Demand Side Analytics
DATA DRIVEN RESEARCH AND INSIGHTS

Energy Trust of Oregon Nest Thermostat Seasonal Savings Pilot Evaluation

Prepared by Apex Analytics, LLC and Demand Side Analytics
November 22, 2017

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Acknowledgements

The Evaluation Team would like to acknowledge the collaborative support offered by Nest Labs and, in particular, Michael Blasnik, Aaron Berndt, and Jeff Gleason.

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1. Executive Summary

Energy Trust of Oregon (Energy Trust), in collaboration with their implementation contractor, CLEAResult, and Nest Labs (Nest), offered a Seasonal Savings Pilot (Pilot) to homeowners during the 2016 summer season (summer deployment) and 2016/2017 winter season (winter deployment). This evaluation, led by Apex Analytics (Apex) and Demand Side Analytics (collectively, "the Evaluation Team"), sought to validate the Nest-claimed impacts and compile customer and staff feedback on their experiences with the Pilot.

Pilot Background

Nest Seasonal Savings is a thermostat setback optimization service designed for existing Nest customers. The underlying theory behind the service is that small setpoint and schedule adjustments are imperceptible to occupants but can produce significant savings throughout a heating or cooling season on top of the savings achieved by a Nest thermostat alone. Nest applies a series of optimizations over a three-week period that make small adjustments to the thermostat's setpoints and schedule. The customer can override any of the adjustments or opt-out at any point.

The Pilot was delivered using an experimental design known as a randomized encouragement design (RED). The RED is like a randomized controlled trial (RCT) often used with behavioral conservation programs like Home Energy Reports, except that it includes an opt-in component. Thermostats in the target population were randomly assigned to either a control group or an intention-to-treat (ITT) group.[1] The thermostats in the ITT group were then screened for eligibility, which entailed being connected to the relevant heating, ventilation, and air conditioning (HVAC) system for the season and operating a heating/cooling schedule.[2] The thermostats that passed the technical screening were then *offered* the opportunity to participate in the Pilot. Some of the offered participants accepted (opt-in) and others refused (did not accept).

There was no cost to participants, but Energy Trust paid Nest an incentive for each successful opt-in participant. Nest quantifies electric and natural gas savings based on the reduction in heating or cooling runtime of the HVAC systems compared with the average runtime of the control group of Nest devices selected from the same population.

[1] The ITT group are the customers randomly selected to be screened and offered participation in the Pilot.

[2] Control group participants do not receive the same assignment into qualified versus unqualified groups because these criteria are applied by algorithms sent to each thermostat in the treatment group. It is assumed that the control group has the same proportion of qualified versus non-qualified thermostats.

Evaluation Methodology

The primary objectives of this evaluation were to assess the customer experience (opt-in rates, satisfaction, and changes to home comfort levels), validate the Nest savings estimation methodology, and perform an independent assessment of the electric and natural gas savings estimates associated with the Pilot. To accomplish each of these objectives, the Evaluation Team:

- Developed a customer survey for each seasonal offering
- Reviewed and validated the Nest savings methodology, data, code, and findings
- Developed an independent billing analysis to validate the Nest findings using participant energy usage data

Key Findings and Recommendations

A summary of the findings associated with the key research objectives from the evaluation are noted below.

Research Objective: Document the implementation of the Pilot, its successes, and areas for improvement, including customer opt-in and attrition rates.

Finding: The Pilot was almost seamlessly implemented as a turnkey service, with high opt-in rates among qualified devices for the summer and winter deployments.

Table 1 summarizes the thermostat counts and calculates the key participation metrics among the control and ITT groups. Only 59% of the targeted thermostats qualified for the summer deployment of the Pilot due to a low prevalence of cooling systems operating a cooling schedule during the deployment period. In contrast, 94% of the targeted thermostats qualifed for the winter deployment. Among those offered the opportunity to participate in the pilot, the opt-in rate was high and quite similar across seasons (80% for the summer cooling season and 78% for the winter heating season). Attrition over the course of the Pilot was minimal, with less than 5% of the opt-in participants ultimately opting-out.

Table 1: Qualification and Opt-In Rate by Season

Study Group	Summer*	Winter*
Control	5,873	6,024
ITT Group	5,954	9,144
Did Not Qualify	2,459	579
Did Not Accept	705	1,849
Opt-In	2,790	6,716
Qualification Rate	58.7%	93.7%
Opt-In Rate Among Offered	79.8%	78.4%
Effective Opt-In Rate	46.9%	73.4%

*Note. These totals are based on counts of thermostats with valid runtime data in the analysis data set and differ from the counts as provided by Nest in the seasonal memos detailed in Appendices D and E.

Recommendation: Future implementations to expand the Pilot can be planned using the effective opt-in rates noted in this report, but also consider testing multiple modes of communication (e.g., email, phone, postal mail) as well as multiple invitations as a strategy to increase future opt-in rates.

Research Objective: Assess customer satisfaction with the service and the comfort of their home.

Finding: Participants showed high satisfaction and comfort levels with their Nest thermostats across study groups, yet over half of the opt-in survey respodents indicated they noticed temperature changes with the Seasonal Savings settings, one-third of them believed the temperature changes made their homes less comfortable, and in response to the discomfort they overrode some or all of the settings.

Recommendation: Energy Trust should make sure the marketing materials and program communications highlight the lower bills and energy that participants save through the Seasonal Savings program. Utility bill and energy savings were considered the primary drivers for participation and could help reduce the percentage of participants that opt-out or make adjustments that reduce the potential savings. Energy Trust should also monitor participant home comfort over time (either through surveys or tracking the percentage of participants that override the settings), and consider ways to reduce the percentage of participants that find their homes less comfortable (e.g., less aggressive temperature changes from Nest).

Research Objective: Assess the validity of Nest’s internal analysis of energy savings.

Finding: The Nest impact analyses were well-organized and consistent with industry best practices for impact evaluation. The Evaluation Team made several adjustments to the Nest savings claim, including the calculation of the opt-in rate for the summer deployment, limiting the summer analysis to a single model (runtime), the average condensing unit size (increased from 2.88 kW to 3.0 kW), and the average natural gas heating system size (decreased from 70 kBTU/hr to 65 kBTU/hr). Table 2 compares the Nest and Evaluated percent and absolute impacts per opt-in thermostat, by season.

Table 2: Comparison of Nest-Reported and Evaluated Impacts per Opt-In Thermostat

Season	Nest Reported		Evaluated Impacts	
	Percent Reduction	Primary Resource Savings	Percent Reduction	Primary Resource Savings
Summer Cooling	2.40%	12 kWh	0.81%	4 kWh
Winter Heating	4.75%	20 therms	4.75%	18 therms

The Nest Seasonal Savings program showed minor summer season cooling savings of only 4 kWh per opt-in thermostat, while winter heating seasonal savings were significant – approximately 18 therms per opt-in thermostat over the course of the 2016/2017 winter season. This finding is driven largely by climate and the intermittent cooling load used by participants. A supplemental cooling analysis found that average annual air conditioning use among participants is only around 784 kWh per year so there is limited opportunity to save energy in the cooling season compared to the winter.

Table 3 shows the runtime reductions per opt-in thermostat on a percentage basis and in the number of hours of runtime reduced. Impacts are presented for the opt-in thermostats (thermostats in the ITT group where the participants were technically qualified and deployed the Seasonal Savings algorithm on their Nest thermostat).

Table 3: Seasonal Savings Runtime Impact Summary Per Opt-in Thermostat

Season	# Opt-In Thermostats	Baseline HVAC Runtime (Hours)	Percent Runtime Reduction	Baseline HVAC Runtime (Hours)	Average Runtime Reduction (Hours)
Summer Cooling	2,790	168	0.81%	168	1.4
Winter Heating	6,716	596	4.75%	596	28.3

In Table 4, the runtime reductions are converted to energy savings using equipment capacity assumptions. The 6,716 opt-in thermostats for the winter season are split primarily between natural gas furnaces (6,201) and electric heat pumps (440). There were also a small number of thermostats (75) connected to liquid propane and fuel oil heating systems that are included in the calculation of electric fan savings, but not natural gas savings.

Table 4: Seasonal Savings Energy Savings Summary

Season	System	Fuel	Equipment Capacity Assumption	# Opt-In Thermostats	Per Device Impact	Aggregate Impact
Summer Cooling	Central AC and Heat Pump	Electricity	3 kW	2,790	4 kWh	11,379 kWh
Winter Heating	Gas Furnace	Natural Gas	65 kBTU/hour	6,201	18 therms	110,404 therms
		Electricity (Fan)	0.56 kW	6,276	15 kWh	96,275 kWh
	Heat Pump	Electricity	3 kW	440	121 kWh	53,198 kWh

Recommendation: Energy Trust should adopt the per-device savings estimates produced by the runtime analysis and verified in this report. Future savings should be based off the runtime model and the equipment size assumptions presented in this report and agreed to by Nest.

Recommendation: Because the Nest Seasonal Savings service showed robust winter savings and delivered results at low cost, Energy Trust should consider adopting the Seasonal Savings as a full program offering, but only for the winter season – the summer savings are likely to fail cost-effectiveness testing with such low savings. This recommendation is contingent on the winter costs and savings passing cost-effectiveness testing.

Research Objective: Independently evaluate and corroborate energy savings using customer billing data.

Finding: Due to a limited amount of summer cooling and resulting low savings for the summer season, the Evaluation Team only used the billing data to estimate average air conditioner size. For the winter season, however, the Evaluation Team was able to validate the savings analysis using gas billing data. Two different billing analysis approaches returned statistically significant gas savings estimates from the Pilot's winter deployment.

Billing data were only available for survey respondents (approximately 5% of Pilot homes), so the impact estimates from the analysis of utility consumption records were less precise than the thermostat runtime analysis. However, the two billing analysis approaches used returned gas savings estimates that were slightly higher than the runtime analysis, but with the runtime analysis estimates falling within the confidence interval of the billing analysis results. This independent analysis further demonstated the ability of Seasonal Savings to produce statistically significant energy savings during the heating season.

Recommendation: Due to lower precision with billing data analysis as a result of a smaller participant sample and longer time intervals, the Evaluation Team recommends that Energy Trust rely on the runtime analysis discussed above to quantify the energy impacts of the Pilot. The billing results should be used as a directional validation of the runtime based savings estimates.

Research Objective: Assess the validity of Nest's internal analysis of savings persistence.

Finding: The Evaluation Team reviewed persistence by examining the runtime and setpoint differential between the ITT and control groups throughout the entire heating season. There was no indication of any decline in savings or significant attrition from participants by the end of the heating season. Furthermore, the Nest thermostat will continue to run the Seasonal Savings-based scheduling and setpoints during the following season, provided the participant does not override the settings.

Recommendation: A follow-up analysis of the next (2017/2018) winter season runtime differences between RED groups would provide valuable insight into persistence, provided additional Seasonal Savings deployments aren't layered on top of the winter 2016/2017 algorithm or experimental design.

Research Objective: Determine whether Nest Seasonal Savings is a feasible and cost-effective service that can achieve low-cost, non-equipment-based HVAC savings.

Finding: Cost-effectiveness analysis was not part of the research scope, but the Evaluation Team can confirm that Nest Seasonal Savings is a low-cost measure with strong winter-season savings, equivalent to small domestic hot water measures. Anecdotal feedback from staff indicated the winter deployment was likely to pass cost-effectiveness testing.

Recommendation: Energy Trust should run cost-effectiveness tests on the winter season Pilot results to determine whether it passes internal criteria for being offered as a full program.

EnergyTrust of Oregon

MEMO

Date: December 8, 2017
To: Board of Directors
From: Marshall Johnson, Residential Sector Senior Program Manager
Dan Rubado, Evaluation Project Manager
Subject: Staff Response to the Evaluation of the Nest Seasonal Savings Pilot

Energy Trust conducted a pilot to test Nest's Seasonal Savings service during the summer of 2016 and winter of 2016/2017. Nest Seasonal Savings is a thermostat setback optimization service designed for existing Nest customers. The evaluation demonstrated that Seasonal Savings produced substantial heating savings during the winter at a low cost per thermostat. The winter savings should exceed Energy Trust's cost-effectiveness criteria by a wide margin. Energy Trust plans to offer this service to a larger group of Nest customers for the winter of 2017/2018, using the energy saving levels identified from the pilot. The evaluation showed that Seasonal Savings did not produce significant cooling savings during the summer. It is unlikely that this service would produce substantial savings even during an unusually hot summer in Oregon. Energy Trust does not plan to deploy Seasonal Savings during the summer.

The evaluation found that Nest's methods for calculating heating savings using system runtime data were sound, but suggested several minor adjustments that Nest will incorporate in the future. The evaluation team also validated the estimated energy savings through independent, third-party analysis of utility billing data. As a result, Energy Trust will move forward by working with Nest to quantify the energy savings from Seasonal Savings at the end of each season, using their runtime data and the validated analysis methods.

Pilot savings persisted through the winter season, but persistence into subsequent seasons is unknown, although plausible. Energy Trust will collaborate with Nest on analysis in 2018 to determine whether savings persist from one year to the next. Energy Trust may also ask to review Nest's runtime dataset and analysis methods every year or two to ensure they are consistent with the validated methods. Energy Trust may do additional billing analysis, in coordination with Nest, to re-evaluate the energy savings from this service after several years.

The pilot was straightforward to implement, had a high opt-in rate, and reasonably high levels of participant satisfaction. Participant comfort in their homes with the service was lower than with the Nest thermostat without the service. This caused many participants to override some or all of the adjustments to their thermostat settings made by the Seasonal Savings algorithm. Energy Trust will monitor participant comfort and satisfaction in future efforts to ensure that participants are happy with the service so that it is successful. If participant comfort continues to be an issue, then Energy Trust will work with Nest to change the service to improve comfort.

2. Introduction

The Energy Trust of Oregon (Energy Trust) Existing Homes program has recently pursued low-cost, non-equipment energy savings offerings to increase and diversify residential portfolio savings. One potential offering that received promising early indications was based on the Nest thermostat device.[3] As of late 2015, Nest had over 16,000 registered devices in Energy Trust service territory. In early 2016, the Program Management Contractor, CLEAResult, began development of a new pilot for Nest customers. Energy Trust offered the Nest Seasonal Savings Pilot (Pilot) within their Existing Homes program in mid-2016. The Seasonal Savings service was managed by Nest Labs, under contract with CLEAResult. The primary goal of the Pilot was to determine whether Nest's Seasonal Savings service can be successfully deployed in Oregon and result in significant, cost-effective energy savings. Because of the large, and growing, base of installed Nest thermostats in Energy Trust territory, there is considerable potential to expand the Seasonal Savings service if proven to provide robust energy savings.

Nest Seasonal Savings is a thermostat setback optimization service designed for existing Nest customers.[4] The underlying theory behind the service is that small setpoint and schedule adjustments are imperceptible to occupants but can produce significant savings throughout a heating or cooling season in excess of the savings achieved by a Nest thermostat alone. For the service, randomly selected Nest customers are recruited via a notification on the thermostat and a follow-up email from Nest promoting the free energy-saving service. There is no cost to participants to opt in to the service, but incentives are paid by Energy Trust to Nest based on the number of customers that enroll in each season. Once enrolled, Nest applies a series of optimizations over a three-week period that make small adjustments to the thermostat's setpoints and schedule. The customer can override any of the adjustments or opt out at any point.[5] The resulting changes in temperature made by the thermostat typically average less than 1.5 degrees Fahrenheit (°F).

The Pilot included two deployments of the Seasonal Savings service: one in the summer of 2016 (summer deployment) and another in the 2016/2017 winter season (winter deployment). Each deployment was delivered using an experimental design known as a randomized encouragement design (RED). The RED is similar to a randomized controlled trial (RCT) often used with behavioral conservation programs like Home Energy Reports, except that it includes an opt-in component. Figure 1 provides a visual overview of the Seasonal Savings RED. In the RED process, thermostats in the target population are first randomly assigned to either a control group or an intention-to-treat (ITT) group. The

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[3] Staff interviews indicated an early pilot in Massachusetts and another in California showed promise and evidence of cost-effective savings.

[4] The Pilot did not screen for residential only customers, and 2% of all target population and 1.3% of opt-ins were self-reported to be businesses.

[5] Discussions with Nest revealed that attrition was less than five percent of both Pilot season opt-in participants. Details on opt-in participant attrition are reviewed below.

thermostats in the ITT group are then recruited and offered the opportunity to participate. Customers eligible to be included in the RED study (ITT or control group) first had to meet the following criteria:

- Have a Nest installed and an online account
- Have any forced-air heating or cooling system connected to thermostat
- Located in Energy Trust service territory in Oregon and heating with electricity or gas or cooling with electricity from one of Energy Trust's participating utilities (Portland General Electric (PGE), Pacific Power, NW Natural, Cascade Natural Gas, and Avista)[6]

The thermostats in the ITT group were then screened for technical eligibility, including the following criteria:

- Thermostat connected to internet
- Actively operating a heating/cooling schedule

Nest sent a notification to all eligible ITT thermostats, inviting them to opt-in to Seasonal Savings.[7] Some of the eligible ITT customers that received the offer accepted it (opt-ins) and others do not accept (opt-outs).

Figure 1: Randomized Encouragement Design

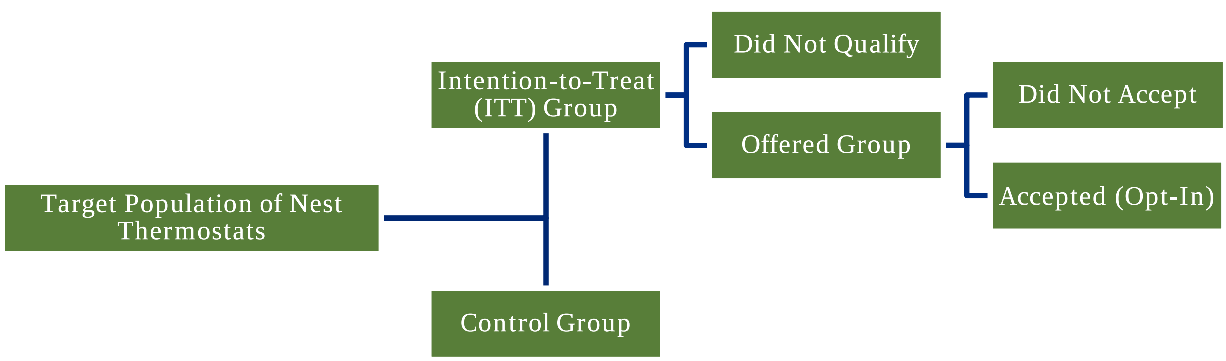

Table 5 summarizes the thermostat counts and calculates the key participation metrics among the ITT group. Due to a low prevalence of actively operating cooling systems at the time of recruitment, only 58.7% of the ITT group thermostats qualified for the summer deployment, while 93.7% of the ITT group thermostats qualifed for the winter deployment.

