendix B for a list of the paired event days.
Source: Navigant analysis

Figure E-4 displays the TOT impacts as a percent of cooling load by event for each thermostat type. TOT impacts ranged from 65% to 89%.

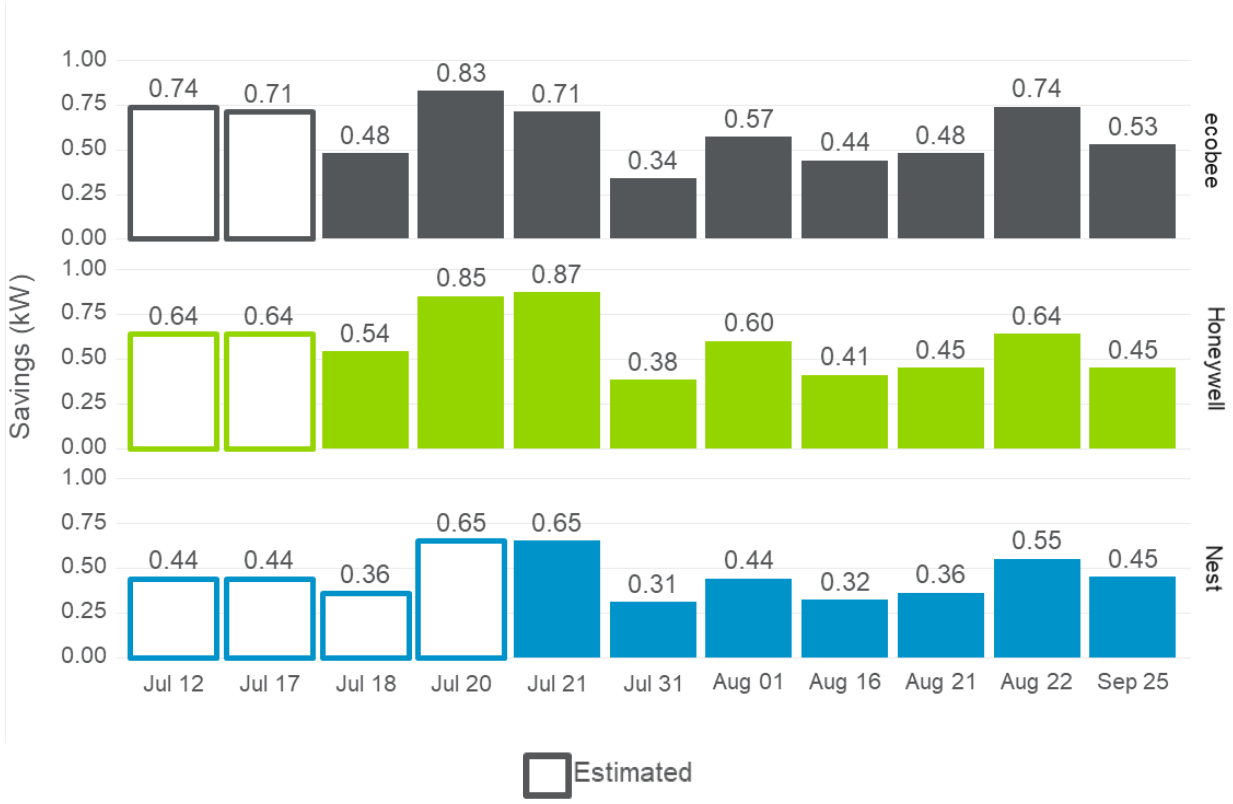
Figure E-4. Average Percent TOT Event Impacts by Device: Massachusetts



Note: Percent savings is shown for events included in the regression analysis.
Source: Navigant analysis

The maximum hourly event impacts typically occur during the first hour of the event and are 10 to 30% greater than the average impact over the full duration of the event. Figure E-5 presents the maximum hourly ATE impacts by event. Maximum hourly impacts ranged from 0.34 kW to 0.83 for ecobee, 0.38 to 0.87 kW for Honeywell and 0.31 to 0.65 kW for Nest.

Figure E-5. Maximum Hourly Event Impacts by Device (ATE)

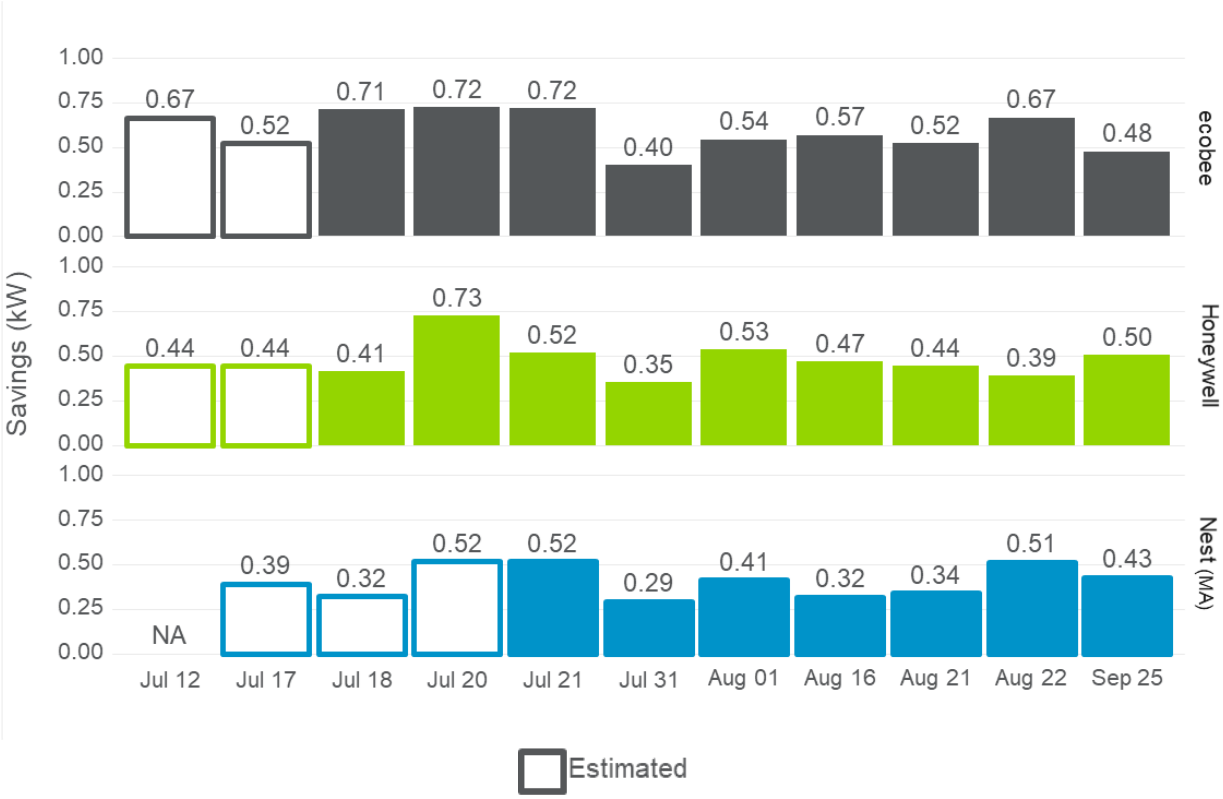


Note: Estimated days were paired to modeled event days based on average temperature and THI during the pre-event and event periods, as well as percent of devices in cool mode at the beginning of the event for each thermostat type. Refer to Appendix B for a list of the paired event days.
Source: Navigant analysis

E.2 Rhode Island

Figure E-6 displays the average impacts (ATE) by event for each thermostat type. Bars with no fill represent estimated impacts while bars with fill represent modeled impacts. Average impacts (ATE) ranged from 0.29 kW to 0.73 kW. July 31 resulted in the lowest average impacts (ATE). This event day followed a cool period resulting in a high percentage (approximately one-third) of AC systems being in off or heat mode. July 20 and August 22 resulted in the highest average impacts (ATE). These event days were among the hottest, preceded by similarly hot days.

Figure E-6. Average ATE Event Impacts by Device: Rhode Island



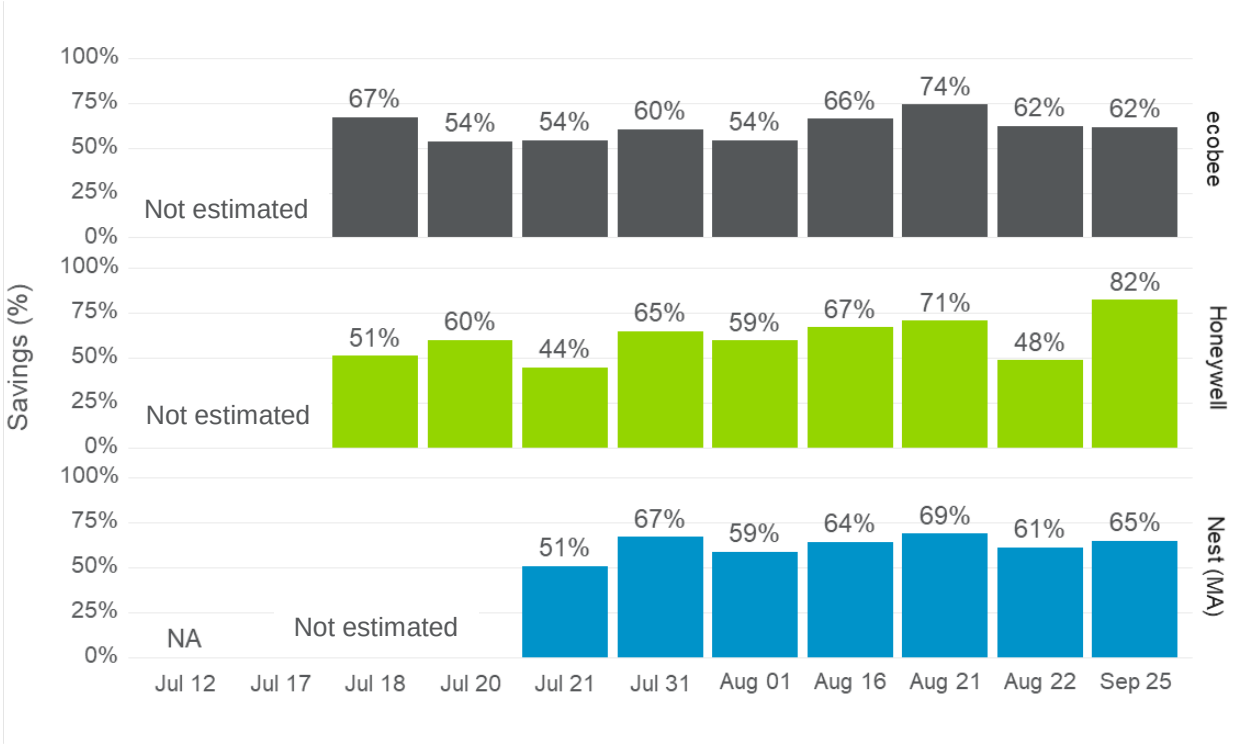
Note: Nest impacts are approximated using Massachusetts data due to late deployment of the experimental design and insufficient Rhode Island data.

Estimated days were paired to modeled event days based on average temperature and THI during the pre-event and event periods, as well as percent of devices in cool mode at the beginning of the event for each thermostat type. Refer to Appendix B for a list of the paired event days.

Source: Navigant analysis.

Figure E-7 displays the average impacts (ATE) as a percent of cooling load by event for each thermostat type. Average impacts (ATE) ranged from 44% to 82%.

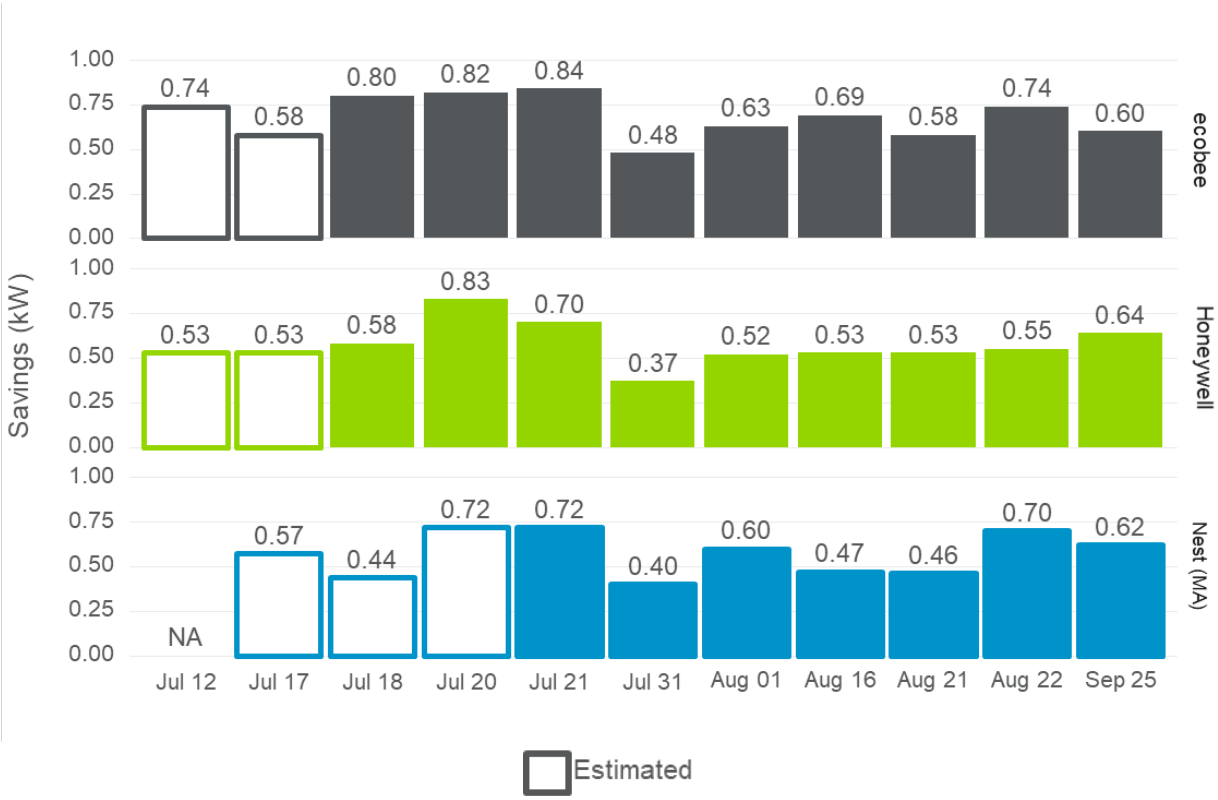
Figure E-7. Average Percent ATE Event Impacts by Device: Rhode Island



Note: Percent savings is shown for events included in the regression analysis.
Source: Navigant analysis

Figure E-8 presents the TOT impacts by event representing the impacts of full participants only (i.e., excluding devices that opt out, where the AC system is in off or heat mode, and devices with connectivity or failure issues). These ranged from 0.37 kW to 0.84 kW. Similar trends are observed as with ATE, impacts track temperature. The largest impacts are estimated on hotter event days when more cooling is occurring.

Figure E-8. Average TOT Event Impacts by Device: Rhode Island



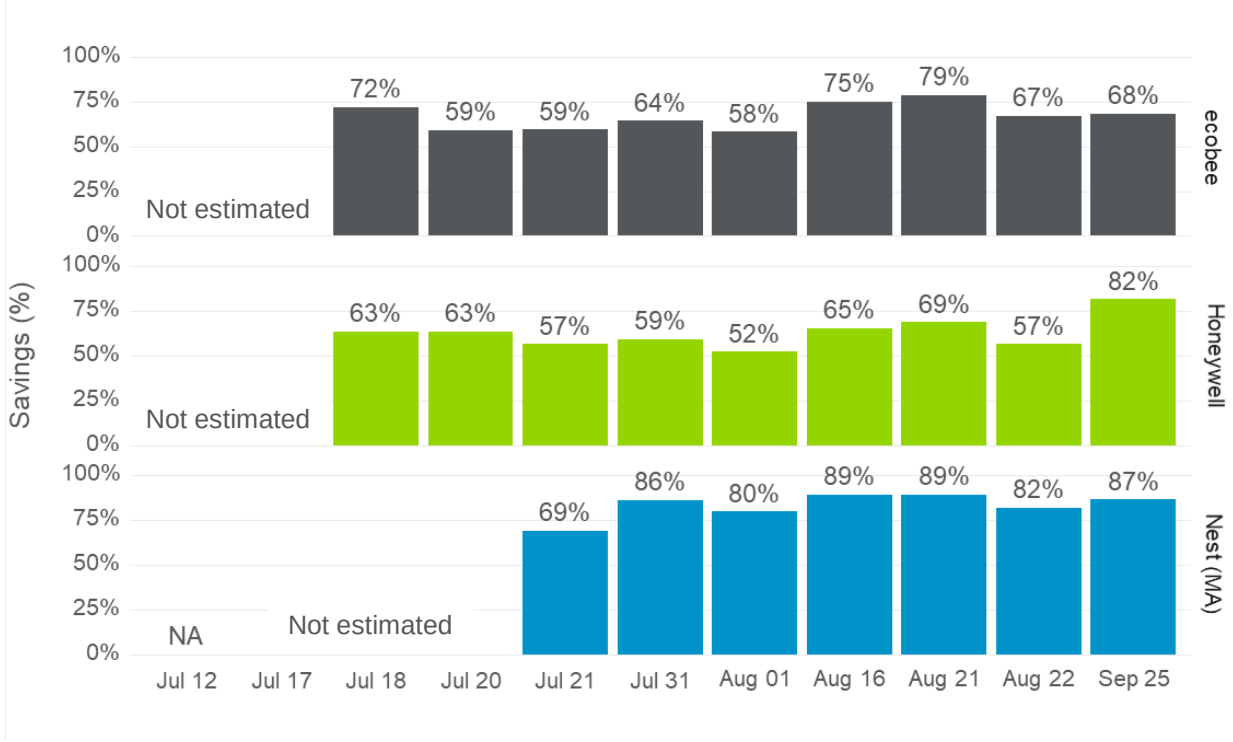
Note: Nest impacts are approximated using Massachusetts data due to late deployment of the experimental design and insufficient Rhode Island data.

Estimated days were paired to modeled event days based on average temperature and THI during the pre-event and event periods, as well as percent of devices in cool mode at the beginning of the event for each thermostat type. Refer to Appendix B for a list of the paired event days.

Source: Navigant analysis

Figure E-9 displays the TOT impacts as a percent of cooling load by event for each thermostat type. TOT impacts ranged from 52% to 89%.

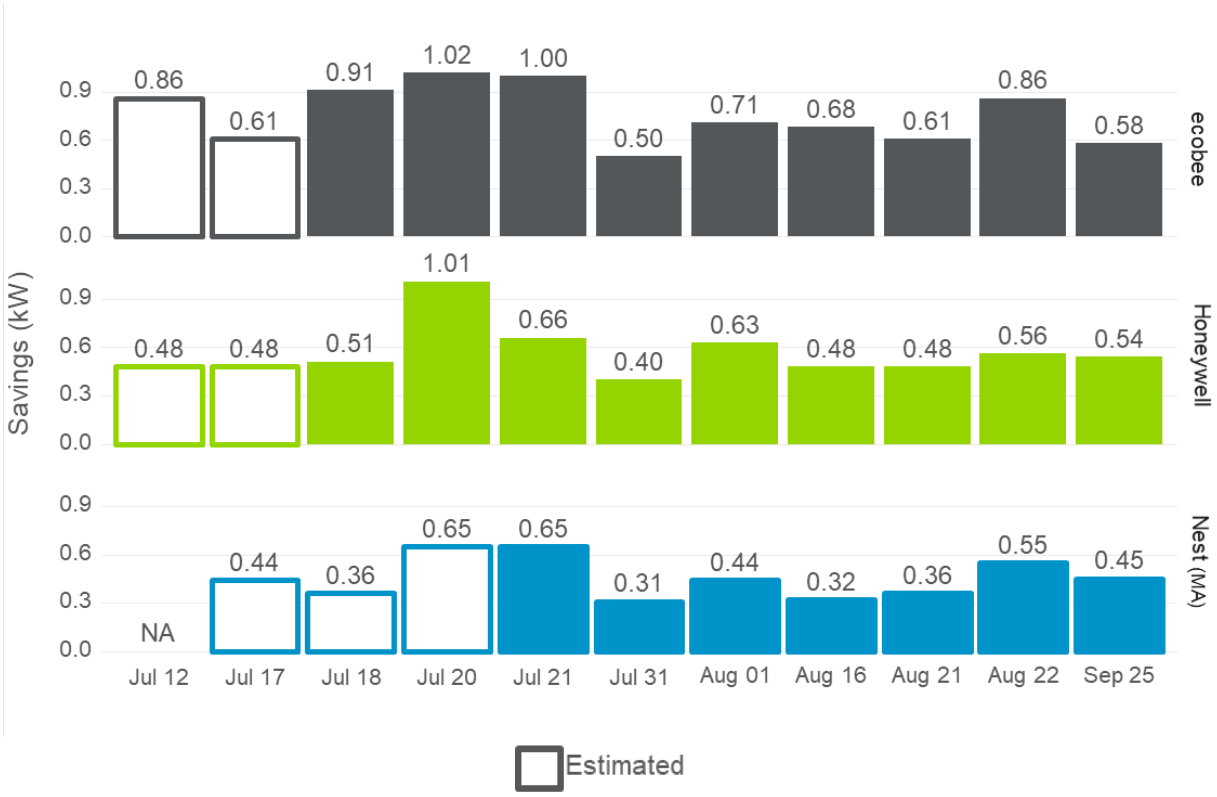
Figure E-9. Average Percent TOT Event Impacts by Device: Rhode Island



Note: Percent savings is shown for events included in the regression analysis.
Source: Navigant analysis

The maximum hourly event impacts typically occur during the first hour of the event and are 10 to 30% greater than the average impact over the full duration of the event. Figure E-10 presents the maximum hourly impacts by event. Maximum hourly impacts ranged from 0.50 kW to 1.02 kW for ecobee, 0.40 to 1.01 kW for Honeywell and 0.31 to 0.65 kW for Nest.

Figure E-10. Maximum Hourly Event Impacts by Device: Rhode Island



Note: Nest impacts are approximated using Massachusetts data due to late deployment of the experimental design and insufficient Rhode Island data.

Estimated days were paired to modeled event days based on average temperature and THI during the pre-event and event periods, as well as percent of devices in cool mode at the beginning of the event for each thermostat type. Refer to Appendix B for a list of the paired event days.

Source: Navigant analysis

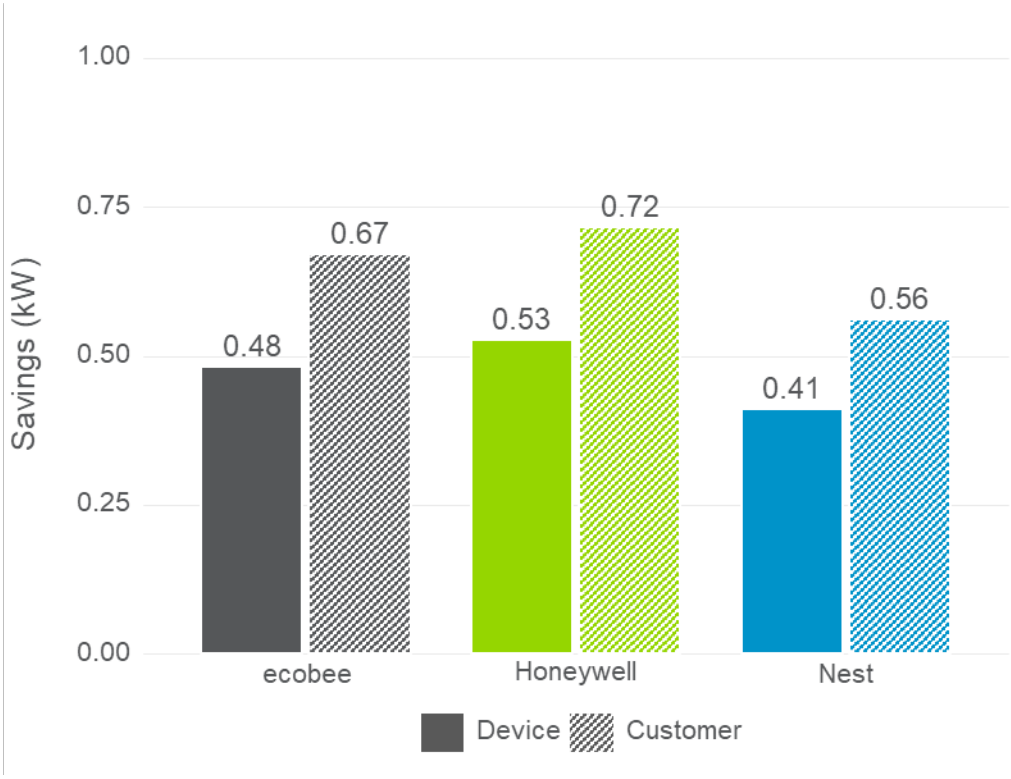
APPENDIX F. CUSTOMER LEVEL IMPACTS

The results presented thus far represent device-level impacts, but often one customer has more than one thermostat. Thus, this section presents the average ATE, ATE by event, and TOT by event at the customer-level.

F.1 Massachusetts

Program participants have, on average, 1.3 thermostats as indicated in Table . To better assess the DR associated with a participating customer, Navigant re-analyzed the thermostat telemetry data, aggregating it to the customer level. Figure F-1 presents a comparison of the average device-level and customer-level impacts (ATE) per event. Customer-level average impacts (0.56 kW to 0.72 kW) are larger than device-level average impacts (0.41 kW to 0.53 kW).[33] Average impacts by event are presented in Figure F-2 (ATE) and Figure F-3 (TOT).

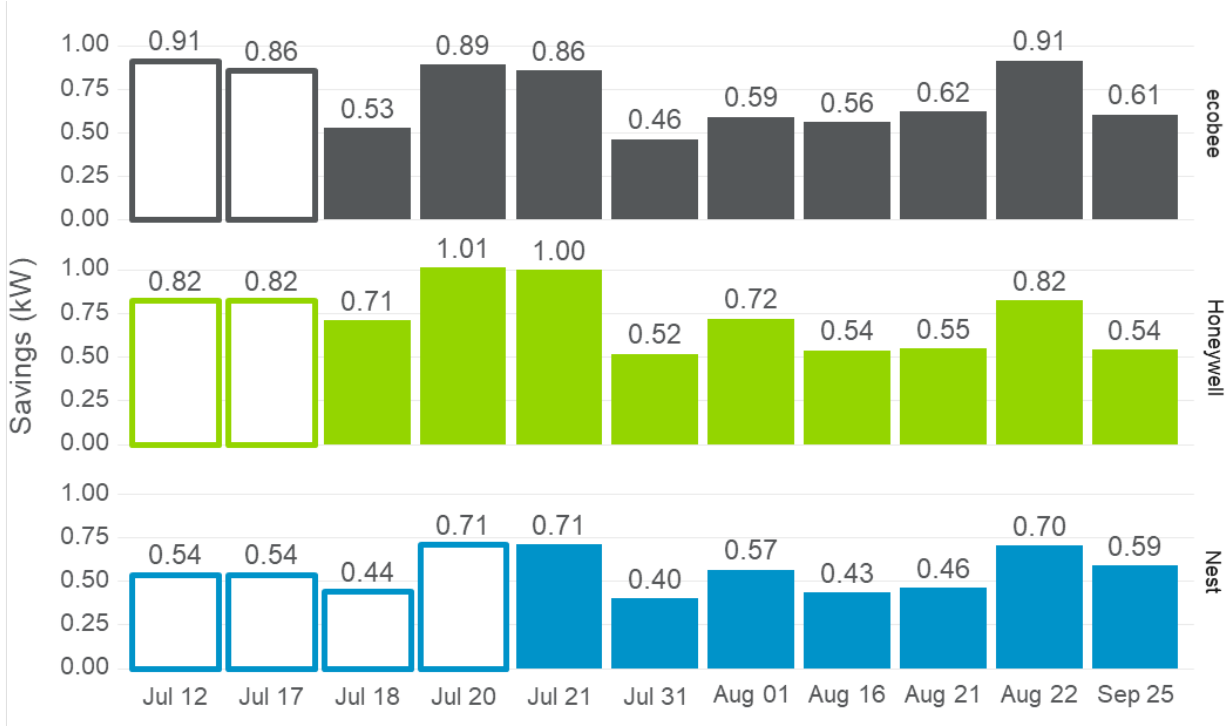
Figure F-1. ATE Device Level vs. ATE Customer Level: Massachusetts



Source: Navigant analysis

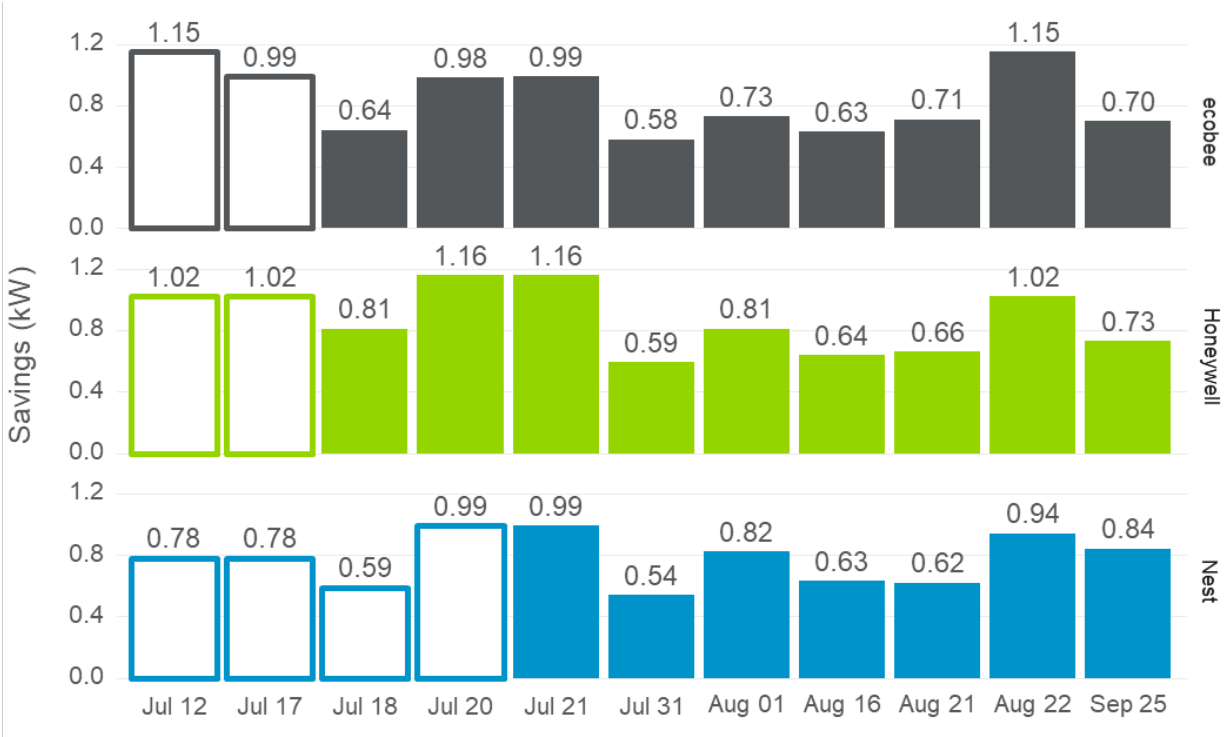
[33] Navigant analyzed device-level impacts for customers with one, two, and three thermostats to determine whether average impacts vary with the number of thermostats. Results suggested each additional thermostat yields lower impacts, though this difference was not statistically significant.

Figure F-2. ATE Event Impacts by Customer: Massachusetts



Source: Navigant analysis

Figure F-3. TOT Event Impacts by Customer: Massachusetts



Source: Navigant analysis

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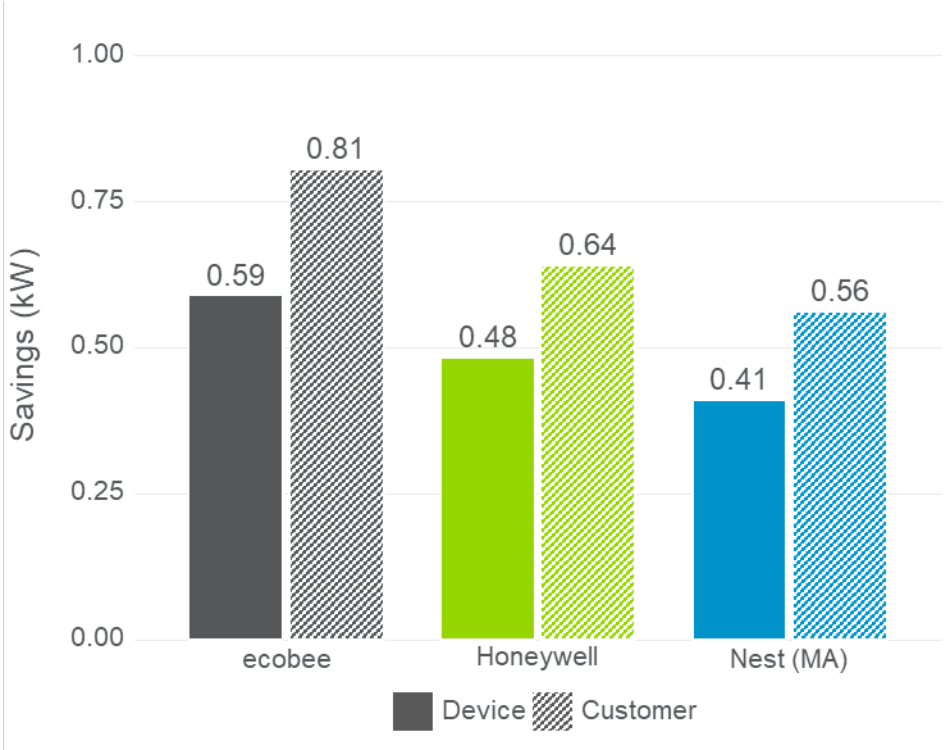
F.2 Rhode Island

Program participants have, on average, 1.4 thermostats as indicated in Table . To better assess the DR associated with a participating customer, Navigant re-analyzed the thermostat telemetry data, aggregating it to the customer level. Figure F-4 presents a comparison of the average device-level and customer-level impacts (ATE) per event. Customer-level average impacts (0.56 kW to 0.81 kW) are larger than device-level average impacts (0.41 kW to 0.59 kW).[34] Average impacts by event are presented in Figure F-5 (ATE) and Figure F-6 (TOT).

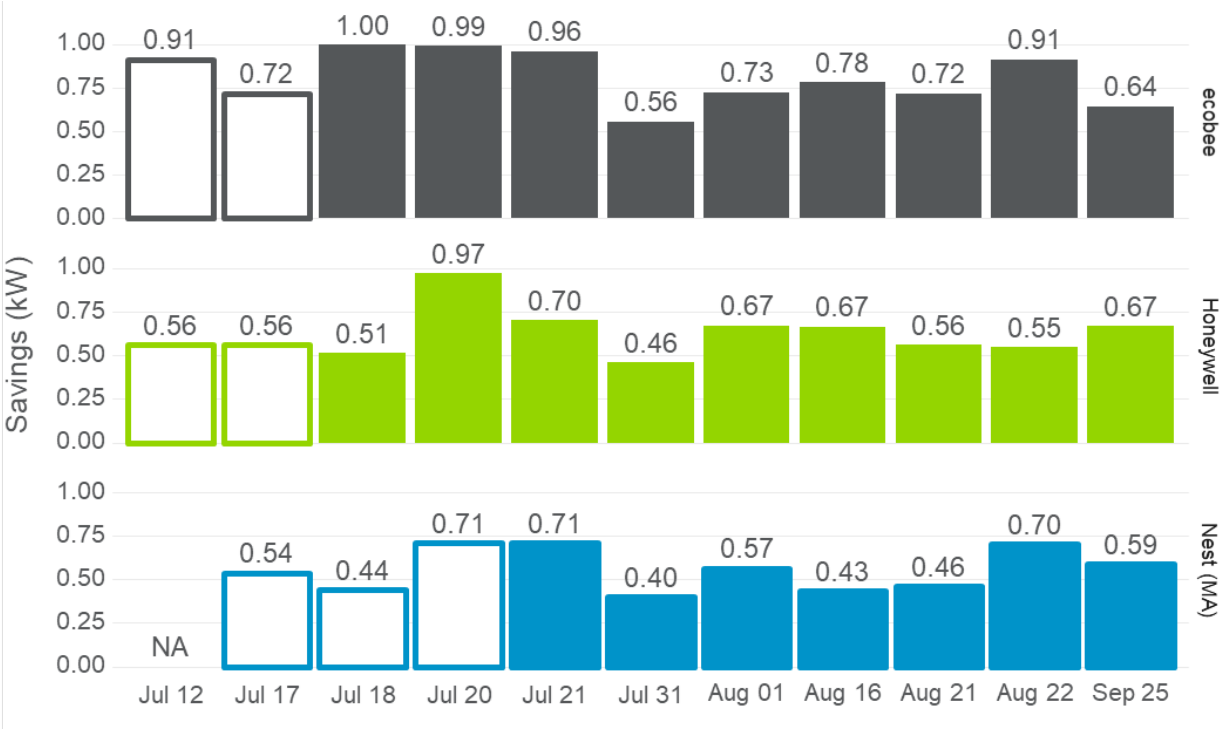
Figure F-4. ATE Comparison: Device vs. Customer



Source: Navigant analysis

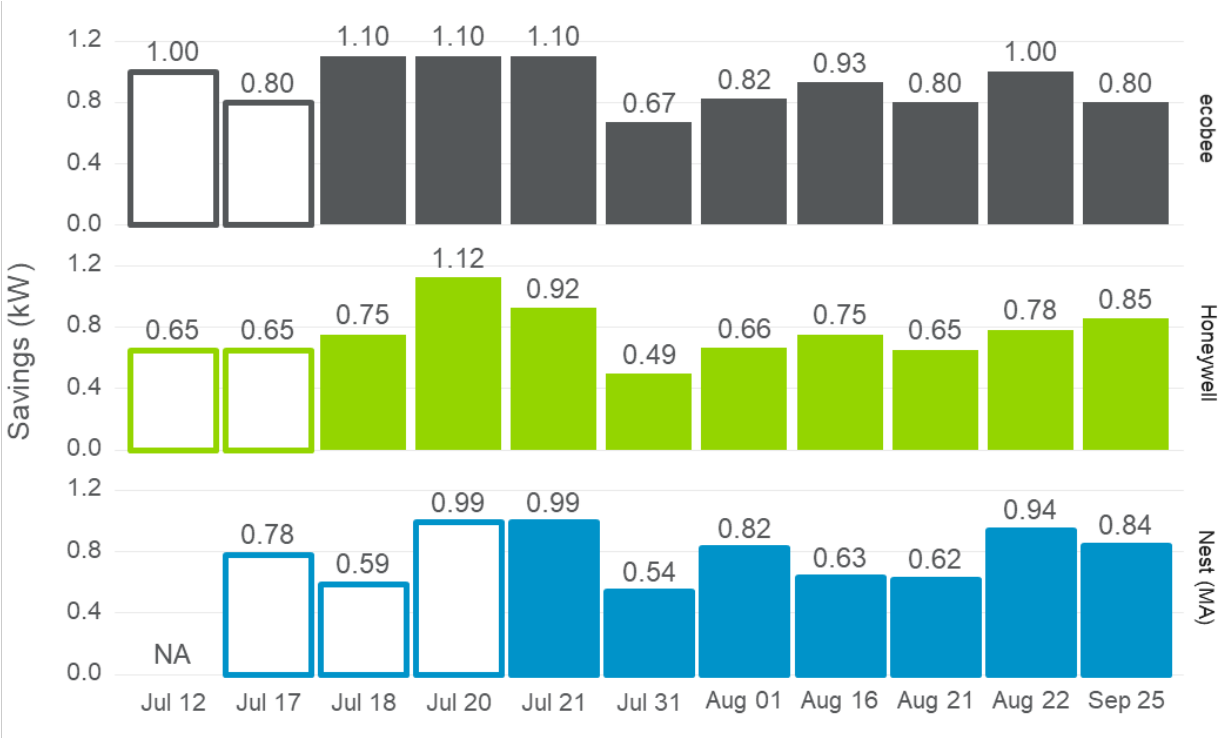
[34] Navigant analyzed device-level impacts for customers with one, two, and three thermostats to determine whether average impacts vary with the number of thermostats. Results suggested each additional thermostat yields lower impacts, though this difference was not statistically significant.