[6] The Existing Homes Program provided Nest with a list of eligible zip codes where a large majority of households is served by these utilities.

[7] The notification is shown on the cover page of this report, in the image of the Nest thermostat.

Table 5: Qualification and Opt-In Rate by Season

Study Group	Summer*	Winter*
Control	5,873	6,024
ITT Group	5,954	9,144
Did Not Qualify	2,459	579
Did Not Accept	705	1,849
Opt-In	2,790	6,716
Qualification Rate	58.7%	93.7%
Opt-In Rate Among Offered	79.8%	78.4%
Effective Opt-In Rate	46.9%	73.4%

* Note. These totals are based on counts of thermostats with valid runtime data in the analysis data set and differ from the counts as provided by Nest in the seasonal memos detailed in Appendices D and E.

It is important to note that opt-in participants that drop-out at any point of the season remain within the pool of ITT opt-in group participants[8] and are identified as participant "attrition". Nest indicated that there was less than five percent attrition rates for opt-in participants for both seasons.[9] According to Nest, these customers will still achieve some degree of savings since the changes made by Seasonal Savings are not completely undone by their actions. The following group of customers are classified as dropping out:

- Opted out during or after the three-week schedule adjustment period
- Manually adjusted their thermostats back to original schedules
- Other actions/settings that cause the algorithm to pause or exit early

Nest normally offers a standard customer satisfaction survey, which is administered at the end of each Seasonal Savings season. Nest agreed to collaborate with Apex Analytics (Apex) and Demand Side Analytics (collectively, "the Evaluation Team"), along with Energy Trust, to incorporate a link to an Evaluation Team-administered survey, to allow additional questions to be asked. This survey also enabled the collection of customer addresses, which allowed the Evaluation Team to identify the homes involved in the study for the billing analysis.

2.1 Evaluation Goals and Objectives

The Pilot was launched to explore potential energy savings associated with the Nest Seasonal Savings service, as well as customer acceptance and satisfaction with deployment of the service. The primary research questions of the Pilot were:

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[8] The attrition group remain in the opt-in group for Nest runtime and setpoint savings analysis.

[9] Attrition values provided in conversations with Nest.

- What are the heating and cooling savings associated with Nest Seasonal Savings?
- What is the persistence of these savings?
- Does Seasonal Savings achieve high levels of customer opt-in and acceptance?

To help answer the Pilot research questions, the primary objectives of this evaluation were to:

- Document the implementation of the Pilot, its successes, and areas for improvement, including customer opt-in and attrition rates
- Assess customer satisfaction with the service and the comfort of their home
- Assess the validity of Nest's internal analysis of energy savings
- Assess the validity of Nest's internal analysis of savings persistence
- Independently evaluate and corroborate energy savings and persistence using customer billing data
- Determine whether Nest Seasonal Savings is a feasible and cost-effective service that can achieve low-cost, non-equipment-based heating, ventilation, and air conditioning (HVAC) savings.

This evaluation report contains the following chapters:

- Chapter 3 contains the results of the customer surveys and staff interviews
- Chapter 4 provides an overview of the approach and high level findings for the validation of the Nest Seasonal Savings findings
- Chapter 5 provides the detailed methodology and findings for the summer season savings analysis
- Chapter 6 provides the detailed methodology and findings for the winter season savings analysis
- Chapter 7 contains the conclusions and recommendations

3. Customer Surveys and Staff Interviews

3.1 Staff Interviews

The Evaluation Team developed an interview guide (see Appendix A) for program staff at Energy Trust and CLEAResult who were involved in the design, management, and implementation of the Pilot. After both summer and winter results had been reported by Nest, the Evaluation Team interviewed Energy Trust and key CLEAResult staff. Each interview lasted approximately one hour. The objectives of staff interviews were to get their perspectives on partnering with Nest, participant opt-in and attrition rates, logistical and communication issues, customer reactions to the Pilot, and feasibility for successful deployment of the Pilot to a larger customer base. The team also held several meetings with Energy Trust and Nest staff to discuss Pilot implementation and Nest's savings methodology.

Energy Trust and CLEAResult staff believed the implementation of the Pilot ran smoothly, supported by regular ongoing meetings, dedicated staff, and a turnkey service, all of which helped make the Pilot a success. Nest presented the Pilot as a package offering, which had the advantage of simplifying the process but limited the amount of customization and messaging by Energy Trust. Staff believed the Pilot development and processes were transparent, which included Nest providing detailed estimates for Pilot anticipated metrics: Nest provided accurate estimates for the number of opt-ins, the number of refusals, and the number who would not qualify, and provided real-time updates on the Pilot status. Nest was also savvy with pricing; staff believed Nest had thought of the value of the service based on energy savings, and Nest structured pricing so it wasn't too expensive.[10] And related to pricing, staff were initially confused about what point in deployment the number of "participants" would be considered final to determine how much Energy Trust would pay Nest.

There were some challenges noted during staff interviews, which were deemed unavoidable given the nature of the delivery of the Pilot. One of the most significant challenges included the inability to identify Energy Trust customers for recruitment and guarantee only customers of Energy Trust's funding utilities would receive the Pilot recruitment emails. The Energy Trust implementation team had to rely on zip codes to target customers most likely to be Energy Trust customers for Nest recruitment.[11] This issue is compounded by the proper assignment of savings, including gas versus electric, partially because participants may not know or accurately respond to the heating fuel question when they fill out the initial thermostat settings questionnaire.

The only participant-facing challenge the Evaluation team was made aware of was one anecdote that an Energy Trust staff member had received. According to Energy Trust staff, a Pilot participant had received

[10] Staff did note though the per-participant cost was low, the initial logistical cost to run the Pilot was moderate.

[11] Nest does not store or identify thermostats by address, which could be linked with utility customer data, and Energy Trust could not obtain and distribute the entire utility customer database list of addresses to Nest.

messaging on their Nest from PGE, telling them that PGE was helping save energy as part of the Rush Hour Rewards program, even though they were only enrolled in the Energy Trust Seasonal Savings Pilot as a NW Natural gas customer. The Evaluation team was unsure of the source or underlying cause of this communication mix-up, but believes there was some confusion for those participants that were aware of the distinctions between these two Pilots.

3.2 Customer Surveys

The Evaluation Team developed online surveys for the two seasonal iterations of the Pilot. Each seasonal survey was deployed subsequent to the completion of each seasonal deployment of the Pilot and administered online in coordination with Nest and Energy Trust. The Evaluation Team worked with Energy Trust and Nest to recruit survey participants using an invitation and a survey link provided to participants in a direct solicitation email from Nest.[12] Nest customers were offered the chance to win a new Nest Cam[13] for completing the survey, as similar incentives have proven to be highly successful in increasing the prior survey response rates for studies conducted by Apex on behalf of Energy Trust.[14]

The Evaluation Team identified four survey strata. Each of these four strata received unique survey web link, based on their Pilot participation status. The survey groups included:

- **ITT Opt-In Group** – Group includes qualified participants who received an invitation to join the Pilot and agreed to participate. These participants received the full participant survey.
- **ITT Did Not Accept Group** – Group includes qualified ITT customers who received an invitation to participate but did not opt in. This group received an abbreviated version of the ITT Opt-In Group survey, since they did not participate.
- **ITT Did Not Qualify Group**[15] – Though this group was originally selected by Nest to be included in the ITT group and receive the offer to participate, this group ultimately did not receive the offer because they weren't operating a cooling or heating schedule, didn't have a cooling or appropriate heating system, or were not connected to the internet. The survey was limited to asking about experiences with Nest and their address (same as the control group survey).
- **Control Group** – Group includes customers who did not receive the participation offer. The control group includes some Nest thermostat owners who would not have passed the technical

[12] As noted above, Nest usually conducts short follow-up surveys for all Seasonal Savings participants after each deployment.

[13] Nest manufactures a security camera that can connect to wireless networks and send live-stream to users smartphones.

[14] See Heat Pump Pilot and Smart Thermostat Pilot reports, available here: https://www.energytrust.org/wp-content/uploads/2016/12/Nest_Pilot_Study_Evaluation_wSR.pdf; http://assets.energytrust.org/api/assets/reports/Smart_Thermostat_Pilot_Evaluation-Final_wSR.pdf

[15] Note only the winter survey was distributed to the ITT Did Not Qualify group.

screening to receive the Seasonal Savings offer. The survey was limited to asking about experience with Nest and their address.

All surveys were submitted to and approved by Energy Trust prior to fielding and also received feedback from Nest to ensure the recruitment language met their corporate guidelines. The surveys were brief, with season-neutral questions that focused on addressing the following key objectives:

- To identify participants and enable the collection of billing data by asking for the home address (across all strata)
- To gauge feedback on customer experience with the Nest (across all strata) by asking about satisfaction and home comfort with the Nest in general
- To understand Pilot opt-in participants' experiences by asking about satisfaction and comfort with Seasonal Savings (asked of ITT Opt-In Group only)
- To assess the key drivers behind opting out of the Pilot by asking why qualified ITT customers opted out of the Pilot (asked of the ITT Did Not Accept Group only)

The final question in the summer deployment opt-in survey asked participants if they would be willing to allow PGE to release their short interval electricity usage data, also known as Automated Metering Infrastructure (AMI) usage data, to Energy Trust. Having customer AMI data would allow the Evaluation Team to analyze usage, cooling load, and runtime with greater accuracy than relying on monthly utility billing data. Customer data sharing agreements between PGE and Energy Trust required that Energy Trust receive participant data release agreements, which required participants to sign a legally binding document. The Evaluation Team received approval from PGE to use an online, legally binding signature application, called RightSignature.[16] Participants from all strata were redirected from the survey to a RightSignature page with an Energy Trust-branded AMI data release form. All completed release forms were provided to PGE as proof of customer acceptance for AMI usage data release. Full copies of the final surveys are included in Appendices B and C. Participant details relevant to billing analysis were used as inputs to the billing analysis described in Billing Analysis Verification (Section 6.3).

Previous Energy Trust smart thermostat studies involved a greater degree of active involvement with participants than the Seasonal Savings Pilot, including directly installing the units (heat pump pilot) or recruitment and incentives coordinated by Energy Trust (smart thermostat pilot). The Seasonal Savings Pilot simplified the participation process to such a degree that many participants didn't even recall opting-in (over 20%, as demonstrated below in Figure 2). It is likely because of the lack of involvement and minimal interactivity with the service that the Seasonal Savings surveys achieved a lower-than-anticipated response rate, with the summer season survey showing a higher overall rate (8%), compared to the winter season survey (5%). The Control group showed the highest response rate of any group,

[16] RightSignature.com - Data is protected by up to 256-bit SSL encryption when in transit and with Amazon Web Services cloud infrastructure. Electronic contracts have the same legal validity and enforceability of pen-and-paper documents when executed in compliance with e-signature laws.

which held true between the summer and winter surveys. A summary of the emails distributed, completed surveys, and response rates, are shown in Table 6 below.

Table 6. Energy Trust Seasonal Savings Pilot Summer and Winter Survey Response Rates

Season	Survey Strata	Emails Distributed	Completed Surveys	Response Rate
Summer (2016)	ITT - Opt-In	2,219	155	7.0%
	ITT - Did Not Accept	643	43	6.7%
	Control	4,830	420	8.7%
	Total	**7,692**	**618**	**8.0%**
Winter (2016/2017)	ITT - Opt-In	5,122	245	4.8%
	ITT - Did Not Accept	1,319	74	5.6%
	ITT - Did Not Qualify*	730	19	2.6%
	Control	4,720	277	5.9%
	Total	**11,891**	**615**	**5.2%**

** Note. The winter season survey included a Treatment - Did Not Qualify group while the summer season survey did not.*

As noted in Section 3.2 above, survey respondents who were customers of PGE were also asked whether they would be willing to allow Energy Trust to access and analyze their PGE AMI interval data. If they agreed, respondents were redirected to a signature release form that allowed PGE to release their short interval data to Energy Trust. A summary of the AMI data release rates from the surveys is shown in Table 7 below. Just under one-third of all survey respondents were willing to release their utility data for further analysis.

Table 7. Energy Trust Seasonal Savings Pilot Summer AMI Data Release Summary

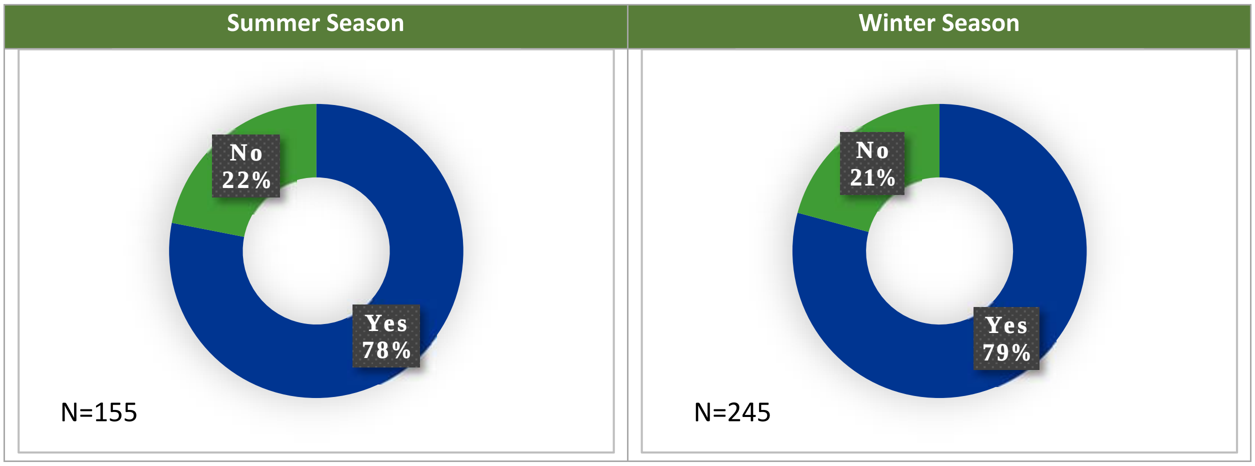
Season	Survey Strata	Completed Surveys	AMI Data Release Agreements*	Data Release Rate
Summer (2016)	ITT - Opt-In	155	43	27.7%
	ITT - Did Not Accept	43	9	20.9%
	Control	420	135	32.1%
	Total	**618**	**187**	**30.3%**

**Count of signed AMI data releases includes all customers where AMI data was provided to Energy Trust and does not account for customers where AMI data were not usable, as indicated in Table 12. There were a total of 200 signed data releases across all three strata, but AMI data were not provided in all cases.*

The first aspect of the Pilot the surveys investigated was specific to the ITT opt-in group – those who received and accepted the invitation to participate in Seasonal Savings. To help understand the Pilot experience for those who recalled opting-in, the survey first asked if the respondents recalled enabling

Seasonal Savings. Figure 2 below shows the results of respondent recall: over one-fifth of summer and winter season ITT opt-in respondents didn't recall enabling Seasonal Savings. The high percentage of those who didn't recall enabling the Seasonal Savings could be a mix of those who had opted in and truly didn't recall and those whose partners, housemates, or other entity may have opted in without telling the survey participant.[17]

Figure 2. Did ITT Opt-in Respondents Recall Enabling Seasonal Savings?

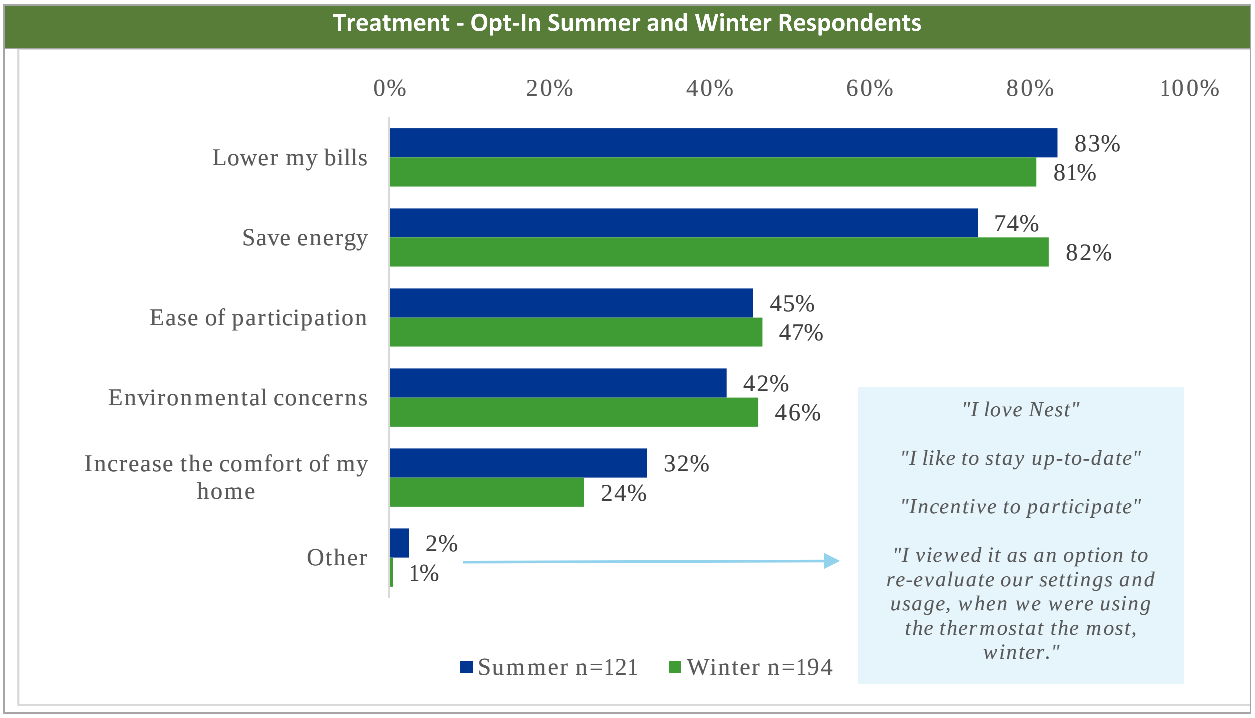


***Question**: In [**June/summer or November/winter**], you should have received an invitation to enable the Seasonal Savings feature on your Nest thermostat. The invitation looked like the image above. Do you recall enabling Seasonal Savings on your Nest?*

The next several questions were targeted to the ITT opt-in respondents who recalled enabling the Seasonal Savings feature (121 summer and 194 winter ITT opt-in respondents). When asked to select primary motivators for participating, saving money and saving energy were the most frequent motivators. Almost all opt-in respondents (except for 13 across the two seasons), selected either "lower my bills" or "save energy" as one of their primary motivators to enabling Seasonal Savings. Almost half of the opt-in respondents reported that "ease of participation" was a primary motivator (45% of summer and 47% of winter participants). Figure 3 reports the results for primary motivators for opting-in, along with a few "other" responses.

[17] The email recruitment distributed by Nest targeted the primary contact associated with the thermostat, which may not have been the same as the person that opted in.

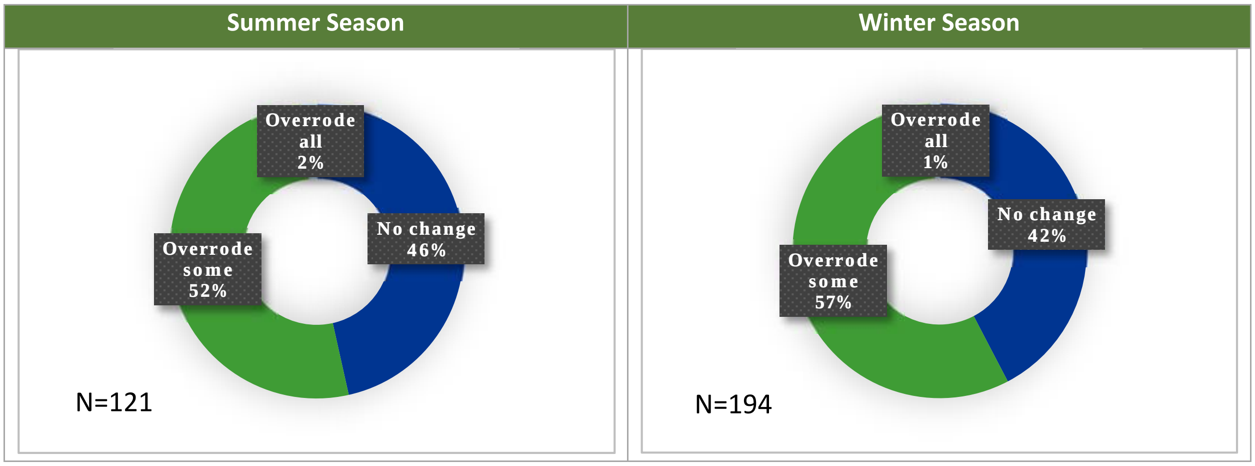
Figure 3. Primary Motivations for Opting-in to Nest's Seasonal Savings Program



***Question**: Please select any of your primary motivations for participating in Nest's Seasonal Savings program from the following list (multiple response allowed).*

Despite the common motivation to save money and/or energy, over half of the ITT opt-in respondents reported overriding some or all of the temperature settings. Figure 4 shows that over half of summer (52%) and winter (57%) ITT opt-in respondents said they overrode *some* of the Seasonal Savings temperature settings, and two summer and two winter respondents said they overrode *all* of the Seasonal Savings temperature settings. Therefore, less than half of summer (46%) and winter (42%) respondents said they did not change the temperature settings after enabling Seasonal Savings.

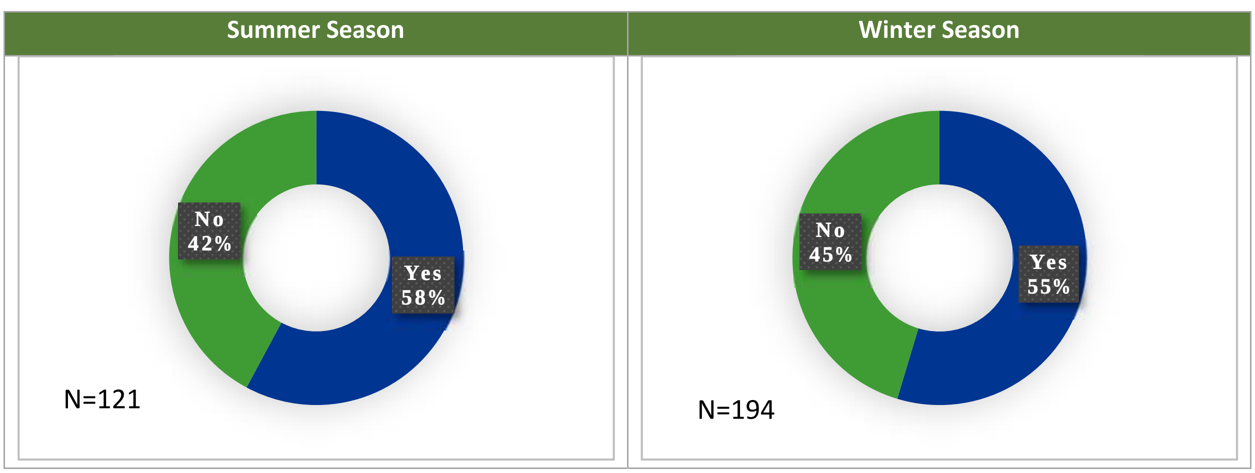
Figure 4. Did ITT Opt-in Respondents Override the Seasonal Savings Settings?



Question*: Your Nest thermostat automatically made small adjustments to your temperature settings after you enabled the Seasonal Savings. Did you leave the settings alone or did you manually override them afterwards by changing the thermostat temperature?*

ITT opt-in participants were asked if they noticed temperature changes in their home due to the seasonal savings adjustments. Figure 5 shows that over half of summer and winter respondents (58% summer and 55% winter) noticed changes in temperature. For those respondents who noticed temperature changes in their home, the majority of these respondents made changes to the temperature settings on the thermostat, though a greater proportion of winter respondents (79%) relative to summer (70%) overrode some or all of the Seasonal Savings settings. Conversely, the Evaluation Team looked at the respondents that did *not* notice a temperature change and found that the majority of respondents left the settings alone. Sixty-five (65) percent (33 of 51) of summer and 66% (58 of 88) of winter ITT opt-in respondents, respectively, reported neither noticing a temperature change nor adjusting the thermostat.

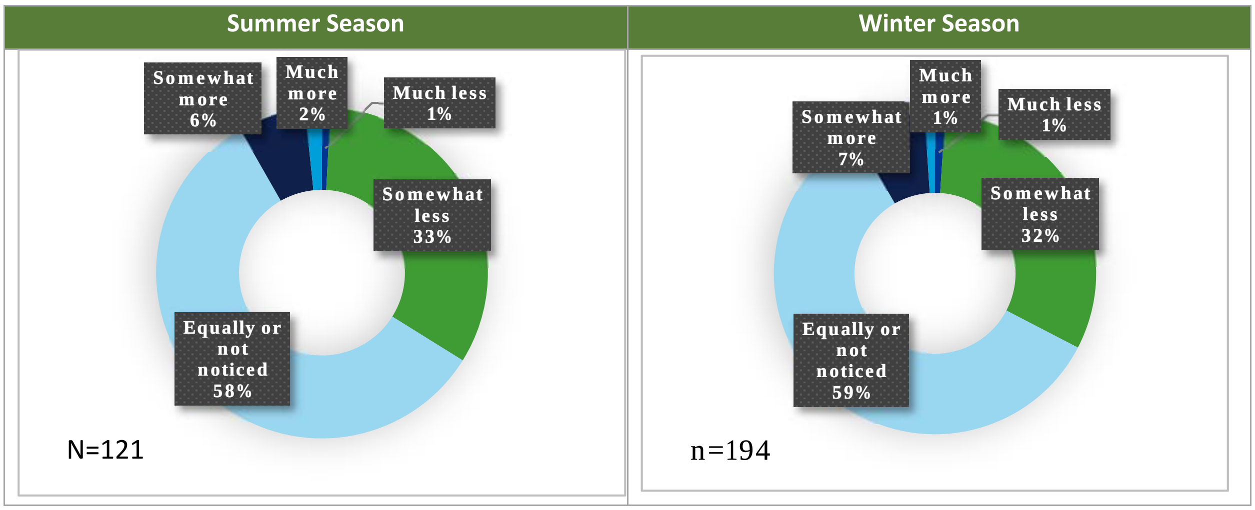
Figure 5. Did Respondent Notice Seasonal Savings Temperature Changes in Their Home?



Question*: After you opted in to the Seasonal Savings program, did you notice any changes to the temperature in your home?*

A majority of both summer and winter ITT opt-in respondents that were aware of the Seasonal Savings Pilot either did not notice temperature changes or believed their homes were equally comfortable. Figure 6, however, shows that one-third of these opt-in respondents believed that Seasonal Savings made their homes somewhat *less* comfortable (32% of summer and 33% of winter), while only a few respondents reported being much less comfortable (n=1 in summer and n=2 in winter). A minority of both summer and winter (8%) respondents that noticed a change in temperature believed their homes were more comfortable after the seasonal savings settings.

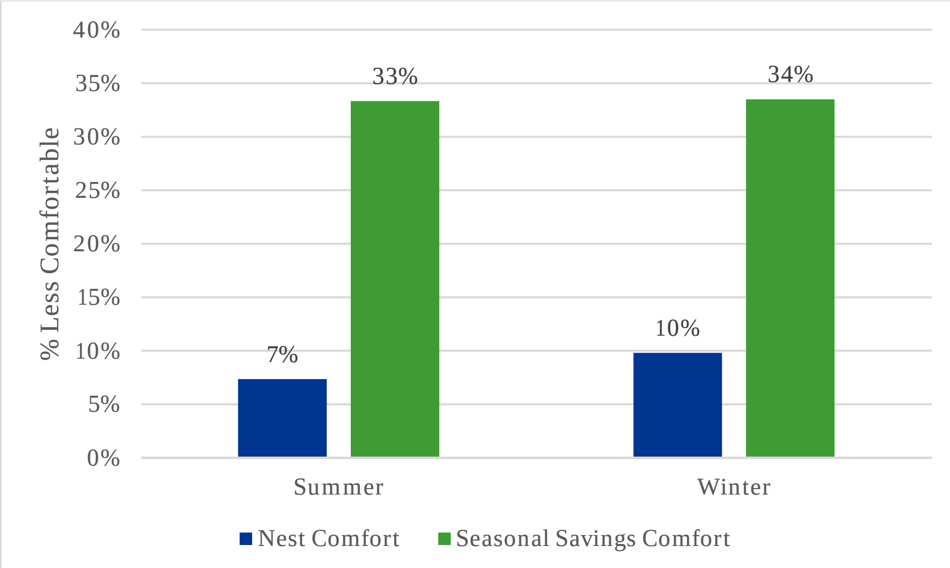
Figure 6. Did Seasonal Savings Settings Make Home More or Less Comfortable?



***Question**: Did the changes to the temperature in your home make it more or less comfortable than before you enabled Seasonal Savings?*

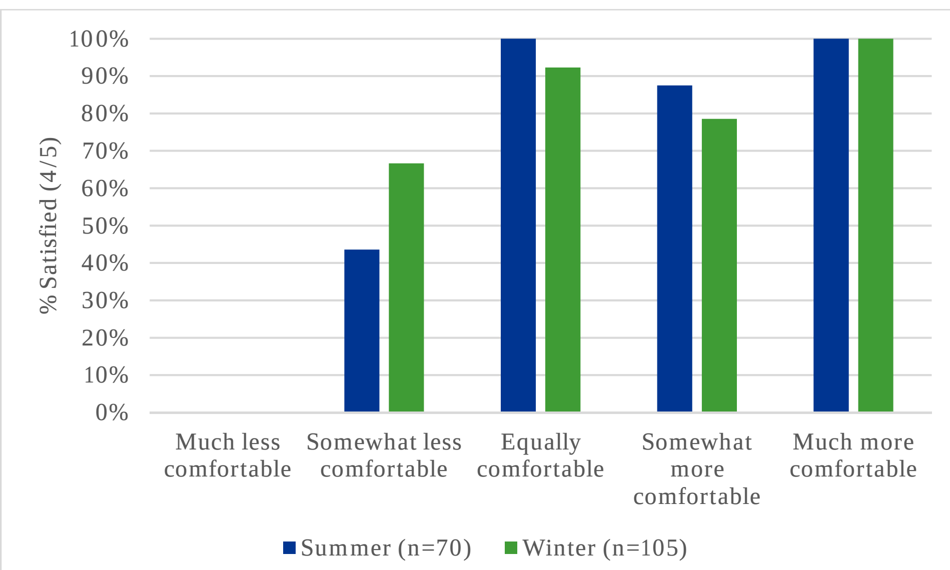
The decreased comfort as a result of Seasonal Savings issue is even more evident when comparing the home comfort levels resulting from the Nest thermostat device itself. A comparison of the percentage of ITT opt-in respondents that found their homes less comfortable with the Seasonal Savings relative to the Nest thermostat is shown in Figure 7.

Figure 7. Percentage of ITT Opt-in Respondents Indicating Decreased Comfort



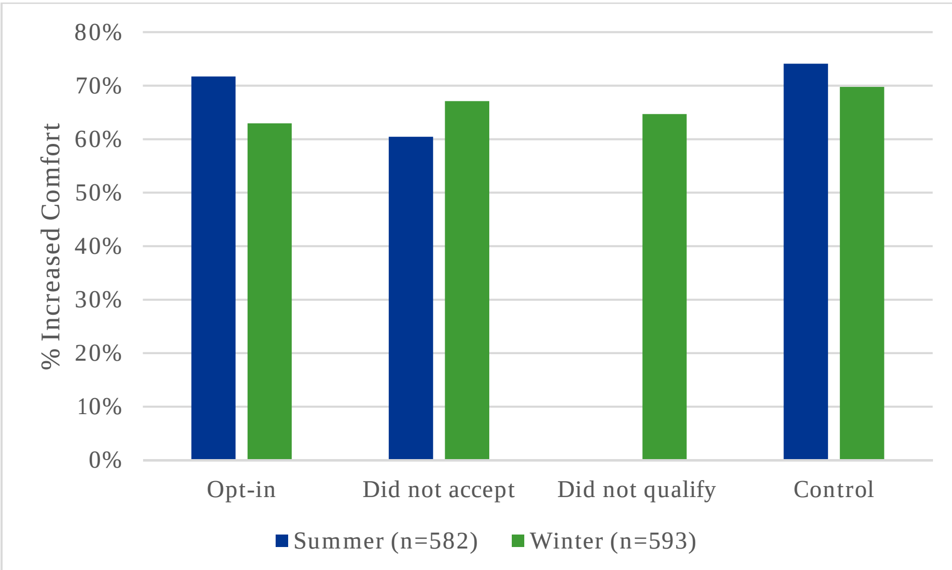
For the ITT opt-in survey respondents, the comfort levels associated with the Seasonal Savings service were positively correlated with the satisfaction scores for Seasonal Savings: the average satisfaction across summer and winter for Seasonal Savings was higher for opt-in participants who indicated their homes were more comfortable with the service and vice versa. A comparison of home comfort relative to satisfaction is shown in Figure 8, which designates the percentage of respondents that were satisfied (scoring a 4 or 5 on a scale from 1 to 5 where 1 was dissatisfied and 5 was completely satisfied) for each comfort level.

Figure 8. Seasonal Savings Comfort and Satisfaction



The survey, across all the strata, also investigated home comfort levels and overall satisfaction with the Nest thermostat. Figure 9 presents the home comfort findings by strata and by season. Across all the strata, over 60% of survey respondents believed their homes experienced an increase in comfort as a result of the Nest thermostat.

Figure 9. Did Nest Make Home More or Less Comfortable?

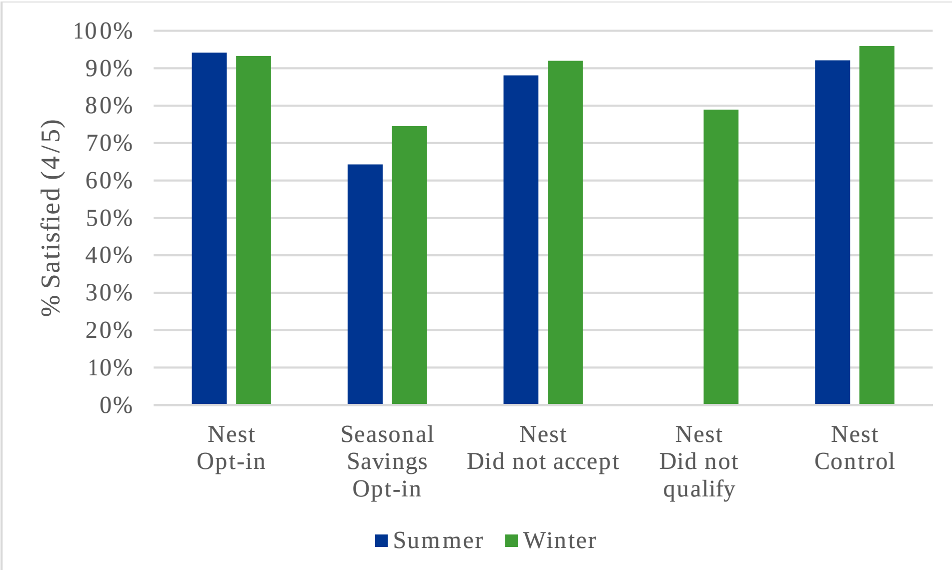


***Question**: Is the temperature in your home more or less comfortable now than before you installed the thermostat? Using a 5-point scale where 1 is Much less comfortable, 2 is Somewhat less comfortable, 3 is Equally comfortable, 4 is Somewhat more comfortable, and 5 is Much more comfortable.*

***Question**: Is the temperature in your home more or less comfortable now than before you installed the thermostat? Using a 5-point scale where 1 is Much less comfortable, 2 is Somewhat less comfortable, 3 is Equally comfortable, 4 is Somewhat more comfortable, and 5 is Much more comfortable.*

Overall satisfaction with the Nest thermostat was greater than the satisfaction with the Seasonal Savings service. Over 90% of summer and winter respondents across all strata (except for the “did not qualify” group) rated their overall satisfaction with Nest a 4 or 5 (on a scale from 1 to 5), while only 64% of summer and 75% of winter opt-in respondents rated the Seasonal Savings equivalently. The winter “did not qualify” was the only survey strata that gave lower satisfaction scores, with just under 80% rating the Nest a 4 or 5. The results of the overall satisfaction questions are shown in Figure 10 below.