Figure F-5. ATE Event Impacts by Customer: Rhode Island



Source: Navigant analysis

Figure F-6. TOT Event Impacts by Customer: Rhode Island



Source: Navigant analysis

APPENDIX G. POST-SEASON SURVEY AND RESULTS – HONEYWELL AND ECOBEE

This section includes the survey instrument and responses to the multi-choice questions.

0. Approximately when did you enroll in ConnectedSolutions? {Enter 2-digit month and 4-digit year}

1. About how many Peak Energy Events do you remember occurring between June 1 and September 30? (Please make your best estimate).
    a. {ENTER NUMBER}
    b. Don't know

2. What time did Peak Energy Events typically start?
    a. 10 am
    b. 11 am
    c. 12 pm
    d. 1 pm
    e. 2 pm
    f. 3 pm
    g. 4 pm
    h. 5 pm
    i. Other_____
    j. Don't Know

3. What time did Peak Energy Events typically end?
    a. 2 pm
    b. 3 pm
    c. 4 pm
    d. 5 pm
    e. 6 pm
    f. 7 pm
    g. 8 pm
    h. Other_____
    i. Don't Know

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4. During this past summer, how did you become aware that a Peak Energy Event was going to occur? (select all that apply)
    a. Email
    b. ConnectedSolutions web portal
    c. Thermostat
    d. Other. Specify
    e. Never notified_____
    f. Don't know

[IF Q4 <> e, CONTINUE. ELSE SKIP TO Q8]

5. During this past summer, approximately how far in advance were you typically notified that a Peak Energy Event was set to occur?
    a. < 1 hour
    b. 1 hour
    c. 2 hours
    d. 3 hours
    e. 4 hours
    f. 5 hours
    g. 6 hours
    h. > 6 hours
    i. Never notified
    j. Don't know

[IF Q5 <> i, CONTINUE. ELSE SKIP]

6. Using a scale of 1 to 5, where 1 means "Very Dissatisfied" and 5 means "Very Satisfied", what is your level of satisfaction with the notification you receive about a Peak Energy Event that is set to occur?

a. Very Dissatisfied	b.	c. Neutral	d.	e. Very Satisfied	f. I have not been aware of any Peak Energy Event notifications	g. Don't Know
1	2	3	4	5		

[IF Q6 = a-b (1-2), CONTINUE. OTHERWISE SKIP]

7. What caused the Peak Energy Event notification to be less than satisfying? **[OPEN-END, OPTIONAL]**

8. This summer, for the Peak Energy Events you can recall, about how often were you or another family member home during the Peak Energy Event hours?
    a. Home for all Peak Energy Event hours
    b. Home for most Peak Energy Event hours
    c. Home for some Peak Energy Event hours
    d. Never at home during Peak Energy Event hours
    e. Don't know

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9-11. On a scale of 1 through 5, where 1 is "Very dissatisfied" and 5 is "Very satisfied", how would you rate your satisfaction with the following aspects of the **Connected**Solutions program?

	a. Very Dissatisfied	b.	c. Neutral	d.	e. Very Satisfied	f. Don't know
	1	2	3	4	5	
9. Number of Peak Energy Events during the 2017 summer season						
10. Length of Peak Energy Events						
11. Timing of Peak Energy Events (i.e. what period during the day events occurred)						

[IF Q9 = a-b (1-2), CONTINUE. ELSE SKIP TO Q14]

12. Did the number of Peak Energy Events that occurred on consecutive days impact your satisfaction level?
    a. Very Much
    b. Somewhat
    c. Not At All

[IF Q9 = a-b (1-2), CONTINUE. ELSE SKIP TO Q14]

13. On a scale of 1 through 5, where 1 is "Very dissatisfied" and 5 is "Very satisfied", how satisfied would you have been with the number of Peak Energy Events if there had been 5 fewer events over the course of the summer?

a. Very Dissatisfied	b.	c. Neutral	d.	e. Very Satisfied	f. Don't Know
1	2	3	4	5	

[IF Q10 = a-b (1-2), CONTINUE. ELSE SKIP TO Q17]

14. Please let us know why you are not fully satisfied with the length of the Peak Energy Events.

_____

[IF Q10 = a-b (1-2), CONTINUE. ELSE SKIP TO Q17]

15. On a scale of 1 through 5, where 1 is "Very dissatisfied" and 5 is "Very satisfied", how satisfied would you have been with the length of Peak Energy Events if they had been 1 hour shorter?

a. Very Dissatisfied	b.	c. Neutral	d.	e. Very Satisfied	f. Don't Know
1	2	3	4	5	

[IF Q10 = a-b (1-2), CONTINUE. ELSE SKIP TO Q17]

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16. On a scale of 1 through 5, where 1 is "Very dissatisfied" and 5 is "Very satisfied", how satisfied would you have been with the length of Peak Energy Events if they had been 2 hours shorter?

a. Very Dissatisfied	b.	c. Neutral	d.	e. Very Satisfied	f. Don't Know
1	2	3	4	5	

[IF Q11 = a-b (1-2), CONTINUE. ELSE SKIP TO Q18]

17. Please let us know why you are not fully satisfied with the timing of some or all of the Peak Energy Events.

    _____

18. Based on your experience with the program this summer, what would the optimal start time be for a Peak Energy Event (i.e. for a temperature increase in your home)?
    a. 10 am
    b. 11 am
    c. 12 pm
    d. 1 pm
    e. 2 pm
    f. 3 pm
    g. 4 pm
    h. 5 pm
    i. Other_____
    j. I don't have a strong opinion
    k. Don't Know

19. Based on your experience with the program this summer, what would the optimal end time be for a Peak Energy Event?
    a. 2 pm
    b. 3 pm
    c. 4 pm
    d. 5 pm
    e. 6 pm
    f. 7 pm
    g. 8 pm
    h. Other_____
    i. I don't have a strong opinion
    j. Don't Know

20. At any point over the course of the summer, did you contact support services regarding the program?
    a. Yes, I contacted support during the summer
    b. No, I did not contact any party about the program

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[IF Q20 = a, CONTINUE. OTHERWISE SKIP TO Q25]

21. What method did you use to contact support about the program? (select all that apply)
    a. Webform provided on the **Connected**Solutions website
    b. Email to National Grid
    c. Phone call to National Grid
    d. Email to my thermostat manufacturer
    e. Phone call to my thermostat manufacturer
    f. Other. Specify_____

22. Please describe your reason(s) for contacting support. **[OPEN-ENDED]**

23. Using a scale of 1 to 5, where 1 means "Very Dissatisfied" and 5 means "Very Satisfied", what is your level of satisfaction with the support you received?

a. Very Dissatisfied	b.	c.	d.	e. Very Satisfied	f. Don't Know
1	2	3	4	5	

[IF Q23 = a OR b, CONTINUE. OTHERWISE SKIP TO Q25]

24. Why was the support you received less than satisfactory? **[OPEN-ENDED]**

25. In future summers, on a scale of 1-5, where 1 is "Very Unlikely" and 5 is "Very Likely," how likely would you be to participate in the **Connected**Solutions program?

a. Very Unlikely	b.	c.	d.	e. Very Likely	f. Don't Know
1	2	3	4	5	

[IF Q25 = a OR b, CONTINUE. OTHERWISE SKIP TO Q27]

26. What change(s) to the **Connected**Solutions program would encourage you to continue participating? **[OPEN-END, OPTIONAL]**

[IF Q25 = c-f, CONTINUE. OTHERWISE SKIP TO Q28]

27. What recommendations would you make to help improve the **Connected**Solutions program going forward? **[OPEN-END, OPTIONAL]**

28. In future summers, on a scale of 1-5, where 1 is "Very Unlikely" and 5 is "Very Likely," how likely would you be to participate in the **Connected**Solutions program <u>if you are not provided advance notice of Peak Energy Events before they occur</u>?

a. Very Unlikely	b.	c.	d.	e. Very Likely	f. Don't Know
1	2	3	4	5	

29. During the summer, for how many weekdays per week is <u>at least one</u> person home from 2 p.m. to 5 p.m.? (enter a number from 0 to 5) _____ {programmed to accept numeric input only}

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30. We'd like to understand how you typically used your air conditioner throughout the past summer. Which of the following best describes the way you use your air conditioner?
    a. Turn on cooling at the beginning of summer, follow a temperature schedule, and turn off cooling at the end of the summer
    b. Only turn on cooling when it's hot and/or humid and otherwise have my air conditioner off or in heating mode

[If Q30 = b, CONTINUE. ELSE SKIP TO Q32]

31. Above what temperature do you typically turn your air conditioning on? Please enter a temperature in degrees F. **[ENTER NUMERIC]**

32. Over the past summer, how did you typically monitor the temperature of your home or adjust the setting of your Wi-Fi thermostat? (select all that apply)
    a. On the Wi-Fi thermostat itself
    b. **Connected**Solutions web portal
    c. App provided by Wi-Fi thermostat manufacturer
    d. Other_____
    e. Don't know

33. Now we'd like to understand the frequency with which you adjusted your Wi-Fi thermostat's setting or schedule during this summer. Would you say it was…
    a. More than once a day
    b. Once a day
    c. A few times per week
    d. Once or twice monthly
    e. Once or twice over the whole summer
    f. Not at all
    g. Other _____
    h. Don't know

[IF Q33 = f, SKIP]

34. We'd also like to understand whether the frequency with which you adjusted your Wi-Fi thermostat's setting or schedule was different on Peak Energy Event days compared to other days. Would you say you adjusted your home's temperature…
    a. More on Peak Energy Event days than on other days
    b. Less on Peak Energy Event days than on other days
    c. About the same amount regardless of whether it was a Peak Energy Event day or not
    d. Don't know

35. When no family member is at home, which of the following best describes the way you use your air conditioner?
    a. I always have my air conditioner follow a temperature schedule.
    b. Depending on the weather, I sometimes set my air conditioner to off or heating mode.
    c. When no family member is home, my air conditioner is off or in heating mode.
    d. Other. Please specify _____

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[If Q8 = d, SKIP]

36. When you or a family member was at home for any part of a Peak Energy Event, what actions, if any, did you take to reduce your electricity use during the Peak Energy Event? (select all that apply)
    a. Discussed energy conservation strategies with my family
    b. Pre-cooled my home during morning off-peak hours
    c. Sought activities outside of the home
    d. Avoided use of certain appliances or electricity intensive devices
    e. None
    f. Other (Please specify)
    g. Don't know

[IF Q8 = a, b, OR c, CONTINUE. ELSE SKIP TO Q38]

37. During the Peak Energy Events, how would you generally describe your comfort compared to typical afternoons with similar outdoor temperatures? Would you say it was…?

a. Much more comfortable	b. Somewhat more comfortable	c. About the same	d. Somewhat less comfortable	e. Much less comfortable	f. Don't Know
1	2	3	4	5	

38. On Peak Energy Event days, did you ever "opt-out" or override your Wi-Fi thermostat setting to stop the program from adjusting your Wi-Fi thermostat during the Peak Energy Event? (select all that apply)
    a. Yes, before the Peak Energy Event started
    b. Yes, during the Peak Energy Event
    c. No
    d. Don't know

[IF Q38 = a OR b, CONTINUE. ELSE SKIP Q40]

39. Why did you opt-out or override the Wi-Fi thermostat setting? (select all that apply)
    a. Someone in the home needed the temperature cooler for health reasons
    b. Someone in the home wanted the temperature cooler
    c. Wanted the home cooler for a pet
    d. Felt too uncomfortable during previous Peak Energy Events
    e. Had guests/visitors over
    f. Other (Please specify)
    g. Don't know

40. On a scale of 1-5, where 1 is "Not influenced at all" and 5 is "Strongly influenced", how much would you say the program's $25 participation incentive influenced you not to opt-out or override the Wi-Fi thermostat setting during Peak Energy Events?

a. Not influenced at all	b.	c.	d.	e. Strongly influenced	g. Don't Know
1	2	3	4	5	

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[IF Q38 = a OR b, CONTINUE. ELSE SKIP TO Q43]

41. Using a scale of 1 to 5, where 1 means "Very Difficult or Confusing" and 5 means "Very Easy", how easy was it to opt-out of or override Peak Energy Events?

a. Very Difficult/Confusing	b.	c. Neutral	d.	e. Very Easy	g. Don't Know
1	2	3	4	5	

[IF Q41 = a-b (1-2), CONTINUE ELSE SKIP TO Q43]

42. What issues did you encounter when trying to opt-out or override scheduled events?
    _____

43. Do you have any comments on the performance of your Wi-Fi thermostat in general over the course of the summer? _____ **[OPEN-END, OPTIONAL]**

44. What were your main reasons for getting a Wi-Fi thermostat(s)? (select all that apply)
    a. Ability to remotely control thermostat
    b. "Learning" features offered by the thermostat
    c. Save money on my energy bills
    d. Maximize comfort in my home
    e. Reduce my environmental impact
    f. I wanted the latest and greatest technology
    g. Incentive(s) offered. Specify the incentive(s) you received _____.
    h. I was encouraged by my home energy auditor
    i. Other **[OPEN-END]**

45. Did a contractor install your Wi-Fi thermostat(s)?
    a. Yes, a contractor installed my Wi-Fi thermostat
    b. No, I or a family member self-installed

[IF Q45 = a, CONTINUE ELSE SKIP TO Q47]

46. Was the installation of your Wi-Fi thermostat(s) provided as a result of a Home Energy Assessment you received?
    a. Yes
    b. No
    c. Don't know

47. How did you learn about the **Connected**Solutions program? (select all that apply)
    a. National Grid email
    b. National Grid website
    c. National Grid other. Specify _____.
    d. Thermostat manufacturer email. Specify manufacturer _____.
    e. Thermostat manufacturer website. Specify manufacturer _____.
    f. Thermostat manufacturer other. Specify manufacturer and other type of marketing_____.
    g. Home energy auditor
    h. My thermostat installer
    i. Friend/family/neighbor
    j. Other _____

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k. Don't know

48. What were your main reasons for enrolling in the **Connected**Solutions program?
    a. Receive sign-up and participation incentives
    b. Save money on my energy bills
    c. Maximize comfort in my home
    d. Reduce my environmental impact
    e. Reduce the need for additional power plants
    f. Support my community and/or state's energy initiatives
    g. Receive a free Wi-Fi thermostat(s)
    h. Other **[OPEN-END]**

[IF Q45 = a, CONTINUE ELSE SKIP TO Q50]

49. Did your thermostat installer complete the online **Connected**Solutions enrollment process on your behalf?
    a. Yes, my thermostat installer completed the online enrollment.
    b. No, I completed the online enrollment process.
    c. No, a family member other than myself completed the online enrollment process

[IF Q45 = b OR Q49 = b, CONTINUE. OTHERWISE SKIP TO Q52]

50. Using a scale of 1 to 5 where 1 indicates "Very Difficult or Confusing" and 5 indicates "Very Easy," how easy did you find the **Connected**Solutions online enrollment process?
    a. 1 = Very difficult/confusing
    b. 2
    c. 3
    d. 4
    e. 5 = Very easy
    f. Don't know

51. How could the enrollment website be improved? **[OPEN-END, OPTIONAL]**

52. Is there any additional information you wish would have been provided about the program? If so, please specify. **[OPEN-END, OPTIONAL]**

We have a few final questions about yourself and your household and then you'll be done!

53. Are you or is anyone in your household a National Grid employee?
    a. Yes
    b. No

54. What is your gender?
    a. Male
    b. Female

55. Which one of these options best describes this residence?
    a. Single-family detached house
    b. Townhouse, duplex, or row house (shares common wall with neighboring unit from basement to roof)
    c. Apartment with 2-4 units (either rent or own)
    d. Apartment with 5 or more units (either rent or own)
    e. Mobile home or trailer
    f. Other (Please Specify)
    g. Don't know
    h. I prefer not to answer

56. How many square feet of living space are there in this residence, including bathrooms, foyers, and hallways? Please exclude unheated rooms and garages. If you live in an apartment building, please answer for the living space considered "your home."
    a. Less than 1,000
    b. 1,001 – 1,500
    c. 1,501 – 2,000
    d. 2,001 – 2,500
    e. 2,501 – 2,999
    f. 3,000 – 3,500
    g. 3,501 – 4,000
    h. Greater than 4,000
    i. Don't know
    j. I prefer not to answer

57. How many rooms are in this residence? Please exclude bathrooms, halls, pantries, unheated rooms, and garages
    _____ **[ENTER # OF ROOMS]**
    a. Don't know
    b. I prefer not to answer

58. Approximately what year was this residence built?
    a. Before 1930
    b. 1930-1939
    c. 1940-1949
    d. 1950-1959
    e. 1960-1969
    f. 1970-1979
    g. 1980-1989
    h. 1990-1999
    i. 2000-2004
    j. 2005-2009
    k. 2010-present
    l. Unsure/Don't know
    m. I prefer not to answer

59. Please select the range that best describes this household's gross income for 2015 (before adjustments for taxes and credits). Please include all sources of income such as salaries, wages, rent, interest, dividends, pensions, and social security.
    a. Less than $30,000
    b. $30,000 to $49,999
    c. $50,000 to $69,999
    d. $70,000 to $99,999
    e. $100,000 to $149,999
    f. $150,000 to $199,999
    g. $200,000 to $249,999
    h. $250,000 to $499,999
    i. $500,000 or higher
    j. Don't know
    k. I prefer not to answer

60. What is the highest level of education completed by the head of household in this residence?
    a. Elementary (Grades 1-8)
    b. Some high school (Grades 9-12)
    c. High School Graduate
    d. Some College/Trade/Vocational School
    e. College Graduate
    f. Postgraduate College
    g. Don't know
    h. I prefer not to answer

[IF Q53 = b, ASK. ELSE SKIP TO END]

61. Thank you for taking the time to complete this survey. For completing the survey, you will receive a $10 Amazon gift card. Please provide your current contact information so that we can email you the gift card.
    a. Name (Please specify)
    b. Email address (Please specify)
    c. Prefer not to receive gift card

62. In addition, we are seeking volunteers to participate in an onsite visit as a follow-up to your survey. Navigant Consulting, Inc. (Navigant) has been retained to conduct onsite visits on behalf of National Grid to collect information about the air conditioning units of program participants. For successfully completing the onsite visit, National Grid would like to offer you a $25 gift card.

    The onsite visit will involve a Navigant representative visiting your home and collecting information about your air conditioner, specifically, the nameplate information which must be read from the air conditioning unit both inside and outside your home. A typical visit takes 15 minutes and will take place during a weekday between 8 am and 6 pm over the next few weeks.

    Your participation in this study will help enhance and improve National Grid's demand response programs. Are you interested in participating?

    a. Yes
    b. No

[IF Q62 = a, ASK. ELSE SKIP TO CLOSING SCREEN]

63. Great! Please provide your contact information below, including a current phone number. We will call you to schedule an appointment. We look forward to connecting with you.

    a. Name (Please specify) **[OPTIONAL]**
    b. Email (Please specify) **[OPTIONAL]**
    c. Phone Number (Please specify) **[OPTIONAL]**
    d. Home Address (Please specify) **[OPTIONAL]**

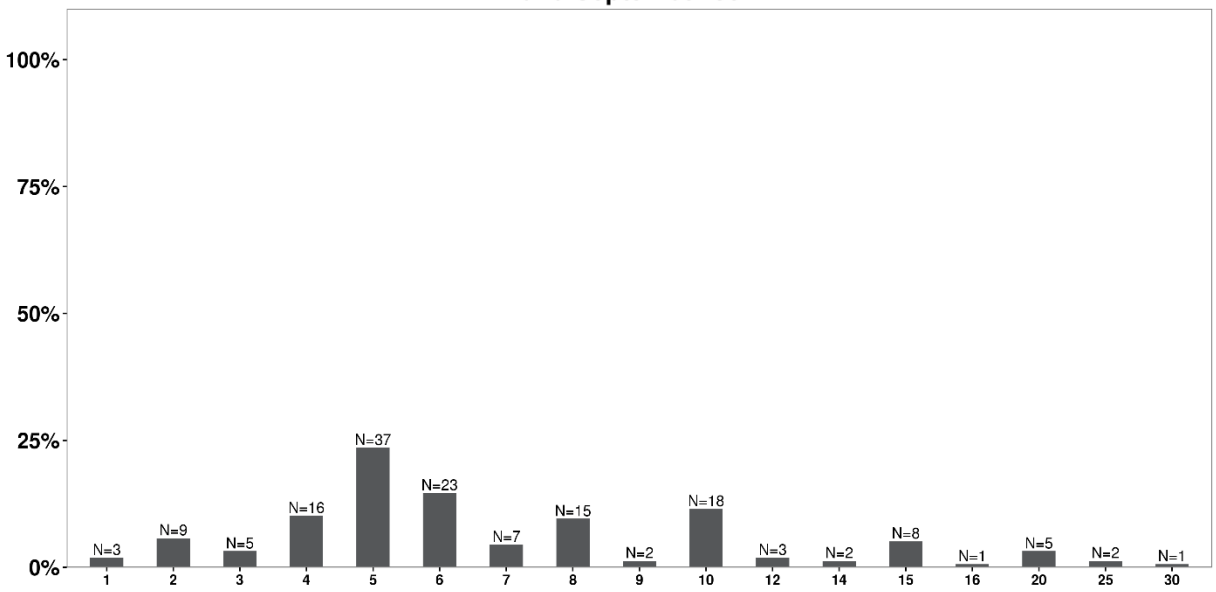
Note: Depending on the number of responses, Navigant may not contact you.

CLOSING SCREEN: Survey Completed! Thank you!

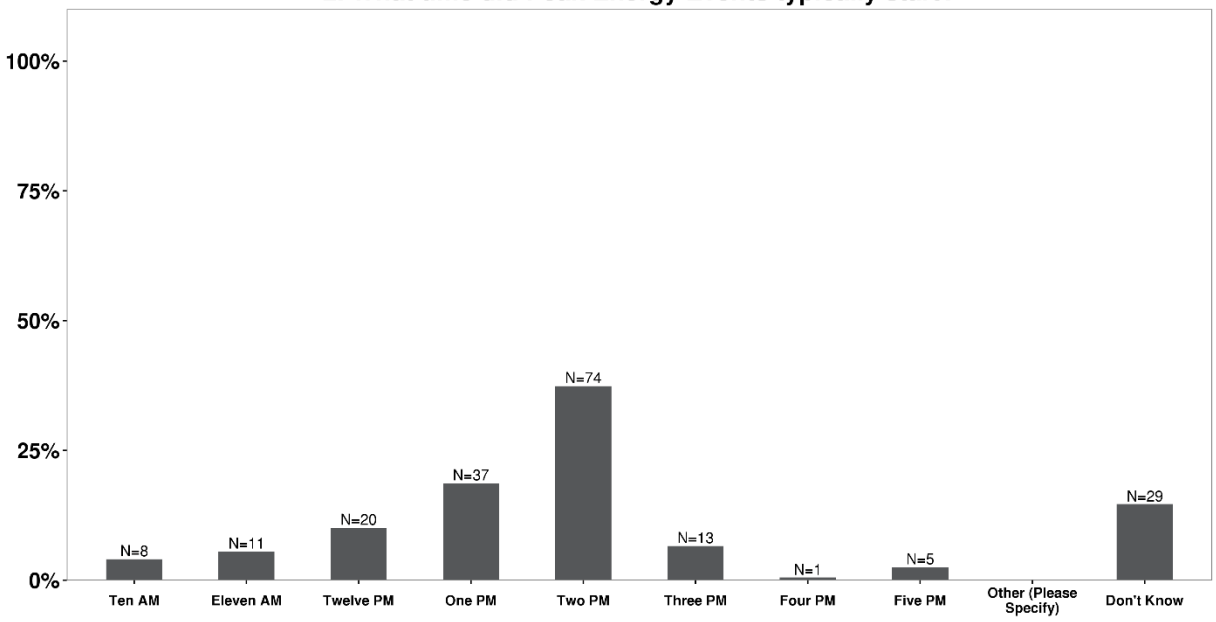
[CLOSE]

Output to multi-choice questions is presented in terms of percentage of respondents (not responses). Therefore, for questions where respondents could select multiple responses, the percentages across columns may sum to greater than 100%.

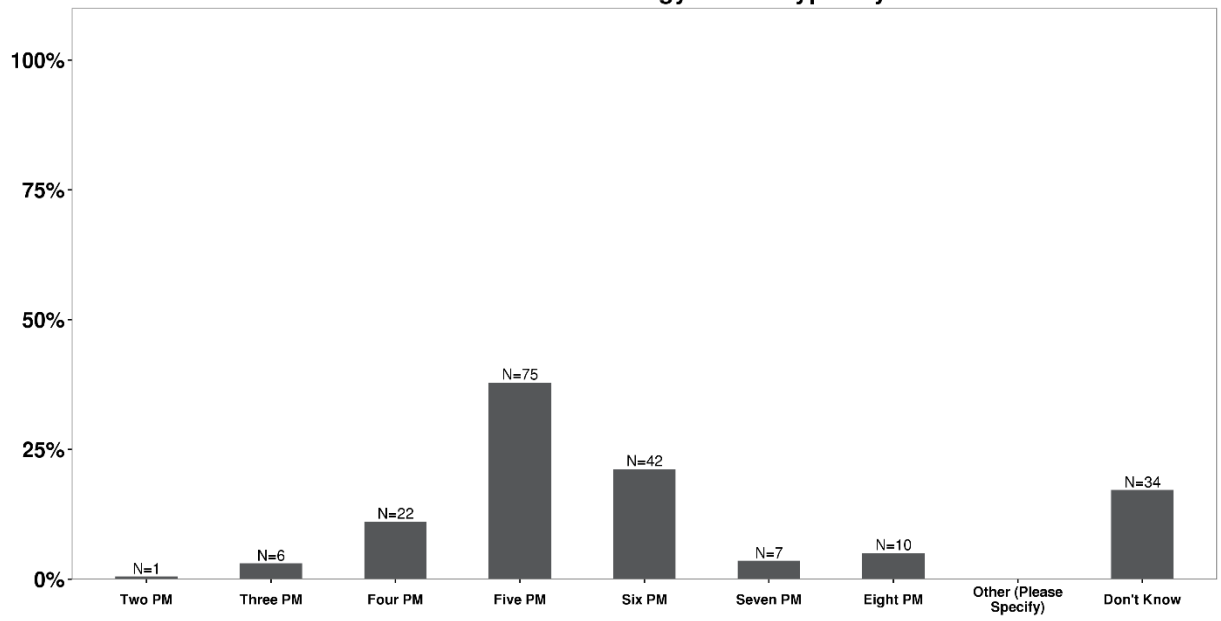
1. About how many Peak Energy events do you remember occurring between June 1 and September 30?



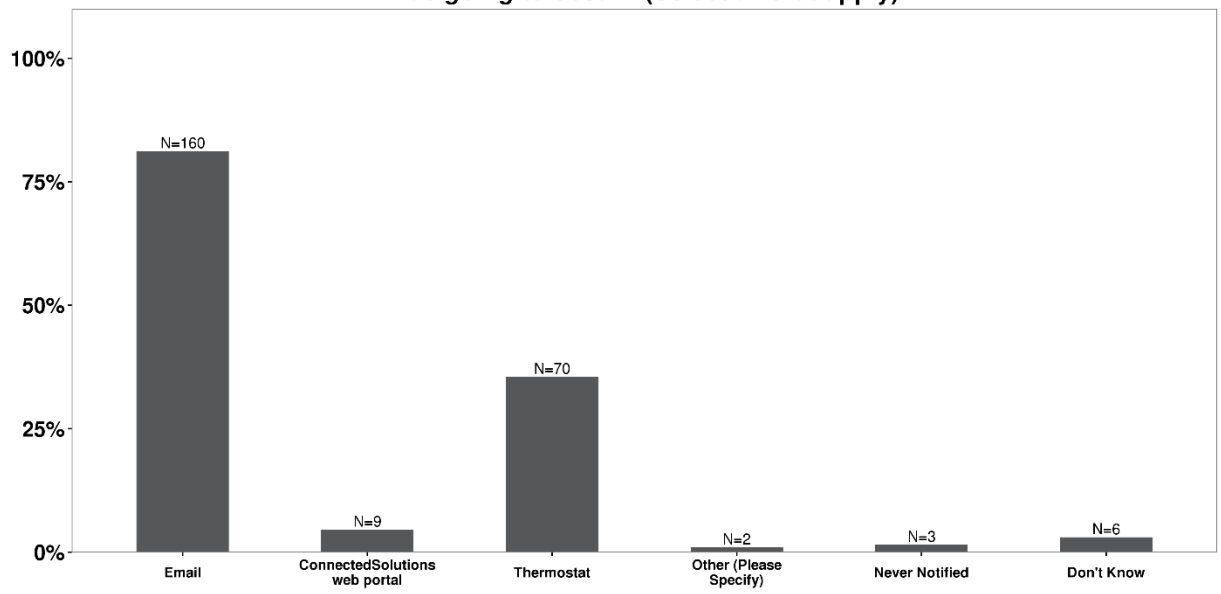
2. What time did Peak Energy Events typically start?



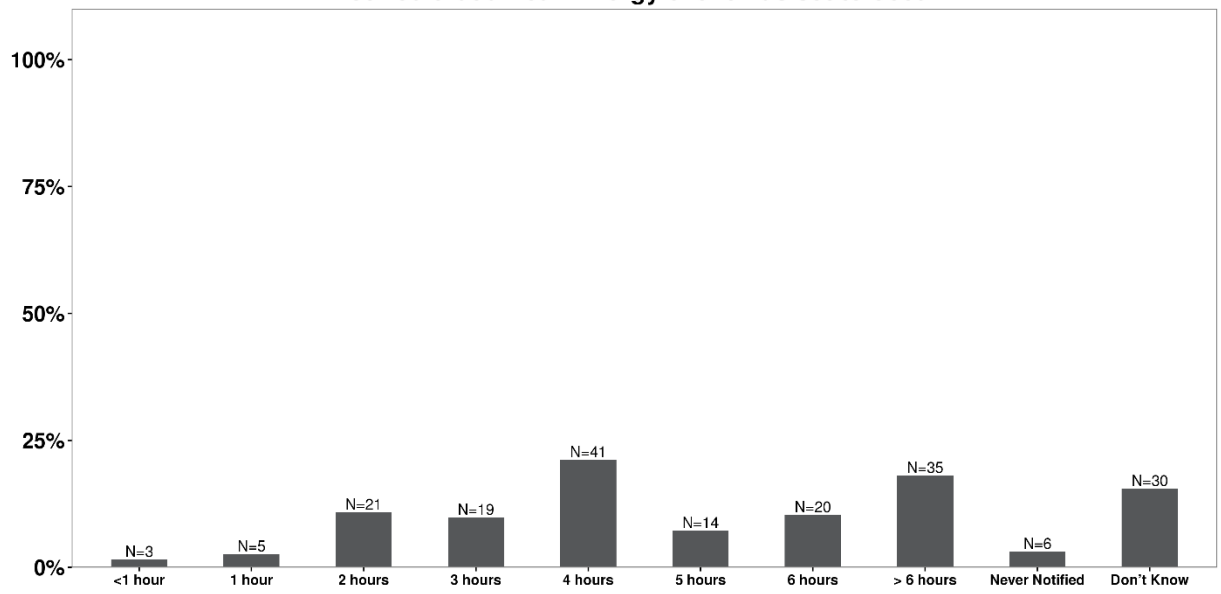
3. What time did Peak Energy Events typically end?



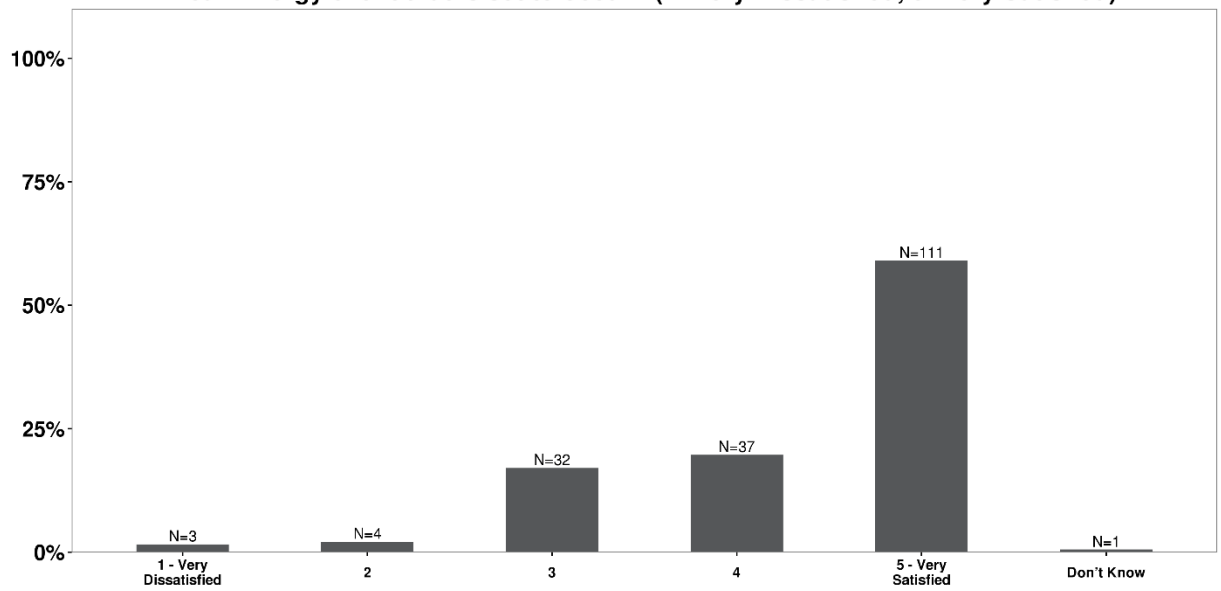
4. During this past summer, how did you become aware that a Peak Energy event was going to occur? (Select all that apply)



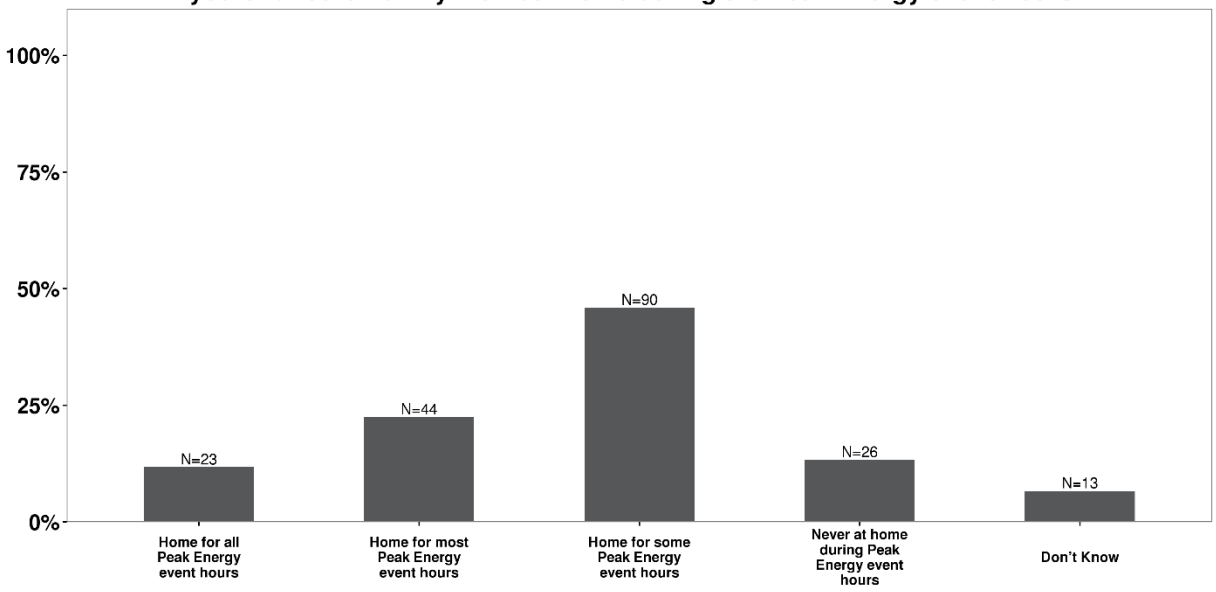
5. During this past summer, approximaetly how far in advance were you typically notified that a Peak Energy event was set to occur?