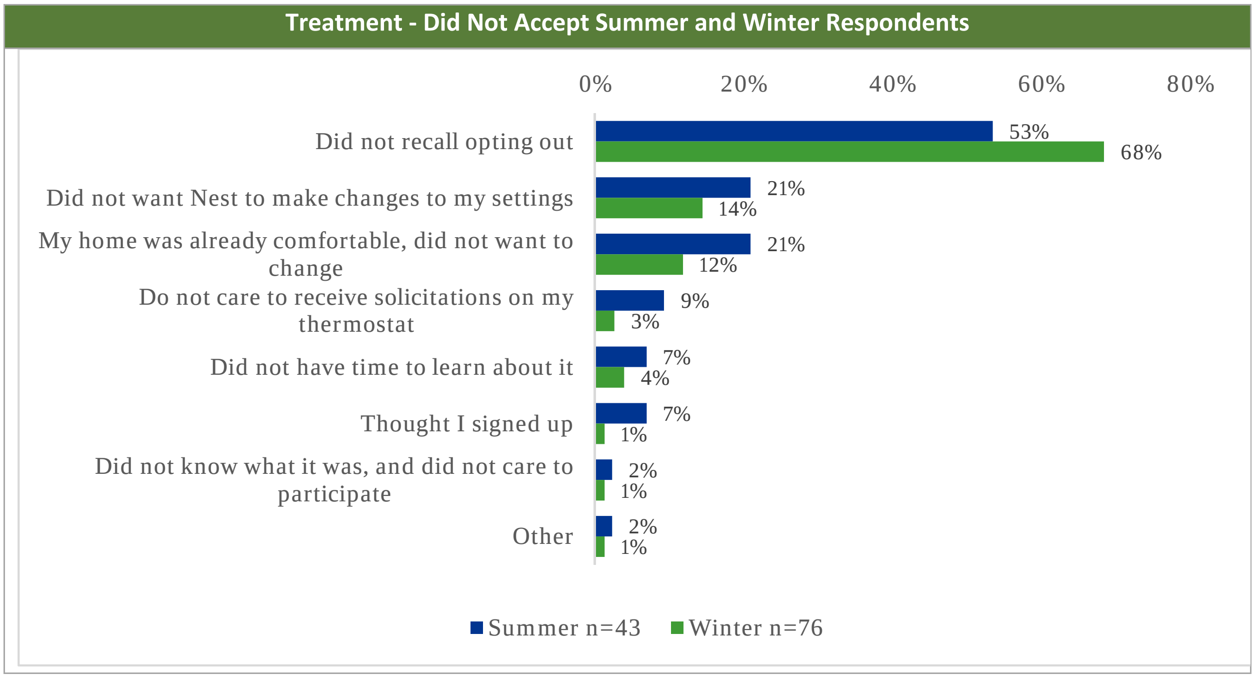
Figure 10. Overall Satisfaction with Nest and Seasonal Savings



***Question**: Please rate your overall satisfaction with your Nest thermostat on a 5-point scale where 5 is very satisfied and 1 is not at all satisfied.*

The survey also asked customers in the ITT - Did Not Accept group why they chose not to opt-in to the Pilot. Over half of the ITT - Did Not Accept respondents did not recall opting out. The prevalence of those not recalling opting out may be evidence for those taking the survey being different than those who opted out of the invitation, or it may also reflect a need to send invitations in multiple modes (e.g., email, postal mail, etc.) and even multiple times to get people's attention. For those who recalled opting out of the Pilot, the two most common reasons were the same across summer and winter: 21% of summer respondents and 14% of winter respondents said they did not want Nest to make changes to their settings, and 21% and 12% said their home was already comfortable (summer and winter, respectively). Figure 11 shows that 7% of summer respondents and 1% of winter respondents thought they had signed up.

Figure 11. Treatment – Did Not Accept Primary Reasons for Opting Out



***Question**: There may have been a number of reasons for opting out of Nest's Seasonal Savings program. Please select all reasons that apply.*

4. Validation of Nest Seasonal Savings Findings

A critical component to this evaluation involved validating the energy savings analysis and findings as developed by Nest Labs. Since Nest administers their own in-house analytics on the Seasonal Savings Pilot, Energy Trust was interested in having a third-party evaluator verify the savings as claimed by Nest. After both the summer and winter deployments, Nest submitted a memorandum to Energy Trust and the Evaluation Team documenting its analysis of Seasonal Savings impacts using the operating data collected by the Pilot thermostats.[18] Nest's modeling assesses the changes in HVAC runtime and setpoints and then uses engineering assumptions to convert the reductions to energy savings (i.e., kWh and therms). Along with the memos documenting its methods and findings, Nest provided the de-identified dataset and the code used for its analysis. The Evaluation Team performed a detailed review of the analysis code Nest used for data management and savings estimation to validate Nest's findings. The review of the 2016 summer season occurred prior to the review of the 2016/2017 winter season, so the winter review methodology was somewhat different in that the winter review built upon the learnings from the summer review.

The analysis of the RED involves comparing the randomized ITT and control groups because the randomization ensures the two groups are equivalent and the impact estimate is unbiased. However, this analysis returns an estimate of the average savings per randomized ITT thermostat. To calculate the average savings per opt-in thermostat, the impact estimate is adjusted by the opt-in rate. For example, if the ITT impact is 3% and the percentage of ITT group thermostats that passed the technical screening *and* accepted the offer is 50%, the Evaluation Team estimates that the savings per opt-in thermostat is 6% (3% divided by 50%). For the summer deployment, thermostats were randomized equally to the ITT and control group. For the winter deployment, 60% of the thermostats were randomized to the ITT group and 40% were randomized to the control group to increase energy savings.

In additional to the runtime and setpoint analysis verification, the evaluation team also used electric and gas billing data from each of the four cohorts – as identified by respondents to the customer survey – to run our own billing analysis. The electric and gas billing analysis task served as an independent check on the impacts calculated via Nest operating characteristics like runtime and setpoint. An electric billing regression of 600 homes had no chance[19] of detecting the summer 2016 cooling impacts of ~4 kWh per device so the Evaluation Team focused on using the consumption data to validate a key savings assumption – the average connected load of participating air conditioners. A similar approach was used for the winter data to estimate the average input capacity of gas heating systems. The treatment effect during the winter heating season was more substantial so the Evaluation Team implemented two types of billing analysis to independently estimate winter impacts among survey respondents.

[18] Copies of the Nest-drafted summer and winter memos are included in Appendices D and E.

[19] The margin of error for the summer treatment effect in a panel model was ± 200 kWh.

Table 8 summarizes the key findings from the analysis. The summer impacts were limited, but the winter season produced significant reductions in heating runtime per opt-in thermostat. The winter season also had a higher effective opt-in rate because 94% of the ITT group passed the technical screening and received the offer to participate in Seasonal Savings. The technical qualification rate for the summer season was just 59%.

Table 8: Evaluated Percent Impacts and Energy Savings by Season and Heating Type

Season	Percent Runtime Reduction	Equipment	Electric Savings (kWh)	Gas Savings (therms)
Summer Cooling	0.81%	CAC/HP	4	0
Winter Heating	4.75%	Gas Furnace	15	18
Winter Heating	4.75%	Heat Pump	121	0

The following report sections include both methods and findings and are organized by research task within each season.

5. Summer Seasonal Savings

Nest's analysis of the summer cooling season relied on an average of two analyses – one of HVAC runtime (4 kWh, or 0.9%) and one of executed thermostat setpoint (19 kWh, or 3.9%). Even though the summer season savings as claimed by Nest were very modest (12 kWh, or 2.4%, per opt-in participant, on average), the Evaluation Team believed it was important to validate Nest's savings methodology because a review:

- Validated if the assumptions and calculations were reasonable,
- Assessed the balance of the RED experimental design and if the data management was sound,
- Investigated if other factors (other than those identified by Nest) contributed to the low savings,
- Helped the Evaluation Team understand how savings were calculated by Nest to prepare for the winter savings analysis verification, and
- Allowed the team to identify any issues and request clarification from Nest to avoid redundancy during the winter savings analysis.

5.1 Validate Nest Runtime Analysis

The Nest analysis was performed in the statistical software package Stata, and the Evaluation Team used Stata for its review and independent calculations. The Nest dataset included daily data for 12,632 thermostats with one record per thermostat per day and included the fields listed below:

- **Serial Number (sn)** – a unique identifier for each thermostat
- **Zip Code (zip)** – the zip code of the participating home
- **Can Cool (can_cool)** – indicator variable equal to 1 if the thermostat is connected to a central cooling system, 0 otherwise
- **Study Group (participation)** – indicator of thermostat assignment to one of four study groups: (1) Control; (2) ITT – Did Not Qualify; (3) ITT – Did Not Accept; or (4) ITT – Opt-In
- **Date (date)** – date the operating characteristics were recorded
- **Outdoor Temperature (tout)** – average daily outdoor temperature for the home
- **Time in Cooling Mode (timecoolmode)** – number of hours the thermostat was in cooling mode (e.g. operating in air conditioning mode but not necessarily calling for cooling from the air conditioning)
- **Cooling Time (coolontime)** – number of hours the thermostat was calling for cooling from the air conditioning unit
- **Scheduled Setpoint (tset_schedcl)** – average scheduled setpoint for the day
- **Executed Setpoint (tset_cl)** – average executed setpoint for the day (executed setpoint differs from scheduled setpoint if the homeowner overrides the schedule manually)

The regression approach used by Nest to estimate ITT impacts is a standard technique to estimate impacts from an RCT or RED like this Pilot. The fixed effects regression model uses daily cooling runtime as the dependent variable and a hierarchical combination of cooling degree days (CDDs), an indicator variable for the performance period, and an indicator variable for the thermostats randomized to the treatment group. The regression mimics a "difference-in-differences" (DID) calculation and estimates the change (pre/post) in the treatment group net of any change observed in the control group. When reviewing this type of analysis, it is useful to start with the simplest form to compare against findings from more complex methods. Table 9 shows a simple comparison of means between groups for the two study periods.

Table 9: Average Hours of Cooling per Day by Group and Period

Study Period	Group	
	Control	Treatment
Pre	1.8106	1.7904
Post	1.6141	1.5843
Change	-0.1965	-0.2061
DID (hours per day)		**-0.0096**
DID (seconds per day)		**-34.56**

In Table 9, notice that both the control group and treatment group used less AC during the post period (July 13, 2016 to October 31, 2016). This difference is a function of weather, with June being the hottest month of the summer and September and October being very mild. Although both groups reduced their cooling usage, the treatment group showed a larger reduction. This DID value is the Seasonal Savings effect. This simple calculation returns a slightly larger savings estimate (34.5 seconds of runtime per day reduced vs. 21.7 seconds per day as reported by Nest from the regression model), but confirms the primary finding that the average Seasonal Savings effect was very limited in 2016.

Regression allows for a more sophisticated comparison of the differences between the treatment and control groups during the performance period by controlling for the observed relationship between cooling runtime and weather, as well as the varying number of runtime observations per thermostat. Formally stated, the regression model (Equation 1) specification is:

Equation 1. Cooling Runtime Regression

$$AC\ Runtime_{td} = \beta_t + \beta_1 * CDD + \beta_2 * CDD * TreatX + \beta_3 * Post + \beta_4 * Post * TreatX + \beta_5 * Post * CDD + \beta_6 * Post * CDD * TreatX$$

Where:

AC $Runtime_{td}$ = The number of seconds of air conditioning runtime for thermostat (t) on day (d)
β_t = Thermostat-specific regression intercept (fixed effect)
β_1-β_6 = Model coefficients determined via regression
CDD = Cooling degree days on day (d). Base 65 (°F)
TreatX = Indicator variable equal to 1 if thermostat (t) is in the ITT group. Zero otherwise
Post = Indicator variable equal to 1 if date (d) is greater than or equal to July 13, 2016

This regression model returns the average daily runtime impact for thermostats in the ITT group. This value is then adjusted by the proportion of ITT thermostats that were in the ITT – Opt-In group to calculate runtime impacts per opt-in device.

Table 9 presents the runtime regression coefficients along with their standard errors, t-statistics, and p-values.

Table 10: Summer Runtime Model Regression Output

Model Term	Coefficient (β)	Robust Standard Error	t	P>t
Intercept	0.9129	0.0073	124.64	0.00
CDD	0.3837	0.0044	86.58	0.00
CDD*TreatX	-0.0056	0.0062	-0.91	0.37
Post	-0.1951	0.0105	-18.50	0.00
Post*TreatX	**-0.0018497**	**0.0144**	**-0.13**	**0.90**
Post*CDD	0.0109	0.0027	4.02	0.00
Post*CDD*TreatX	**-0.0018373**	**0.0039**	**-0.47**	**0.64**

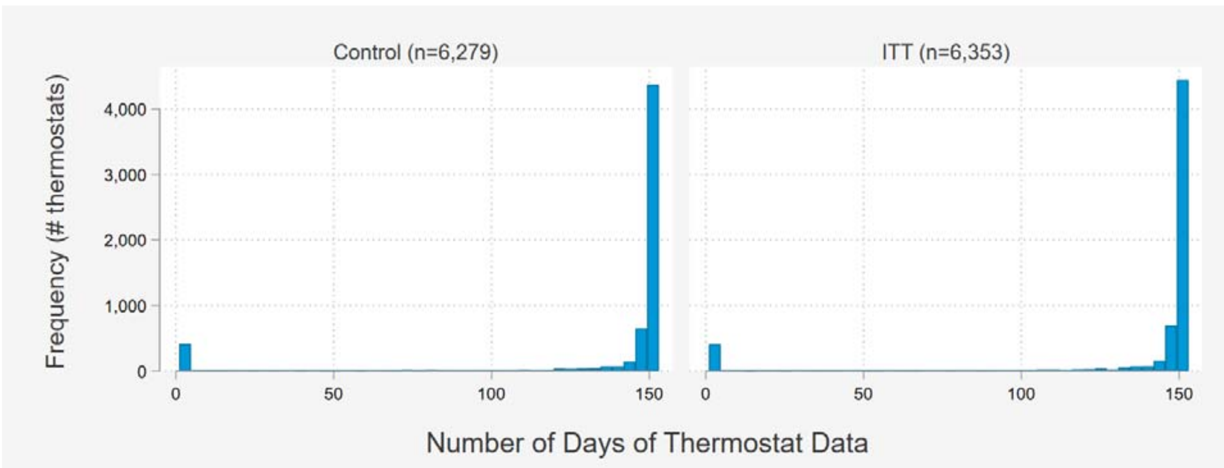
The Seasonal Savings impact is captured in the two bolded terms. The 'Post*TreatX' and 'Post*CDD*TreatX' coefficients estimate the change in the treatment group in the performance period net of pre-post differences in the control group (which are captured by the 'Post' and 'Post*CDD' terms). The coefficients for both impact terms are negative, which indicates that Seasonal Savings led to a reduction in cooling runtime. However, it is very important to note that the terms are not statistically significant on their own or in combination (i.e., while the ITT group experienced a reduction in runtime that was greater than the Control group, the reduction could simply be attributable to noise in the data).

The margin of error around the average ITT impact estimate of 0.38% is ± 1.5% at the 90% confidence level. On an absolute basis the point estimate and margin of error per ITT thermostat is 21.7 seconds per day ± 85.7 seconds per day at the 90% confidence level. Nest correctly calculated the margin of error using the variance-covariance matrix of the two impact coefficients in the regression model. The Evaluation Team found no issues with Nest's runtime regression and calculation of impacts per ITT thermostat. However, the Evaluation Team did not agree with Nest's calculation of the opt-in rate and adjusted the calculation prior to determining the average impact per ITT Opt-In thermostat.

Figure 12 shows the distribution of the number of days of data within the Control and ITT groups and number of thermostats included in the summer season portion of the Pilot. Most thermostats have approximately 150 days of operating data spanning from the beginning of June 2016 to the end of October 2016. However, 805 of the 12,632 (6.4%) thermostats only had a single record with all the system operating data missing. The 805 thermostats were distributed almost identically (406 vs. 399) between the Control and ITT groups. All 399 thermostats with missing operating data in the ITT group were in the ITT – Did Not Qualify group. There were no devices with missing data in the ITT – Did Not

Accept or ITT – Opt-In groups. Whatever the root cause of the missing data for these homes, it shouldn't bias the impact estimates because these thermostats are effectively excluded from the analysis and the exclusion affects the ITT and Control group in equal proportions. The handling and inclusion of missing thermostat data does make a difference regarding inferences about the program population and per-unit impacts. The Evaluation Team recommends that thermostats missing all system operating data be excluded from participation counts and impact estimates. Our team has calculated and presented impacts and participation counts accordingly throughout this report.

Figure 12: Distribution of Number of Days of Data by Study Group



In addition to the 805 thermostats that had no system operation data, the Evaluation Team found 180 thermostats missing data prior to the deployment of Seasonal Savings and 106 thermostats missing data after the deployment of Seasonal Savings. These devices were distributed roughly equally between the Control and ITT – Did Not Qualify groups. These devices were ultimately excluded from the estimation process because the regression model is an analysis of pre-post changes and there is no change to observe for these thermostats.

Nest's reporting of runtime impacts focused on the ITT Opt-In thermostats that qualified and accepted the Seasonal Savings offer. Specifically, the Nest memorandum stated, "*This regression analysis estimated net cooling savings per opt-in participant of 0.9% (± 3.4%).*" This estimated reduction in runtime was based on the 0.38% savings per ITT group thermostat, which was converted to average savings per ITT – Opt-In by dividing 0.38% by the proportion of ITT opt-in homes within the ITT group (2,790/6,353 = 43.9%).[20] The proportion of ITT Opt-in homes that Nest used included the entire population of devices randomized to the ITT group and did not consider whether a thermostat had runtime data available and could be analyzed. The Nest calculation of savings per opt-in participant is shown in Equation 2.

[20] Note the proportion is calculated as the number of ITT - Opt-in Homes divided by the sum of all the ITT group homes, including those that did not opt in as well as those that did not qualify.

Equation 2. ITT Opt-in savings – Nest calculation

$$Average\ Impact\ Tx - Accepted = \frac{0.38\%}{\frac{2{,}790}{6{,}353}} = 0.865\%\ reduction$$

The Evaluation Team calculation uses the counts of thermostats that have operational data in the conversion from ITT impacts to Opt-In impacts, as this is the true denominator of the RED analysis (2,790/5,955 = 46.9%). When this factor is applied to the average ITT group runtime reduction, the per thermostat ITT opt-in savings is 0.81%, rather than Nest's 0.9%. Apex recommended that, for the heating season analysis, Nest adjust the calculation of the opt-in rate to include only those devices with runtime data. This recommendation was adopted in Nest's winter analysis.

Equation 3. ITT Opt-in savings – Evaluated calculation

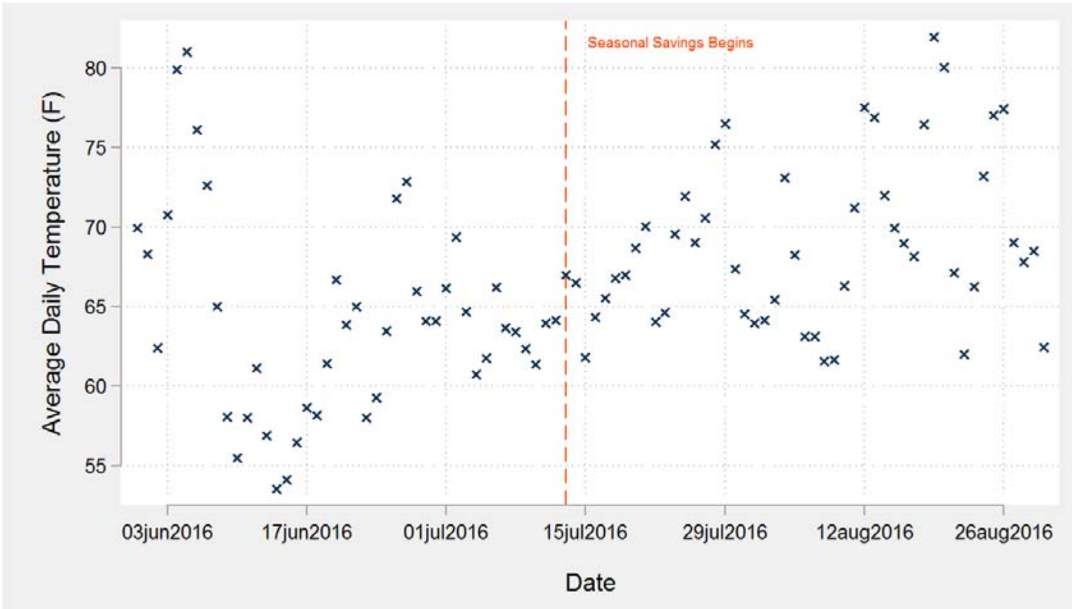
$$Average\ Impact\ Tx - Accepted = \frac{0.38\%}{\frac{2{,}790}{5{,}955}} = 0.811\%\ reduction$$

5.2 Validate Nest Setpoint Analysis

Nest also performed analysis of summer cooling impacts that compared the change in executed cooling setpoints of the treatment and control group during the performance period. The Evaluation Team believes thermostat setpoint is a secondary metric at best in a mild climate like Oregon because cooling mode is used intermittently. It is also subject to variations in time of day. For example, a setpoint of 75 °F might result in a reduction of thermostat runtime during the day when the outdoor temperature is 85 °F, but it would not result in any runtime in the middle of the night when the outdoor temperature is 60 °F. This temperature fluctuation can create challenges when analyzing daily averages because the data do not indicate which hours the units were in cooling mode (if fewer than 24).

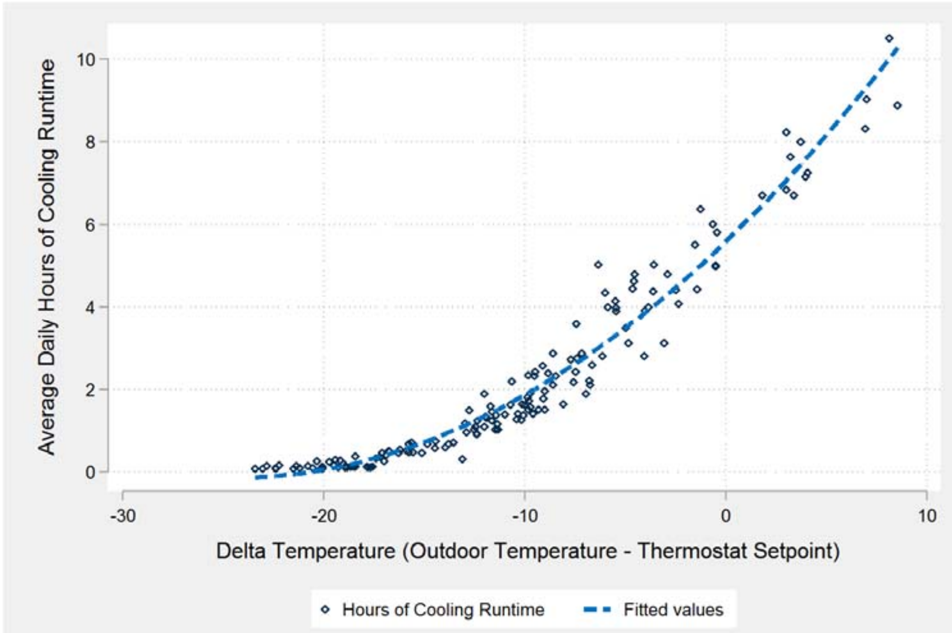
Nest's execution of the setpoint analysis was straightforward and error-free. One technical observation that may warrant reconsideration is basing the setpoint levels for the "pre" period on a single week of observations. Figure 13 shows that the week prior to summer deployment was mild, so it may not be an ideal period to use as the basis of the analysis. Apex would recommend using a month to six weeks to get a more stable measurement of pre-deployment setpoint – particularly with deployment closely following Independence Day and likely many summer vacations that come with a national holiday.

Figure 13: Average Daily Temperature by Date



As noted in Nest's reporting, the impact estimate associated with Nest's setpoint analysis "*depends strongly on the prior estimate of 7.1% cooling savings per degree change in setpoint.*" The Evaluation Team performed an analysis of the 2016 thermostat runtime data and found the estimate to be reasonable, if not conservative. Figure 14 shows a plot of the average daily runtime of the Pilot population against the average temperature difference between the executed thermostat setpoint and the outdoor temperature. Each blue symbol represents a day of data and the dotted line is a quadratic regression model fitted to the data. Notice that runtime is consistently observed even when the daily average setpoint is higher than the average outdoor temperature (negative delta temperature). This finding speaks to temperature variation within a day and internal and solar heat gains. Even if the average temperature over 24 hours is in the 60s, there are hot afternoon hours in the 80s that spur AC usage.

Figure 14: Cooling Runtime vs. Delta Temperature



To estimate the effect of a one-degree increase in thermostat setpoint, Apex used the fitted regression equation to estimate the total summer cooling hours at the observed temperature differential, then reduced the differential by one degree each day (to mimic a one-degree increase in thermostat setpoint), and then predicted the resulting hours of cooling runtime. Table 11 summarizes the results of the analysis.

Table 11: Runtime Savings Estimates for a One-Degree Increase in Setpoint

Predicted Cooling Runtime (Actual 2016 Temperatures)	Predicted Cooling Runtime (One Degree Increase in Setpoint)	Runtime Reduction (Hours)	Percent Reduction
336.1	297.3	38.8	11.5%

Using 11.5% instead of 7.1% in the setpoint analysis would increase the savings estimate by 60%, which underscores the sensitivity of kWh savings to this key assumption. Because of these issues, the Evaluation Team recommends that the runtime analysis be the basis for any Seasonal Savings performance estimates in mild seasons.

5.3 Cooling Connected Load Analysis

In addition to a review and validation of the Nest reported RED impacts, Energy Trust requested that the Evaluation Team conduct an independent analysis of Seasonal Savings impacts via data collected by utility revenue meters (e.g., monthly billing data and hourly/sub-hourly AMI data). One limitation of this analysis is that billing data could only be identified for customers who responded to the survey, because addresses were needed to match thermostats to utility billing information. This limitation meant that the Evaluation Team had billing data for fewer than 600 of 12,000 thermostats in the summer deployment. Billing analysis was not a viable approach for the summer season because of the small impacts. However, Evaluation Team could combine the runtime and billing data sets to estimate the average cooling equipment size – or connected load.

The connected load, or instantaneous power draw of an air conditioning (AC) unit when operating, is an important assumption for the Pilot because it is used to convert runtime measurements captured by the Nest thermostat to kWh – which is the energy performance metric of interest for Energy Trust. Nest assumed an average connected load value of 2.88 kW in their summer 2016 savings analysis. The Evaluation Team tested this assumption by synthesizing Nest's runtime data set and consumption data from survey respondents collected by the utility meter. The premise of the calculation is shown in Equation 4 below.

Equation 4. Cooling Connected Load

$$Cooling\ kW = \frac{Cooling\ kWh}{Cooling\ Hours}$$

The cooling connected load analysis relied on five different data sets:

- The Nest runtime analysis dataset for summer 2016, which included daily runtime totals (in hours) for approximately 12,000 participating devices from four study groups (Control, ITT – Did Not Qualify, ITT – Did Not Accept, and ITT – Opt-In)
- Monthly utility billing records from 572 participating homes after data cleaning – homes for which the customer responded to the survey and provided their address, allowing their billing data to be identified and used in the analysis. The distribution of homes across study group is provided in Table 12. The 'ITT – Did Not Qualify' study group was not included in the summer season survey and therefore this group was not included in the billing analysis.
- Interval meter data of varying quality[21] from 140 survey respondents who signed a Portland General Electric data release authorization form. All homes were customers of PGE. The distribution by study group is shown in Table 12.
- Historic daily records from National Oceanic and Atmospheric Administration (NOAA) weather stations in Astoria, Klamath Falls, Medford, Portland, and Salem (as provided by Energy Trust).
- Long-run typical weather values for the same five weather stations (NOAA Typical Meteorological Year version 3 (TMY3) data as provided by Energy Trust).

The datasets were cleaned, and the usage data were merged with the appropriate weather values for analysis. The analysis was conducted separately for the monthly billing data and the interval data set. The runtime model that minimized the cooling intercept used a 62 °F base temperature, and the best

[21] Some of the PGE data were 15-minute interval data, and other data were hourly interval data. Some of the measurements were at the watt-hour level, while others were integer kWh. Twenty-six homes changed from hourly to 15-minute data during the analysis period.

fitting billing data models used a base in the high 50s, so a common degree-day base of 60 °F was implemented for all regression models for this exercise.

Table 12: Summer Season Device Counts by Analysis Data Set and Study Group

Strata	Population*	Monthly Billing Data	Interval Data
ITT – Opt-In	2,790	142	31
ITT – Did Not Accept	705	39	7
ITT – Did Not Qualify**	2,459	0	0
Control	5,873	391	102
Total	**11,827**	**572**	**140**

** Number of thermostats with at least 1 day of operating data in Nest dataset.*
***The "Treatment – Did Not Qualify" group was not included in the summer season survey, so no monthly or interval data were collected for this group. Homes did not qualify for the Seasonal Savings deployment for a few reasons, including no AC or absence of a programmed cooling setpoint schedule.*

5.3.1 Monthly Billing Data

The Evaluation Team ran a fixed effects panel regression model on the 572 homes with monthly billing data. Consumption records from prior to 2015 were excluded from the analysis to limit the amount of data from prior to the installation of the Nest thermostat in the model, while still including enough data to estimate a reliable model. Table 13 shows the regression output for the pooled model where all study groups are analyzed together. It uses average daily CDD (base 60°F) and average daily HDD (base 60°F) to explain the average daily kWh usage. The 'Daily CDD' term is the key coefficient to consider: its value tells us that the homes analyzed used an average of 1.0348 kWh per CDD.

Table 13: Pooled Electric Billing Regression Output

Model Term	Coefficient	Robust Standard Error	L90	U90
Intercept	18.69	0.25	18.28	19.11
Daily CDD	**1.0348**	**0.04**	**0.97**	**1.10**
Daily HDD	0.61	0.03	0.57	0.66

Next, a similar model was run to estimate cooling runtime per CDD, using the Nest runtime data set at degree day base 60 (°F). This fixed effect regression model used daily CDD to explain daily AC runtime. The 'ITT – Did Not Qualify' group was excluded from the runtime model because this study group was not available to analyze in the energy usage model. Since the Nest data only included the summer months, no HDD term was included. The 'Daily CDD' term is the statistic of interest in Table 14. Seasonal Savings participants are using 0.337 hours of cooling runtime per CDD base 60.

Table 14: Pooled Runtime Model Regression Output

Model Term	Coefficient	Robust Standard Error	L90	U90
Intercept	0.26	0.01	0.24	0.28
Daily CDD	**0.3371**	**0.00**	**0.33**	**0.34**

Dividing the coefficients of interest from the two models returns an average air conditioning connected load of 3.07 kW, as shown in Equation 5. The margin of error is ± 0.18 kW at the 90% confidence level.

Equation 5. Cooling Connected Load

$$Connected\ Load = \frac{1.0348\ kWh\ per\ CDD}{0.337\ hours\ per\ CDD} = 3.07\ kW\ \ \pm 0.18\ kW$$

The Evaluation Team also performed the calculations separately by study group. The results of that analysis are shown in Table 15. The two ITT groups had very similar runtime and kWh regression coefficients. The control group showed a lower average cooling usage than the two ITT groups. This finding is because the homes that would have been assigned to the 'ITT - Did Not Qualify' group if they had been in the treatment group are not excluded from the control group. The primary reason Nest flags devices as technically unable to participate in Seasonal Savings is a lack of air conditioning or not operating a cooling schedule.

Table 15: Regression Coefficients and Average Connected Load by Study Group

Study Group	Runtime Coefficient (hours/CDD)	kWh Coefficient (kWh/CDD)	Connected Load (kW)
Control	0.297	0.935	3.146
ITT - Did Not Accept	0.410	1.259	3.071
ITT – Opt-In	0.398	1.209	3.039

The underlying assumption of this analysis is that the homes that responded to the survey are representative of the Seasonal Savings population. This assumption allows us to divide the kWh analysis results (which are based on a sample of just 572 homes because of Nest data limitations[22]) by the runtime analysis results (which are based on almost 12,000 devices). If the survey sample is composed of homes that use cooling differently from the Seasonal Savings population, then the connected load estimate could be biased.

There is also an implicit assumption in this analysis of a 1:1 relationship between home (or billing account), central AC, and Nest thermostat. If there are homes with multiple AC units, the cooling kWh part of the calculation would be inflated because the Nest runtime is being divided by the usage of two

[22] Nest does not collect address information, so the Evaluation Team had to rely on participant surveys to establish participant details to link their billing data.

air conditioners, not just the one connected to the Nest. In a climate like Oregon's, multiple central AC units is probably uncommon enough that this caveat wouldn't appreciably change the results.

5.3.2 Interval Billing Data

The cooling connected load analysis using interval data proceeded much like the monthly billing dataset. The Evaluation Team ran a fixed effects panel regression model on the 140 homes with interval data. These data were aggregated to daily usage for analysis. The regression model uses base 60 (°F) CDD and HDD to explain daily kWh usage. No historic records were excluded because the earliest record in the data set was dated July 2, 2015. Table 16 shows the regression output for the model. The 'CDD' term is the key coefficient to consider: its value tells us that the homes analyzed used an average of 0.9860 kWh per CDD (base 60).

Table 16: Interval Data Regression Output - Pooled Model

Model Term	Coefficient	Robust Standard Error	L90	U90
Intercept	19.11	0.36	18.51	19.70
CDD	**0.9860**	**0.06**	**0.88**	**1.09**
HDD	0.51	0.05	0.43	0.60

Dividing the coefficient of interest from this model (0.9860) by the cooling hours per CDD estimate from the cooling runtime analysis (0.337) returns an average air conditioning connected load of 2.93 kW, as shown in Equation 6.

Equation 6. Cooling Connected Load

$$Connected\ Load = \frac{0.9860\ kWh\ per\ CDD}{0.337\ hours\ per\ CDD} = 2.93\ kW\ \pm 0.31\ kW$$

Because the sample sizes within each study group are relatively small (only 7 "Treatment – Did Not Accept" homes and 31 "Treatment – Opt-In" homes) for the interval analysis, calculating the connected load for each study group does not make as much sense as it did for the monthly billing analysis.

5.3.3 Cooling Connected Load Assumption

The margin of error of the daily model calculated using the interval billing sample is wider than estimate calculated using the monthly billing data because of the smaller sample size. However, the higher frequency daily data allows for a better model of weather impacts on kWh usage because weather conditions are not averaged over an entire billing cycle. Ultimately the Evaluation Team elected to average the connected load estimate from the interval data sample (2.93 kW) with the estimate from the monthly billing data (3.07 kW). An average cooling connected load of 3.0 kW was used to convert the reductions in AC runtime to kWh (e.g. 1 hour of runtime reduction equals 3 kWh of electric savings).