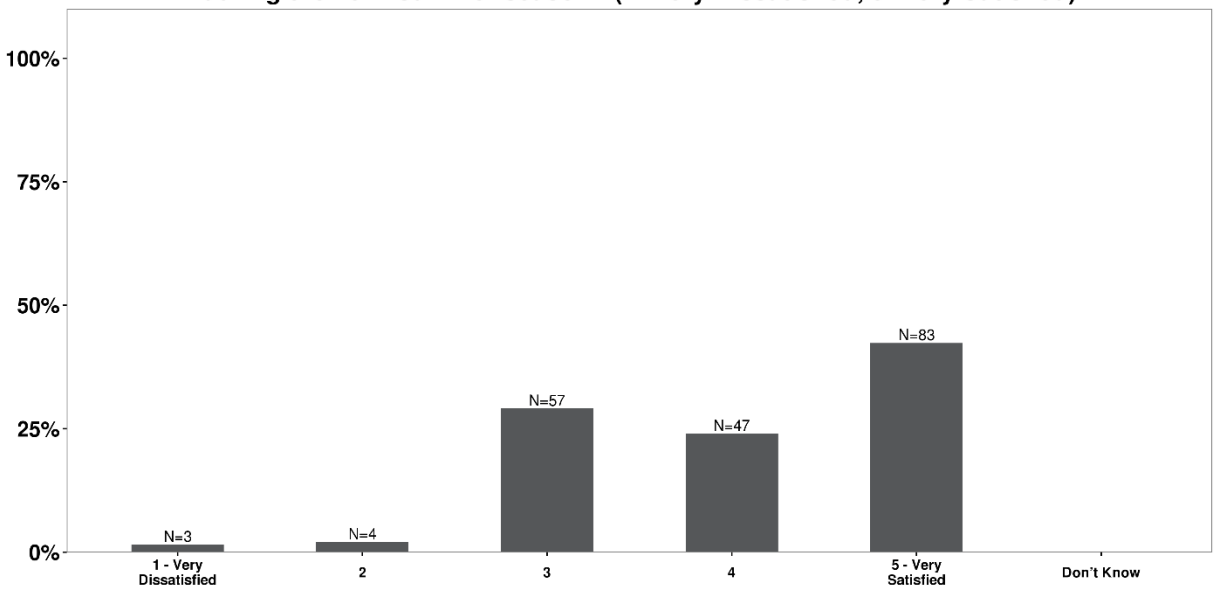
6. What is your level of satisfaction with the notification you receive about a Peak Energy event that is set to occur? (1=Very Dissatisfied, 5=Very Satisfied)



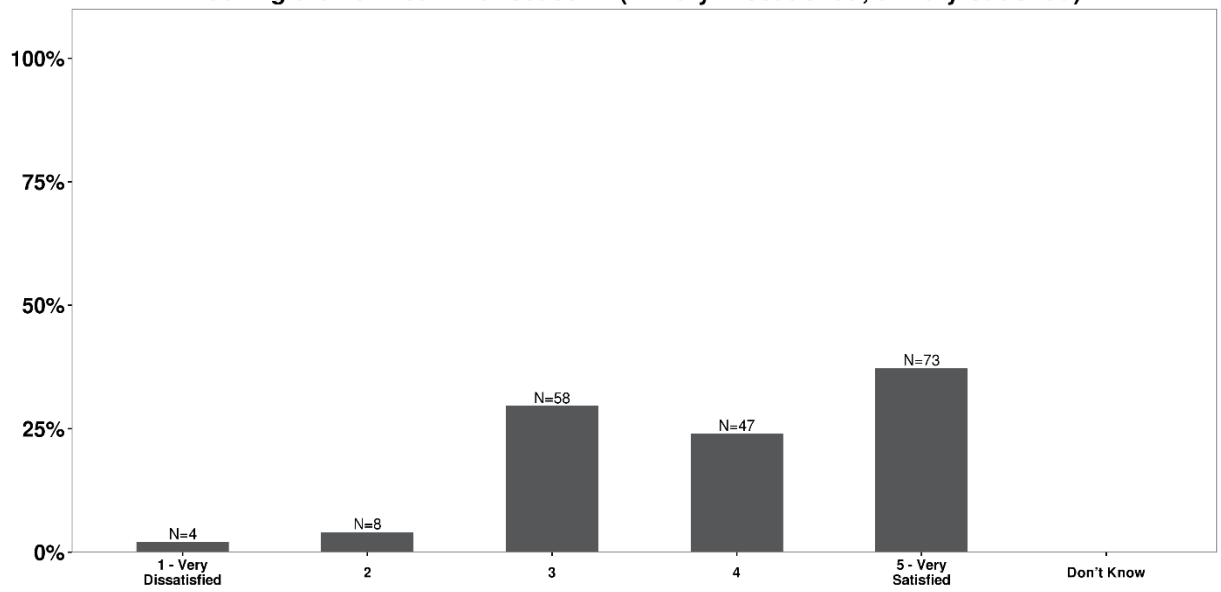
8. This summer, for the Peak Energy events you can recall, about how often were you or another family member home during the Peak Energy event hours?



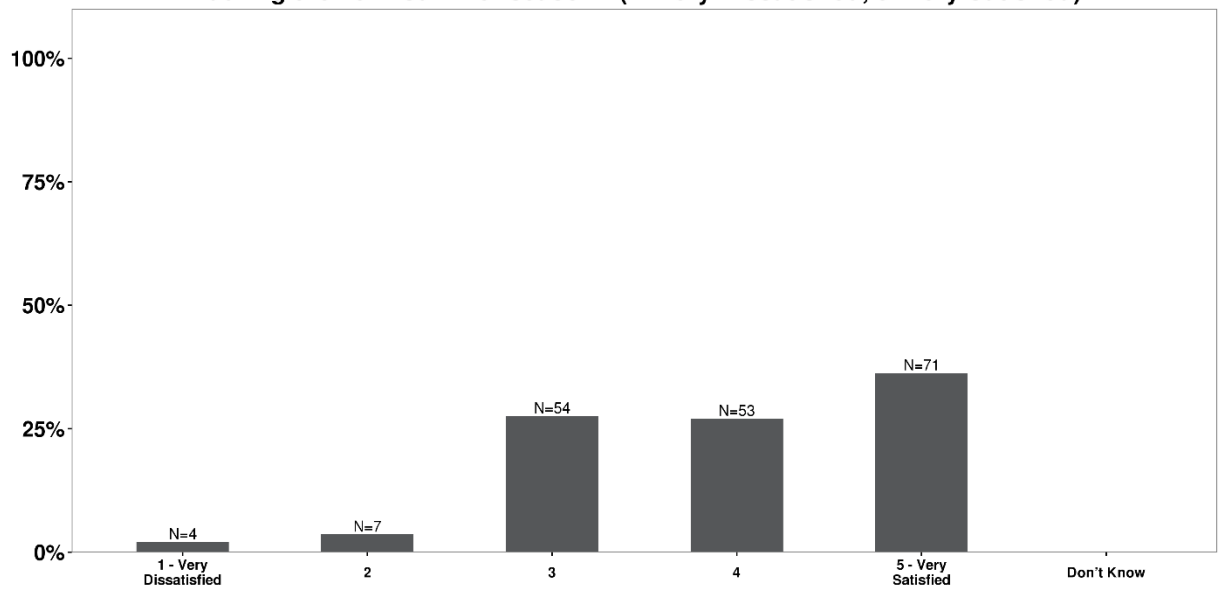
9. How would you rate your satisfaction with the number of Peak Energy events during the 2017 summer season? (1=Very Dissatisfied, 5=Very Satisfied)



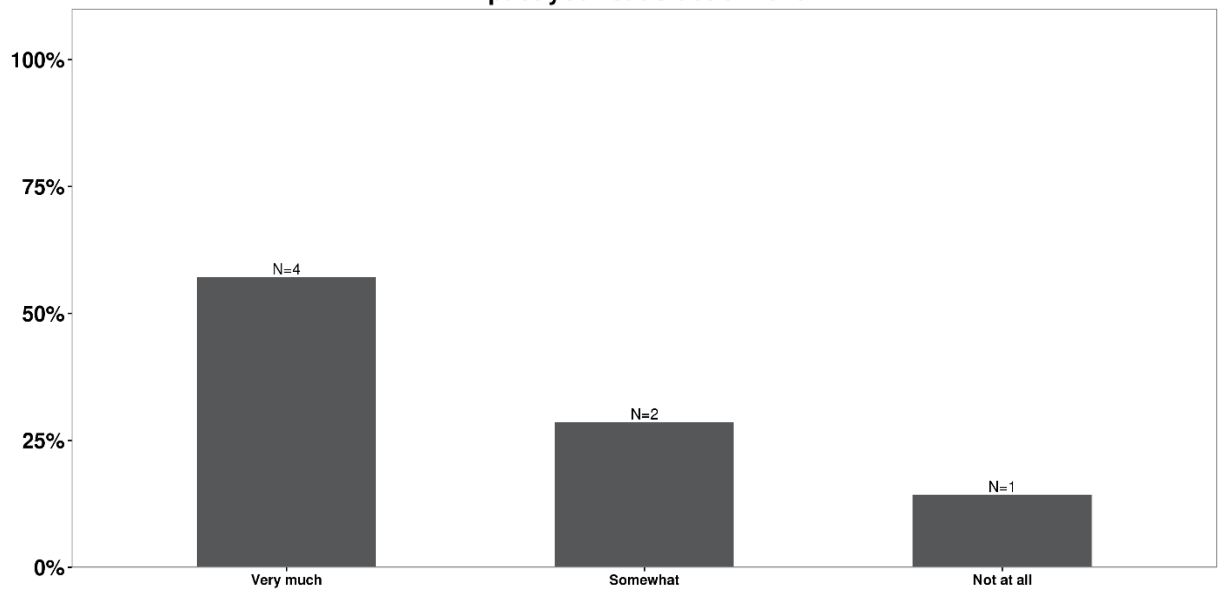
10. How would you rate your satisfaction with the length of Peak Energy events during the 2017 summer season? (1=Very Dissatisfied, 5=Very Satisfied)



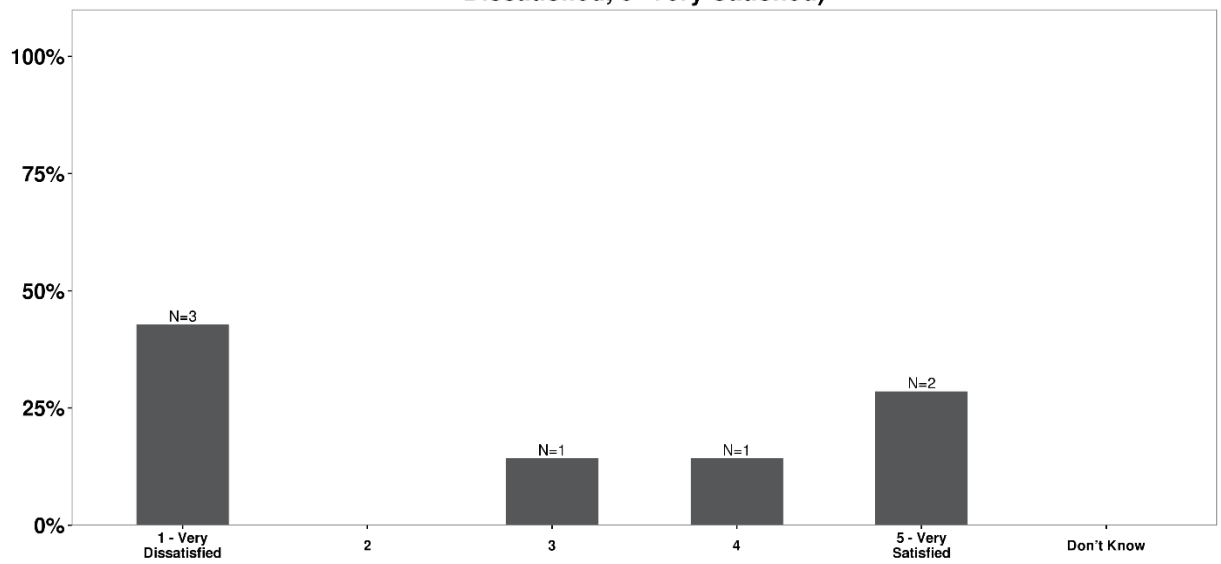
11. How would you rate your satisfaction with the timing of Peak Energy events during the 2017 summer season? (1=Very Dissatisfied, 5=Very Satisfied)



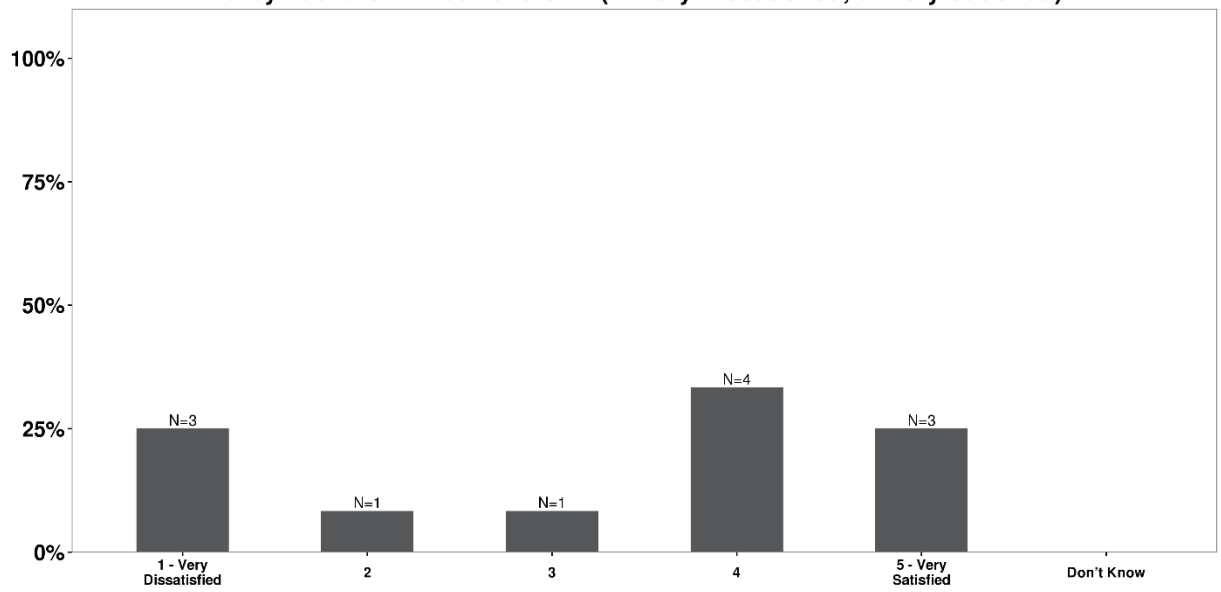
12. Did the number of Peak Energy Events that occurred on consecutive days impact your satisfaction level?



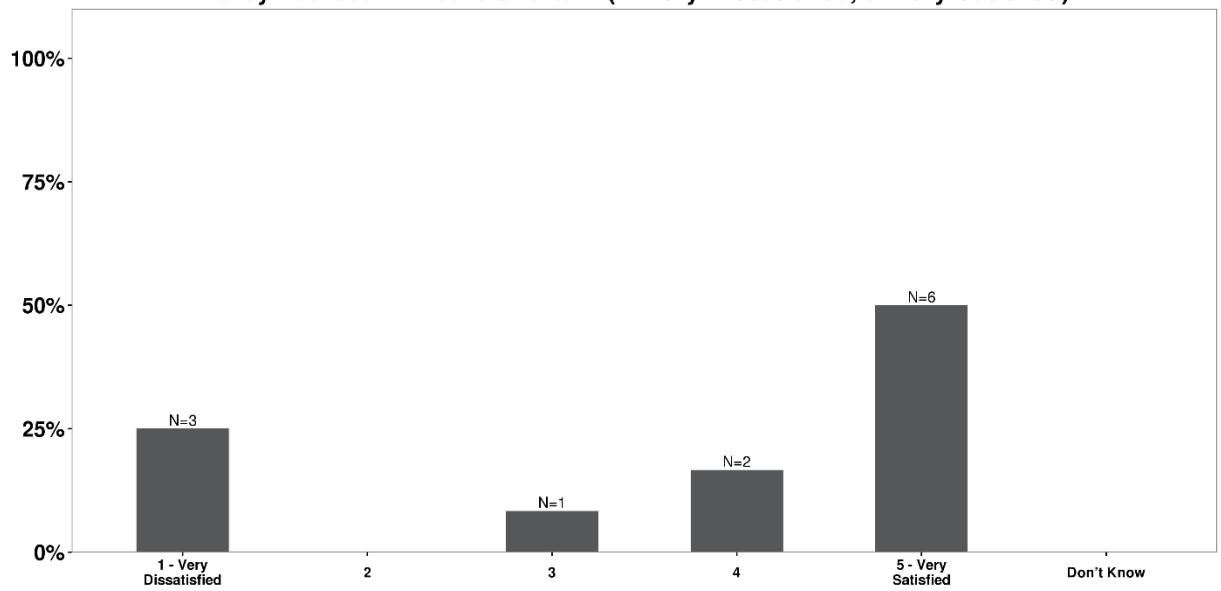
13. How satisfied would you have been with the nunber of Peak Energy Events if there had been 5 fewer events over the course of the summer? (1=Very Dissatisfied, 5=Very Satisfied)



15. How satisfied would you have been with the length of Peak Energy Events if they had been 1 hour shorter? (1=Very Dissatisfied, 5=Very Satisfied)



16. How satisfied would you have been with the length of Peak Energy Events if they had been 2 hours shorter? (1=Very Dissatisfied, 5=Very Satisfied)



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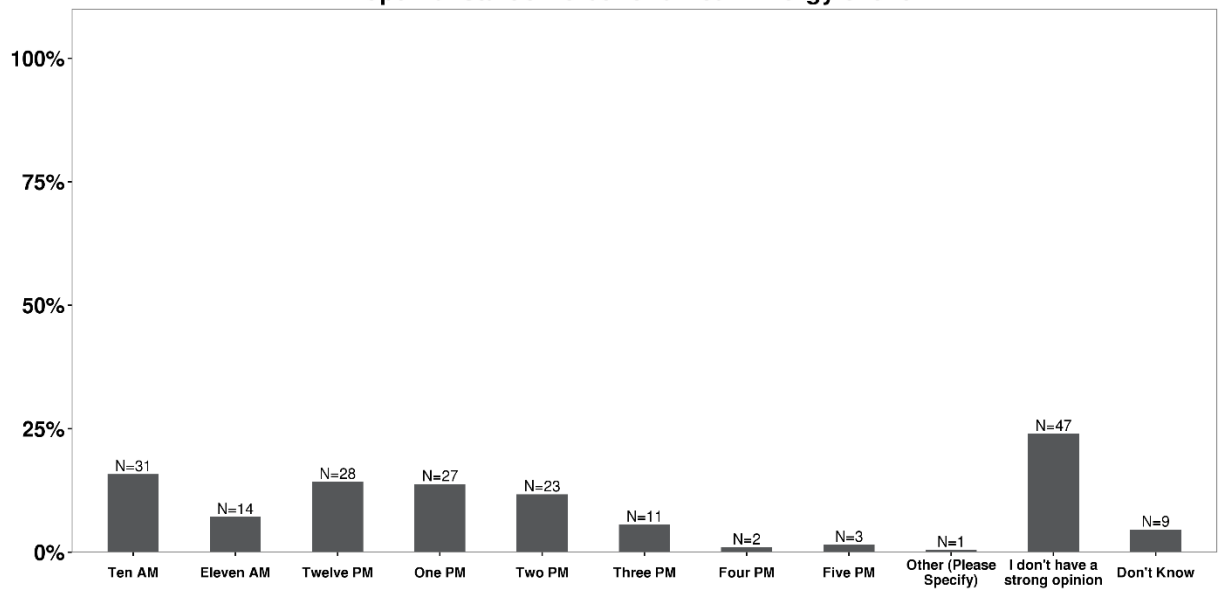
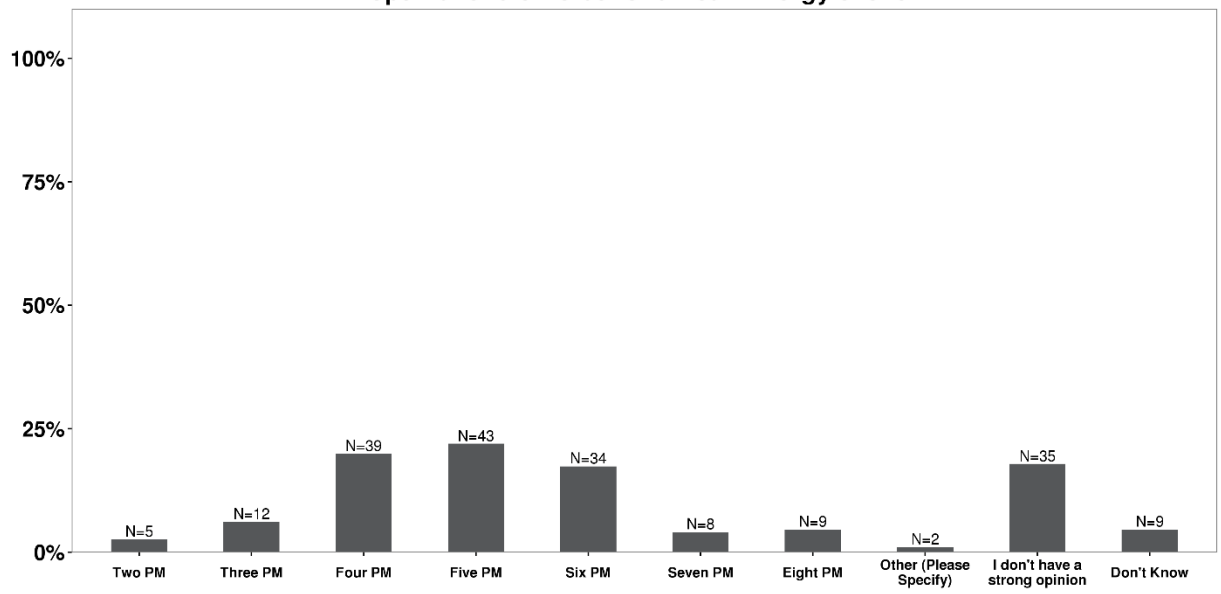
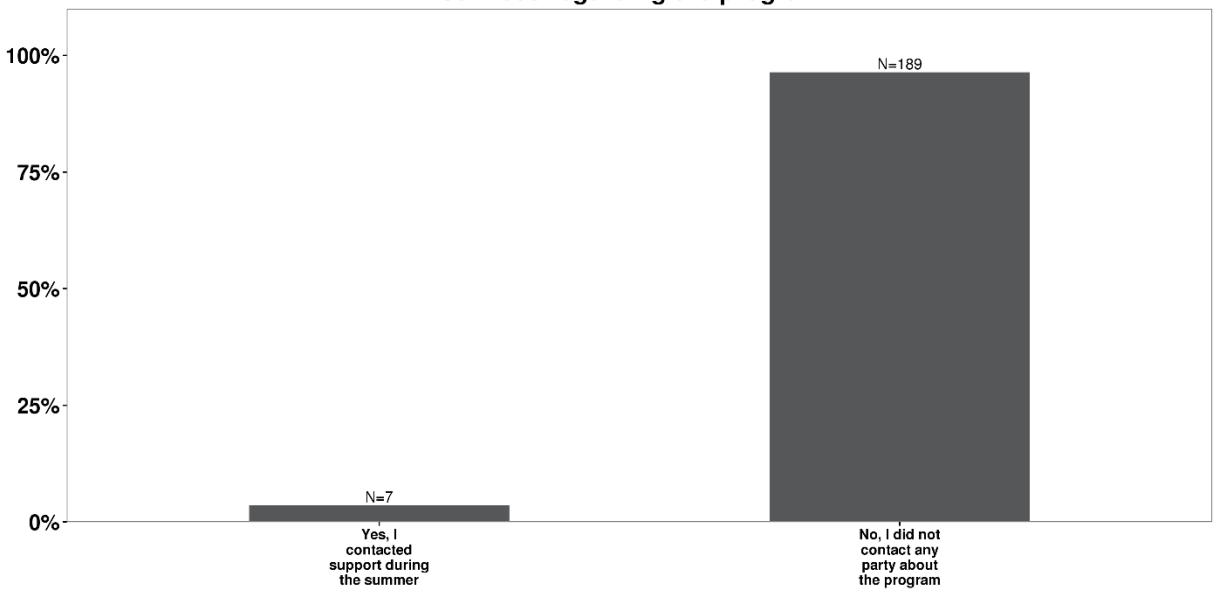
18. Based on your experience with the program this summer, what would the optimal start time be for a Peak Energy event?



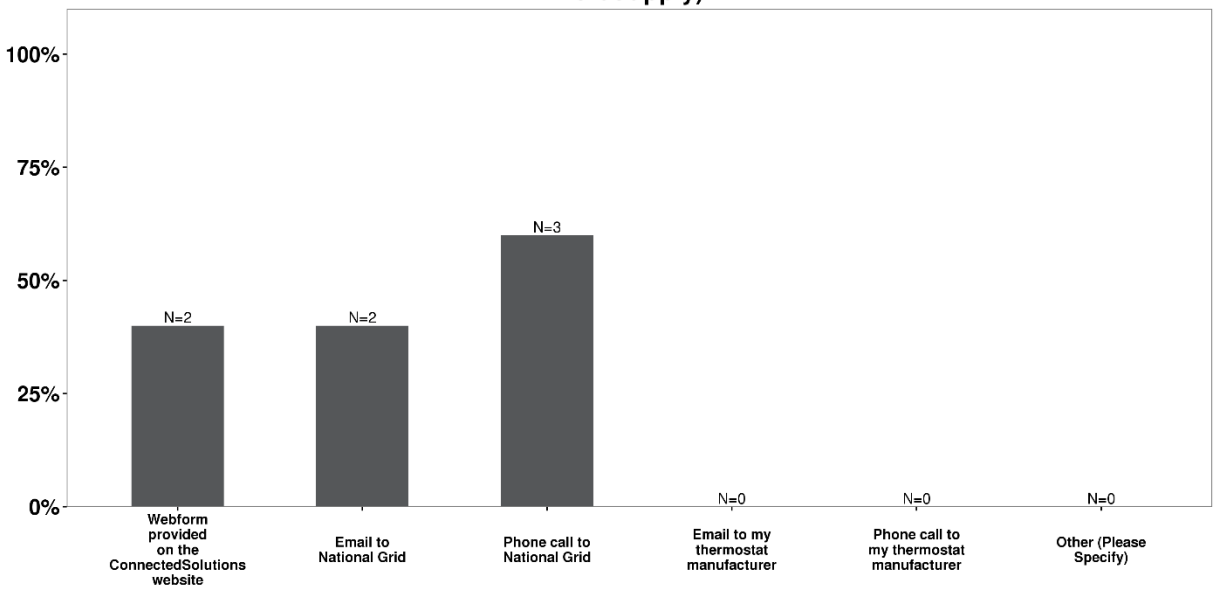
19. Based on your experience with the program this summer, what would the optimal end time be for a Peak Energy event?



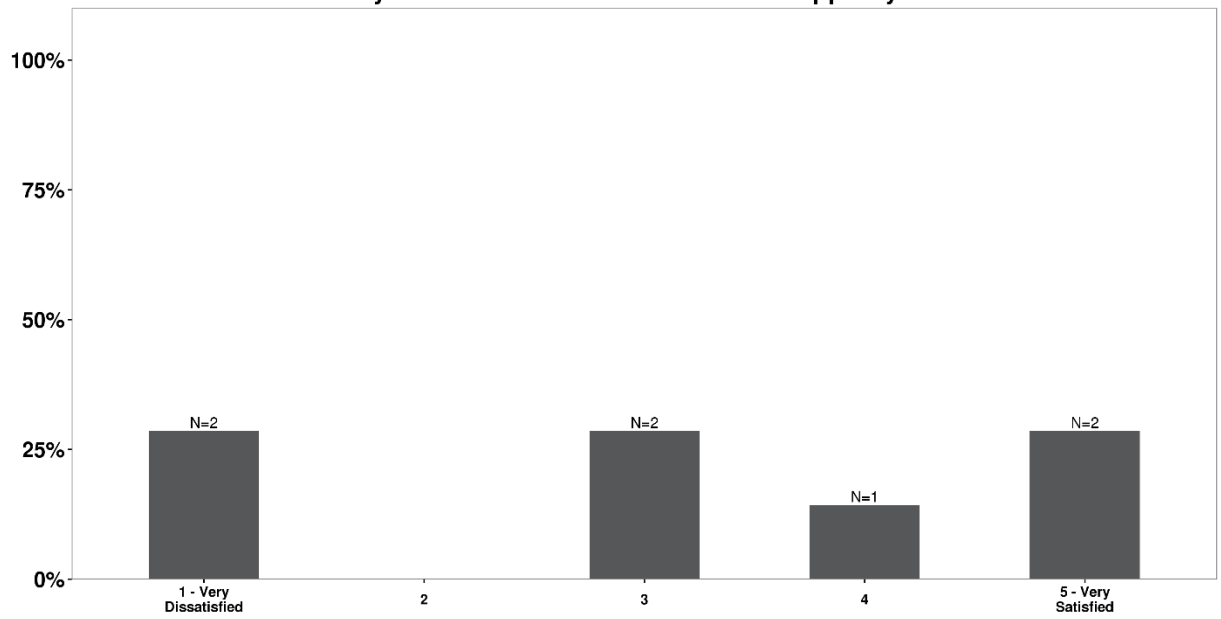
20. At any point over the course of the summer, did you contact support services regarding the program?



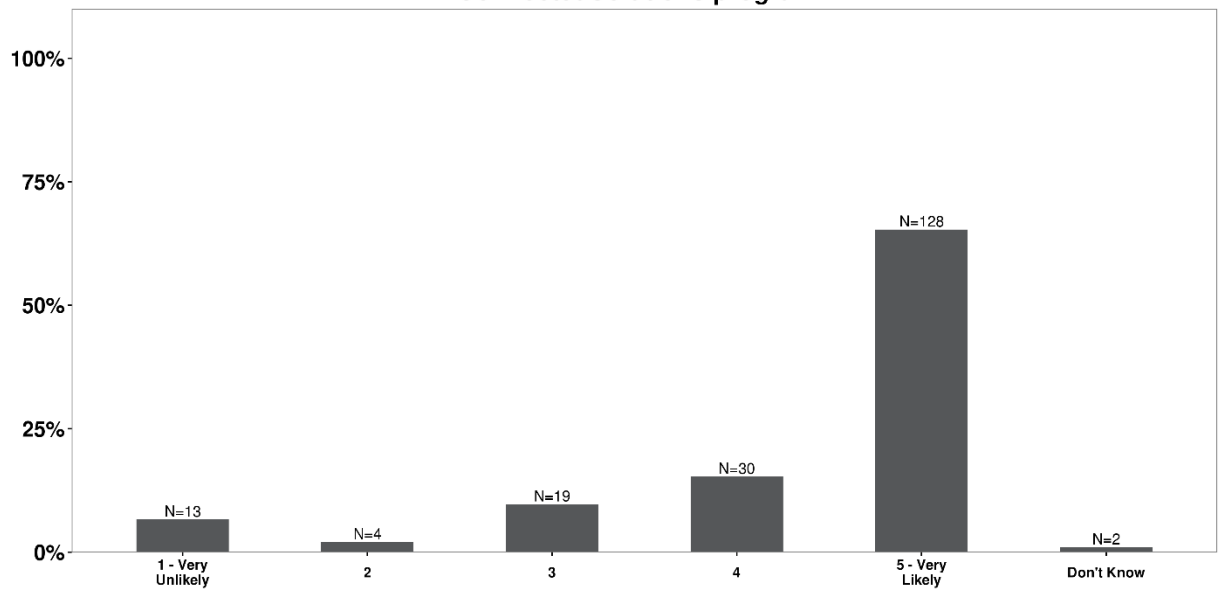
21. What method did you use to contact support about the program? (Select all that apply)



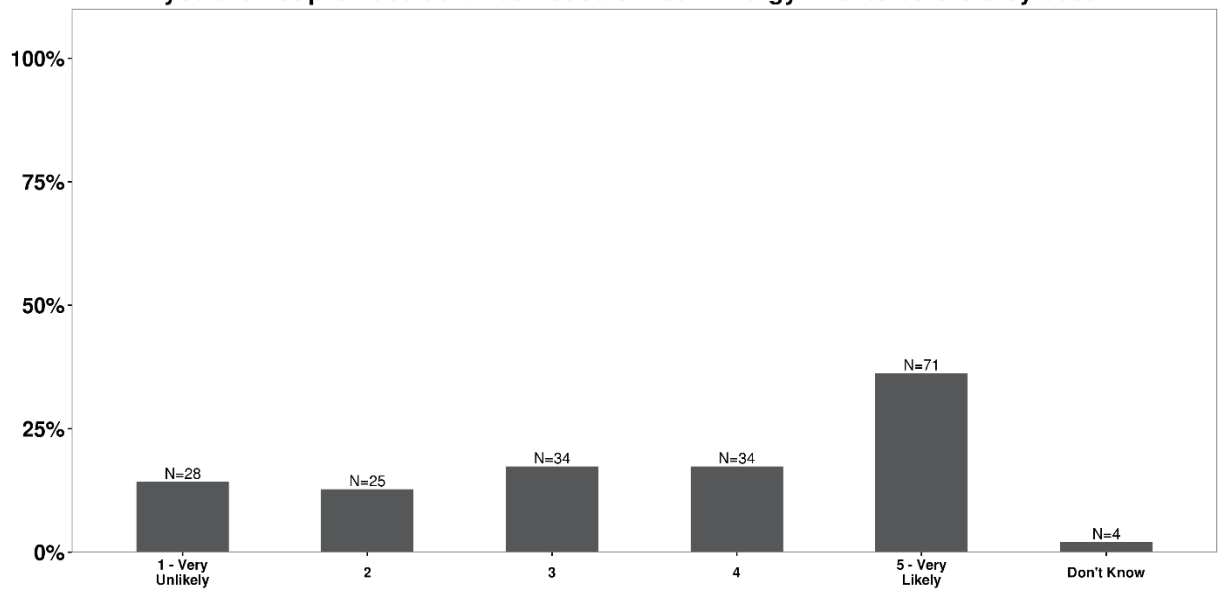
23. What is your level of satisfaction with the support you received?



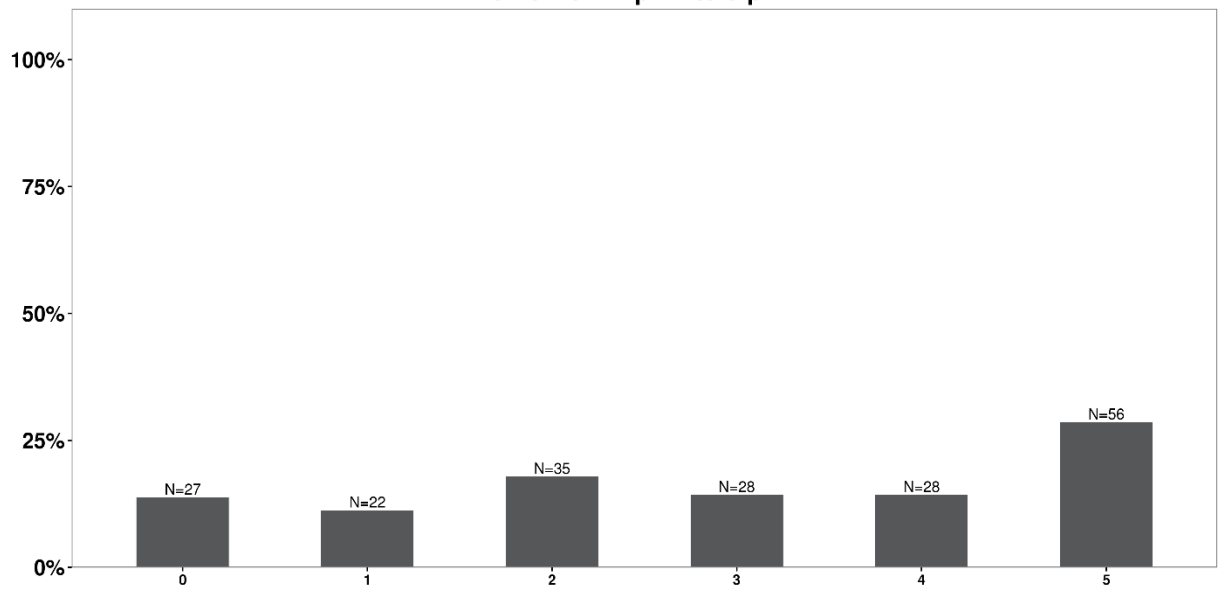
25. In future summers, how likely would you be to participate in the ConnectedSolutions program?