Table 17: Final AC Connected Load Assumption

Connected Load Analysis Dataset	Estimated Connected Load per Thermostat (kW)
Monthly Billing	3.07
Interval Meter Data	2.93
Recommended Assumption	**3.00**

5.4 Recommended Summer Savings Estimates

The Nest analysis of cooling runtime was well-organized and consistent with industry-standard practice for analysis of an RED. The Evaluation Team's summer estimates differed from Nest's for three reasons.

1) The Evaluation Team relied exclusively on the results of the thermostat runtime model, while Nest average the results of their runtime and executed setpoint models.
2) The Evaluation Team only used thermostats with operating data in the opt-in rate calculation
3) The Evaluation Team used the results of the cooling connected load analysis to convert runtime savings to kWh savings. The Evaluation Team's assumption (3.0 kW) was slightly larger than Nest's (2.88 kW).

Figure 15 summarizes the calculation steps and results of the Evaluation Team's summer analysis.

Figure 15: Summer Season Calculation Summary

1

- Thermostats randomized to the ITT group showed an average reduction in cooling runtime of **0.006 hours per day** (or 21.7 seconds)

2

- The average ITT group thermostat called for cooling 1.59 hours per day during the performance period. This equates to a **0.38%** average reduction in cooling runtime per ITT thermostat

3

- ITT thermostats had an average of **105.5 days** of operational data during the performance period. Multiplying the average daily impact by the number of days returns an average runtime savings of **0.64 hours** per ITT thermostat

4

- Using an assumed connected load of 3.0 kW, this equates to **1.9 kWh** of energy savings per randomized thermostat.

5

- There were 5,955 thermostats randomized to the ITT group with operating data, and 2,790 of these devices opted-in to Seasonal Savings, for an opt-in rate of **46.85%**.

6

- Dividing #3 and #4 by the opt-in rate produces an average ITT Opt-In savings of **1.36 hours** of runtime and **3.9 kWh**.

7

- The Seasonal Savings pilot lowered AC usage by a total of **3,793 hours** in 2016 and achieved aggregate savings of **11,379 kWh**.

The Nest savings estimate of 11 kWh per opt-in participant is based on an average of results from two different analyses: a comparison of thermostat runtime and a comparison of thermostat setpoint. The Evaluation Team believes the runtime analysis should be considered the primary method and the setpoint analysis a secondary investigation. As mentioned in Nest's results memorandum, the energy impact of the setpoint analysis "*depends strongly on the prior estimate of 7.1% cooling savings per degree change in setpoint*". Because condensing unit runtime translates more directly to energy consumption than thermostat setpoint, the Evaluation Team recommends that runtime analysis be the basis of savings estimates. The setpoint analysis is a useful secondary analysis because it is the mechanism by which the Seasonal Savings algorithm achieves savings, but it should not be used as the basis of energy savings estimates.

Table 18 shows the final recommended per device kWh savings for the summer 2016 cooling season. Per-device impacts are presented on both a per ITT thermostat and per ITT - opt-in basis. The aggregate kWh savings for the summer season was 11,379 kWh.

Table 18: Evaluated Summer Cooling Assumptions and kWh Impacts

Parameter	Intention to Treat	Opt-In
Devices	5,955	2,790
Percent Reduction	0.38%	0.81%
Baseline AC Run Hours	168	168
Average Runtime Reduction (Hours)	0.64	1.36
Equipment Size (kW)	3.0	3.0
kWh Savings (per device)	1.9	4.1

5.5 Summer Season Supplemental Analysis

The Evaluation Team used Nest's summer 2016 thermostat runtime dataset to perform several additional analyses of Seasonal Savings performance. The analysis and results discussed in Sections 5.1 through 5.4 and summarized in Table 18 document the actual impacts achieved by the Pilot during the summer 2016 deployment, which didn't begin until July 13, 2016 and observed cooler-than-average weather conditions during the performance period. Energy Trust was interested in understanding what the expected performance would have been if the Pilot had been in place for the entire summer and faced normal weather conditions. To answer this question, the Evaluation Team adjusted the degree day base to 62 °F[23] and modified the regression specification so that the treatment effect was estimated per CDD only. The formal model specification is provided below (Equation 7) and Table 19 presents the model coefficients and their standard errors.

Equation 7. CDD-based Regression

$$AC\ Runtime_{td} = \beta_t + \beta_1 * CDD + \beta_2 * CDD * TreatX + \beta_3 * Post + \beta_4 * Post * CDD + \beta_5 * Post * CDD * TreatX$$

Where:

AC $Runtime_{td}$ = The number of seconds of air conditioning runtime for thermostat (t) on day (d)
β_t = Thermostat-specific regression intercept (fixed effect)
β_1-β_5 = Model coefficients determined via regression
CDD = Cooling degree days on day (d). Base 62 (°F)
TreatX = Indicator variable equal to 1 if thermostat (t) is in the ITT group. Zero otherwise
Post = Indicator variable equal to 1 if date (d) is greater than or equal to July 13, 2016

[23] The Evaluation Team tested models from CDD base 55 (°F) to CDD base 70 (°F). CDD base 62 (°F) produced the model intercept closest to zero. This result means that the variability in cooling runtime is being captured almost exclusively by the CDD term in the regression model and a minimal amount of AC runtime is allocated to daily non-weather dependent operation.

Table 19: Regression Output for Weather Normalized Impacts

Model Term	Coefficient	Robust Standard Error	t	P>t
Intercept	0.54021	0.0095	56.74	0.00
CDD	0.32625	0.0038	86.86	0.00
CDD*TreatX	-0.00439	0.0053	-0.83	0.41
Post	-0.12603	0.0075	-16.85	0.00
Post*CDD	0.00520	0.0020	2.56	0.01
Post*CDD*TreatX	**-0.00218**	**0.0027**	**-0.80**	**0.43**

The bolded row in Table 19 shows that this model returned an average ITT effect per randomized device of -0.00218 hours of runtime per CDD (β_5). Table 20 shows the relative representation of 13 different Oregon weather stations in the Pilot, a weather-normalized cooling impact for each station, and a weighted average for the Pilot population. The weighted average is dominated by the Portland area, with over 90% of Seasonal Savings devices mapped to the Portland Airport weather station. The regression coefficient of the intercept[24] and 'CDD' terms in

Table 19 are also used to estimate the annual air conditioning usage (kWh) for each weather region in Table 20 assuming an average air conditioner size of 3 kW.

[24] The intercept term is multiplied by 150 days. This mirrors the summer cooling dataset used in the model. The effective assumption is that all Oregon AC usage will occur between approximately May 15 and October 15.

Table 20: Weather Normalized Savings Estimates – Full Summer Deployment

Station ID	Station Name	Seasonal Savings Population Weight	Long Run CDD (Base 62)	Annual Cooling kWh	ITT Opt-In Annual Runtime Reduction	ITT Opt-In Annual kWh Reduction
1	Astoria	1.29%	69	310	0.32	0.96
2	Eugene	0.01%	435	669	2.02	6.07
3	Hermiston	0.01%	1,129	1,348	5.25	15.74
4	La Grande	0.01%	596	827	2.77	8.32
5	Klamath Falls	0.91%	458	692	2.13	6.39
6	Medford	2.38%	845	1,070	3.93	11.79
7	North Bend	0.01%	3	246	0.02	0.05
8	Ontario	0.01%	1,081	1,301	5.03	15.08
9	Portland	90.38%	556	787	2.58	7.75
10	Redmond	0.01%	430	664	2.00	6.00
11	The Dalles	0.01%	1,232	1,449	5.73	17.19
12	Salem	4.97%	499	731	2.32	6.96
13	Roseburg	0.01%	599	829	2.78	8.35
Seasonal Savings Population-Weighted Cooling Avg. (per ITT Opt-in device)			**552.6**	**784 kWh**	**2.57 hours**	**7.71 kWh**

Table 18 in Section 5.4 of this report showed that the approximately 6,000 thermostats randomized to the summer season ITT group only saved about 2 kWh per randomized thermostat and 4 kWh per opt-in participant between July 13, 2016 and October 31, 2016. Based on the observed response in 2016, the Evaluation Team estimates that average ITT group savings would have been about 4 kWh per randomized thermostat or 8 kWh per opt-in participant for a full summer under typical weather conditions.

The Annual Cooling kWh column of Table 20 allows for inferences about the magnitude of conservation opportunities that target AC usage in Oregon. The statewide average of 541 kWh per year uses the weights in the Seasonal Savings Pilot population, which may or may not be appropriate for other analyses. The key takeaway from Table 20 is that there is a limited amount of AC load on average among Nest customers in Oregon, so the energy savings potential from measures that target reductions in cooling usage will also be limited. Even a measure that saves 10% of annual cooling usage would produce less than 80 kWh/year of savings on average.

Considering the limited amount of cooling and small cooling season response observed across the total Pilot population, the Evaluation Team chose to examine if the Seasonal Savings response varied depending on the level of cooling usage. The premise of this investigation was that there might be a segment of heavy AC users within the Pilot population that exhibited a larger response and that the program might choose to target only these devices in the future. The Evaluation Team assigned each device with operating data into one of four quartiles based on the average daily hours of cooling runtime before the summer deployment of Seasonal Savings (June 1, 2016– July 12, 2016). Apex then estimated a separate regression model for each quartile. The model specification captured the ITT treatment effect as a function of base 62 CDD.

Table 21 takes the ITT impacts and incorporates the proportion of devices that qualified and accepted the Seasonal Savings offer and estimates impacts per ITT opt-in thermostat. It's important to keep in mind that confidence intervals get even wider when the population is divided into four groups for analysis and that the differences among quartiles are not statistically significant. While Quartile 1 shows a large estimate per opt-in thermostat, very few of the devices in this quartile even received the Seasonal Savings offer. In addition, Quartile 4 – the largest users –showed the smallest reduction in runtime.

Table 21: Per ITT Opt-In Thermostat Impact Estimates by Quartile

Quartile	Average Daily Hours of Cooling in "Pre" Period	Opt-in Rate	Annual Hours of Cooling Runtime Reduced	Annual kWh Savings	kWh Savings Margin of Error (90% Confidence)
1	0.04	1.3%	28.8	86.4	± 619
2	0.77	54.8%	2.0	5.9	± 25.6
3	1.86	68.6%	5.3	15.9	± 21.7
4	4.01	69.2%	0.3	0.9	± 27.9

The results in Table 21 don't provide any evidence to suggest a smaller Seasonal Savings deployment focused exclusively on the largest cooling users would produce substantially improved per-device impact estimates. Almost 80% of the devices in Quartile 1 are not even connected to a central cooling system (per the 'can_cool' indicator variable), so the inclusion of these devices in a summer cooling savings initiative undoubtedly dilutes the impacts.

The Evaluation Team also explored a model using only the warmest days of the summer to see if a more intense response was observed on the hottest days. When the input days were limited to just those with a weighted average daily temperature above 70 °F, the regression impact coefficient per degree day went down slightly compared to the model estimated with all days, although the difference was statistically indistinguishable.

6. Winter Seasonal Savings

The impacts of Seasonal Savings during the winter deployment were far more significant than impacts during the summer deployment, which is expected given Oregon's cool climate. Nest's runtime analysis produced an estimate of 4.75% savings per ITT Opt-In thermostat, and the setpoint analysis produced an estimate of 4.5% savings per opt-in thermostat. Nest converted the runtime savings to energy savings using an assumed heating system size of 70 kBTU/hour and estimated 20 therms of natural gas savings per ITT Opt-In thermostat. Two types of natural gas billing analysis completed by the Evaluation Team both returned winter savings estimates very close to the thermostat runtime and setpoint models.

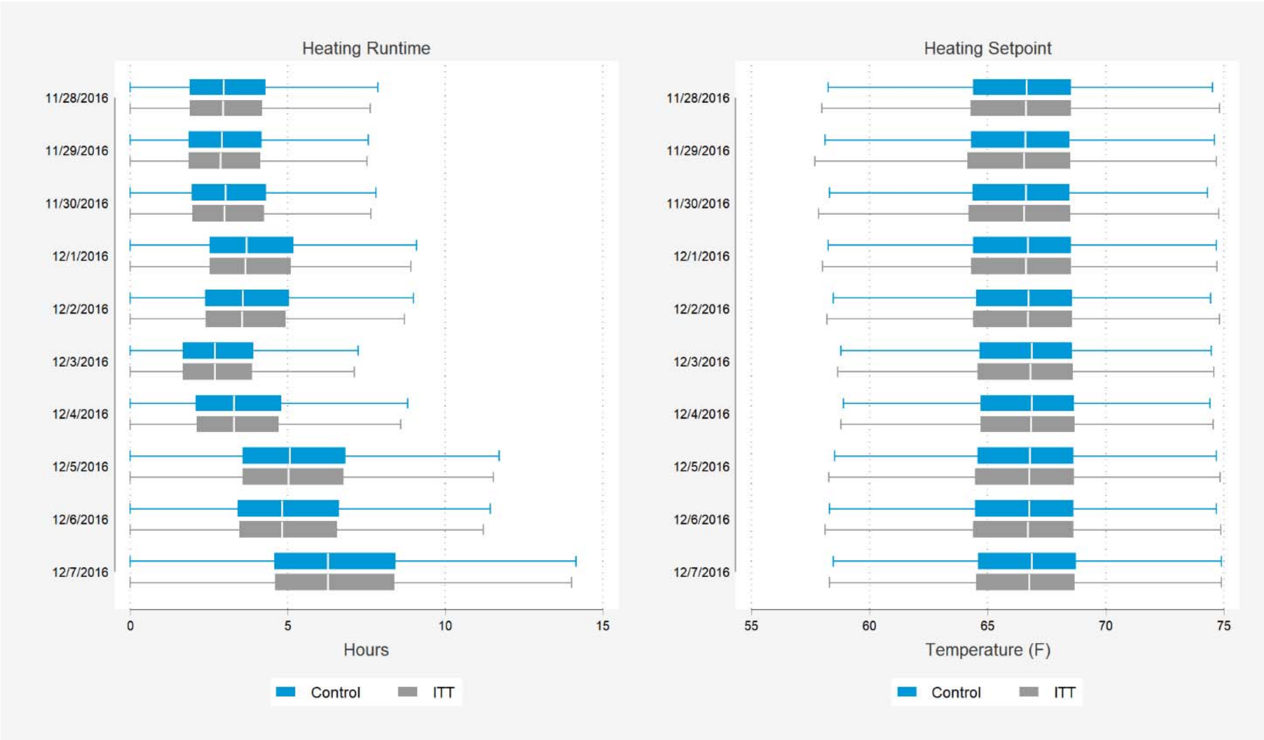
6.1 Validate Nest Runtime Analysis

With the mechanics of the Nest analysis vetted through the summer review, the Evaluation Team's review of the winter season focused on a thorough independent validation of the experimental design and a comparison of impact estimates across various runtime model specifications. The data structure checks are a key step because they rule out alternative explanations of the estimated treatment effect. Before independently estimating winter (or summer) impacts, the Evaluation Team examined the following questions:

- Are there missing values in the dataset? If so, are missing values evenly distributed among the treatment and control groups?
- Is the assignment of thermostats to study groups consistent throughout the analysis?
- Is the indicator variable for the deployment period and its interaction with the treatment group indicator variable coded correctly?
- Are there differences in the ITT and control groups during the pre-treatment period with respect to runtime or thermostat setpoint?
- Do the ITT and control groups experience equivalent weather conditions, indicating geographical equivalency?
- Is the distribution of heating fuels equivalent between the ITT and control groups?

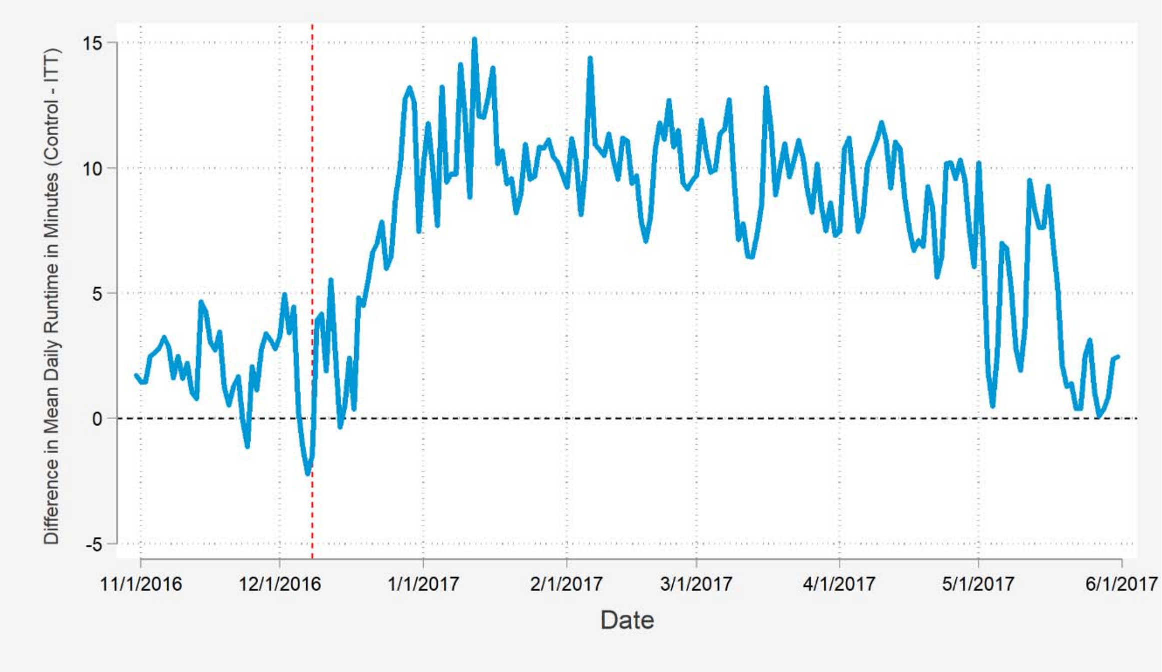
Visual checks were conducted to validate the equivalence of the control group and the ITT group. As an example, Figure 16 shows boxplots that compare the distribution of heating runtime and average daily heating setpoint across the control and ITT groups over a 10-day period leading up to the Seasonal Savings deployment. The white line in the middle of each boxplot represents the median, the shaded box stretches from the 25th percentile to the 75th percentile (the interquartile range), and the 'whiskers' stretch 1.5 times the length of the interquartile range, or to the lowest/highest value in the data set.

Figure 16: Comparison of Heating Runtime and Average Setpoint Prior to Seasonal Savings Deployment



The differences between the two groups are very small in the pre-deployment period. This finding limits the corrections required of the model to net out pre-existing differences and allows for no other plausible explanation of the differences observed in the deployment period other than the Seasonal Savings algorithm. Figure 17 shows the difference in average daily runtime between the two groups for each day from November 1, 2016 to May 31, 2017. The vertical red line is the start of the Seasonal Savings deployment and the horizontal black is added for emphasis of the zero point on the y-axis. On average, the control group has approximately two minutes of additional heating runtime per day than the ITT group from November 1st to December 8th.

Figure 17: Difference in Average Daily Heating Runtime Between the Control Group and ITT by Date



While two minutes per day doesn't sound like much in homes with several hours of heating runtime per day, the Seasonal Savings effect of interest is also subtle, so it's important to implement a model that nets out the pre-deployment differences via a DID calculation. The manual DID calculation is shown in Table 22.

Table 22: Manual DID Runtime Calculation for the Heating Season

Study Period	Group	
	Control	Treatment
Pre (hours per day)	2.7301	2.6966
Post (hours per day)	3.6300	3.4767
Change	0.8999	0.7801
DID (hours per day)		**-0.1198**
DID (minutes per day)		**-7.19**
% Change	**-0.1198 / (3.4767 + 0.1198) = -3.33%**	

Nest reported an effective opt-in rate (i.e., inclusive of those that did not qualify) of 74% for the winter season, which is consistent with the 73.45% effective opt-in rate calculated by the Evaluation Team. With an effective opt-in rate of 73.45% for the winter deployment, this simple analysis returns an estimate of 4.53% savings per opt-in thermostat, which is very close to the Nest analysis result.

Once these initial checks confirmed there were no issues with the randomization or data structure, the Evaluation Team estimated a series of different regression model specifications on the heating runtime data to test the sensitivity of the results to model specification. Tested models are shown in Table 23. The Nest runtime model is 'Model D'. Each model included thermostat-level fixed effects with daily hours of heating runtime as the dependent variable. Model G also includes fixed effects by date. Additional information on the different independent variables is provided after the table. Interaction terms are presented using a "var1*var2" convention.

Table 23: Summary of Winter Season Runtime Models Tested by the Evaluation Team

Model	Description	Independent Variables
A	Simplest model	Post, Post*Treat
B	Simple model + time effects	Post, Post*Treat, Date
C	Simple model + weather	Post, Post*Treat, HDD
D[1]	Fully interacted weather model	Post, Post*Treat, HDD, Post*HDD, Treat*HDD, Post*Treat*HDD
E	Simple + time + weather	Post, Post*Treat, HDD, Date
F	Fully interacted time + weather	Post, Post*Treat, HDD, Post*HDD, Treat*HDD, Post*Treat*HDD, Date
G	Two-way fixed effects on thermostat and date	Post, Post*Treat, HDD, Post*HDD, Treat*HDD, Post*Treat*HDD

[1] Model selected by Nest to estimate savings.

- **Post:** This is an indicator variable for the Seasonal Savings deployment period. It is equal to 0 up to and including December 8, 2016 and equal to 1 from December 9, 2016 forward.
- **Treat**: This is an indicator variable for randomized study group. It is equal to 0 for the control group and 1 for the ITT group.
- **HDD**: This represents heating degree days using a base of 60 °F. If the average daily temperature is above 60 °F, then HDD is 0. If the average daily temperature is below 60 °F, HDD is the difference between 60 and the average daily temperature.
- **Date**: This represents the day of thermostat operating data to which the record corresponds. Note that date is treated as a categorical variable.

Table 24 presents the results of the Evaluation Team's independent runtime modeling effort. The seven models were each assigned a letter in Table 23 along with a description of their specifications. Note that Model D is the specification used by Nest to develop its estimate of 4.75% ± 0.95% savings per opt-in thermostat. Models F and G represent two different ways to implement the same specification (e.g., a dummy variable for each date and date-level fixed effects absorb the same variance in the data and result in identical impact coefficients and standard errors).

Table 24: Heating Runtime Model Results Comparison

Model	ITT Impact (Hours per Day)		ITT Opt-In Impact (Hours per Day)		ITT % Impact		ITT Opt-In % Impact	
	Impact	90% CI ±	Impact	90% CI ±	% Impact	90% CI ±	% Impact	90% CI ±
A	-0.113	0.026	-0.154	0.036	-3.17%	0.74%	-4.27%	1.00%
B	-0.111	0.025	-0.151	0.034	-3.12%	0.71%	-4.20%	0.96%
C	-0.116	0.025	-0.158	0.035	-3.24%	0.71%	-4.36%	0.96%
D	-0.125	0.026	-0.170	0.036	-3.49%	0.73%	-4.69%	0.98%
E	-0.129	0.029	-0.176	0.040	-3.61%	0.82%	-4.85%	1.10%
F	-0.123	0.026	-0.167	0.035	-3.43%	0.72%	-4.61%	0.96%
G	-0.123	0.026	-0.167	0.035	-3.43%	0.72%	-4.61%	0.96%

Although not identical, the Evaluation Team's estimate for Model D effectively replicates the Nest result (4.69% vs. 4.75%). More importantly, the seven models considered all produce savings estimates within each other's error bound. Based on these results, the Evaluation Team did not adjust the Nest savings claim and used 4.75% per ITT opt-in thermostat as the basis for the winter energy savings estimates.

6.2 Validate Nest Setpoint Analysis

Nest also conducted an analysis of the change in executed thermostat setpoint for the winter season and found an average reduction of 0.52 °F per ITT thermostat. Dividing this value by the winter opt-in rate returns an estimated 0.69 °F reduction per opt-in thermostat. The setpoint data is far less noisy than the runtime data because it isn't subject to the equipment, envelope, and weather considerations that lead to variation in runtime. Because of the lower variance, the setpoint model produces a narrower confidence interval (± 0.05 °F at the 90% confidence level).

On one hand, the setpoint analysis is the more direct measurement of the intervention – the Seasonal Savings treatment is effectively just a small reduction in setpoint. Modeling the change in setpoint directly tells us the magnitude of the change after accounting for the 3-week ramping in period and customer overrides. On the other hand, setpoint is a less direct measurement of *energy* consumption than runtime because it requires an intermediate assumption to convert setpoint change to runtime reduction. Nest presented two potential conversion factors:

- 6.4% per 1-degree (°F) change in setpoint. This statistical estimate is based on a similar analysis to the one presented in Section 5.2 for the cooling season.

- 6.7% per 1-degree (°F) change in setpoint. This estimate is based on an engineering estimate using the physics of heat loss and difference between indoor and outdoor temperature.

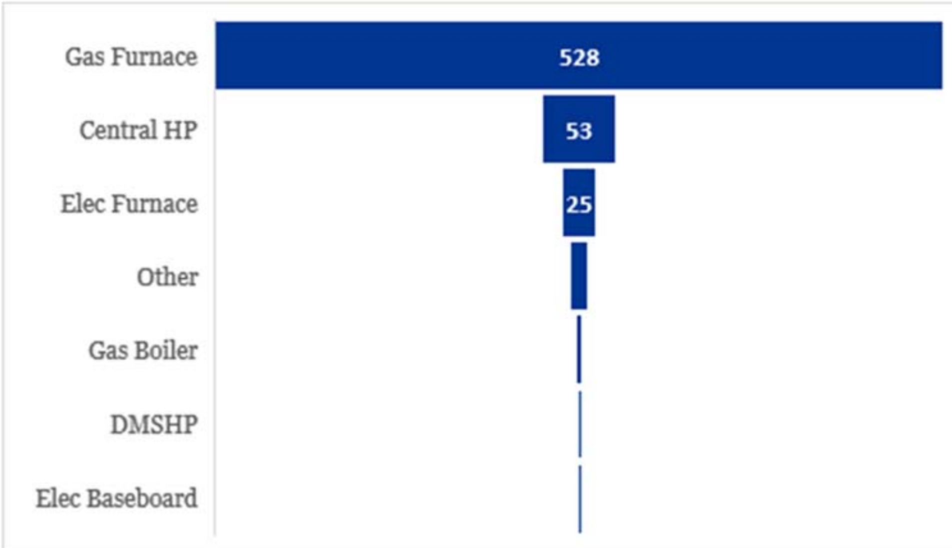
Nest used an average of these two values to estimate a 4.5% reduction in heating runtime based on the 0.69-degree reduction in setpoint per ITT opt-in thermostat. The regression model specification for the setpoint analysis was reasonable and the execution was error-free. The similarity of the runtime and setpoint analyses (and the gas billing analysis discussed in Section 6.3) provide compelling evidence that the Winter Seasonal Savings deployment generated real heating energy savings of 4-5%. The Evaluation Team agrees with Nest's recommendation to use the runtime model results for the final savings estimate for consistency with the evaluation plan and with the summer analysis (where the runtime model produced slightly lower savings estimates than the setpoint analysis). Runtime is also a more direct measurement of the parameter of interest (energy consumption) so the Evaluation Team recommends runtime models be used to estimate impacts from any future Seasonal Savings deployments.

6.3 Billing Analysis Verification

In addition to a review and validation of the Nest reported RED impacts, Energy Trust requested that the Evaluation Team conduct an independent analysis of Seasonal Savings impacts via data collected by utility revenue meters (e.g., monthly billing data and hourly/sub-hourly AMI data). One limitation of this analysis is that billing data could only be identified for customers who responded to the survey, because addresses were needed to match thermostats to utility billing information. This limitation meant that fewer than 600 of 15,000 thermostats in the winter deployment could be included in the billing analysis. However, the billing analysis still served as a useful independent validation of the primary RED impacts.

To inform the heating season billing analysis, the Evaluation Team was provided with monthly electric and gas billing data for 612 unique residential customer accounts where Energy Trust could identify utility accounts from the addresses received via the survey. The raw dataset contained a total of 78,208 records and spanned a period from May 2011 to June 2017. Several steps were taken to prepare the raw billing data for analysis. One initial step was limiting the billing data to natural gas records. Natural gas furnaces were the dominant heating system in the Pilot, so gas billing data was the focus of the winter analysis. The distribution of heating systems for all winter survey respondents is shown in Figure 18.

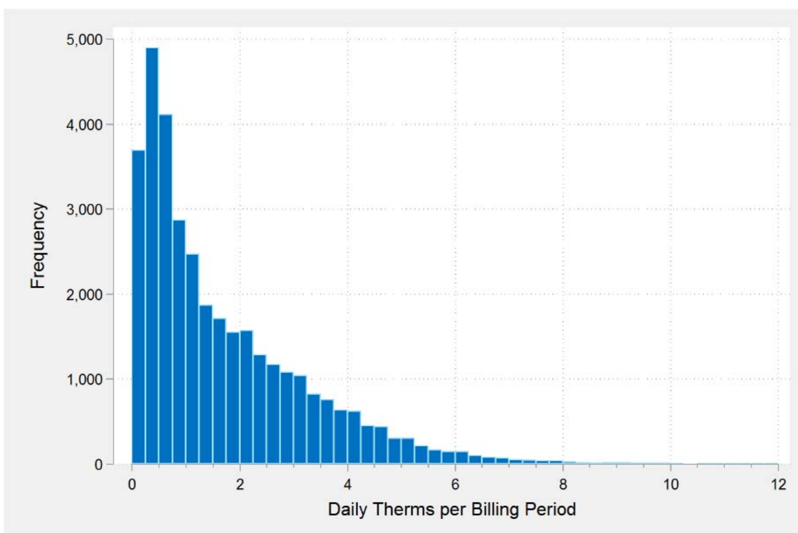
Figure 18: Winter Season Distribution of Heating System for Survey Respondents



Additional data cleaning steps are noted below:

- Duplicate records were dropped.
- Records with non-residential rate codes were dropped.
- Any billing records with average daily therms greater than 12 were labeled as extreme outliers and dropped from the analysis. The distribution of average daily therms per billing period is shown in Figure 19.

Figure 19: Winter Season Distribution of Average Daily Therms per Billing Period



- A handful of records (< 0.5%) had lengthy periods (> 50 days) between meter reads. Records with lengthy periods or following a lengthy period were dropped.

Each home was mapped to one of thirteen Oregon weather stations by zip code using a zip code to weather station lookup table provided by Energy Trust. Energy Trust also provided daily weather records for each of the 13 stations, which were used calculate the number of HDD and CDD in each billing period.

The final dataset contained 571 distinct Energy Trust customers and 34,880 total records from January 2012 to June 2017. Table 25 shows the distribution of survey strata at the account level for Pilot and for the final natural gas winter analysis dataset. Also note that the proportion of ITT customers that qualified and opted in is 72%. The calculation is shown in Equation 8 below.

Equation 8. ITT Opt-in Proportion

$$Proportion\ of\ ITT\ Group\ that\ Opted\ In = \frac{225}{225 + 72 + 16} = 0.72$$

Table 25: Final Winter Season Analysis Customer Counts by Study Group

Survey Strata	Population Size	Number of Homes	Percentage of Gas Billing Analysis Homes
ITT – Opt-In	6,716	225	39.4%
ITT – Did Not Accept	1,849	72	12.6%
ITT – Did Not Qualify	579	16	2.8%
Control	6,024	258	45.2%
Total	**15,168**	**571**	**100%**

The Evaluation Team performed two sets of regression analyses on the prepared gas billing data.

1) **Panel Regression Model** – All 571 homes included in a single model with premise-level fixed effects and cluster-robust standard errors. Degree day base 60 °F was used for all homes. The coefficients from the panel represent the average relationship across the panel. These results are presented in Section 6.3.1.
2) **Individual Customer Regressions with Variable Degree-Day Base** – This "two-stage" approach models each home separately and then examines the central tendency across the individual customer estimates. Separate regression models are estimated using a range of integer degree-day bases between 40 °F and 70 °F. The model with the highest R^2 value is selected for each home and used to estimate the Seasonal Savings winter treatment effect. The results of this analysis are presented in Section 6.3.2.

To create an "apples-to-apples" comparison between the billing analysis results (which are at the household level) and the runtime or setpoint analysis results (which are at the thermostat level), the number of thermostats per home must be accounted for. Nest reported 1.07 thermostats per home in its winter results memo, so the Evaluation Team divided the results of the billing analysis by 1.07 to estimate the average gas savings per thermostat.

6.3.1 Panel Regression Model

To estimate the number of therms saved per opt-in participant, the Evaluation Team first ran a fixed effects panel regression model on the 571 homes in the cleaned billing data set. The model specification is:

Equation 9. Panel Regression

$$Daily\ Therms_{hp} = \beta_0 + \beta_1 * Post + \beta_2 * Post * Treat + \beta_3 * Daily\ HDD + \beta_4 * Daily\ CDD$$

Where:

Daily Therms = The average daily therm usage in home (h) during billing period (p)
β_0 = Premise-specific regression intercept (fixed effect)
β_1-β_4 = Model coefficients determined via regression
Daily CDD = Average daily cooling degree days during period (p) at home (h). Base 60 (°F)
Daily HDD = Average daily heating degree days during period (p) at home (h). Base 60 (°F)
Treat = Indicator variable equal to 1 if home (h) is in the ITT group. Zero otherwise
Post = Indicator variable equal to 1 if billing period (p) begins after December 8, 2016. Zero otherwise.

Regression results are shown in Table 29. The interaction between the 'post' and 'treat' variable captures the Seasonal Savings effect in the ITT group, net of any changes in the Control group – which as captured by the 'post' term.

Table 26: Fixed Effects Regression Output – Winter Gas Billing

Model Term	Coefficient	Robust Standard Error	L90	U90
Intercept (β_0)	0.528	0.021	0.494	0.563
Post (β_1)	-0.060	0.033	-0.114	-0.006
Post*Treat (β_2)	**-0.096**	**0.048**	**-0.176**	**-0.017**
Daily HDD (β_3)	0.159	0.003	0.155	0.164
Daily CDD (β_4)	-0.012	0.002	-0.015	-0.009

The coefficient for the 'Post*Treat' variable (-0.096) indicates that, net of any pre-post differences in the control group and controlling for the effect of CDD and HDD, accounts in the ITT group used 0.096 fewer therms per day in the post period. This effect is statistically significant at the 90% confidence level. As noted elsewhere, converting from average savings per ITT home to average savings per ITT opt-in participant is simply a matter of dividing the average savings per ITT home by the proportion of ITT homes that opted in (72%). This calculation is shown in Equation 10 below.

Equation 10. ITT Opt-in Savings

$$Average\ Daily\ ITT\ Opt\ In\ Impact = {0.096}/{\tfrac{225}{313}} = 0.134\ therms$$

To express this estimate as a seasonal impact rather than a daily impact, the Evaluation Team took the following steps to establish a days-per-season conversion factor:

- Create a 'duration' variable that counts the number of days between the start date of the first billing cycle that started after the Seasonal Savings Program (12/8/2016) began and the end date of the final billing cycle for the account. Note that billing cycles that included the first day of the Pilot were not included in the 'duration' calculation.
- For just the ITT opt-in participants, calculate the average duration. This value came out to 170.87.

Table 27 summarizes the key outputs from panel regression model. Multiplying the average daily impact estimate of 0.134 therms per opt-in thermostat by the mean of the duration variable yields a seasonal impact estimate of 22.89 therms per opt-in home. At the 90% confidence level, the margin of error around this estimate is ± 18.9 therms. To account for homes with multiple thermostats, we divide by Nest's estimate of 1.07 thermostats per household. This returns a per-thermostat impact of 21.4 therms (± 17.6 therms) over the winter deployment period.