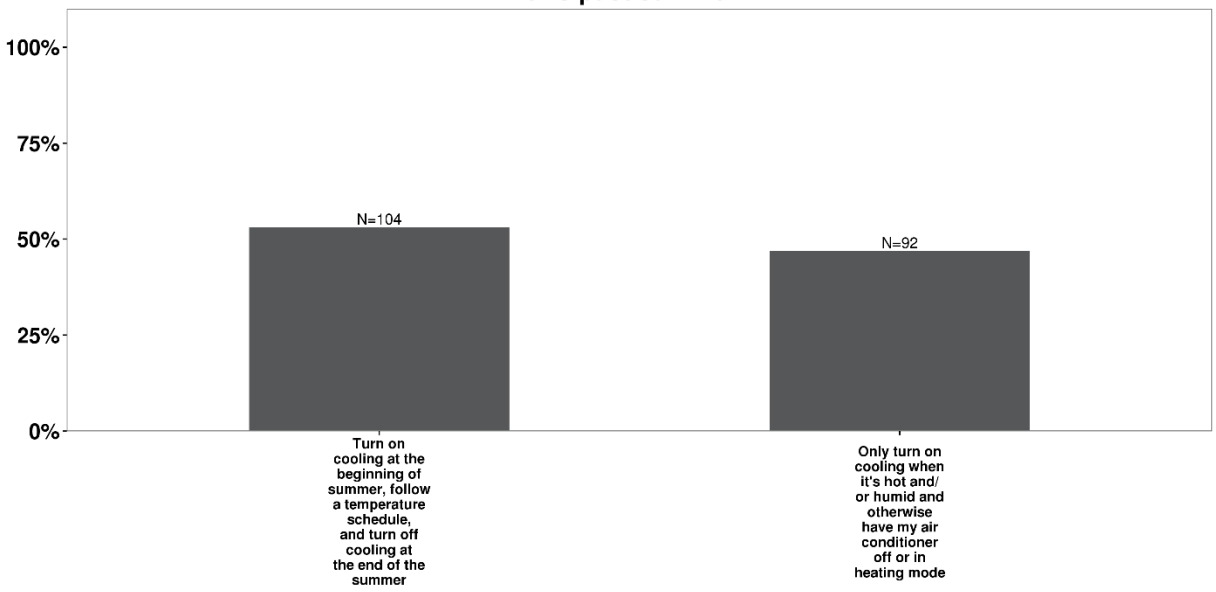
28. How likely would you be to pariticpate in the ConnectedSolutions program if you are not provided advance notice of Peak Energy Events before they occur?



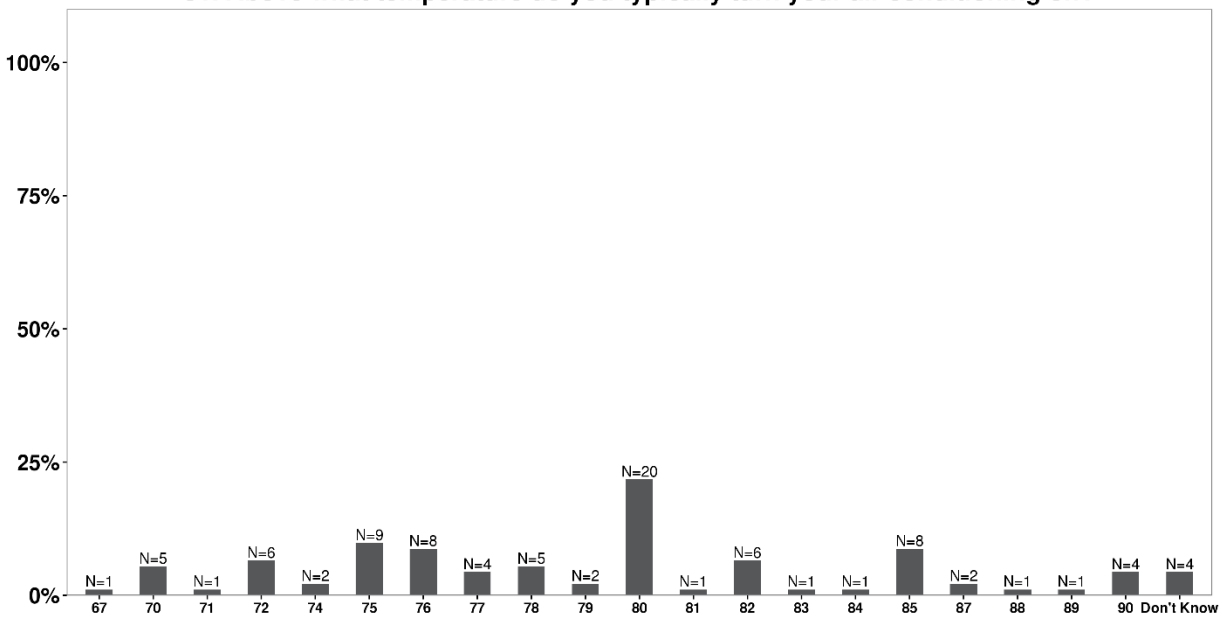
29. During the summer, for how many weekdays per week is at least one person home from 2 p.m. to 5 p.m.?



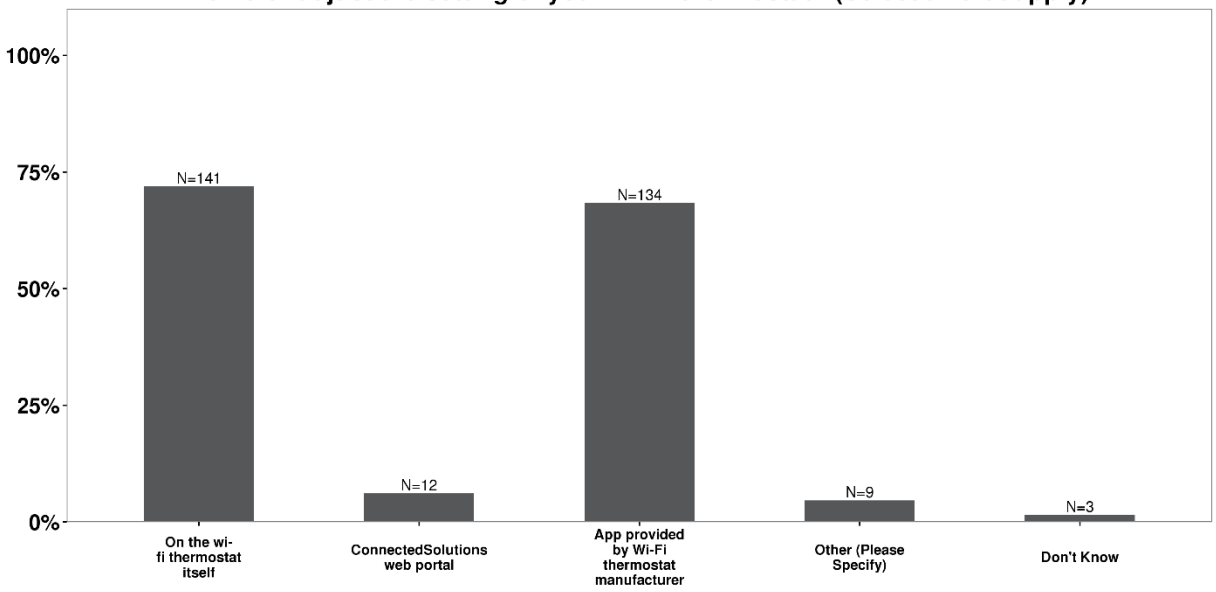
30. Which of the following best describes the way you used your air conditioner this past summer?



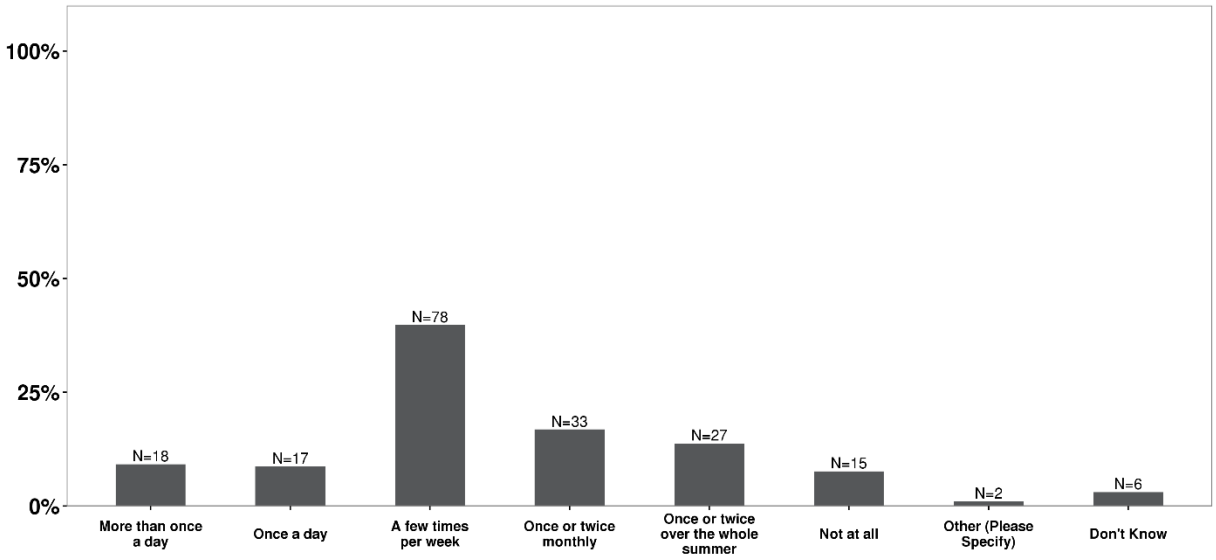
31. Above what temperature do you typically turn your air conditioning on?



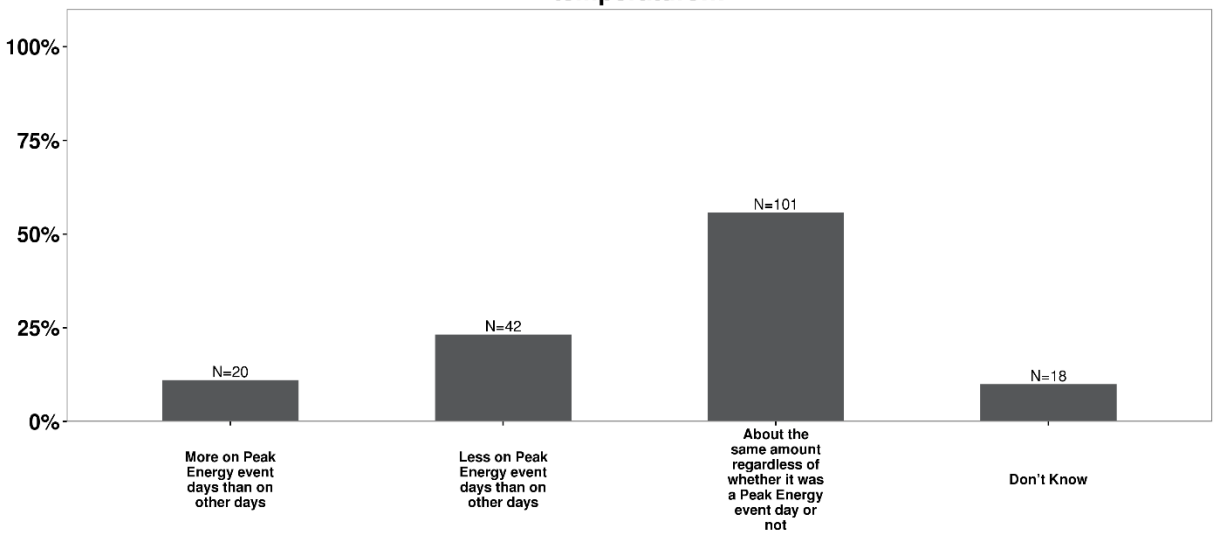
32. Over the past summer, how did you typically monitor the temperature of your home or adjust the setting of your Wi-Fi thermostat? (Select all that apply)



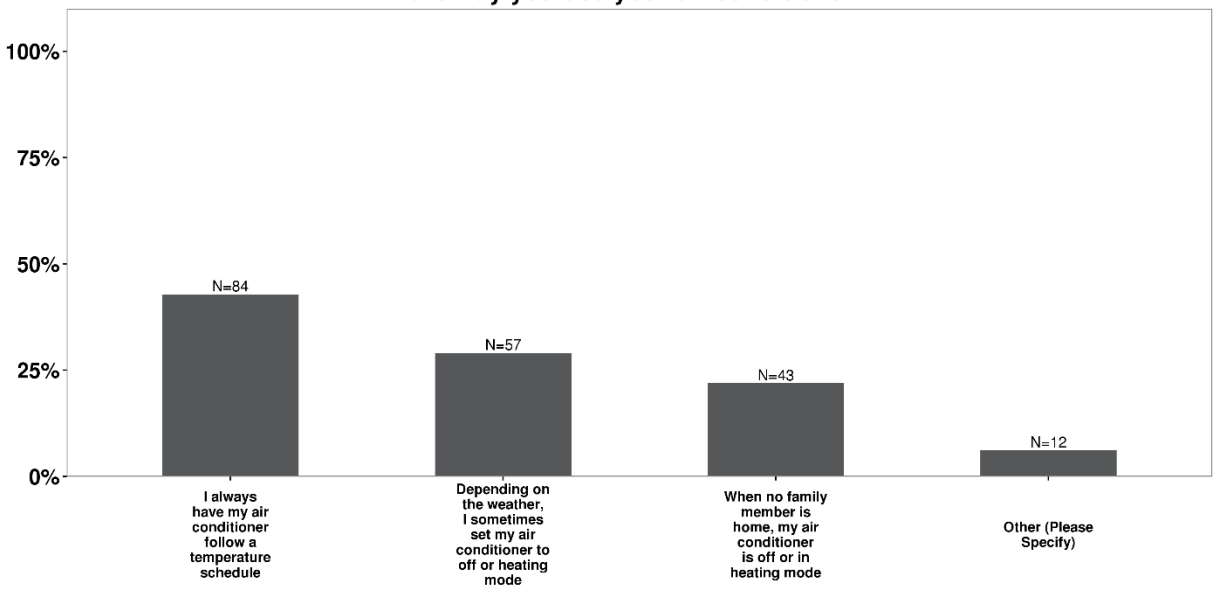
33. Now we'd like to understand the frequency with which you adjusted your Wi-Fi thermostat's setting or schedule during this summer. Would you say it was…



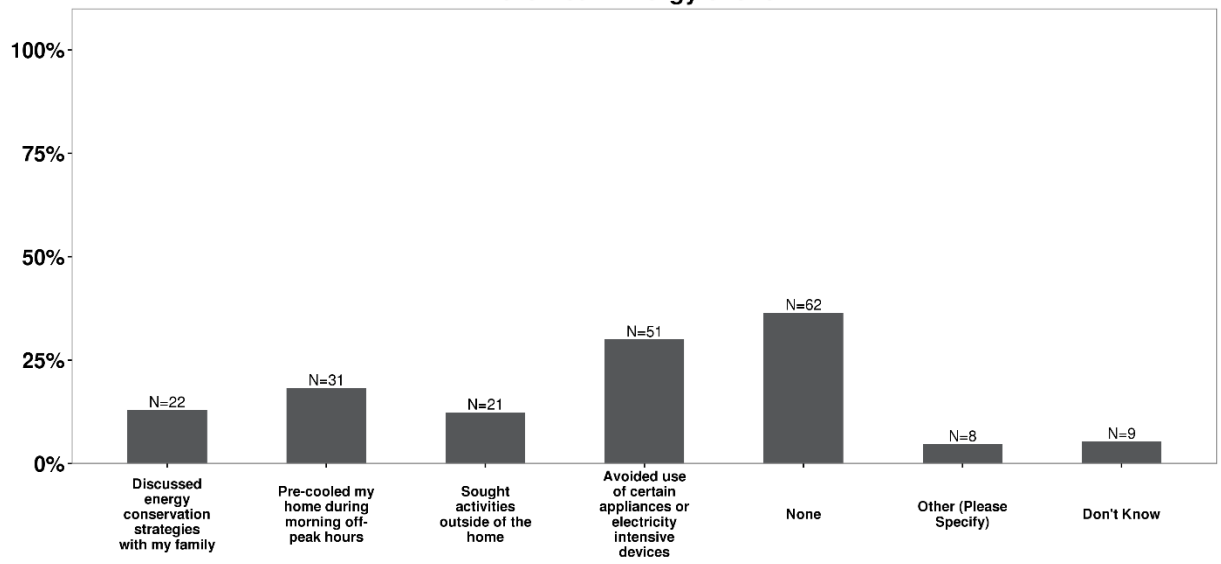
34. We'd also like to understand whether the frequency with which you adjusted your Wi-Fi thermostat's setting or schedule was different on Peak Energy Event days compared to other days. Would you say you adjusted your home's temperature…



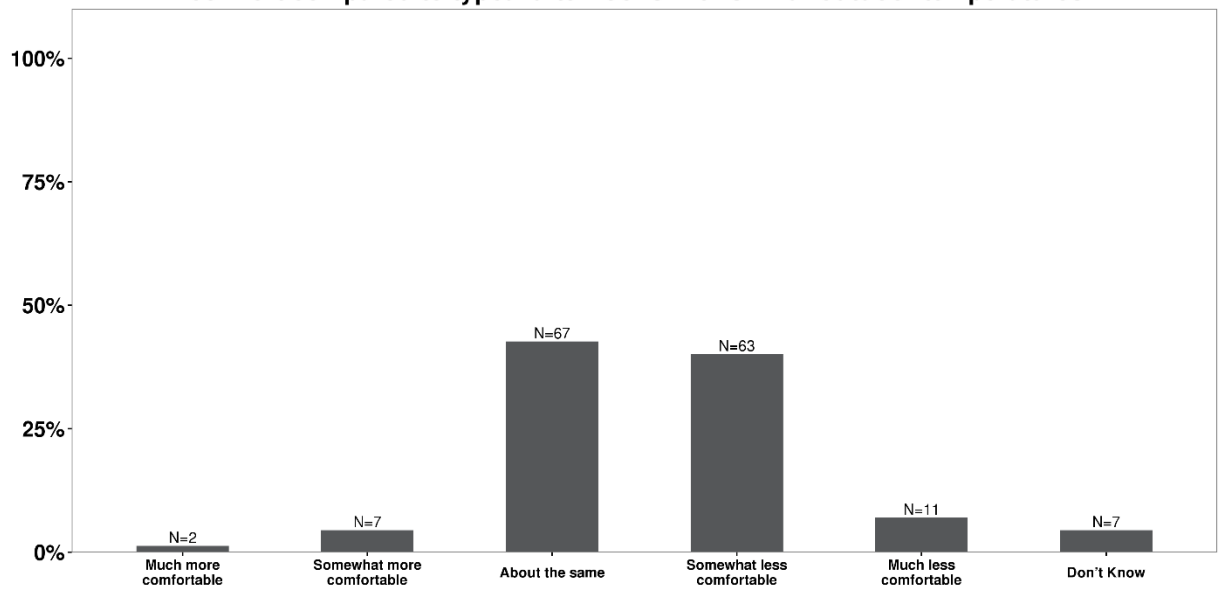
35. When no familiy member is at home, which of the following best describes the way you use your air conditioner?



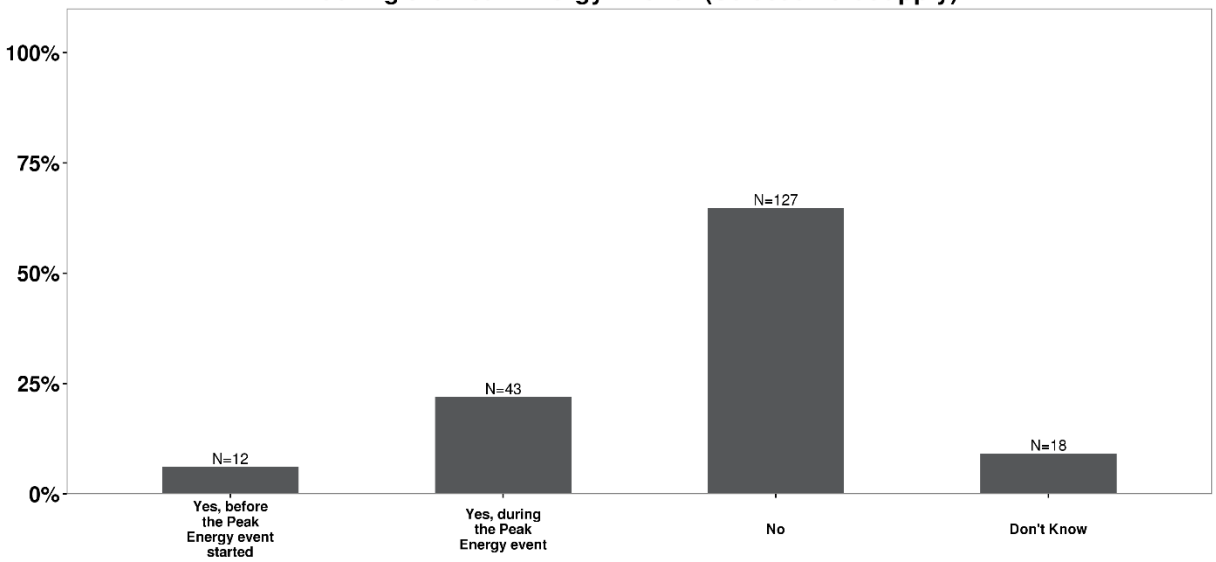
36. When you or a family member was at home for any part of a Peak Energy event, what actions, if any, did you take to reduce your electricity use during the Peak Energy event?



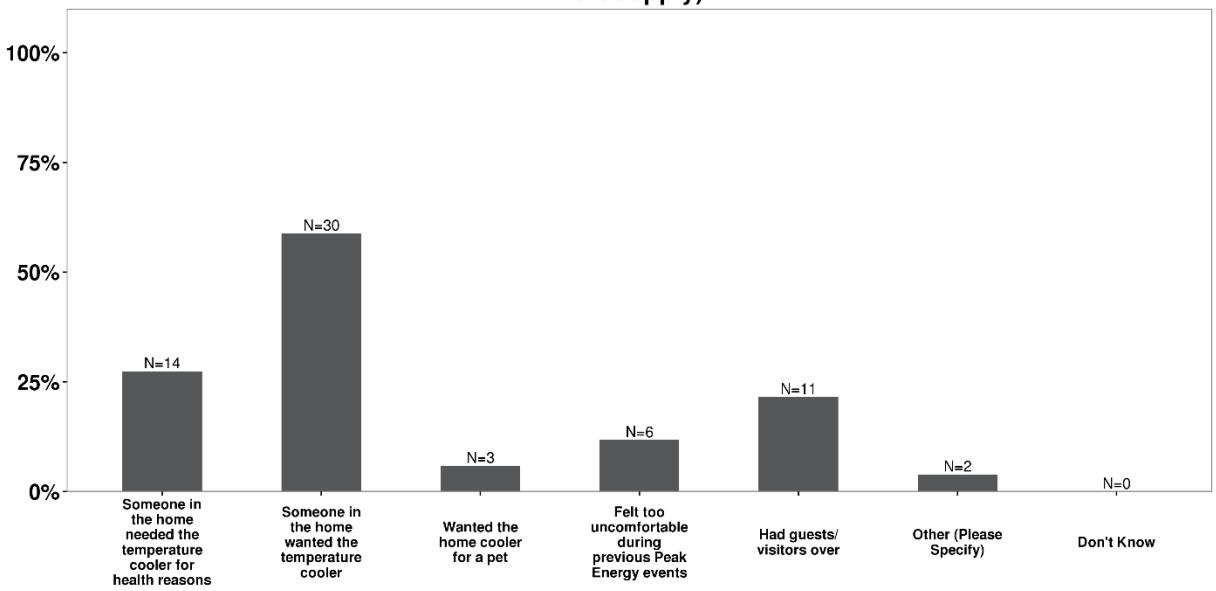
37. During the Peak Energy events, how would you generally describe your comfort compared to typcal afternoons with similar outdoor temperatures?



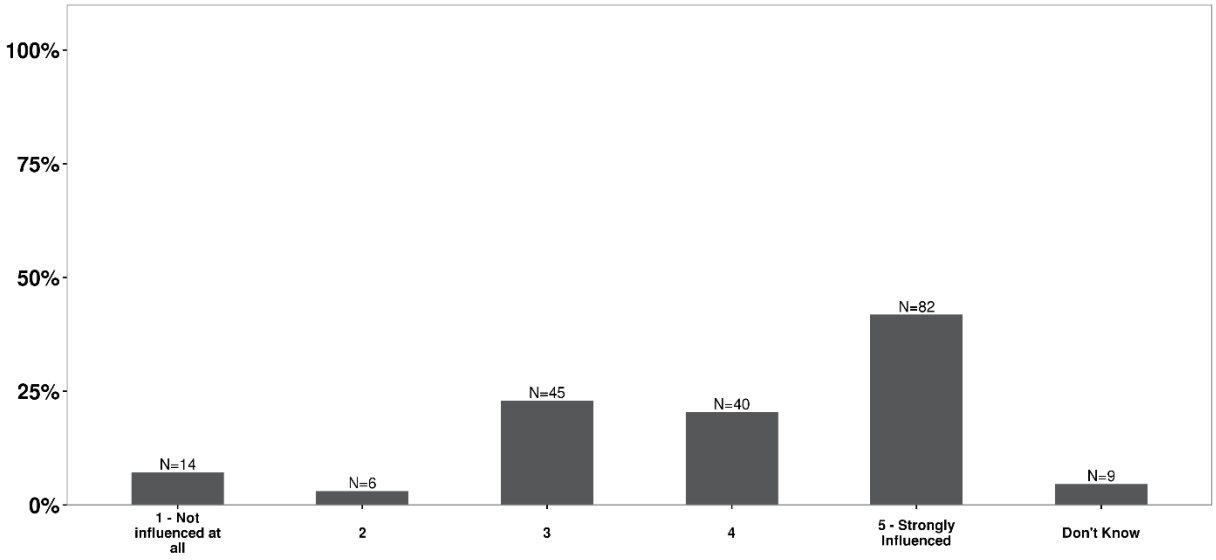
38. On Peak Energy Event days, did you ever "opt-out" or override your Wi-Fi thermostat setting to stop the program from adjusting your Wi-Fi thermostat during the Peak Energy Event? (Select all that apply)



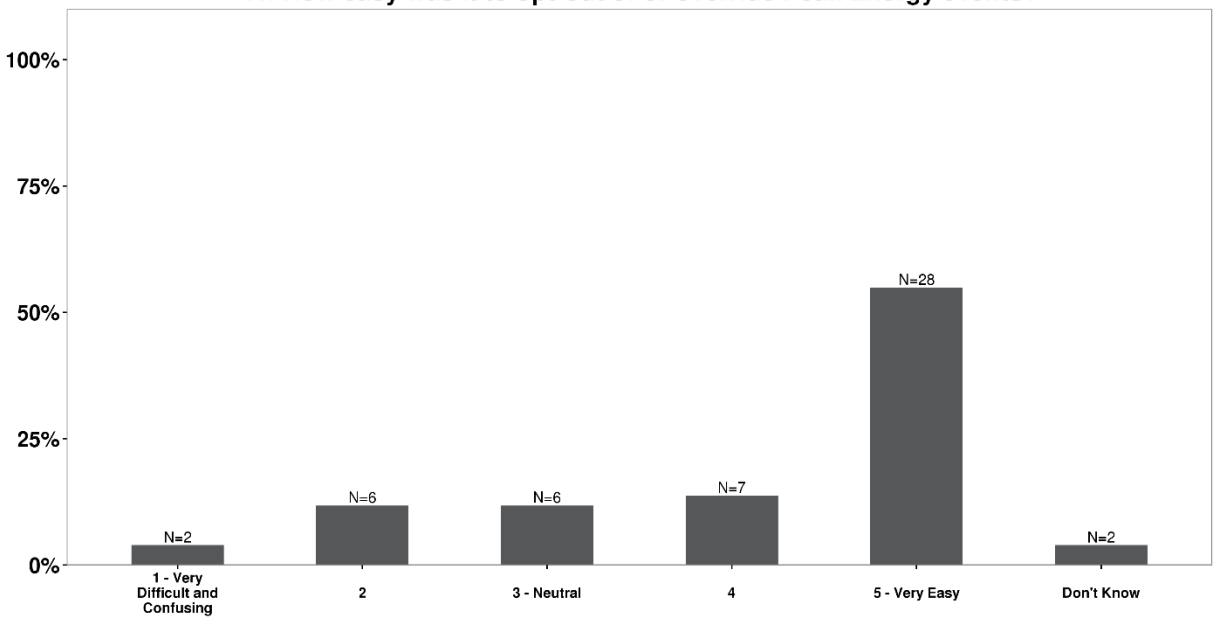
39. Why did you opt-out or override the Wi-Fi thermostat setting? (Select all that apply)



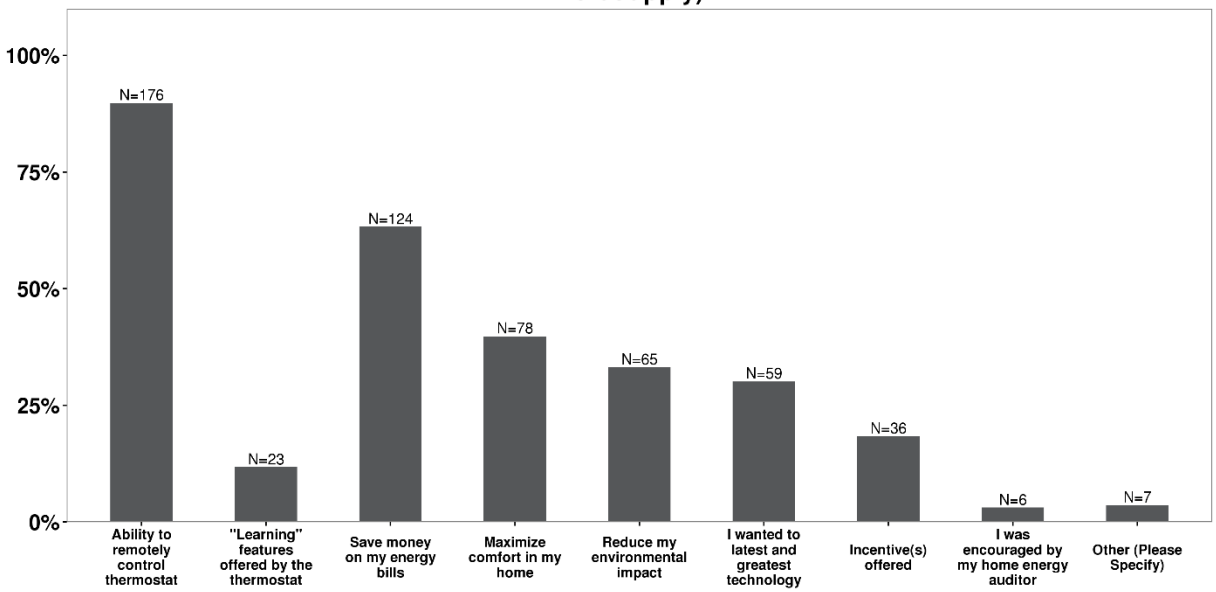
40. How much would you say the program's $20 participation incentive influenced you not to opt-out or override the Wi-Fi thermostat setting during Peak Energy events?



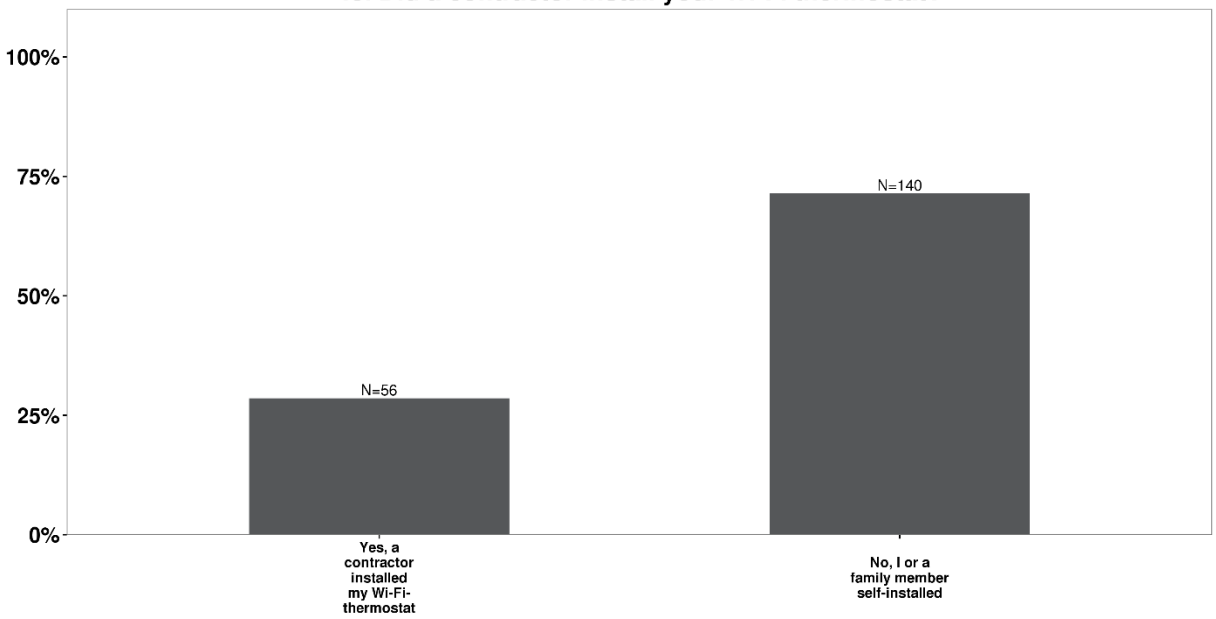
41. How easy was it to opt-out of or override Peak Energy events?



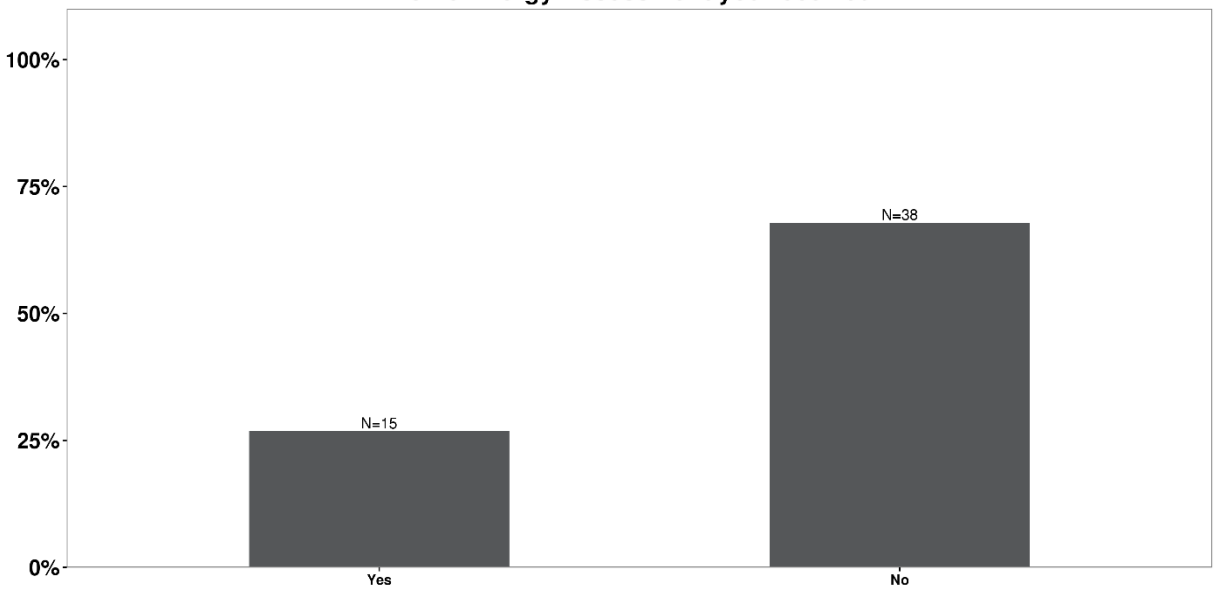
44. What were your main reasons for getting a Wi-Fi thermostat(s)? (Select all that apply)



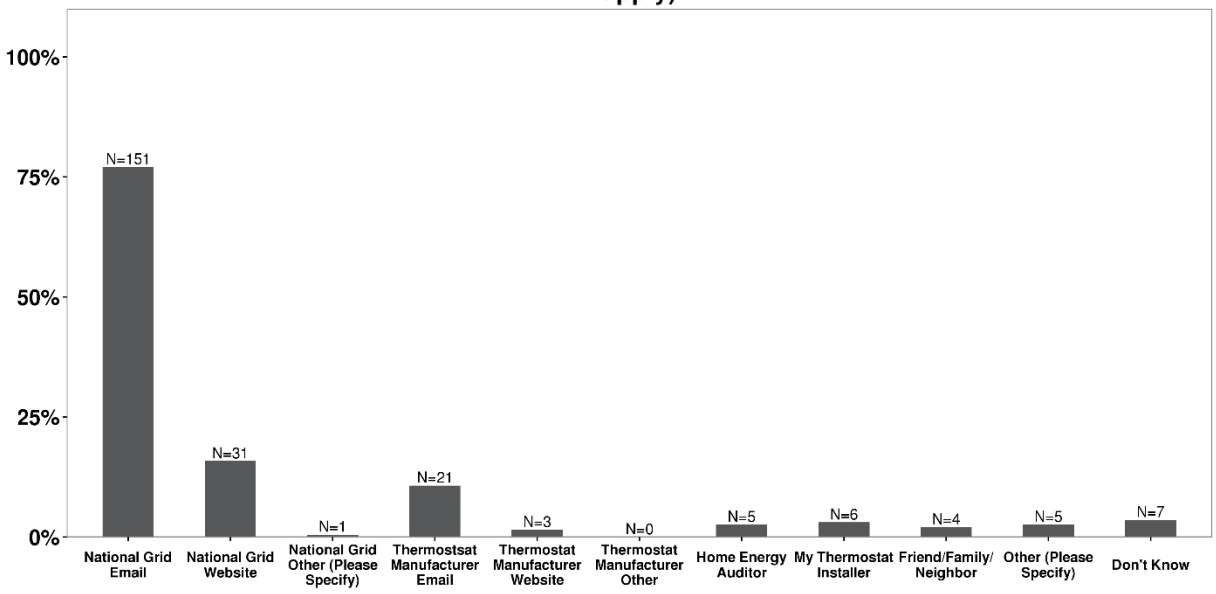
45. Did a contractor install your Wi-Fi thermostat?



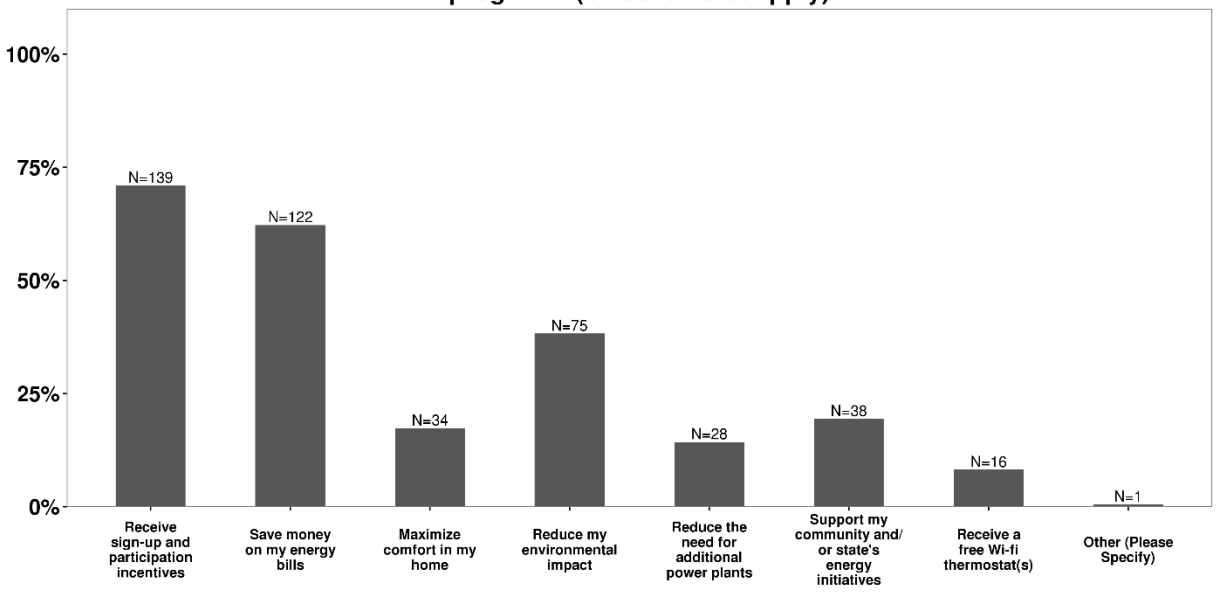
46. Was the installation of your Wi-Fi thermostat(s) provided as a result of a Home Energy Assessment you received?



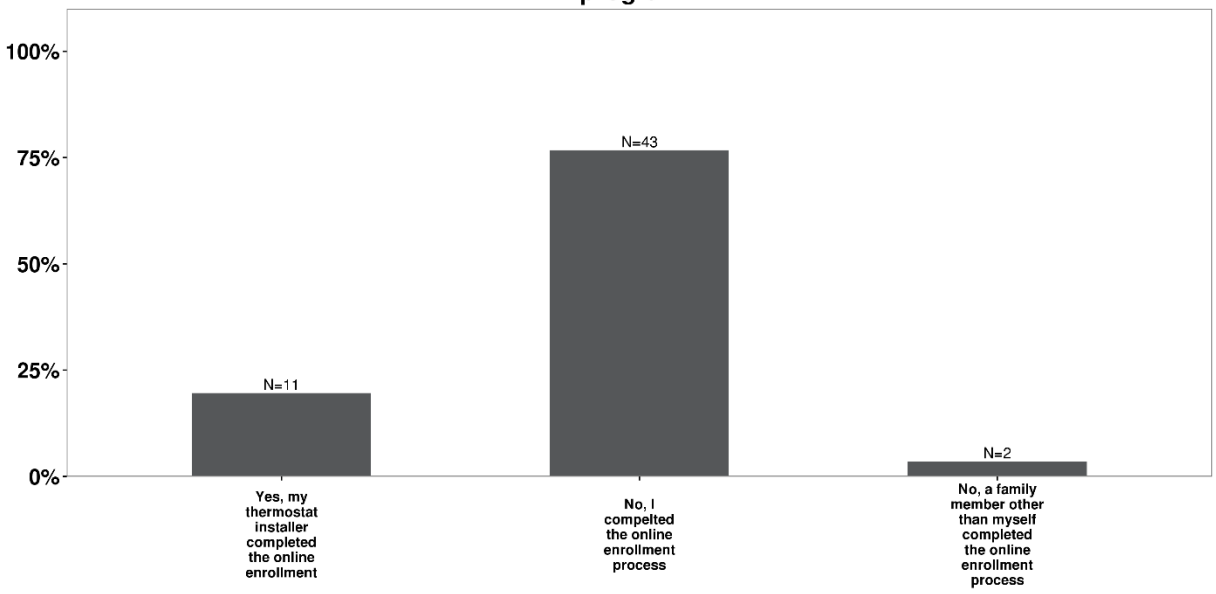
47. How did you learn about the ConnectedSolutions program? (Select all that apply)



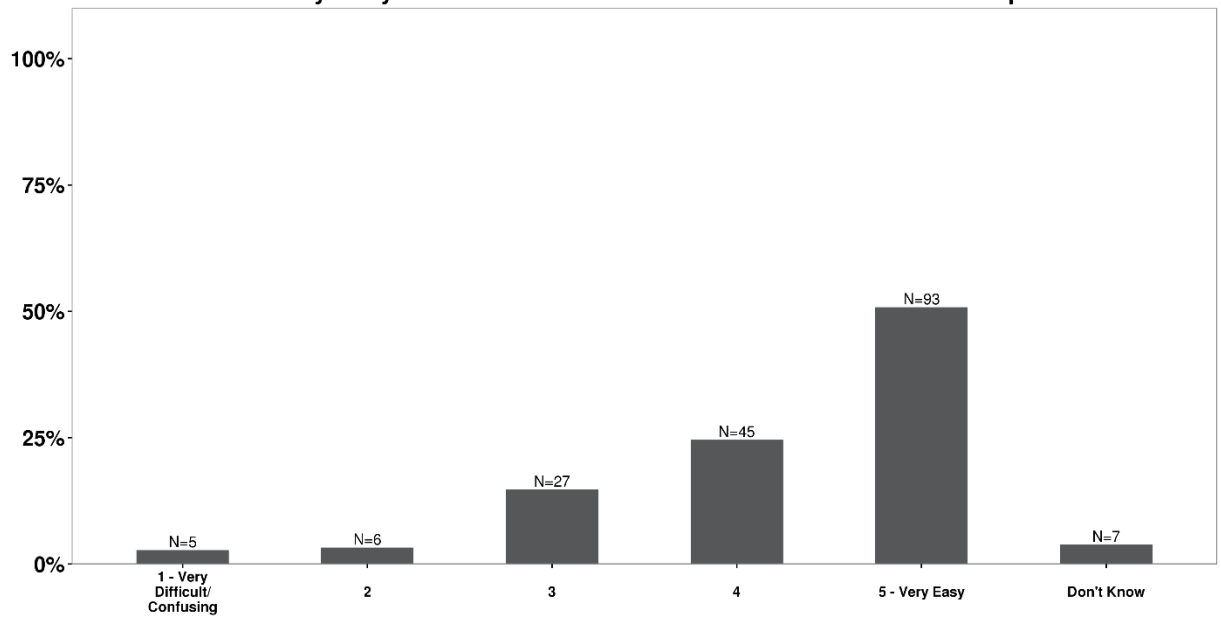
48. What were your main reasons for enrolling in the ConnectedSolutions program? (Select all that apply)



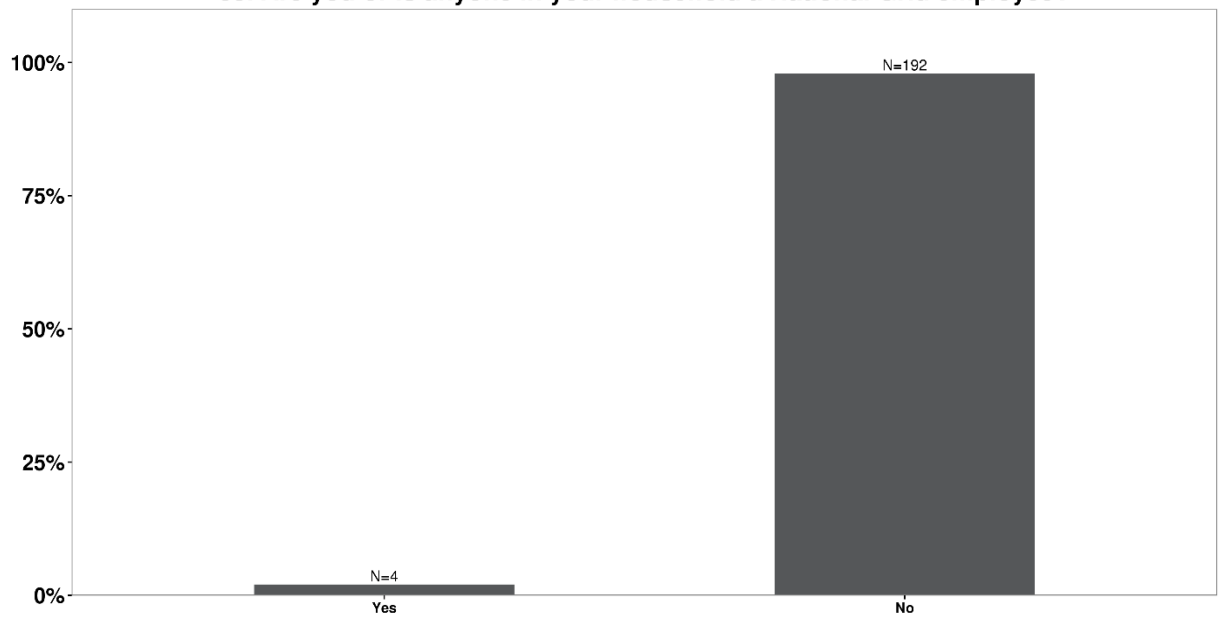
49. Did your thermostat installer complete the online ConnectedSolutions program?



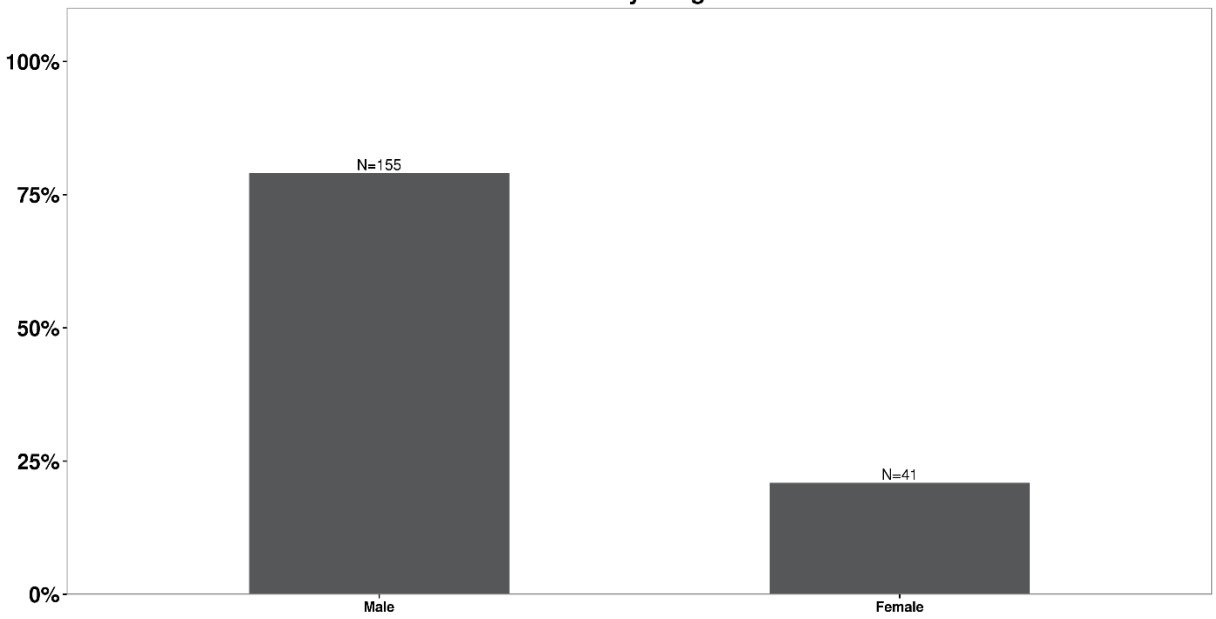
50. How easy did you find the ConnectedSolutions online enrollment process?



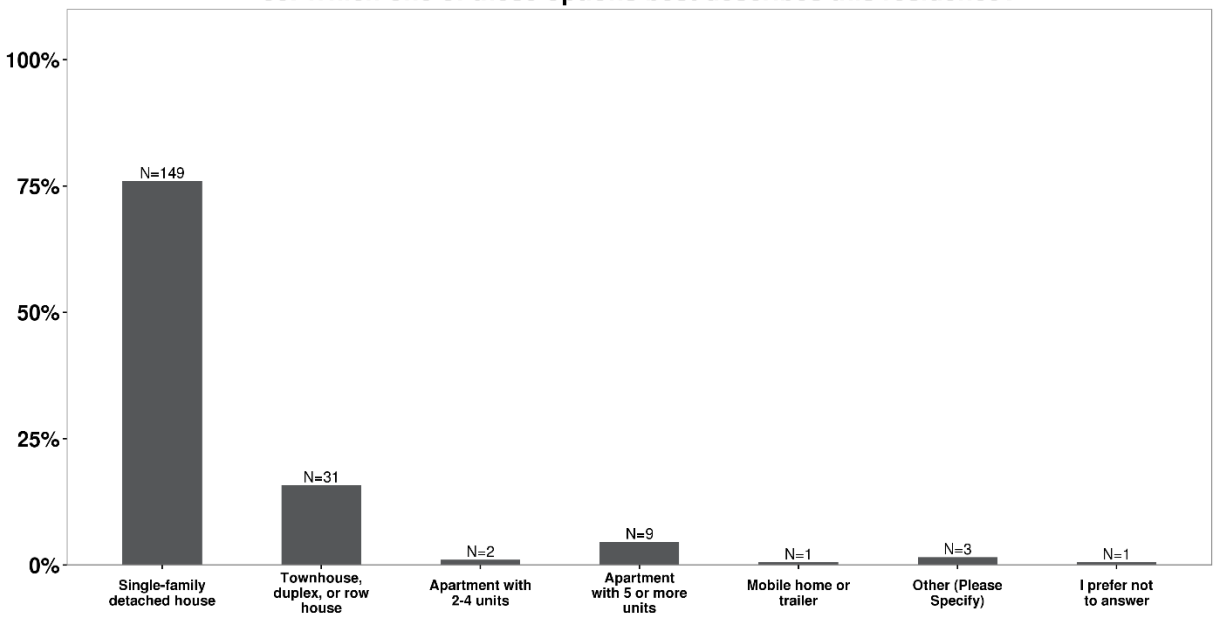
53. Are you or is anyone in your household a National Grid employee?



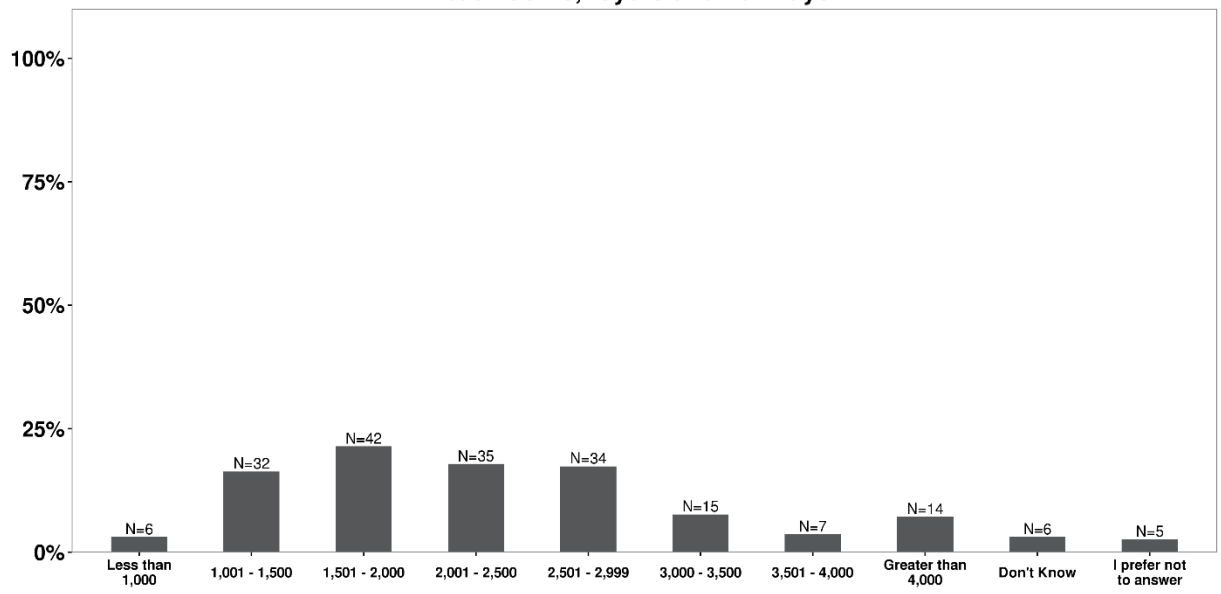
54. What is your gender?



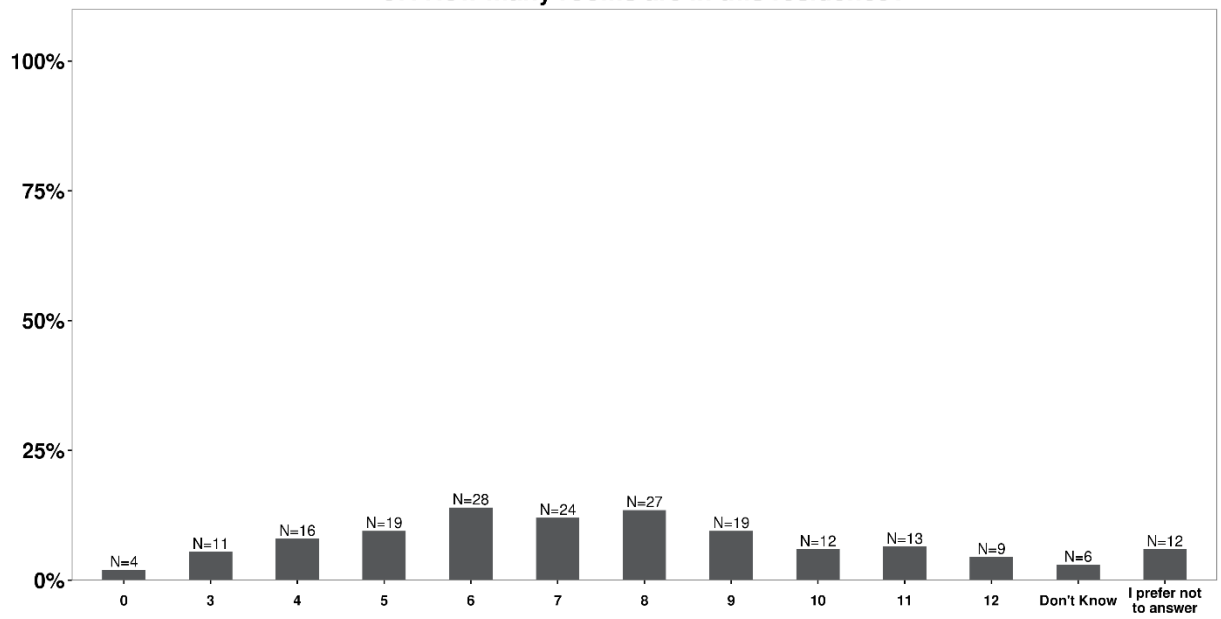
55. Which one of these options best describes this residence?



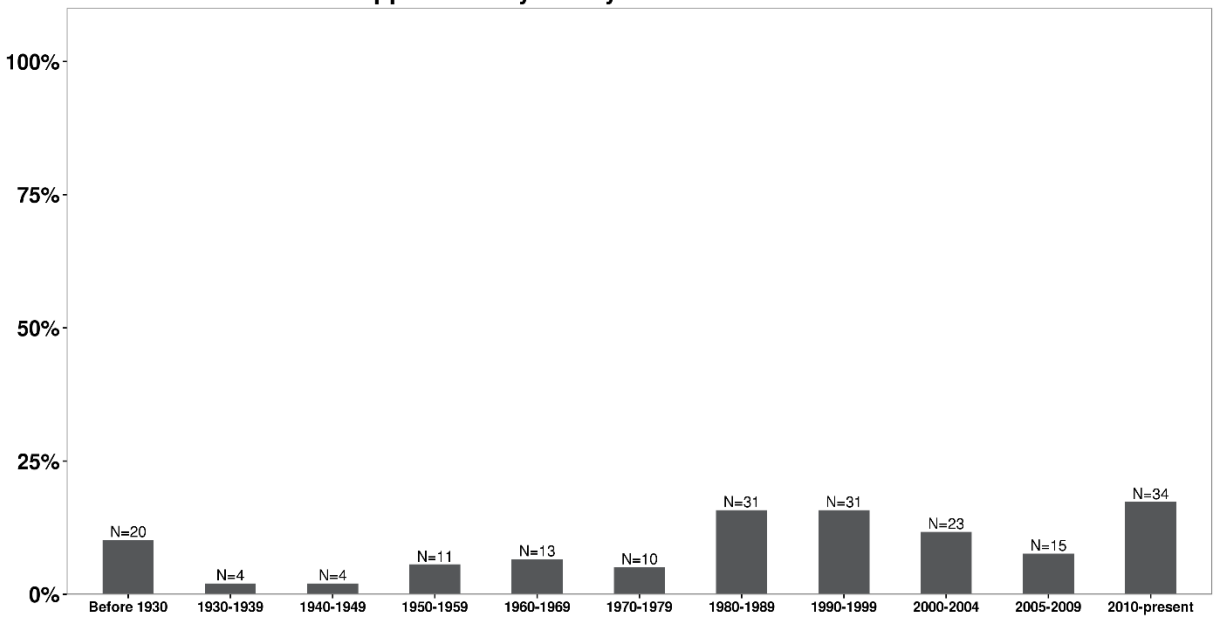
56. How many square feet of living space are there in this residence, including bathrooms, foyers and hallways?



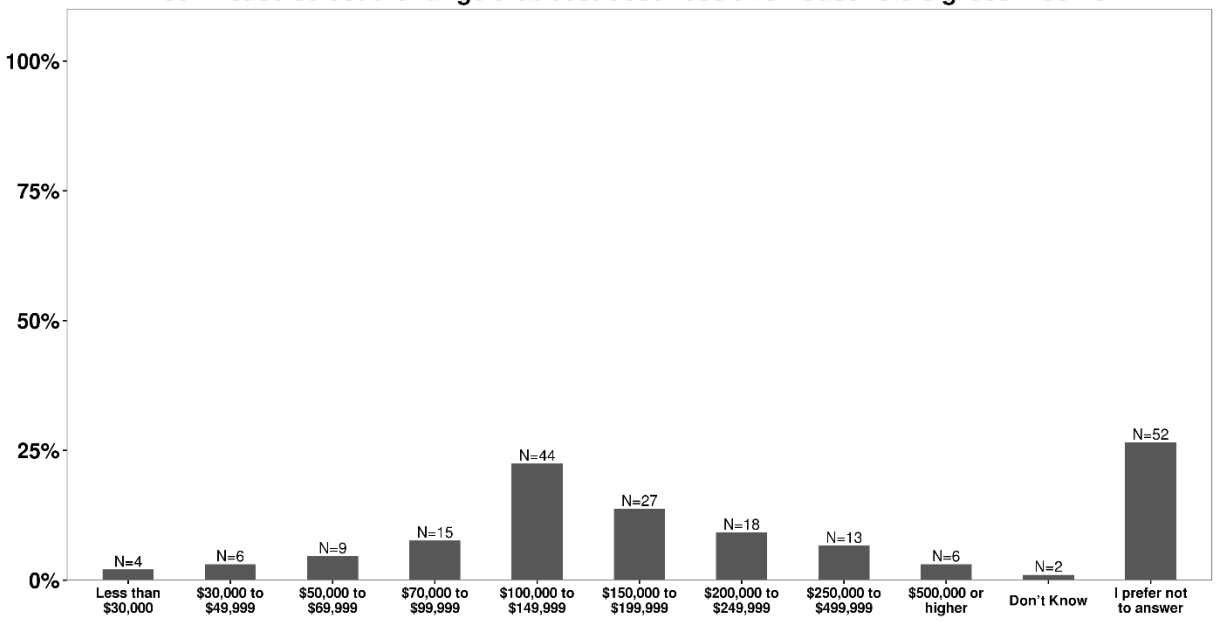
57. How many rooms are in this residence?



58. Approximately what year was this residence built?



59. Please select the range that best describes this household's gross income:



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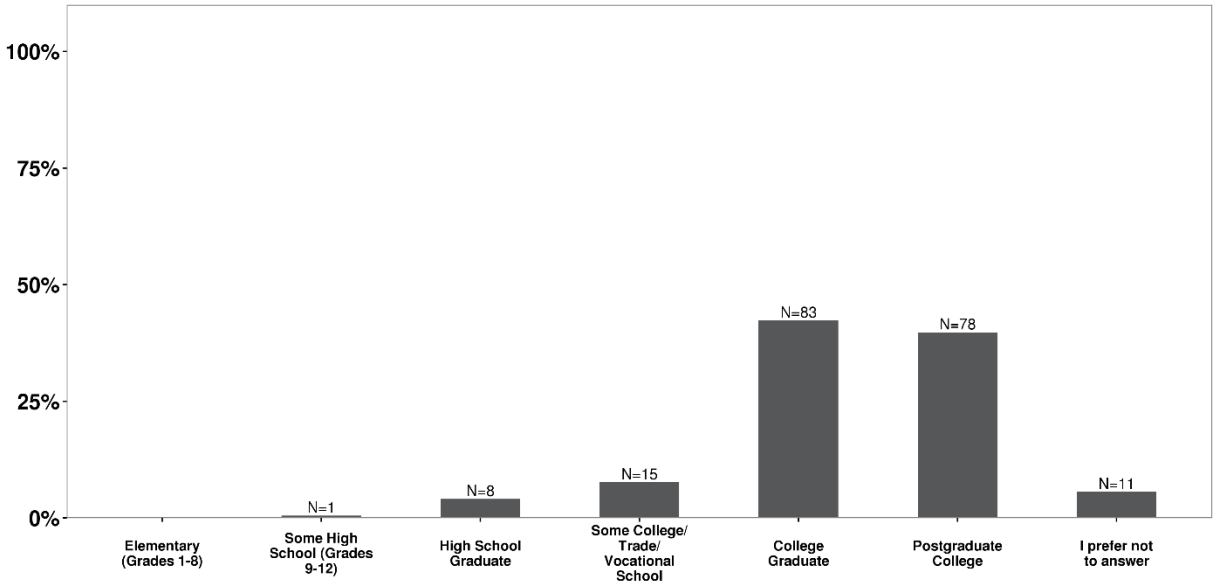
60. What is the highest level of education completed by the head of household in this residence?



APPENDIX H. POST-SEASON SURVEY AND RESULTS – NEST

This section includes the survey instrument and responses to the multi-choice questions.

0. Approximately when did you enroll in Rush Hour Rewards? {Enter 2-digit month and 4-digit year}

1. About how many Rush Hour events do you remember occurring between June 1 and September 30? (Please make your best estimate).
    a. {ENTER NUMBER}
    b. Don't know

2. What time did Rush Hour events typically start?
    a. 10am
    b. 11 am
    c. 12 pm
    d. 1 pm
    e. 2 pm
    f. 3 pm
    g. 4 pm
    h. 5 pm
    i. Other_____
    j. Don't Know

3. What time did Rush Hour events typically end?
    a. 2 pm
    b. 3 pm
    c. 4 pm
    d. 5 pm
    e. 6 pm
    f. 7 pm
    g. 8 pm
    h. Other_____
    i. Don't Know

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4. During this past summer, how did you become aware that a Rush Hour event was going to occur? (select all that apply)
    a. Email
    b. Nest app
    c. Nest website
    d. Nest thermostat
    e. Other. Specify _
    f. Never notified
    g. Don't know

[IF Q4 <> f, CONTINUE. ELSE SKIP TO Q8]

5. During this past summer, approximately how far in advance were you typically notified that a Rush Hour event was set to occur?
    a. < 1 hour
    b. 1 hour
    c. 2 hours
    d. 3 hours
    e. 4 hours
    f. 5 hours
    g. 6 hours
    h. > 6 hours
    i. Never notified
    j. Don't know

[IF Q5 <> i, CONTINUE. ELSE SKIP]

6. Using a scale of 1 to 5, where 1 means "Very Dissatisfied" and 5 means "Very Satisfied", what is your level of satisfaction with the notification you receive about a Rush Hour event that is set to occur?

a. Very Dissatisfied	b.	c. Neutral	d.	e. Very Satisfied	f. I have not been aware of any Rush Hour event notifications	g. Don't Know
1	2	3	4	5		

[IF Q6 = a-b (1-2), CONTINUE. OTHERWISE SKIP]

7. What caused the Rush Hour event notification to be less than satisfying? **[OPEN-END, OPTIONAL]**

8. This summer, for the Rush Hour events you can recall, about how often were you or another family member home during the Rush Hour event hours?
    a. Home for all Rush Hour event hours
    b. Home for most Rush Hour event hours
    c. Home for some Rush Hour event hours
    d. Never at home during Rush Hour event hours
    e. Don't know

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9-11. On a scale of 1 through 5, where 1 is "Very dissatisfied" and 5 is "Very satisfied", how would you rate your satisfaction with the following aspects of the Rush Hour Rewards program?

	a. Very Dissatisfied	b.	c. Neutral	d.	e. Very Satisfied	f. Don't know
	1	2	3	4	5	
9. Number of Rush Hour events during the 2017 summer season						
10. Length of Rush Hour events						
11. Timing of Rush Hour events (i.e. what period during the day events occurred)						

[IF Q9 = a-b (1-2), CONTINUE. ELSE SKIP TO Q14]

12. Did the number of Rush Hour events that occurred on consecutive days impact your satisfaction level?
    a. Very Much
    b. Somewhat
    c. Not At All

[IF Q9 = a-b (1-2), CONTINUE. ELSE SKIP TO Q14]

13. On a scale of 1 through 5, where 1 is "Very dissatisfied" and 5 is "Very satisfied", how satisfied would you have been with the number of Rush Hour events if there had been 5 fewer events over the course of the summer?

a. Very Dissatisfied	b.	c. Neutral	d.	e. Very Satisfied	g. Don't Know
1	2	3	4	5	

[IF Q10 = a-b (1-2), CONTINUE. ELSE SKIP TO Q17]

14. Please let us know why you are not fully satisfied with the length of the Rush Hour events.

_____

[IF Q10 = a-b (1-2), CONTINUE. ELSE SKIP TO Q17]

15. On a scale of 1 through 5, where 1 is "Very dissatisfied" and 5 is "Very satisfied", how satisfied would you have been with the length of Rush Hour events if they had been 1 hour shorter?

a. Very Dissatisfied	b.	c. Neutral	d.	e. Very Satisfied	g. Don't Know
1	2	3	4	5	

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[IF Q10 = a-b (1-2), CONTINUE. ELSE SKIP TO Q17]

16. On a scale of 1 through 5, where 1 is "Very dissatisfied" and 5 is "Very satisfied", how satisfied would you have been with the length of Rush Hour events if they had been 2 hours shorter?

a. Very Dissatisfied	b.	c. Neutral	d.	e. Very Satisfied	g. Don't Know
1	2	3	4	5	

[IF Q11 = a-b (1-2), CONTINUE. ELSE SKIP TO Q18]

17. Please let us know why you are not fully satisfied with the timing of some or all of the Rush Hour events.

    _____

18. Based on your experience with the program this summer, what would the optimal start time be for a Rush Hour event (i.e. for a temperature increase in your home)?
    a. 10 am
    b. 11 am
    c. 12 pm
    d. 1 pm
    e. 2 pm
    f. 3 pm
    g. 4 pm
    h. 5 pm
    i. Other_____
    j. I don't have a strong opinion
    k. Don't Know

19. Based on your experience with the program this summer, what would the optimal end time be for a Rush Hour event?
    a. 2 pm
    b. 3 pm
    c. 4 pm
    d. 5 pm
    e. 6 pm
    f. 7 pm
    g. 8 pm
    h. Other_____
    i. I don't have a strong opinion
    j. Don't Know

20. At any point over the course of the summer, did you contact support services regarding the program?
    a. Yes, I contacted support during the summer
    b. No, I did not contact any party about the program

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[IF Q20 = a, CONTINUE. OTHERWISE SKIP TO Q25]

21. What method did you use to contact support about the program? (select all that apply)
    a. Email to National Grid
    b. Phone call to National Grid
    c. Email to Nest
    d. Phone call to Nest
    e. Online chat with Nest
    f. Tweet with Nest
    g. Other. Specify_____

22. Please describe your reason(s) for contacting support. **[OPEN-ENDED]** _____

23. Using a scale of 1 to 5, where 1 means "Very Dissatisfied" and 5 means "Very Satisfied", what is your level of satisfaction with the support you received?

a. Very Dissatisfied	b.	c.	d.	e. Very Satisfied	g. Don't Know
1	2	3	4	5	

[IF Q23 = a OR b, CONTINUE. OTHERWISE SKIP TO Q25]

24. Why was the support you received less than satisfactory? **[OPEN-ENDED]**

25. In future summers, on a scale of 1-5, where 1 is "Very Unlikely" and 5 is "Very Likely," how likely would you be to participate in the Rush Hour Rewards program?

a. Very Unlikely	b.	c.	d.	e. Very Likely	g. Don't Know
1	2	3	4	5	

[IF Q25 = a OR b, CONTINUE. OTHERWISE SKIP TO Q27]

26. What change(s) to the Rush Hour Rewards program would encourage you to continue participating? **[OPEN-END, OPTIONAL]**

[IF Q25 = c-f, CONTINUE. OTHERWISE SKIP TO Q28]

27. What recommendations would you make to help improve the Rush Hour Rewards program going forward? **[OPEN-END, OPTIONAL]**

28. In future summers, on a scale of 1-5, where 1 is "Very Unlikely" and 5 is "Very Likely," how likely would you be to participate in the Rush Hour Rewards program <u>if you are not provided advance notice of Rush Hour events before they occur</u>?

a. Very Unlikely	b.	c.	d.	e. Very Likely	g. Don't Know
1	2	3	4	5	

29. During the summer, for how many weekdays per week is <u>at least one</u> person home from 2 p.m. to 5 p.m.? (enter a number from 0 to 5) _____ {programmed to accept numeric input only}

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30. We'd like to understand how you typically used your air conditioner throughout the past summer. Which of the following best describes the way you use your air conditioner?
    c. Turn on cooling at the beginning of summer, follow a temperature schedule, and turn off cooling at the end of the summer
    d. Only turn on cooling when it's hot and/or humid and otherwise have my air conditioner off or in heating mode

[If Q30 = b, CONTINUE. ELSE SKIP TO Q32]

31. Above what temperature do you typically turn your air conditioning on? Please enter a temperature in degrees F. **[ENTER NUMERIC]**

32. Over the past summer, how did you typically monitor the temperature of your home or adjust the setting of your Nest thermostat? (select all that apply)
    f. On the Nest thermostat itself
    g. Nest app
    h. Nest website
    i. Other_____
    j. Don't know

33. Now we'd like to understand the frequency with which you adjusted your Nest thermostat's setting or schedule during this summer. Would you say it was…
    i. More than once a day
    j. Once a day
    k. A few times per week
    l. Once or twice monthly
    m. Once or twice over the whole summer
    n. Not at all
    o. Other _____
    p. Don't know

[IF Q33 = f, SKIP]

34. We'd also like to understand whether the frequency with which you adjusted your Nest thermostat's setting or schedule was different on Rush Hour event days compared to other days. Would you say you adjusted your home's temperature…
    a. More on Rush Hour event days than on other days
    b. Less on Rush Hour event days than on other days
    c. About the same amount regardless of whether it was a Rush Hour event day or not
    d. Don't know

35. When no family member is at home, which of the following best describes the way you use your air conditioner?
    a. I always have my air conditioner follow a temperature schedule.
    b. Depending on the weather, I sometimes set my air conditioner to off or heating mode.
    c. When no family member is home, my air conditioner is off or in heating mode.
    d. Other. Please specify _____

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[If Q8 = d, SKIP]

36. When you or a family member was at home for any part of a Rush Hour event, what actions, if any, did you take to reduce your electricity use during the Rush Hour event? (select all that apply)
    a. Discussed energy conservation strategies with my family
    b. Pre-cooled my home during morning off-peak hours
    c. Sought activities outside of the home
    d. Avoided use of certain appliances or electricity intensive devices
    e. None
    f. Other (Please specify)
    g. Don't know

[IF Q8 = a, b, OR c, CONTINUE. ELSE SKIP TO Q38]

37. During the Rush Hour events, how would you generally describe your comfort compared to typical afternoons with similar outdoor temperatures? Would you say it was…?

a. Much more comfortable	b. Somewhat more comfortable	c. About the same	d. Somewhat less comfortable	e. Much less comfortable	f. Don't Know
1	2	3	4	5	

38. On Rush Hour event days, did you ever "opt-out" or override your Nest thermostat setting to stop the program from adjusting your Nest thermostat during the Rush Hour event? (select all that apply)
    a. Yes, before the Rush Hour event started
    b. Yes, during the Rush Hour event
    c. No
    d. Don't know

[IF Q38 = a OR b, CONTINUE. ELSE SKIP TO Q40]

39. Why did you opt-out or override the Nest thermostat setting? (select all that apply)
    a. Someone in the home needed the temperature cooler for health reasons
    b. Someone in the home wanted the temperature cooler
    c. Wanted the home cooler for a pet
    d. Felt too uncomfortable during previous Rush Hour events
    e. Had guests/visitors over
    f. Other (Please specify)
    g. Don't know

40. {Blank}

[IF Q38 = a OR b, CONTINUE. ELSE SKIP TO Q43]

41. Using a scale of 1 to 5, where 1 means "Very Difficult or Confusing" and 5 means "Very Easy", how easy was it to opt-out of or override Rush Hour events?

a. Very Difficult/Confusing	b.	c. Neutral	d.	e. Very Easy	g. Don't Know
1	2	3	4	5	

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[IF Q41 = a-b (1-2), CONTINUE ELSE SKIP TO Q43]

42. What issues did you encounter when trying to opt-out or override scheduled events?
    _____

43. Do you have any comments on the performance of your Nest thermostat in general over the course of the summer? _____ **[OPEN-END, OPTIONAL]**

44. What were your main reasons for getting a Nest thermostat(s)? (select all that apply)
    a. Ability to remotely control thermostat
    b. "Learning" features offered by the thermostat
    c. Save money on my energy bills
    d. Maximize comfort in my home
    e. Reduce my environmental impact
    f. I wanted the latest and greatest technology
    g. Incentive(s) offered. Specify the incentive(s) you received _____.
    h. I was encouraged by my home energy auditor
    i. Other **[OPEN-END]**

45. {Blank}

46. {Blank}

47. How did you learn about the Rush Hour Rewards program? (select all that apply)
    a. National Grid email
    b. National Grid website
    c. National Grid other. Specify _____.
    d. Nest email.
    e. Nest website.
    f. Nest other. Specify other type of marketing_____.
    g. Home energy auditor
    h. My thermostat installer
    i. Friend/family/neighbor
    j. Other _____
    k. Don't know

48. What were your main reasons for enrolling in the Rush Hour Rewards program?
    a. Receive sign-up incentive
    b. Save money on my energy bills
    c. Maximize comfort in my home
    d. Reduce my environmental impact
    e. Reduce the need for additional power plants
    f. Support my community and/or state's energy initiatives
    g. Other **[OPEN-END]**

We have a few final questions about yourself and your household and then you'll be done!

49. {Blank}

50. {Blank}
51. {Blank}

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52. {Blank}

53. Are you or is anyone in your household a National Grid employee?
    a. Yes
    b. No

54. What is your gender?
    a. Male
    b. Female

55. Which one of these options best describes this residence?
    a. Single-family detached house
    b. Townhouse, duplex, or row house (shares common wall with neighboring unit from basement to roof)
    c. Apartment with 2-4 units (either rent or own)
    d. Apartment with 5 or more units (either rent or own)
    e. Mobile home or trailer
    f. Other (Please Specify)
    g. Don't know
    h. I prefer not to answer

56. How many square feet of living space are there in this residence, including bathrooms, foyers, and hallways? Please exclude unheated rooms and garages. If you live in an apartment building, please answer for the living space considered "your home."
    a. Less than 1,000
    b. 1,001 – 1,500
    c. 1,501 – 2,000
    d. 2,001 – 2,500
    e. 2,501 – 2,999
    f. 3,000 – 3,500
    g. 3,501 – 4,000
    h. Greater than 4,000
    i. Don't know
    j. I prefer not to answer

57. How many rooms are in this residence? Please exclude bathrooms, halls, pantries, unheated rooms, and garages
    _____ **[ENTER # OF ROOMS]**
    a. Don't know
    b. I prefer not to answer

58. Approximately what year was this residence built?
    a. Before 1930
    b. 1930-1939
    c. 1940-1949
    d. 1950-1959
    e. 1960-1969
    f. 1970-1979
    g. 1980-1989
    h. 1990-1999
    i. 2000-2004
    j. 2005-2009
    k. 2010-present
    l. Unsure/Don't know
    m. I prefer not to answer

59. Please select the range that best describes this household's gross income for 2015 (before adjustments for taxes and credits). Please include all sources of income such as salaries, wages, rent, interest, dividends, pensions, and social security.
    a. Less than $30,000
    b. $30,000 to $49,999
    c. $50,000 to $69,999
    d. $70,000 to $99,999
    e. $100,000 to $149,999
    f. $150,000 to $199,999
    g. $200,000 to $249,999
    h. $250,000 to $499,999
    i. $500,000 or higher
    j. Don't know
    k. I prefer not to answer

60. What is the highest level of education completed by the head of household in this residence?
    a. Elementary (Grades 1-8)
    b. Some high school (Grades 9-12)
    c. High School Graduate
    d. Some College/Trade/Vocational School
    e. College Graduate
    f. Postgraduate College
    g. Don't know
    h. I prefer not to answer

[IF Q53 = b, ASK. ELSE SKIP TO END]

61. Thank you for taking the time to complete this survey. For completing the survey, you will receive a $10 Amazon gift card. Please provide your current contact information so that we can email you the gift card.
    a. Name (Please specify)
    b. Email address (Please specify)
    c. Prefer not to receive gift card

62. In addition, we are seeking volunteers to participate in an onsite visit as a follow-up to your survey. Navigant Consulting, Inc. (Navigant) has been retained to conduct onsite visits on behalf of National Grid to collect information about the air conditioning units of program participants. For successfully completing the onsite visit, National Grid would like to offer you a **$25 gift card**.

    The onsite visit will involve a Navigant representative visiting your home and collecting information about your air conditioner, specifically, the nameplate information which must be read from the air conditioning unit both inside and outside your home. A typical visit takes 15 minutes and will take place during a weekday between 8 am and 6 pm over the next few weeks.

    Your participation in this study will help enhance and improve National Grid's demand response programs. Are you interested in participating?

    a. Yes
    b. No

[IF Q62 = a, ASK. ELSE SKIP TO CLOSING SCREEN]

63. Great! Please provide your contact information below, including a current phone number. We will call you to schedule an appointment. We look forward to connecting with you.

    a. Name (Please specify) **[OPTIONAL]**
    b. Email (Please specify) **[OPTIONAL]**
    c. Phone Number (Please specify) **[OPTIONAL]**
    d. Home Address (Please specify) **[OPTIONAL]**

Note: Depending on the number of responses, Navigant may not contact you.

CLOSING SCREEN: Survey Completed! Thank you!

[CLOSE]

Output to multi-choice questions is presented in terms of percentage of respondents (not responses). Therefore, for questions where respondents could select multiple responses, the percentages across columns may sum to greater than 100%.

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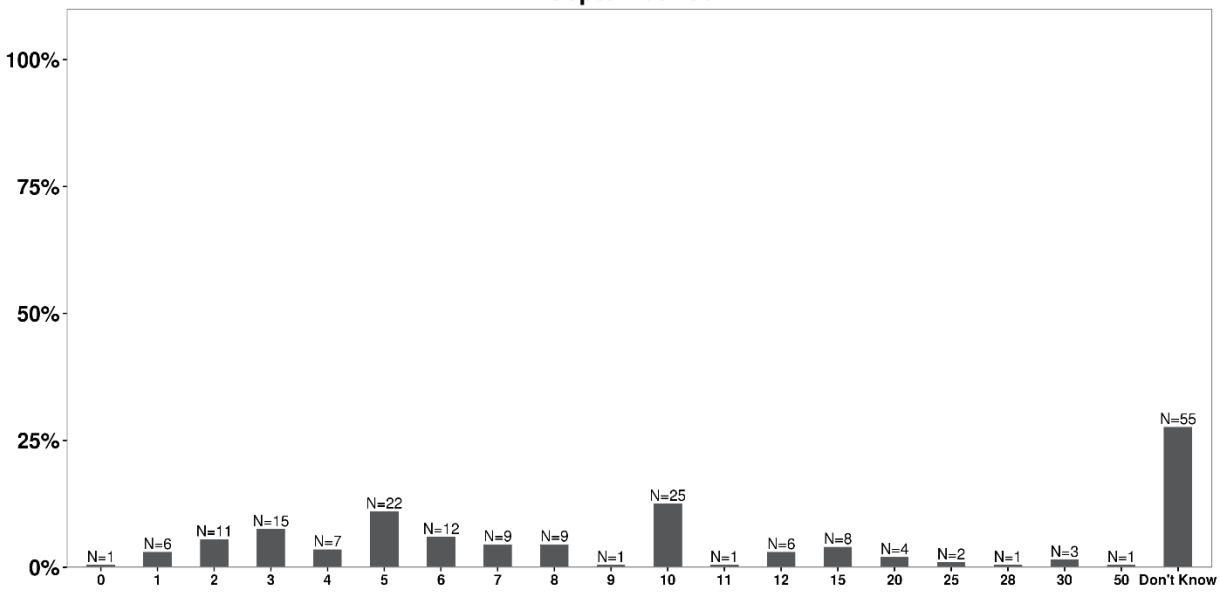
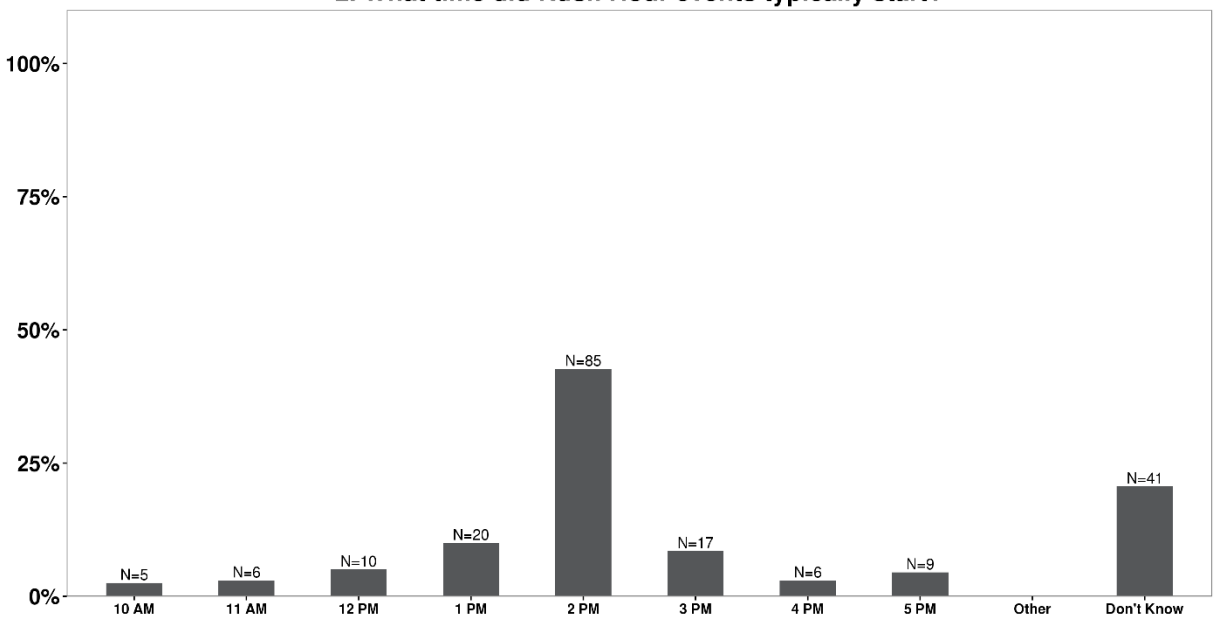
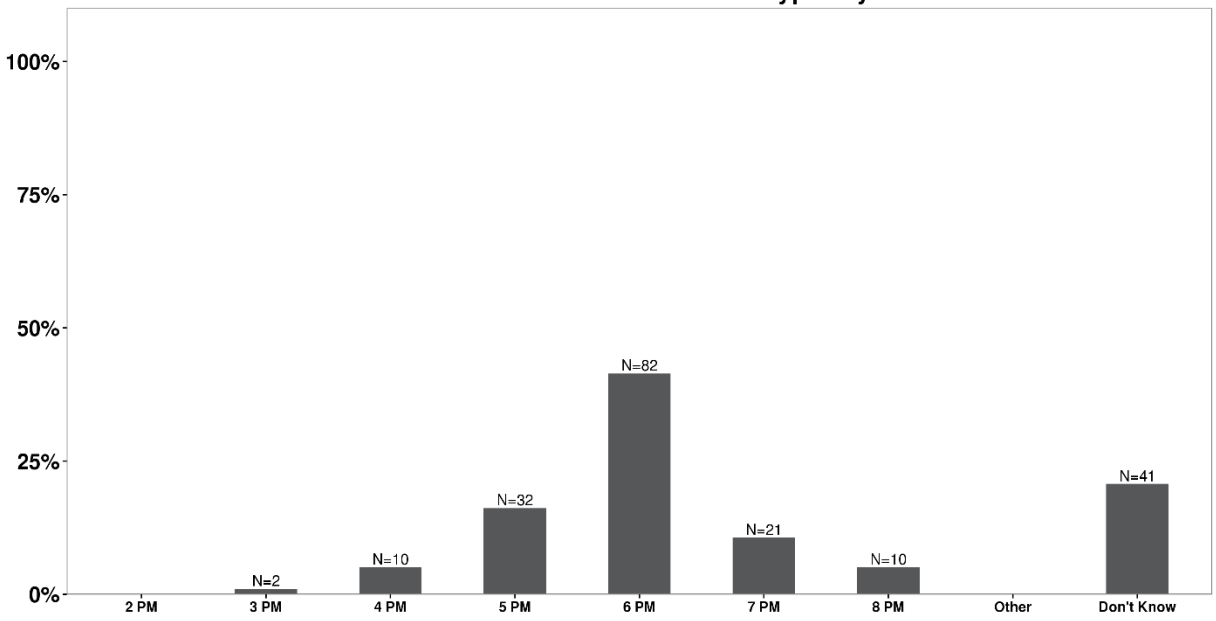
1. About how many Rush Hour events do you remember occurring between June 1 and September 30?



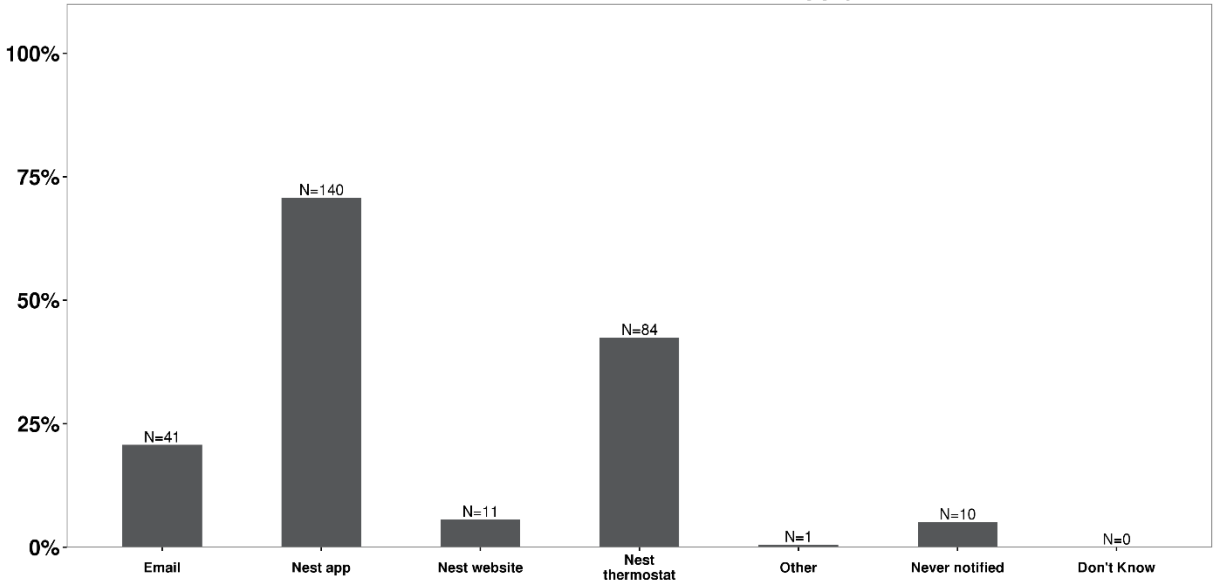
2. What time did Rush Hour events typically start?



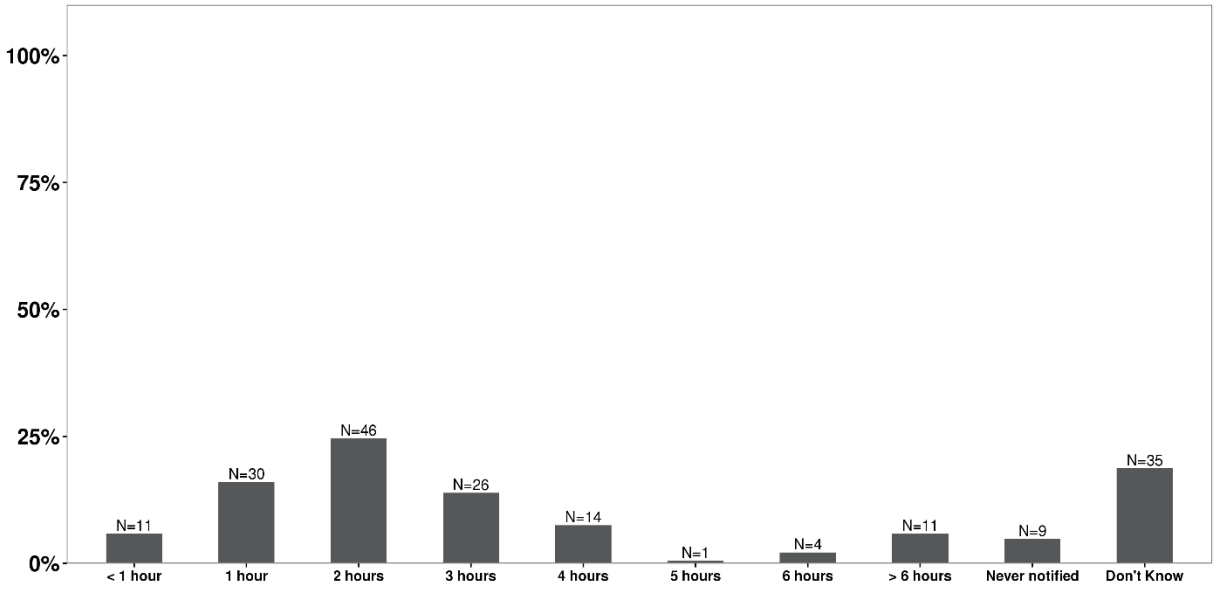
3. What time did Rush Hour events typically end?



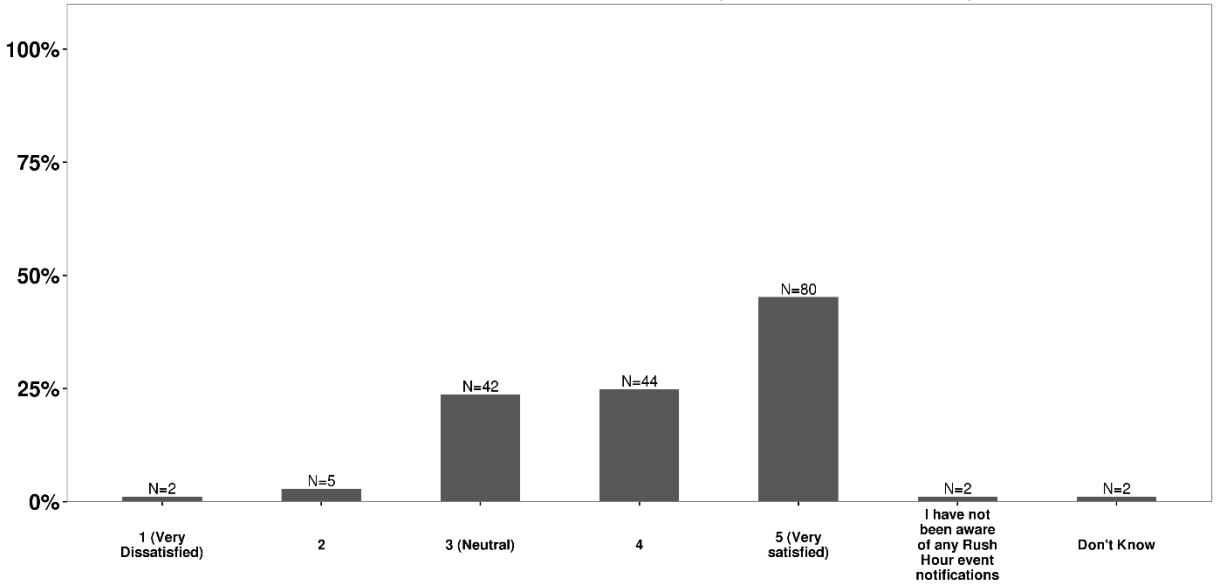
4. During this past summer, how did you become aware that a Rush Hour event was going to occur? (Select all that apply)



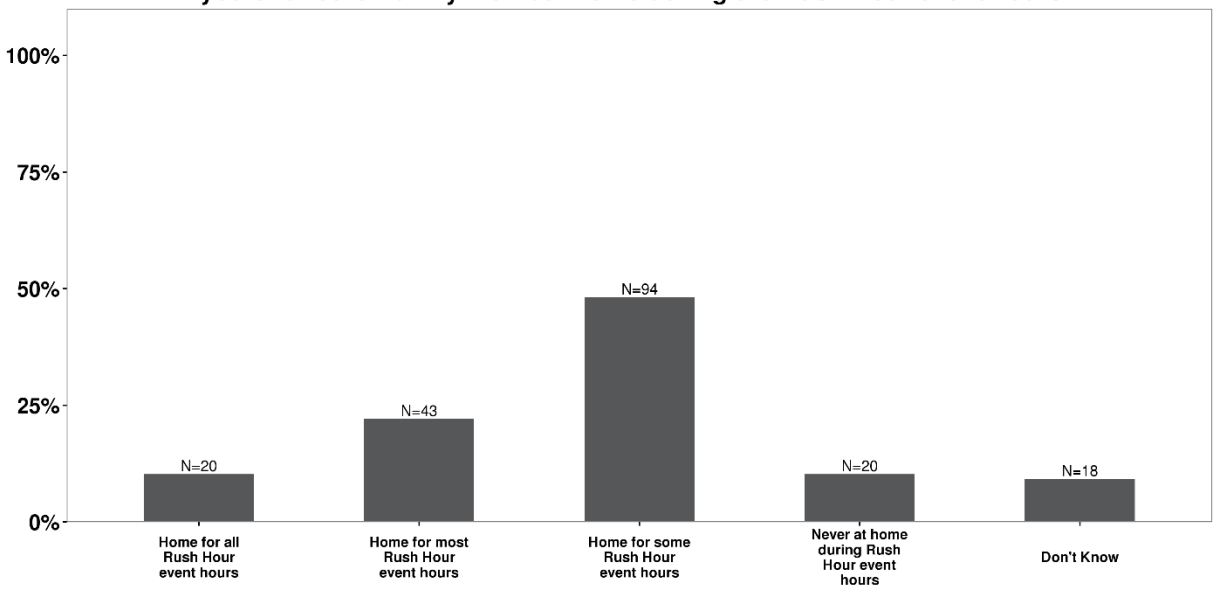
5. During this past summer, approximaetly how far in advance were you typically notified that a Rush Hour event was set to occur?



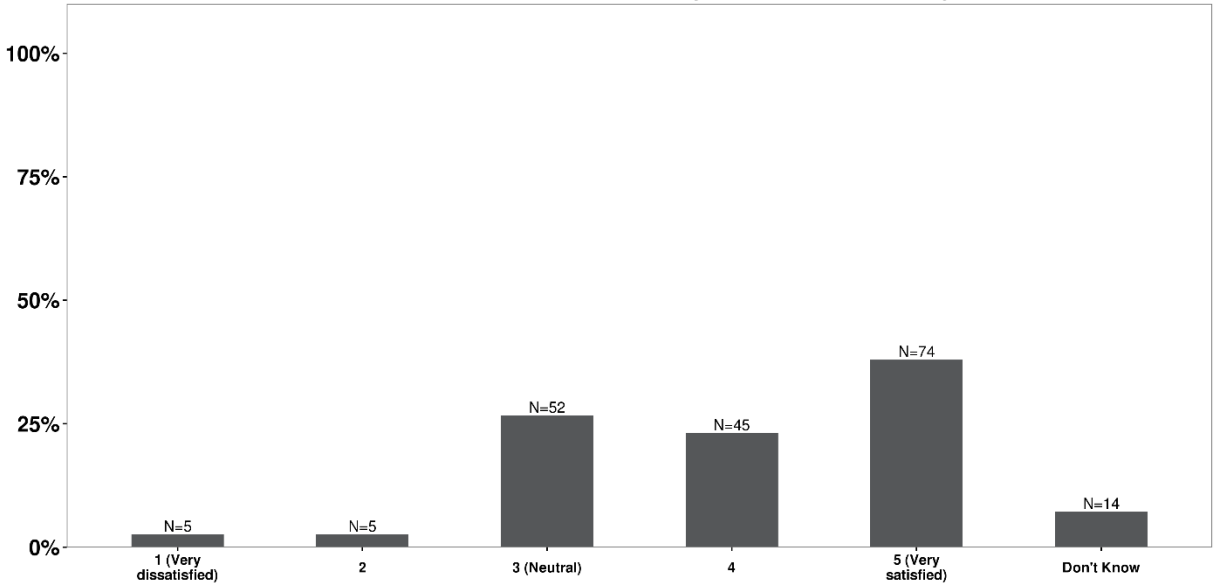
6. What is your level of satisfaction with the notification you receive about a Rush Hour event that is set to occur? (1=Very Dissatisfied, 5=Very Satisfied)



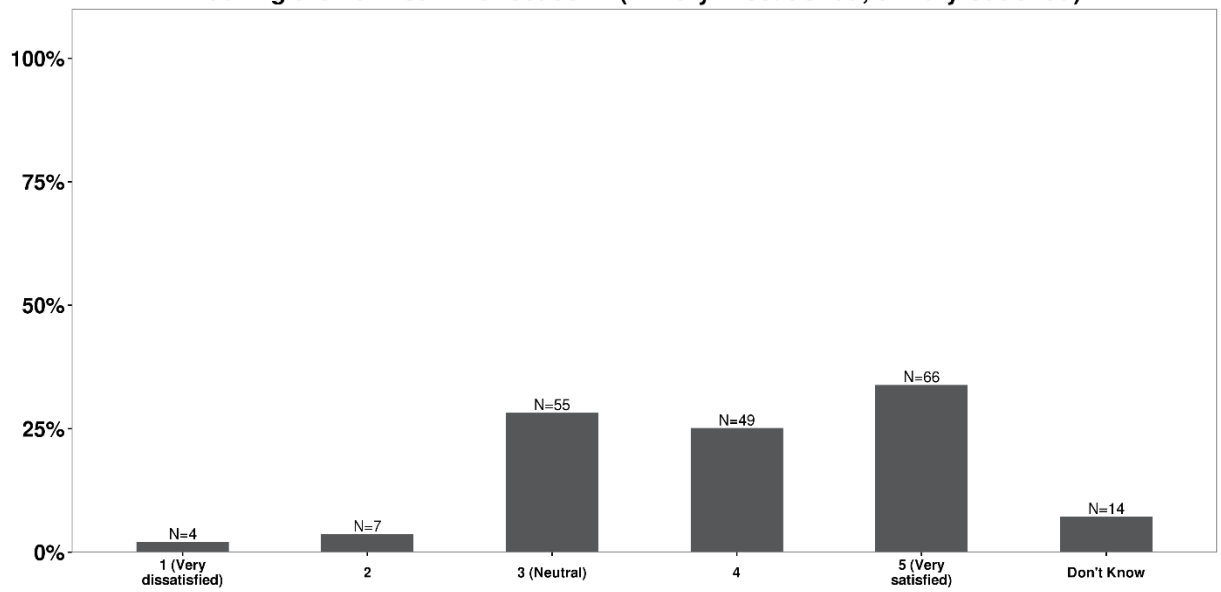
8. This summer, for the Rush Hour events you can recall, about how often were you or another family member home during the Rush Hour event hours?



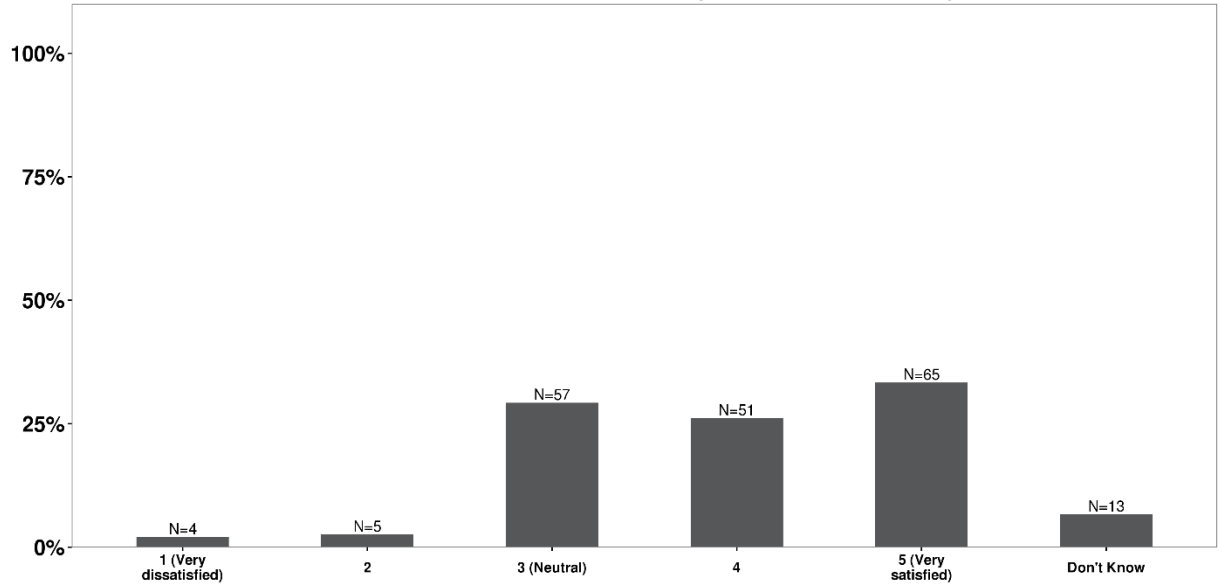
9. How would you rate your satisfaction with the number of Rush Hour events during the 2017 summer season? (1=Very Dissatisfied, 5=Very Satisfied)



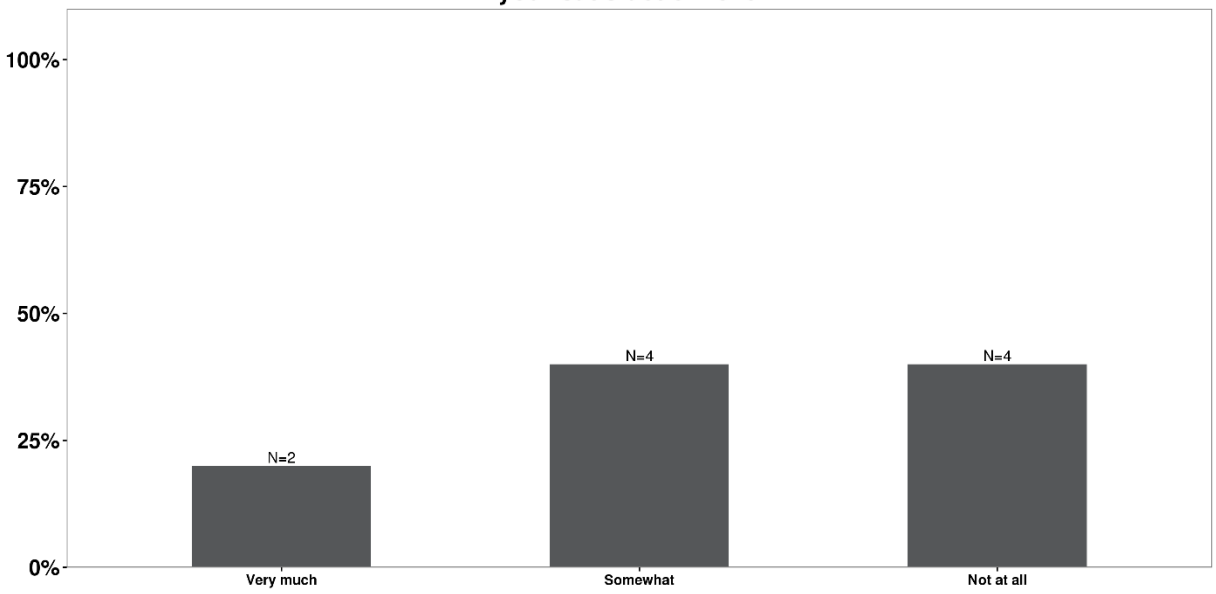
10. How would you rate your satisfaction with the length of Rush Hour events during the 2017 summer season? (1=Very Dissatisfied, 5=Very Satisfied)



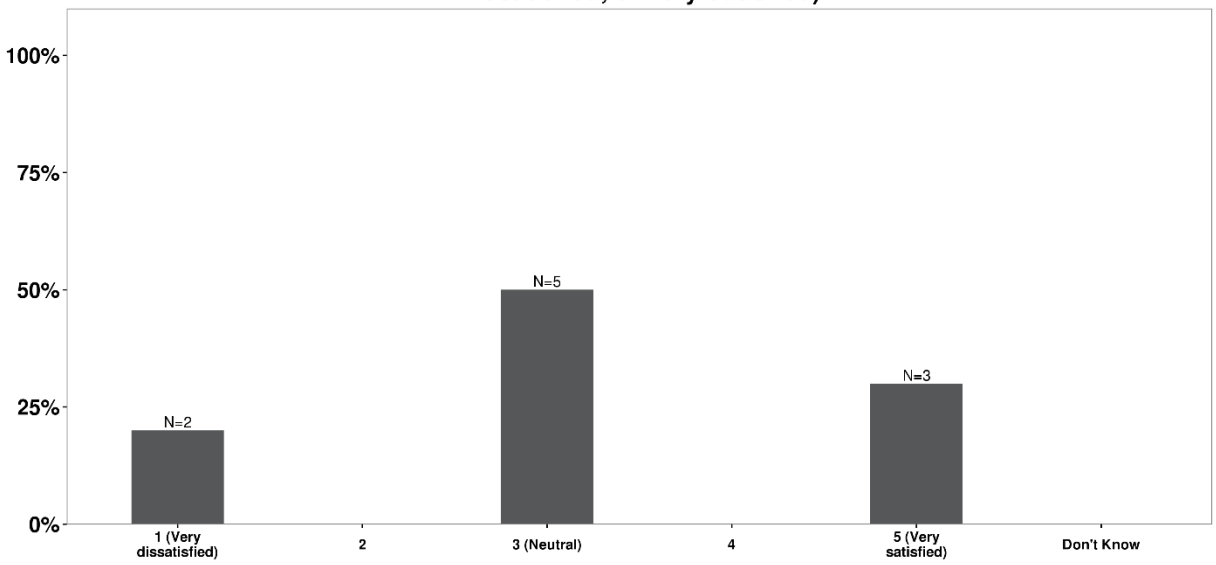
11. How would you rate your satisfaction with the timing of Rush Hour events during the 2017 summer season? (1=Very Dissatisfied, 5=Very Satisfied)



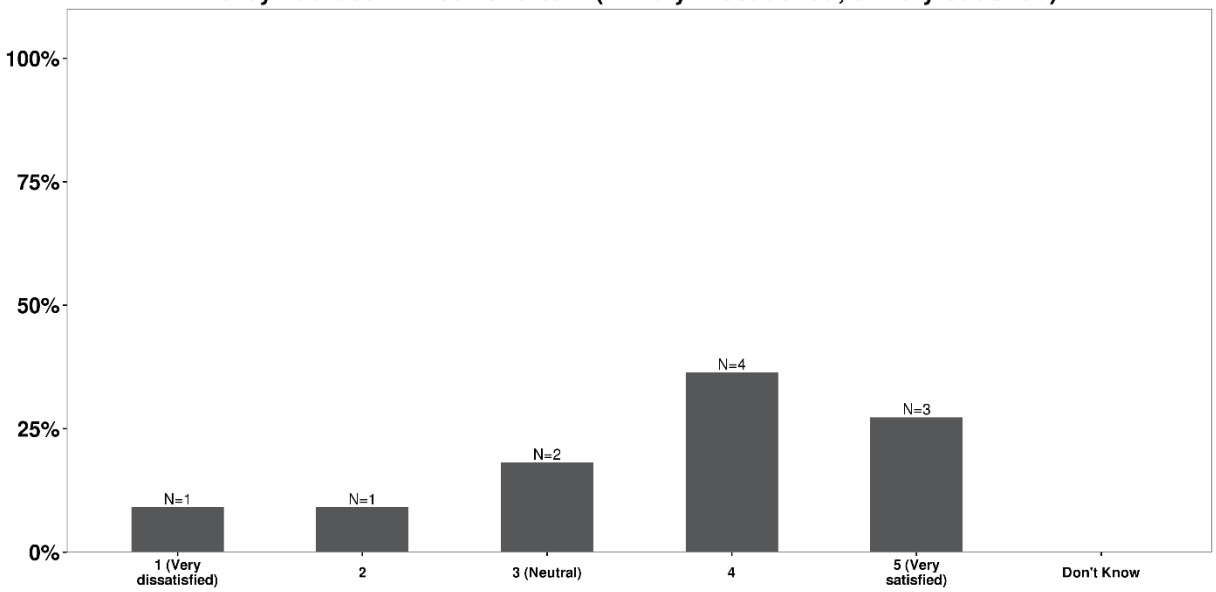
12. Did the number of Rush Hour events that occurred on consecutive days impact your satisfaction level?



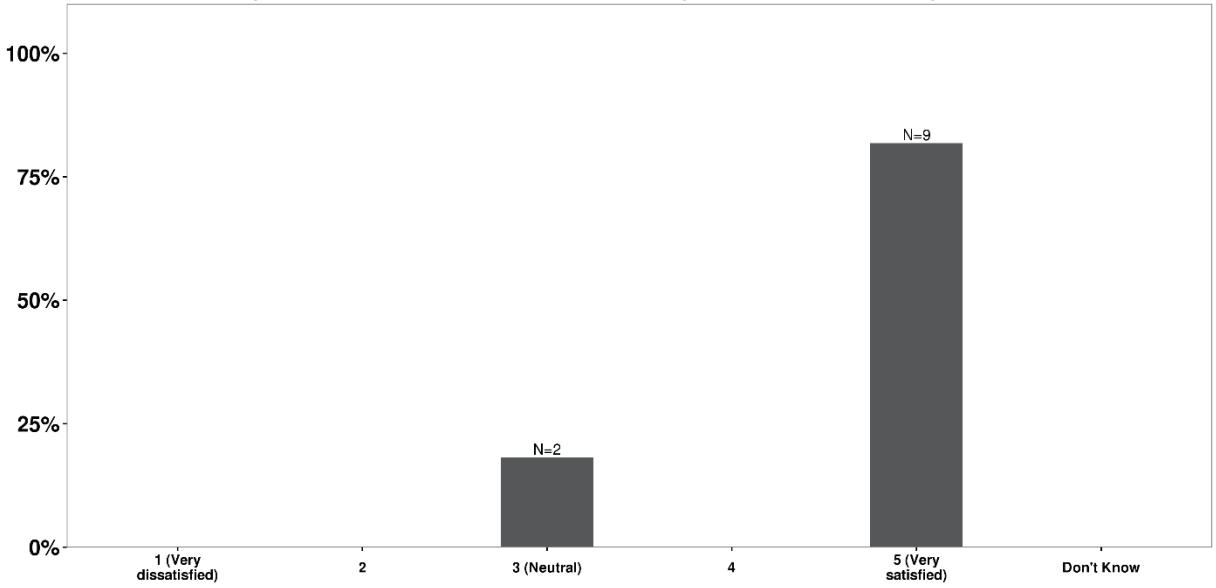
13. How satisfied would you have been with the number of Rush Hour events if there had been 5 fewer events over the course of the summer? (1=Very Dissatisfied, 5=Very Satisfied)



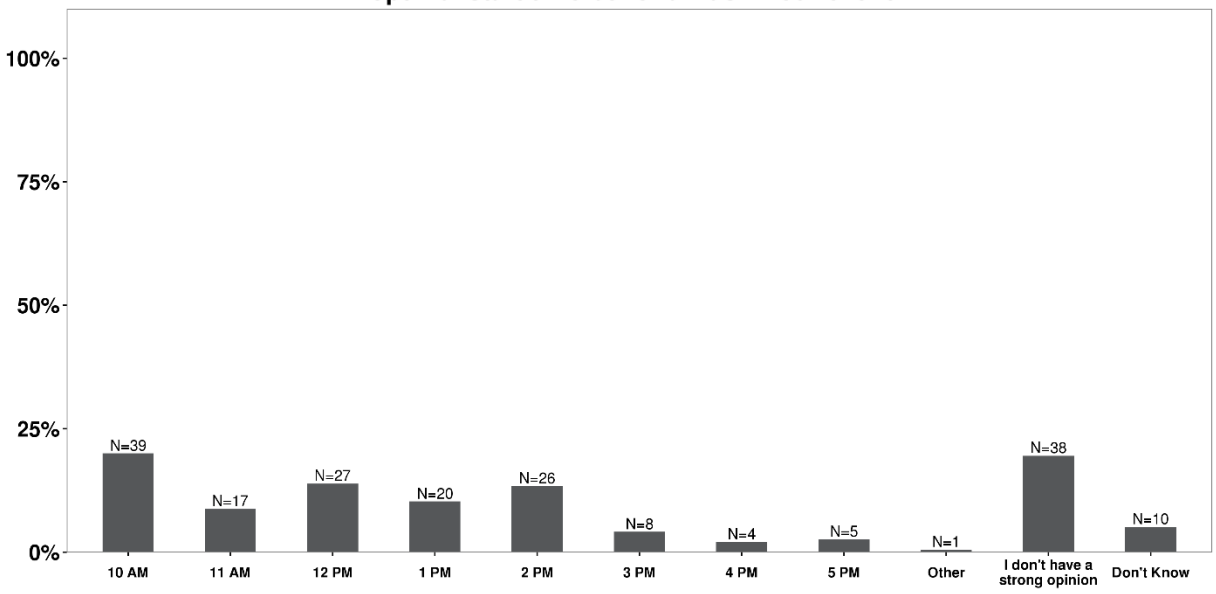
15. How satisfied would you have been with the length of Rush Hour events if they had been 1 hour shorter? (1=Very Dissatisfied, 5=Very Satisfied)



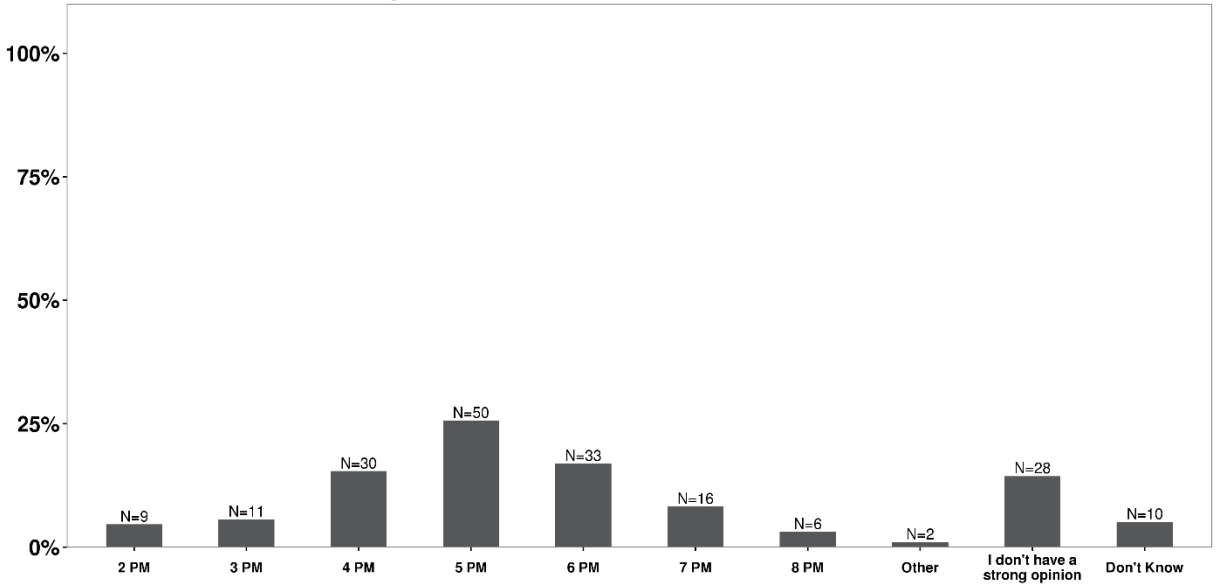
16. How satisfied would you have been with the length of Rush Hour events if they had been 2 hours shorter? (1=Very Dissatisfied, 5=Very Satisfied)



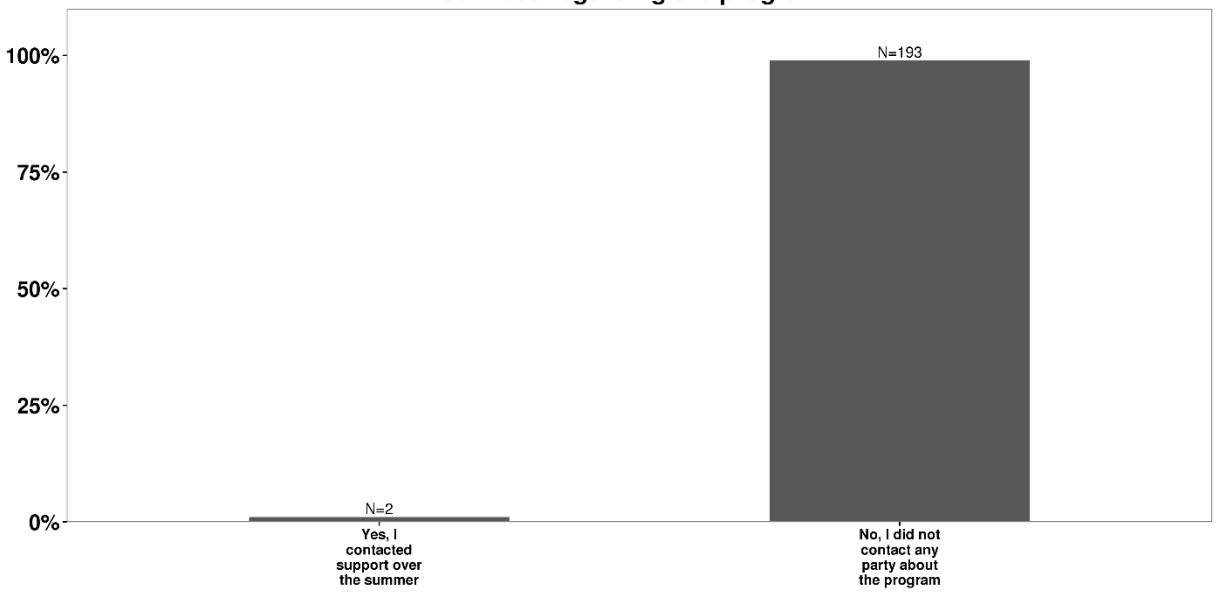
18. Based on your experience with the program this summer, what would the optimal start time be for a Rush Hour event?



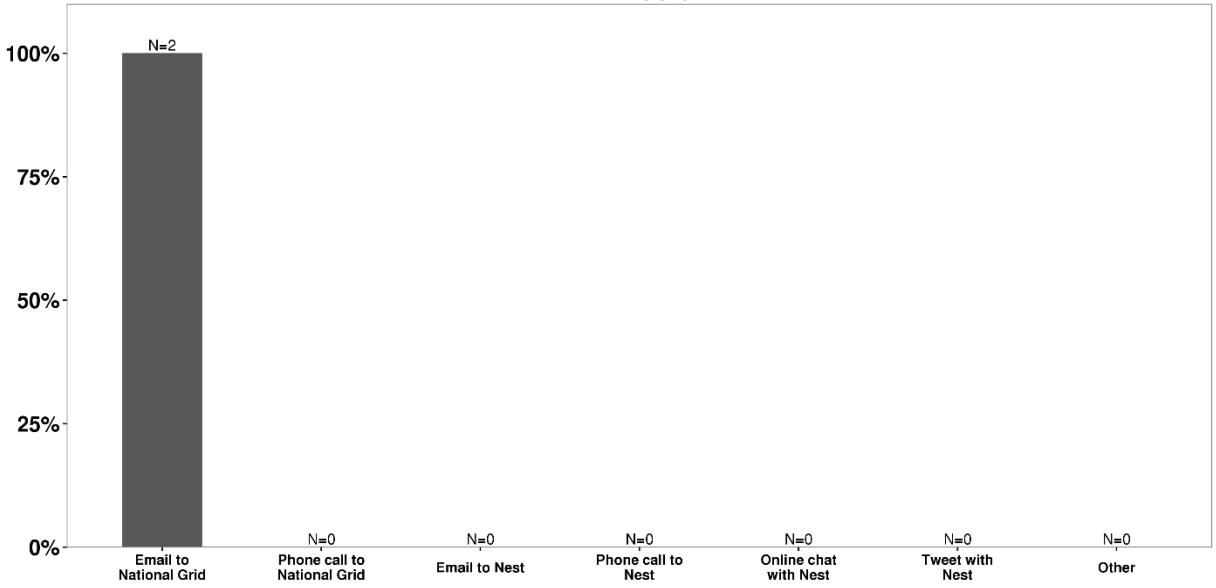
19. Based on your experience with the program this summer, what would the optimal end time be for a Rush Hour event?



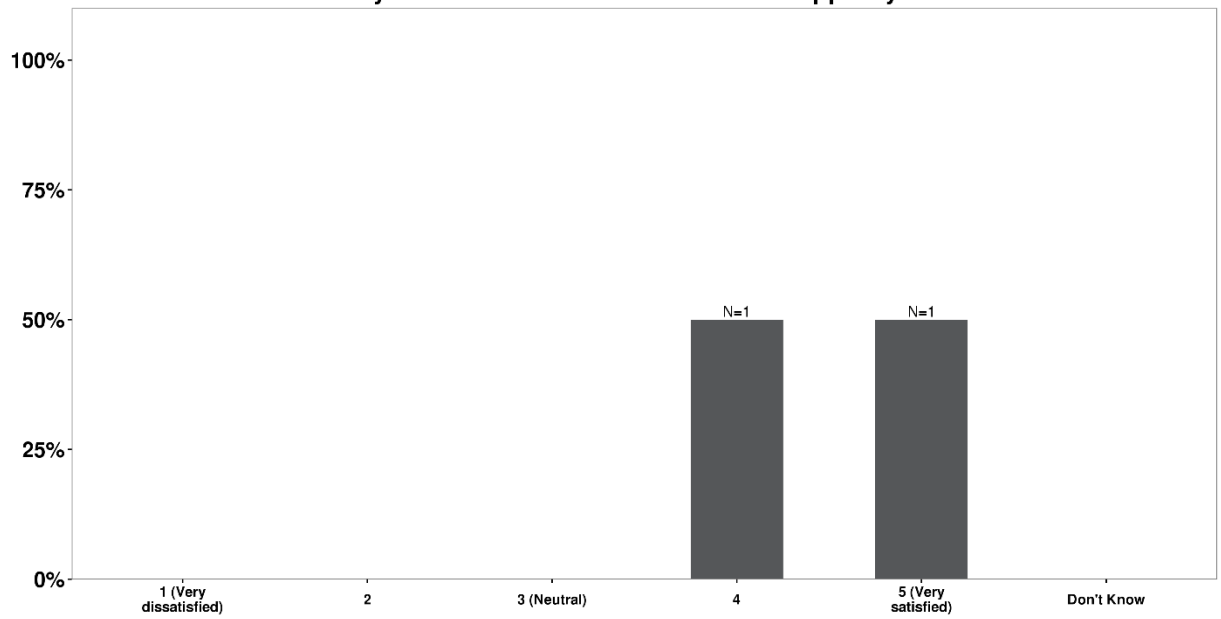
20. At any point over the course of the summer, did you contact support services regarding the program?



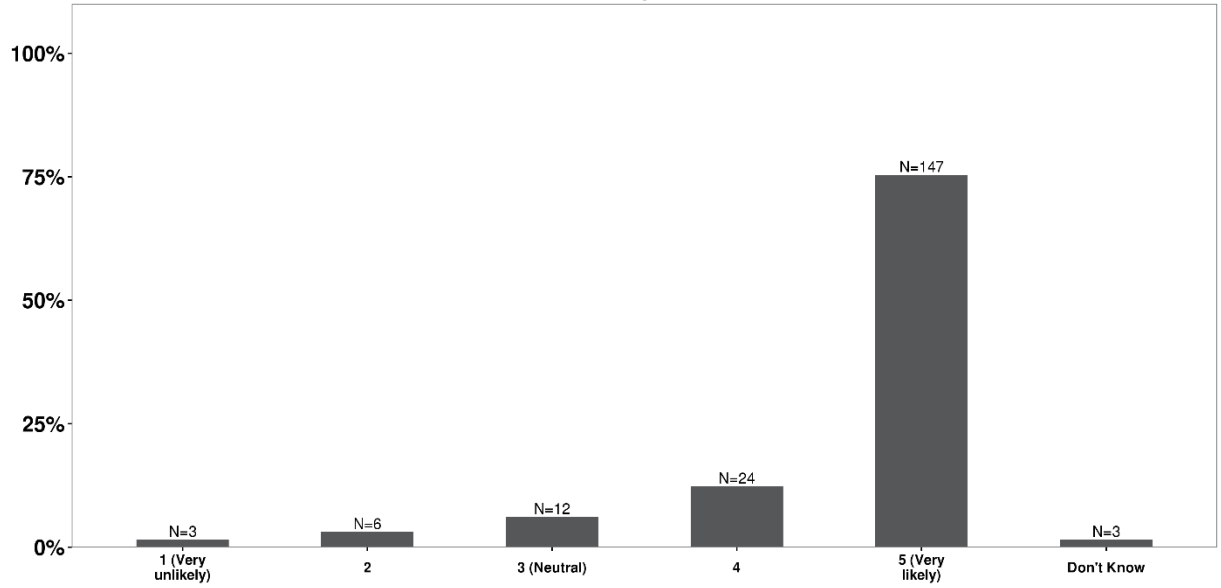
21. What method did you use to contact support about the program? (Select all that apply)



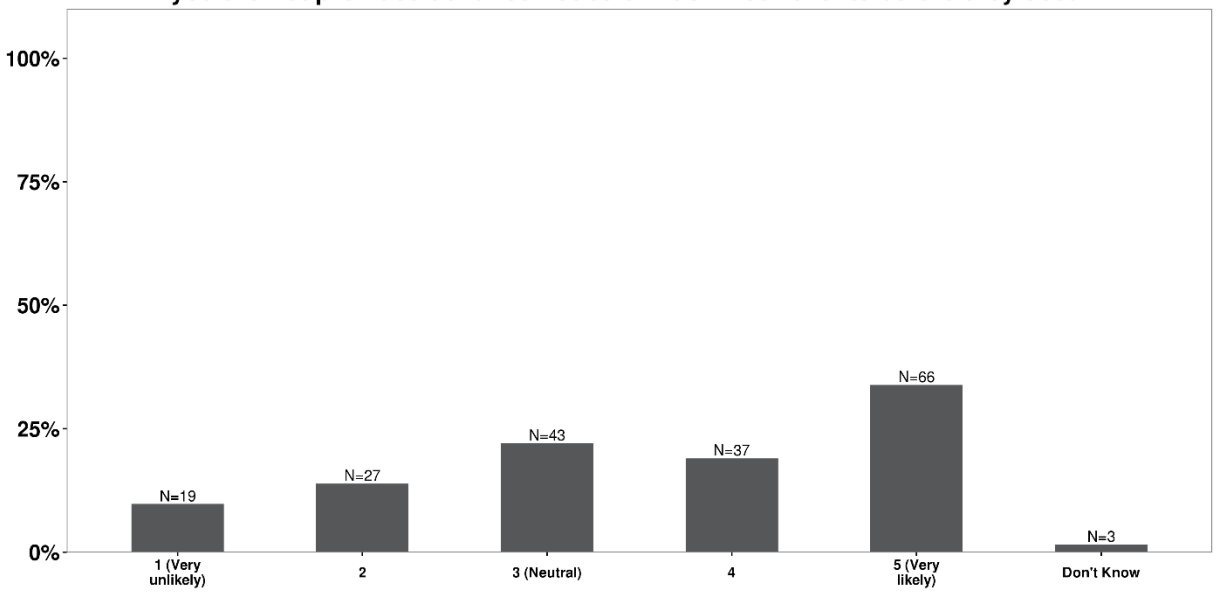
23. What is your level of satisfaction with the support you received?



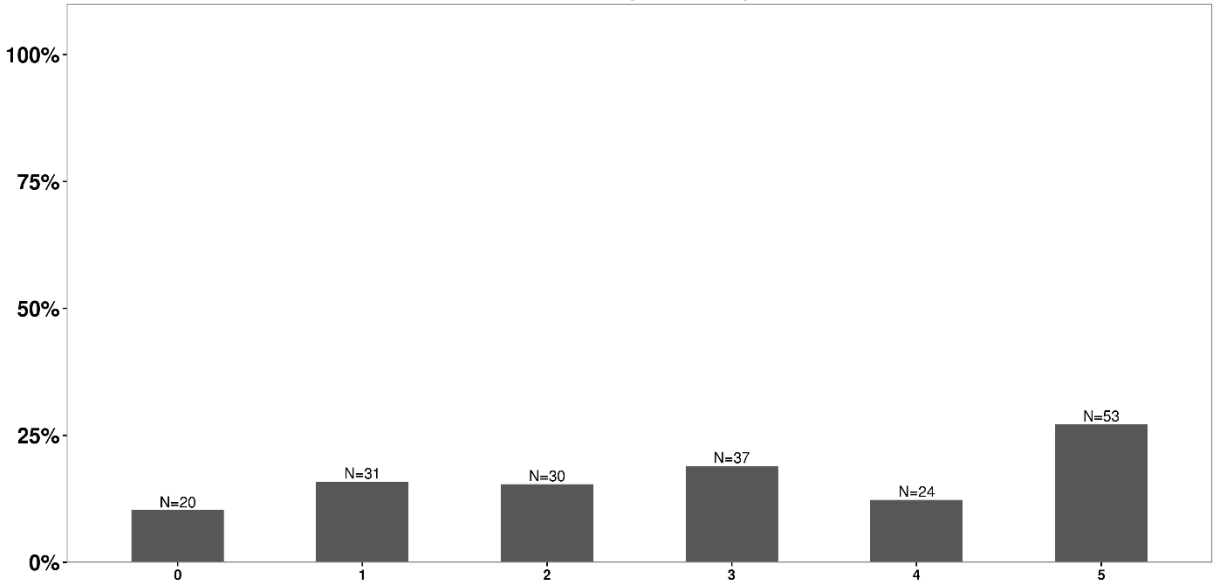
25. In future summers, how likely would you be to participate in the Rush Hour Rewards program?



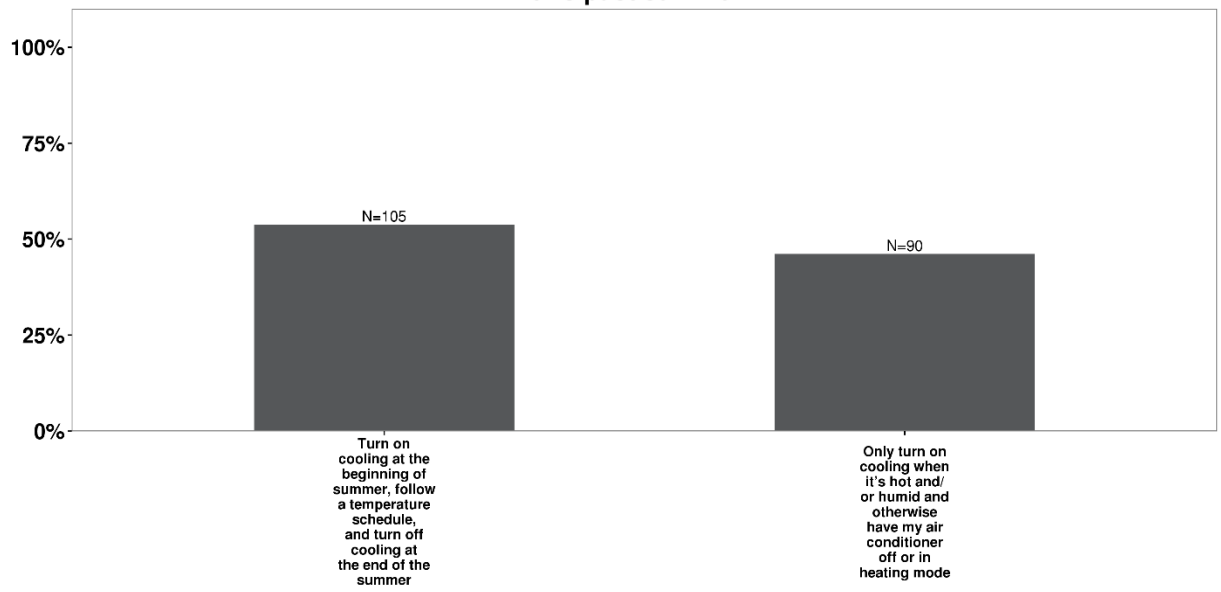
28. How likely would you be to pariticpate in the Rush Hour Rewards program if you are not provided advance notice of Rush Hour events before they occur?



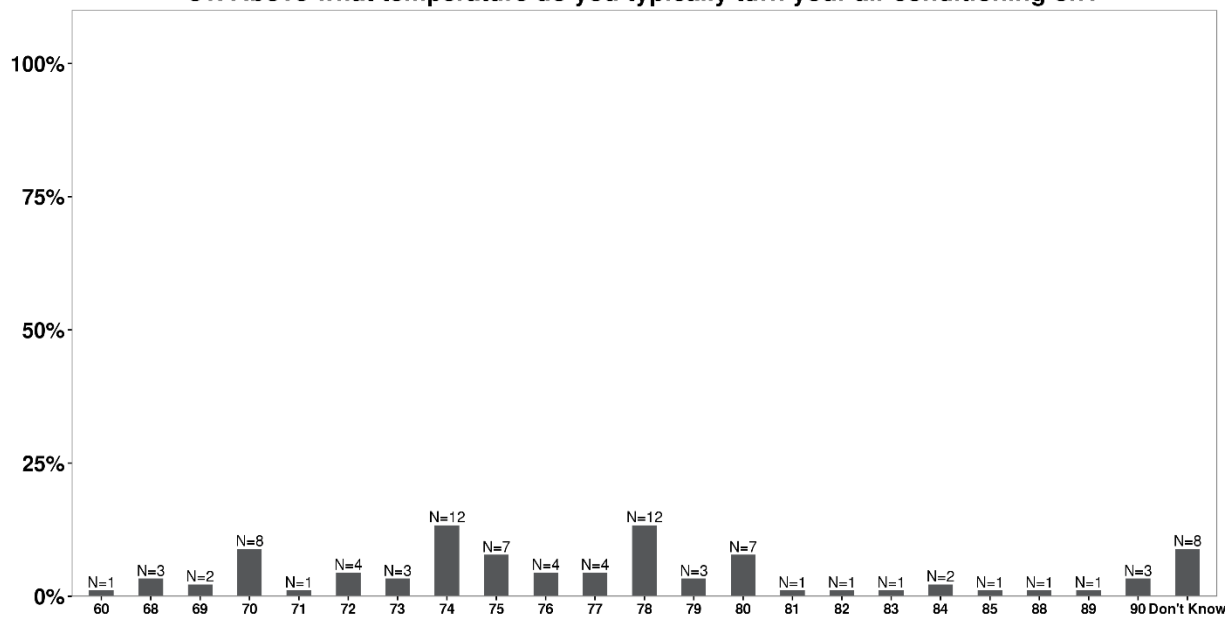
29. During the summer, for how many weekdays per week is at least one person home from 2 p.m. to 5 p.m.?



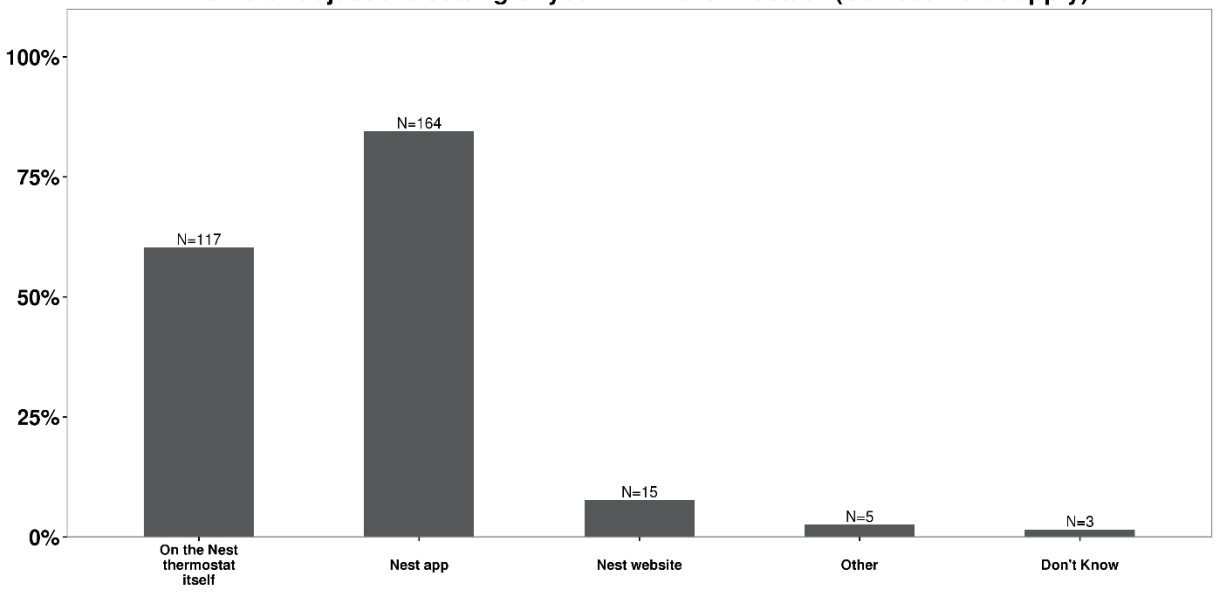
30. Which of the following best describes the way you used your air conditioner this past summer?



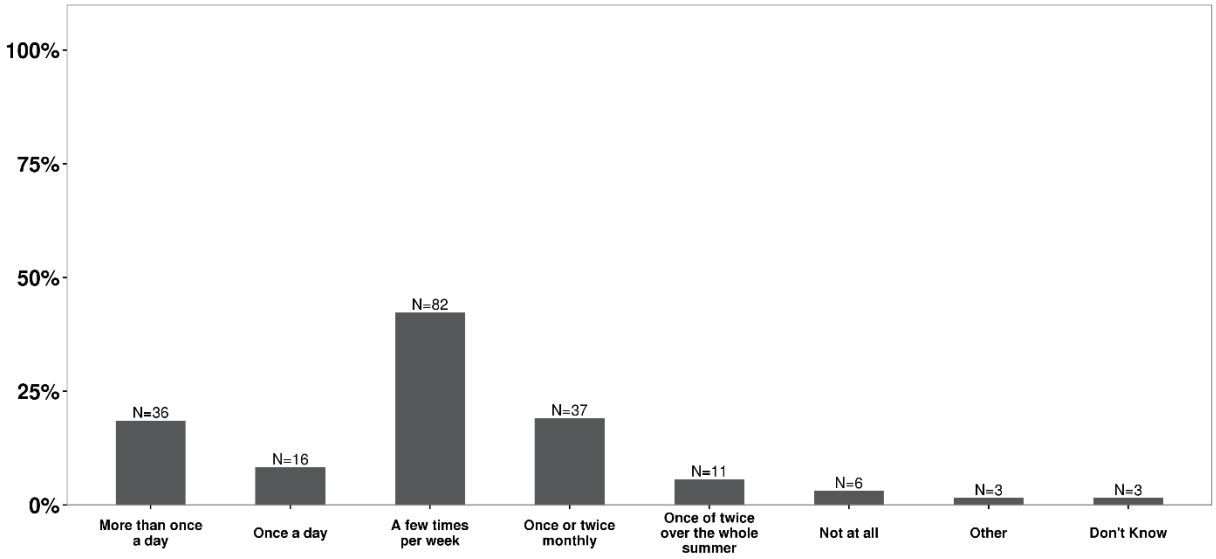
31. Above what temperature do you typically turn your air conditioning on?



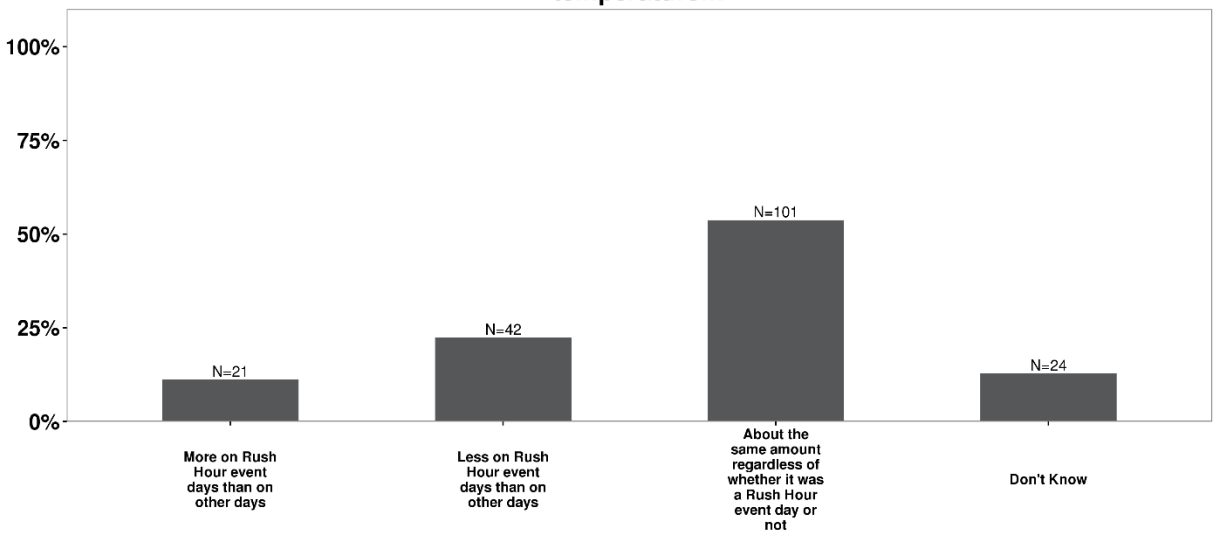
32. Over the past summer, how did you typically monitor the temperature of your home or adjust the setting of your Wi-Fi thermostat? (Select all that apply)



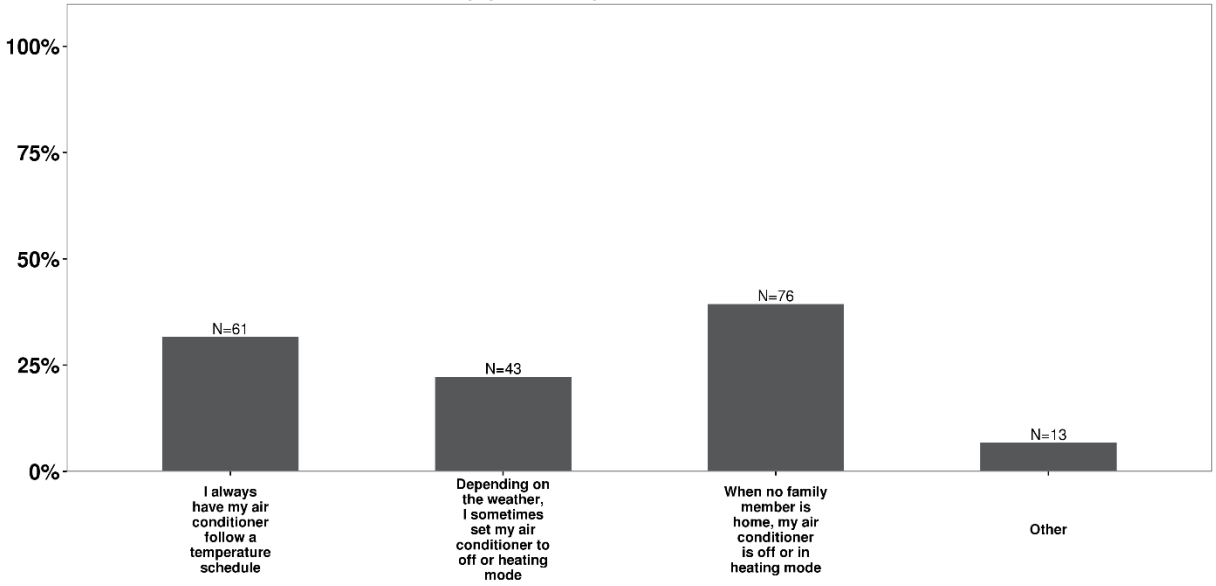
33. Now we'd like to understand the frequency with which you adjusted your Wi-Fi thermostat's setting or schedule during this summer. Would you say it was…



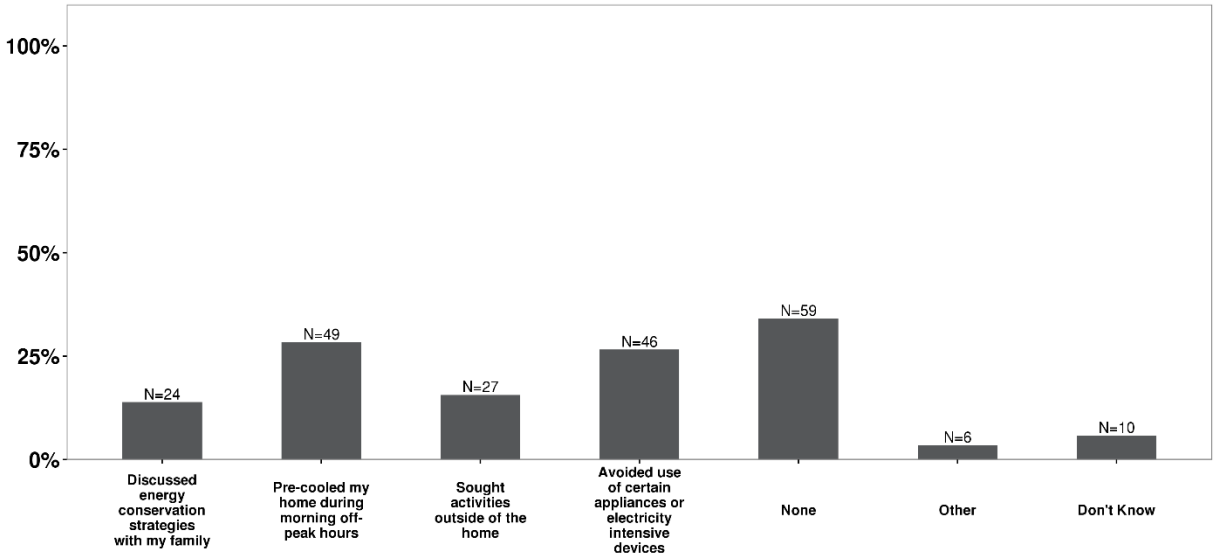
34. We'd also like to understand whether the frequency with which you adjusted your Wi-Fi thermostat's setting or schedule was different on Rush Hour event days compared to other days. Would you say you adjusted your home's temperature…



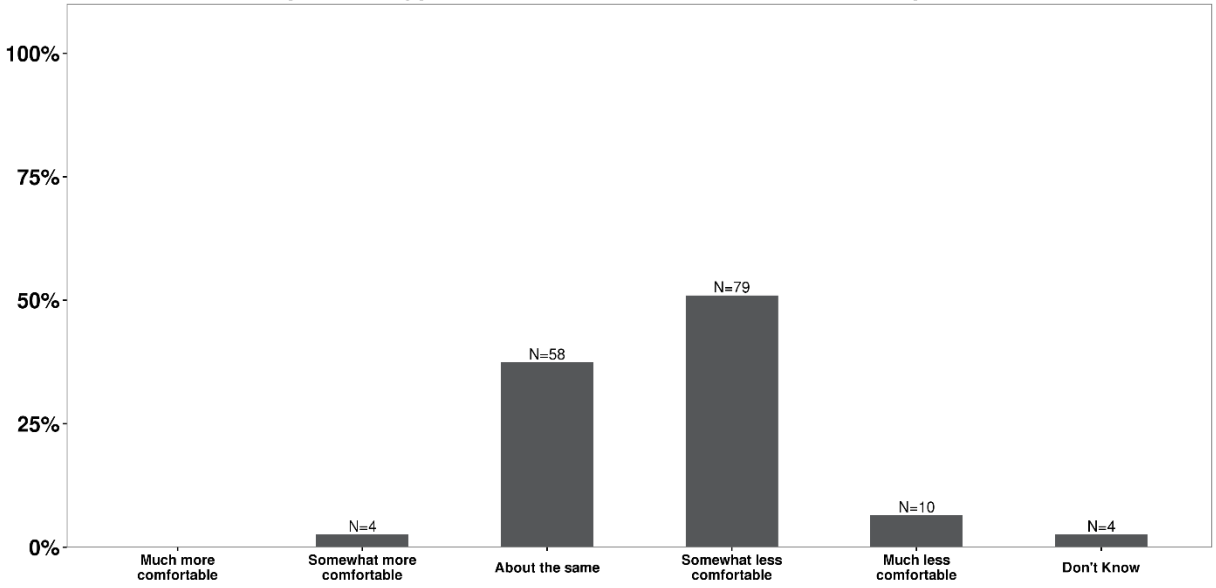
35. When no family member is at home, which of the following best describes the way you use your air conditioner?



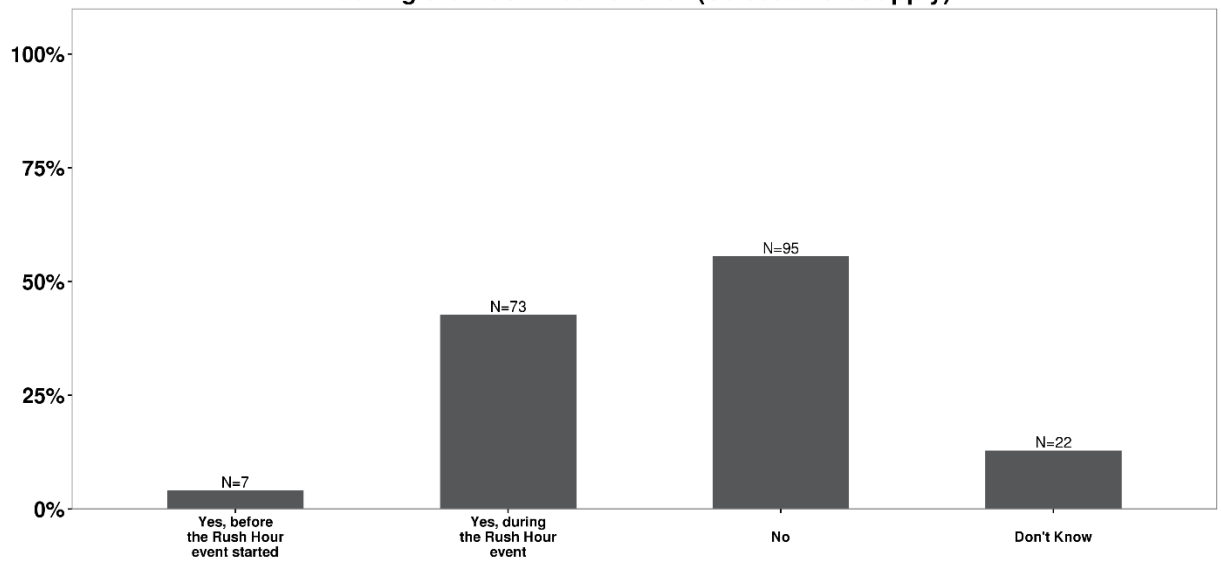
36. When you or a family member was at home for any part of a Rush Hour event, what actions, if any, did you take to reduce your electricity use during the Rush Hour event?



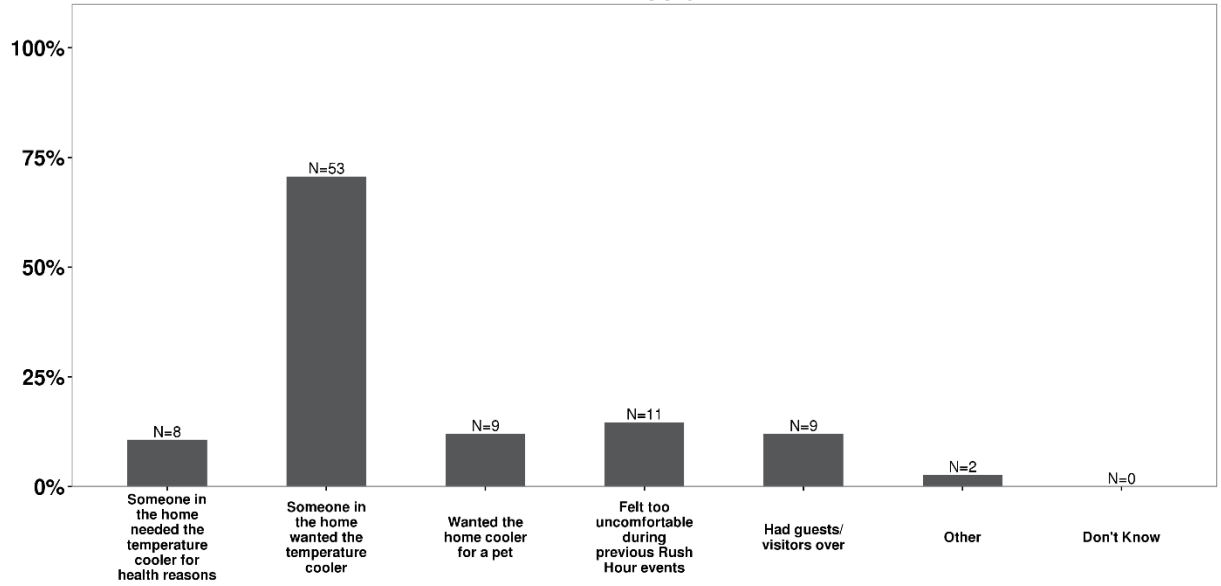
37. During the Rush Hour events, how would you generally describe your comfort compared to typcal afternoons with similar outdoor temperatures?



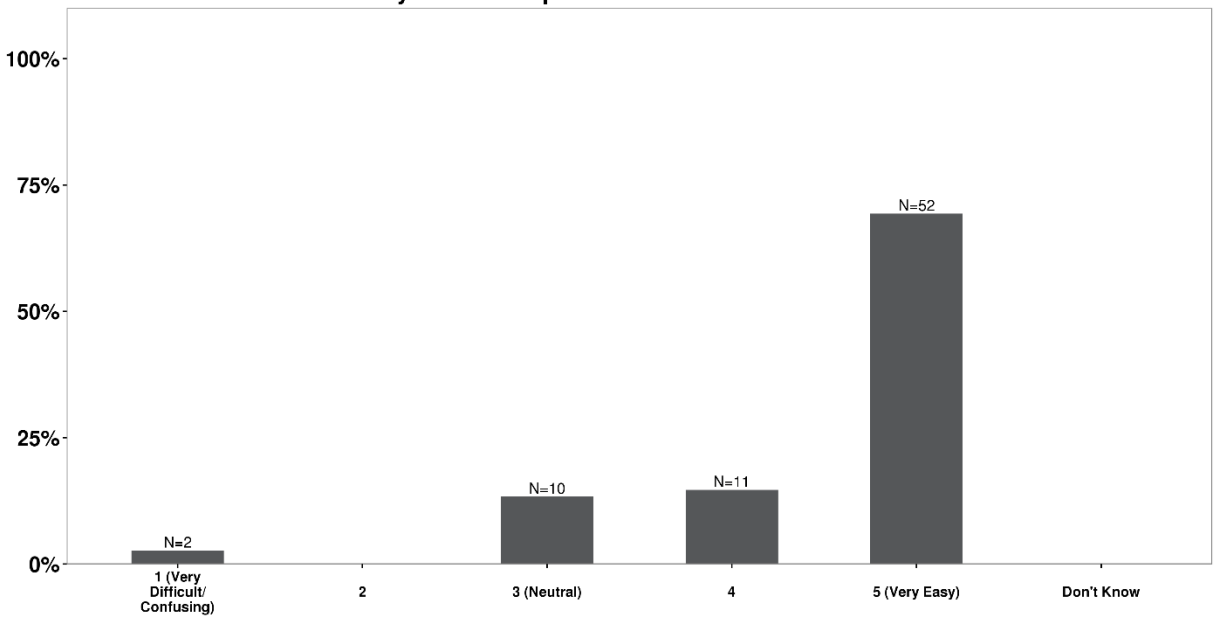
38. On Rush Hour event days, did you ever "opt-out" or override your Wi-Fi thermostat setting to stop the program from adjusting your Wi-Fi thermostat during the Rush Hour event? (Select all that apply)



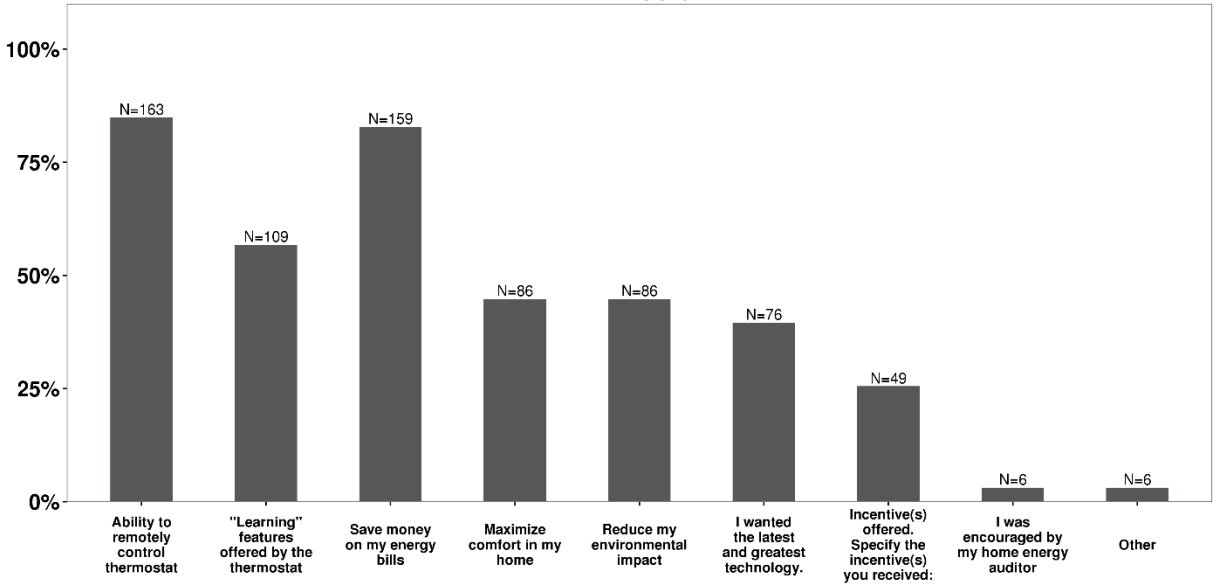
39. Why did you opt-out or override the Wi-Fi thermostat setting? (Select all that apply)



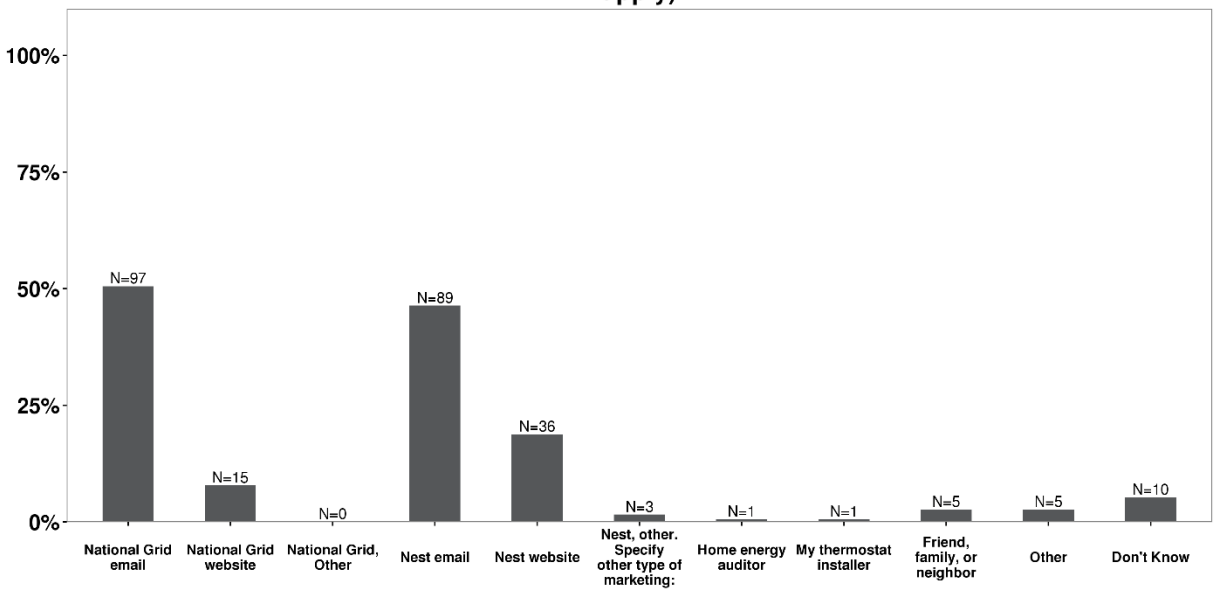
41. How easy was it to opt-out of or override Rush Hour events?



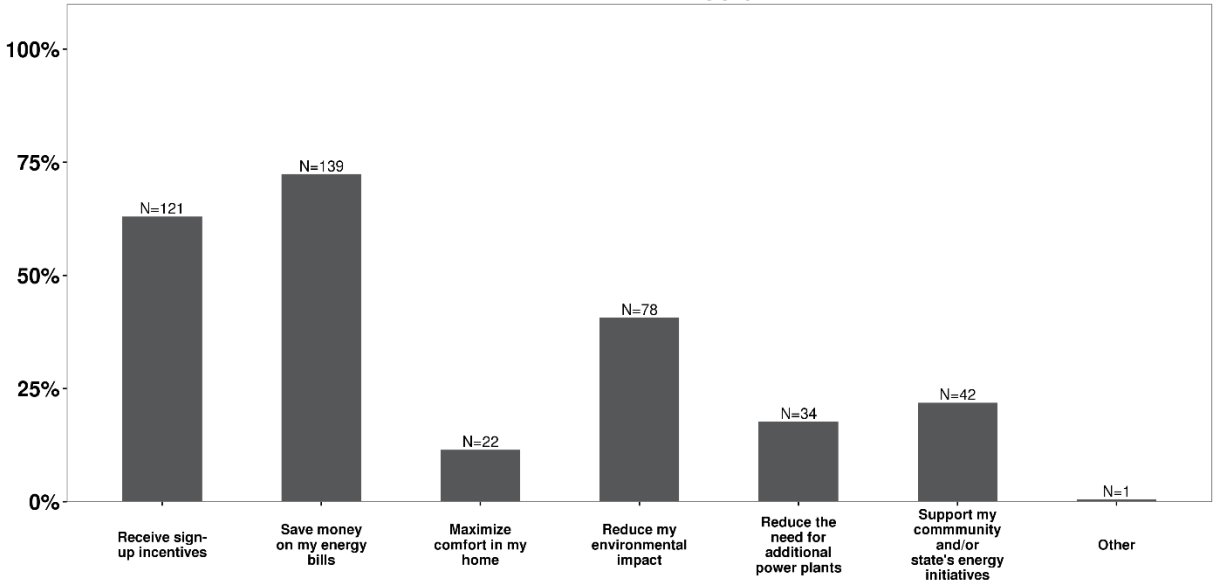
44. What were your main reasons for getting a Wi-Fi thermostat(s)? (Select all that apply)



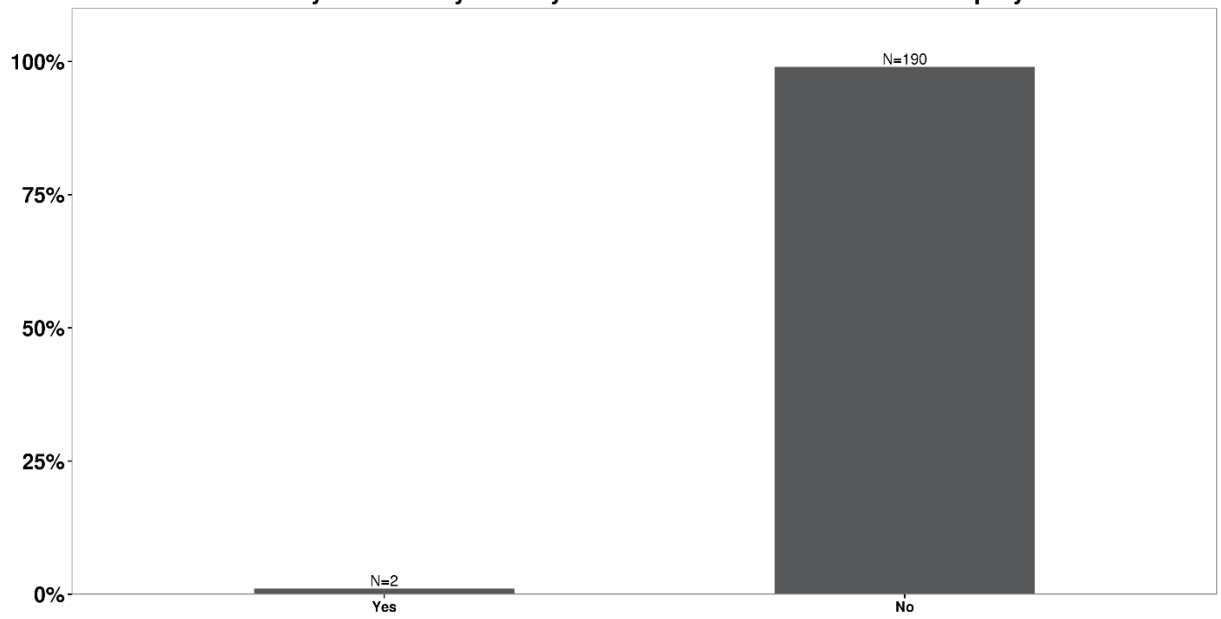
47. How did you learn about the Rush Hour Rewards program? (Select all that apply)



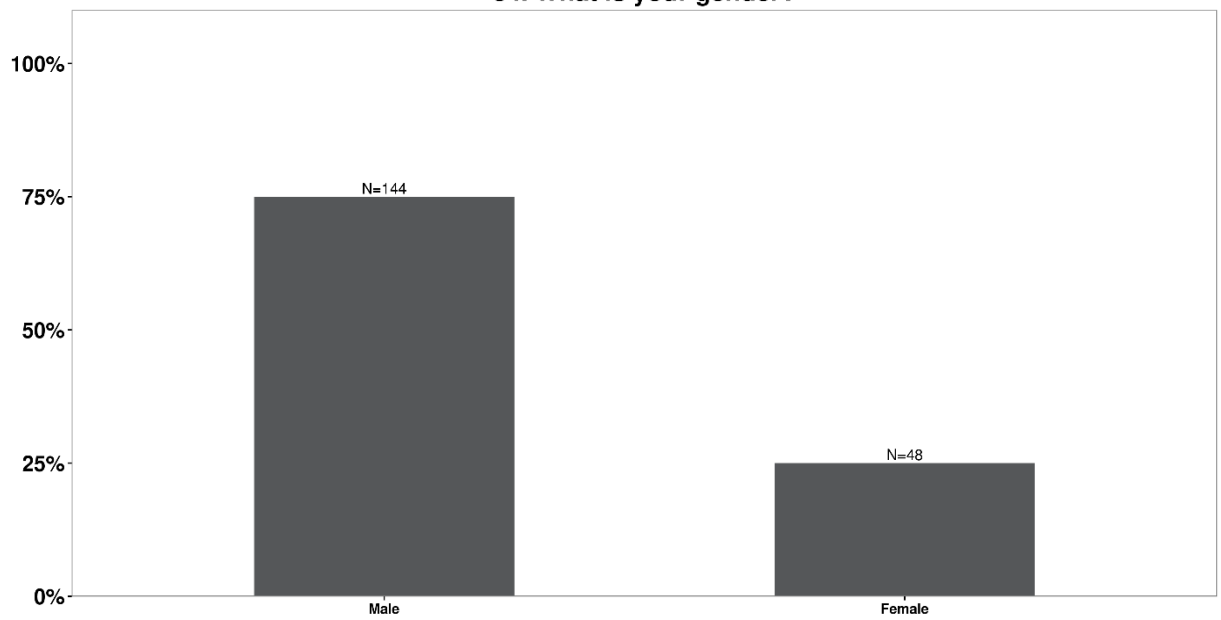
48. What were your main reasons for enrolling in the Rush Hour Rewards program? (Select all that apply)



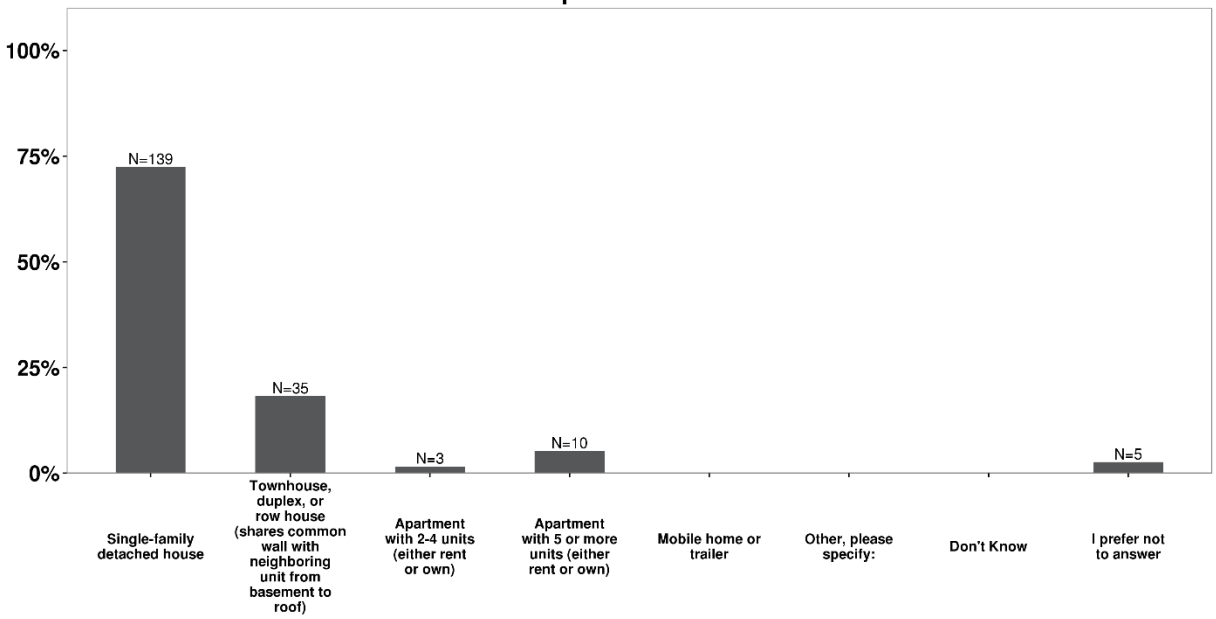
53. Are you or is anyone in your household a National Grid employee?



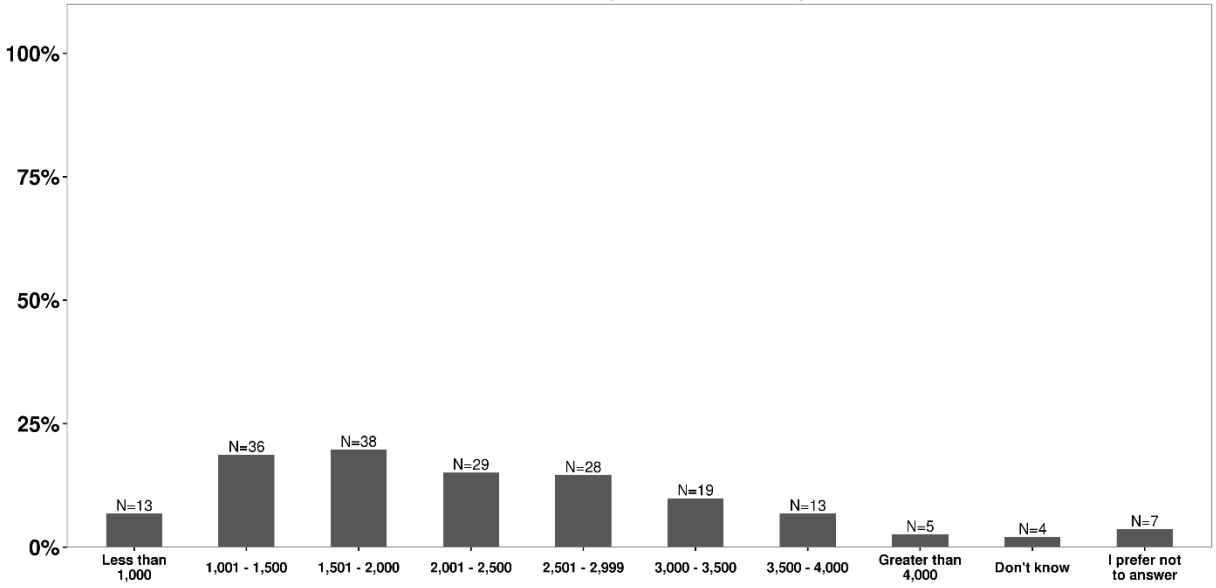
54. What is your gender?



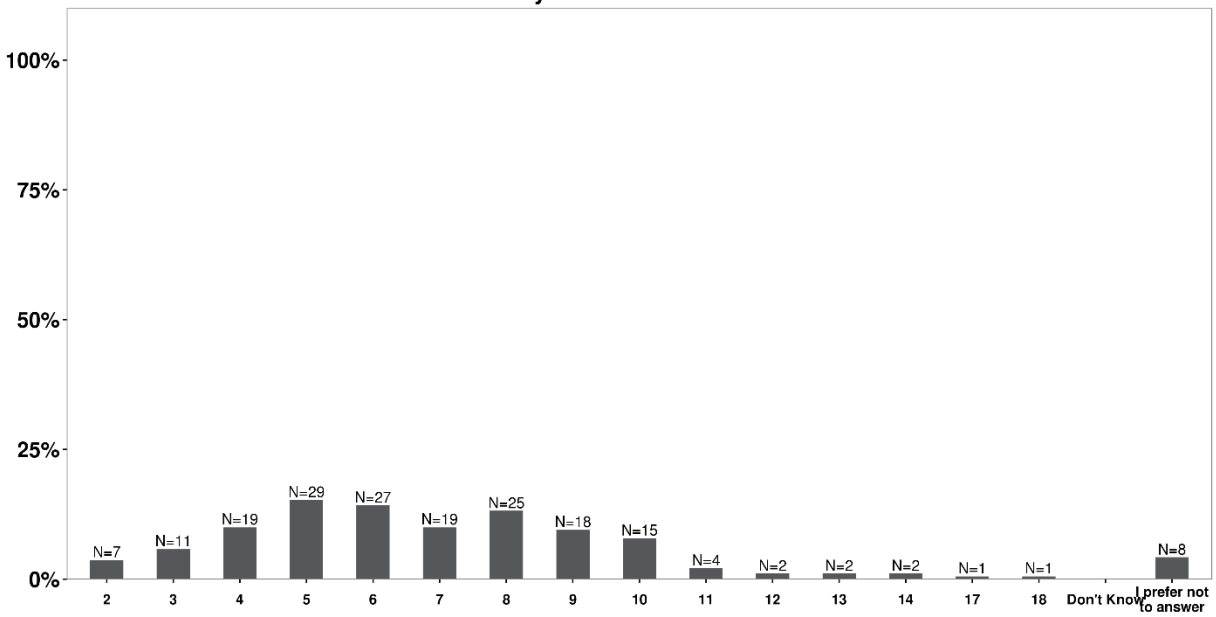
55. Which one of these options best describes this residence?



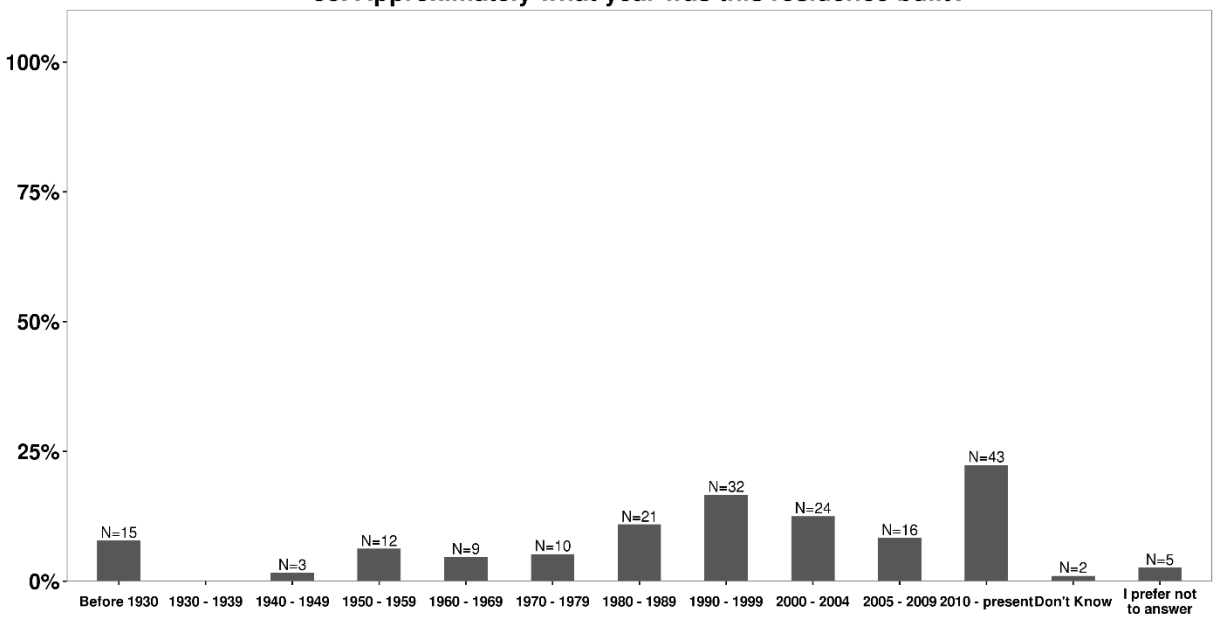
56. How many square feet of living space are there in this residence, including bathrooms, foyers and hallways?



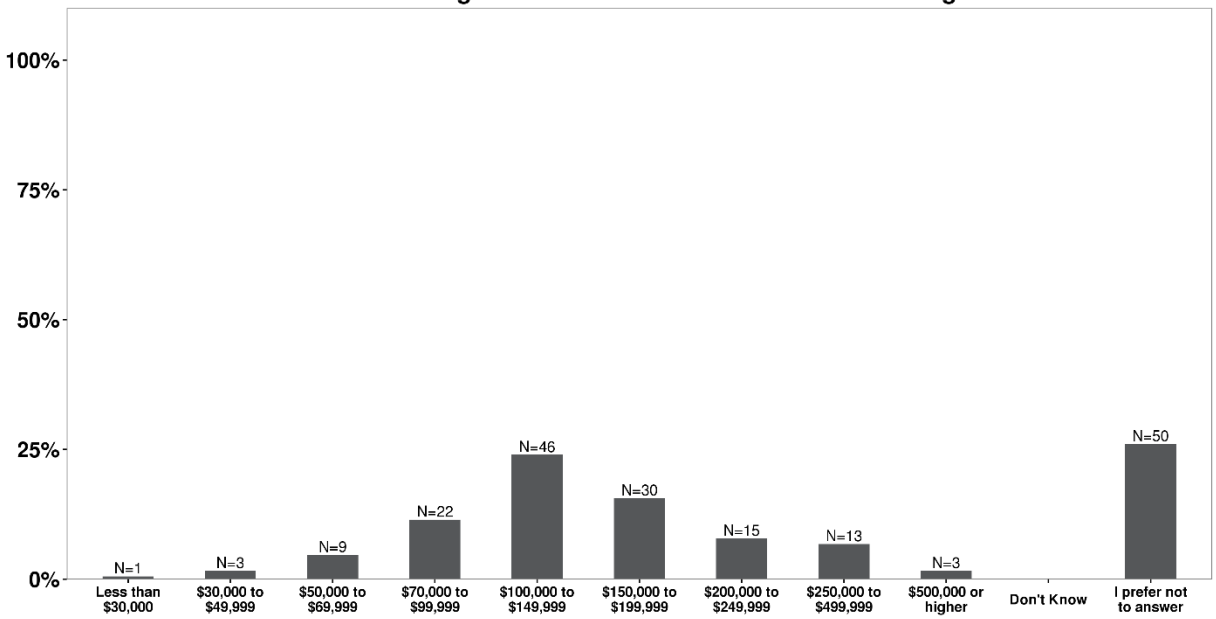
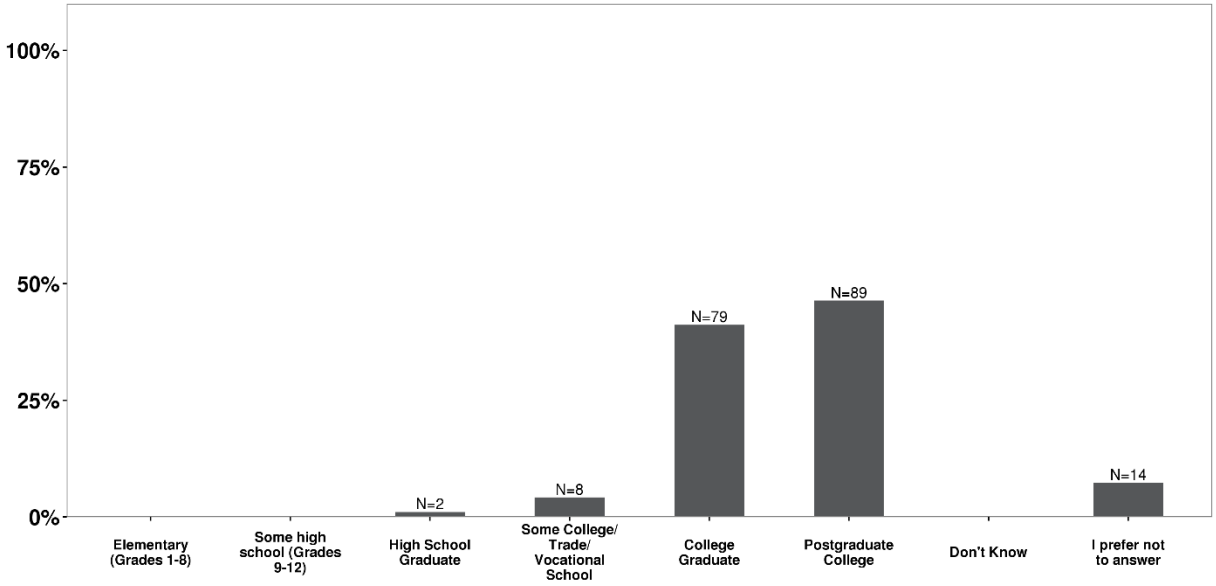
57. How many rooms are in this residence?



58. Approximately what year was this residence built?



59. Please select the range that best describes this household's gross income:



60. What is the highest level of education completed by the head of household in this residence?