Table 27: Winter Impacts per Opt-In Home and Thermostat

Daily Therm Impact (ITT)	Opt-In Rate	Daily Therm Impact (ITT Opt-In)	Duration (Days)	Per ITT Opt-In Home with MOE at 90%	Per ITT Opt-In Thermostat with MOE at 90%
0.096	71.9%	0.134	170.9	22.8 ± 18.9	21.4 ± 17.6

The initial finding from Table 27 is that it is very close to Nest's estimate of 20 therms per opt-in thermostat. It's important to stress there are a few caveats surrounding this conclusion. First, the Evaluation Team limited the billing data to homes with gas billing records, such that the conclusions are limited to homes with gas heating. Second, the margins of error presented Table 27 are wide. The margin of error (17.6) is nearly as large as the seasonal impact estimate per ITT opt-in thermostat (21.4). That said, the impact remains statistically significant and is quite close to the more precise runtime based estimates from the RED. The fact that the point estimate of the panel gas billing model is within the confidence interval of the confidence interval of the runtime estimate helps validate the runtime approach to computing energy savings.

6.3.2 Individual Customer Regressions with Variable Degree Day Base

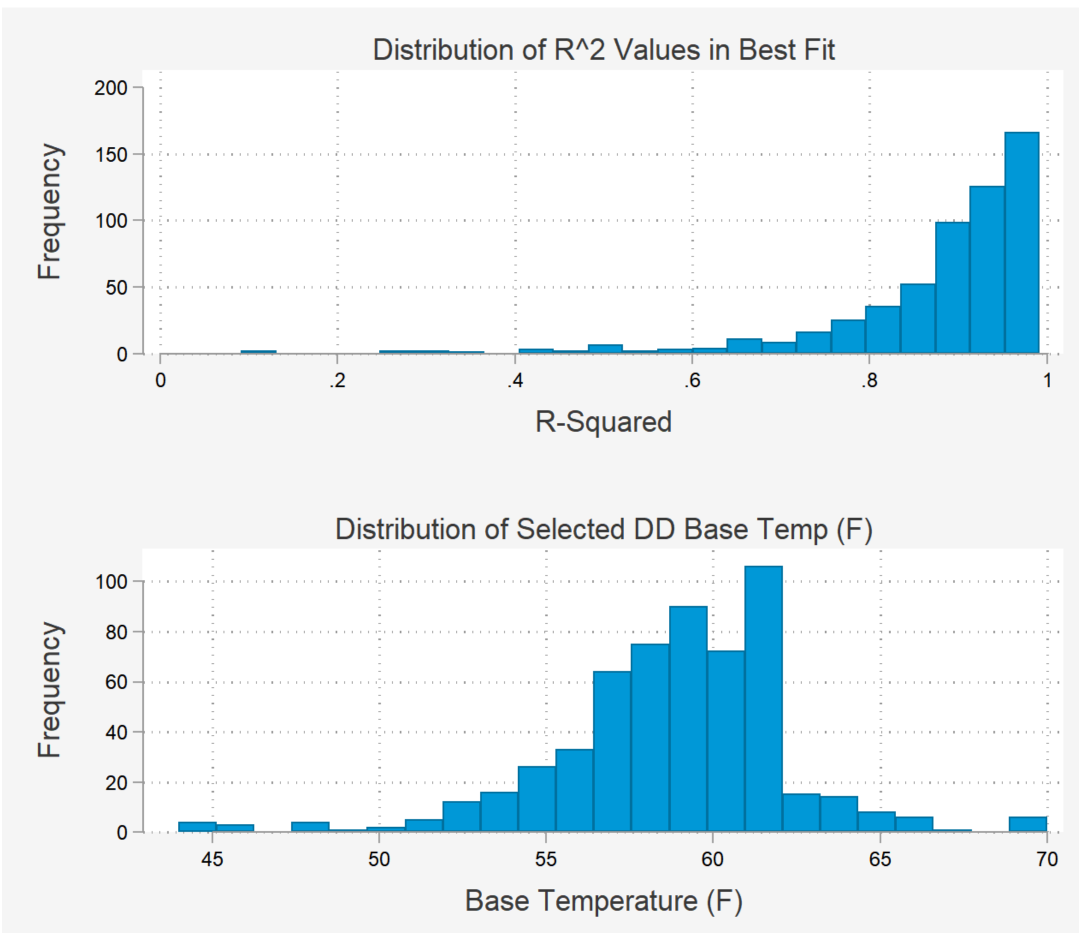
For the individual customer regression analysis, we examined each of the homes in the prepared gas billing data set individually and then averaged the results of the premise-level gas savings estimates to draw inferences about the average Seasonal Savings effect. The first step in the analysis is to select the best degree-day base, or 'change point', for the regression. This is the average daily temperature at which the heating slope (therms/HDD) begins. Equation 11 shows the model specification that was estimated for each home and each integer base temperature between 40 °F and 70 °F. The 'Post' term is equal to 1 for any billing period that starts after December 8, 2016 (when Seasonal Savings was deployed) and zero for billing periods that end prior December 8, 2016. Billing periods that include December 8, 2016 were dropped.

Equation 11. Winter Customer Regression

$$Daily\ Therms = \beta_0 + \beta_1 * HDD + \beta_2 * Post + \beta_3 * HDD * Post + \beta_4 * CDD$$

CDDs were not interacted with the 'Post' indicator variable because there were virtually no CDDs during the winter Seasonal Savings deployment. For each home, the HDD base temperature with the highest model R^2 value was identified. Figure 20 shows the distribution of R^2 values and heating change point values across the gas billing sample.

Figure 20: Distribution of R^2 and HDD Base in Selected Models for Individual Winter Season Pilot Homes

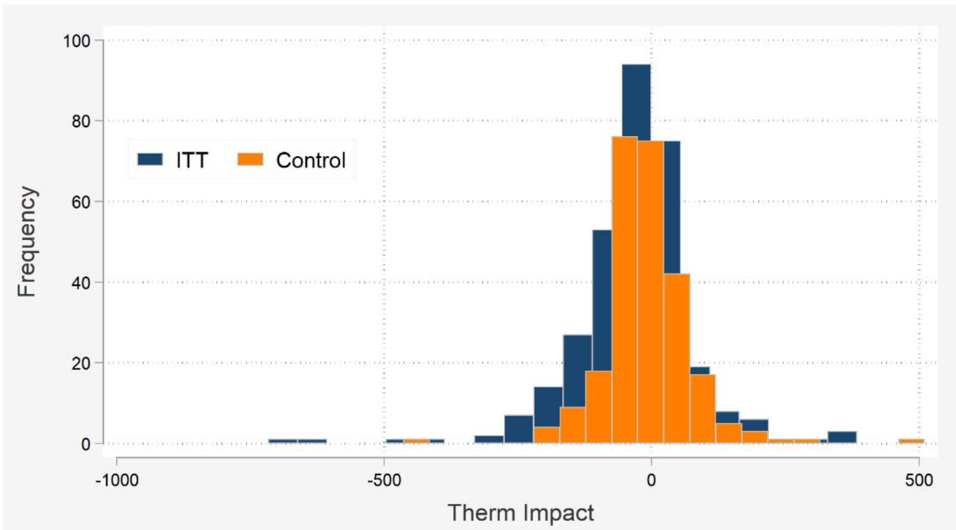


The model fit statistics were quite good, as space heating is the dominant gas end use in a cold climate like Oregon. The distribution of best-fitting degree day base temperatures was clustered around 60 °F.

The mean and median were both 59 °F. This reinforces the decision to use 60 °F as the degree day base in the winter runtime and panel regression models.

The coefficients β_2 and β_3 were then multiplied by the number of days of 'post' data and the average daily HDD for the home (at the selected base temperature). The individual customer pre-post change estimates range widely as shown in Figure 21.

Figure 21: Distribution of Changes in Therms for Individual Winter Season Pilot Homes



While unreliable in isolation, the average trend across several hundred premise-level regressions is useful. Table 28 provides basic summary statistics for the two groups and for the difference between the two groups.

Table 28: Individual Customer Regression Summary Statistics and ITT Savings Results

Group	# Homes	Mean Therms	90% Lower	90% Upper
Control	253	-7.9	-16.5	0.6
ITT	313	-33.2	-44.3	-22.0
Difference		**25.2**	**10.7**	**39.8**

The average therm reduction in the control group underscores why having a control group is so important for this type of analysis. The 7.9 therms-per-home estimate for the control group likely reflects savings from the original installation of the Nest thermostat. The closer the installation to the winter Seasonal Savings deployment, the more influence that equipment transition would have on the results. However, since we found no difference in the age of the Nest thermostats in the two groups, this effect should cancel out.

Table 29 incorporates the opt-in rate for the billing data estimation sample (72%) and the average number of thermostats per home (as a proxy for number of heating systems). This approach produces a slightly higher per-device therm savings estimate than the runtime model and the panel regression model. Like the panel regression model, the margin of error (± 19.0 therms at 90% confidence) is almost as large as the impact estimate. The key takeaway from the panel and individual customer gas billing regressions should be that there is no reason to question the impact estimates determined via runtime analysis.

Table 29: Calculation of Winter Season Gas Savings per ITT Opt-In Device

Calculation	Estimate	90% Lower	90% Upper
Therms per ITT Home	25.2	10.7	39.8
Effective Opt-In Rate	71.9%	71.9%	71.9%
Therm Savings per Opt-In Home	35.1	14.8	55.4
Thermostats per Home	1.07	1.07	1.07
Therm Savings per Opt-in Device	**32.8**	**13.8**	**51.8**

6.4 Average Heating System Size

Table 30 shows the distribution of heating fuel across the winter Seasonal Savings population according to the Nest dataset. With over 90% of the heating systems in the study fueled by natural gas, the average furnace/boiler capacity is the critical savings assumption for converting runtime reductions into fuel savings (therms).

Table 30: Winter Season Distribution of Heating Fuel

Heating Fuel	Number of Thermostats	Percentage of Winter Seasonal Savings Winter Customers
Natural Gas	13,991	90.7%
Liquid Propane	51	0.3%
Fuel Oil	121	0.8%
Electricity	1,127	7.3%
Missing	142	0.9%
Total	**15,432**	**100%**

Nest's analysis assumes an average heating system size of 70 kBTU/hour. The Evaluation Team used a synthesis of the Nest runtime dataset, monthly gas billing data from survey respondents, and the number of thermostats per home (1.07) reported by Nest to validate this key assumption. The output of this analysis informed the Evaluation Team's final savings estimate for the winter deployment.

The furnace size investigation relied on a similar principle as the cooling connected load analysis discussed in Section 5.3, where regression coefficients from two models are combined to estimate the parameter of interest. The two models for the furnace size analysis were:

- Fixed effects panel regression of the Nest daily runtime dataset for the winter season (November 2016 to May 2017). Hours of heating runtime is the dependent variable and HDD base 60 (°F) is the independent variable. The regression coefficient of the HDD term in the model is interpreted as hours of heating runtime per HDD.

- Fixed effects panel regression of the prepared natural gas billing data with a meter read date after November 1, 2016. Data from prior to the beginning of the winter Seasonal Savings dataset were dropped to limit the amount of pre-Nest operation in the model and ensure equal shares of 'pre' and 'post' Seasonal Savings deployment data in the models. Average daily usage (therms) is the dependent variable and HDD base 60 (°F) is the independent variable. The regression coefficient of the HDD term is interpreted as therms used per HDD.

These regression coefficients can be rearranged to estimate the average size of the heating system as shown in Equation 12and Equation 13. The coefficients shown are for the pooled model across all study groups.

Equation 12. HDD Coefficient of Runtime Model

$$Runtime\ Coefficient = 0.23492\ hours\ per\ HDD$$

Equation 13. HDD Coefficient of Gas Billing Model

$$Billing\ Coefficient = 0.159619\ therms\ per\ HDD$$

Conversion from therms to kBTU yields a Billing Coefficient term of 15.96 kBTU per HDD. Dividing the Billing Coefficient by the Runtime Coefficient yields an estimate of the average home heating system size, as shown in Equation 14.

Equation 14. Calculation of Average Heating System Size

$$Average\ Home\ Heating\ System\ Size = \frac{15.96\ kBTU\ per\ HDD}{0.23492\ hours\ per\ HDD} = 67.94\ kBTU/hour$$

This estimate of the average home heating system size is then adjusted by Nest's estimate of 1.07 thermostats per home (as a proxy for number of furnaces), as shown in Equation 15.

Equation 15. Adjustment for Homes with Multiple Furnaces

$$\frac{67.94\ kBTU/hour}{1.07\ furnaces\ per\ home} = 63.5\ kBTU/hour$$

By study group, Table 31 shows the results of the natural gas heating system size analysis. The coefficients and estimated heating system size are relatively stable across the four groups and all slightly below the Nest estimate of 70 kBTU/hour.

Table 31: Estimated Heating System Size by Study Group

Study Group	Runtime Coefficient	Therms Coefficient	Heating Systems per Home	Heating System Size (kBTU/hour) with 90% MOE
Control	0.237	0.161	1.07	63.6 ± 2.6
ITT - Did Not Qualify	0.221	0.153	1.07	64.6 ± 14.0
ITT - Did Not Accept	0.239	0.168	1.07	65.5 ± 5.1
ITT - Opt-In	0.233	0.156	1.07	62.4 ± 2.9
All Groups	**0.235**	**0.160**	**1.07**	**63.5 ± 1.8**

There are a few important caveats to keep in mind when considering the results of this analysis.

- The runtime models are based on all 15,432 thermostats in the winter season deployment of the Seasonal Savings pilot, while the gas billing model included only 571 survey respondents. It's possible that the survey respondents are not representative of the Seasonal Savings pilot population.
- The assumption of 1.07 heating systems per home is based on Nest's estimate of number of Nest thermostats in the Seasonal Savings population. This value may not be representative of the survey respondents used for the gas billing regression.
    - Homes in the pilot could also have a second heating system with a thermostat that is not a Nest.
    - The relationship between furnace and thermostat is not necessarily 1:1. Some homes may have two thermostats connected to a single furnace (e.g. a multi-zone system).

While it does appear that the 70 kBTU/hour heating system size that Nest assumed in their analysis is slightly overstated, the Evaluation Team recognizes the uncertainties in the approach used to develop our independent estimate. Our recommended assumption for heating system size is **65 kBTU/hour**, which is the value used to calculate our estimates of per-thermostat and aggregate natural gas savings.

6.4.1 Heating System Fan Size

Although most of the heating systems in the Pilot run on fossil fuel, they rely on an electric fan motor in the air handler to circulate warm air throughout the home. Most occupants use the 'Auto' setting on their thermostat meaning that the fan only runs when there is a call for heating or cooling. This means that a reduction in the heating runtime will produce a corresponding reduction in fan operation. The Nest analysis assumed fan size is 0.56 kW based on an assumed ¾ horsepower fan motor and a 0.746 conversion factor from horsepower to kW (see Equation 16).

Equation 16. Calculation of Air Handler Fan Size

$$0.75\ HP * 0.746\ {}^{kW}/_{HP} = 0.56\ kW$$

The fan motor size assumption is reasonable given the average input fuel capacity of the heating systems in the pilot.[25] The Apex winter kWh savings calculations share the Nest fan power assumption of 0.56 kW.

6.4.2 Heat Pump Connected Load

440 of the ITT Opt-In thermostats in the winter deployment were identified as connected to Electric heating systems in the Nest analysis dataset. Nest and the Evaluation Team made two somewhat conservative assumptions about the electric heating equipment being controlled by Pilot thermostats.

1) All electric heating systems were assumed to be heat pumps rather than electric furnaces.

2) Runtime reductions were assumed to come from the heat pump compressor rather than the auxiliary resistance heat strips

The Evaluation Team elected to use the same connected load assumption (3.0 kW) for heat pumps that was calculated for the summer cooling season and included a combination of central AC units and heat pumps. A previous Nest thermostat evaluation[26] conducted by Apex Analytics for Energy Trust found that the average heat pump capacity among Nest pilot participants was 3 tons, which converts to approximately 3 kW if we assume an average efficiency level of 12 SEER/8 HSPF.

6.5 Recommended Winter Savings Estimates

Similar to the Summer savings analysis, the Nest analysis of heating runtime was well-organized and consistent with industry-standard practice for analysis of an RED. The aggregate energy savings for the winter season deployment are 110,404 therms of natural gas and 149,473 kWh. Figure 22 summarizes the calculation steps and results of the Evaluation Team's winter analysis, with additional detail following the figure.

[25] Pennsylvania TRM Table 3-67 lists the typical sizes for residential sized fan motors (0.5, 0.75, and 1.0). The Nest assumption is equal to the middle value. http://www.puc.state.pa.us/Electric/docs/Act129/TRM-2016_Errata_Feb2017.docx

[26] http://downloads.nest.com/press/documents/energy-trust-of-oregon-pilot-evaluation-whitepaper.pdf Table 10

Figure 22. Winter Season Calculation Summary

1. Thermostats randomized to the ITT group showed an average reduction in heating runtime of **0.125 hours per day** (or 7.5 minutes)
2. The average ITT group thermostat called for heating 3.45 hours per day during the performance period. This equates to a **3.5%** average reduction in heating runtime per ITT thermostat
3. ITT thermostats had an average of **165.4 days** of operational data during the performance period. Multiplying the average daily impact by the number of days returns an average runtime savings of **20.8 hours** per ITT thermostat
4. Using an assumed furnace size of 65 kBTU/hour, this equates to **13.5 therms** of gas savings per randomized thermostat.
5. There were 9,144 thermostats randomized to the ITT group with operating data, and 6,716 of these devices opted-in to Seasonal Savings, for an opt-in rate of **73.4%**.
6. Dividing #3 and #4 by the opt-in rate produces an average ITT Opt-In savings of **28.3 hours of runtime** and **18 therms**.
7. The Seasonal Savings pilot lowered heating usage across all participants by a total of **190,000 hours** and achieved aggregate natural gas savings of **over 110,000 therms**

To quantify the winter energy savings, the Evaluation Team used the heating fuel information in the Nest dataset. We organized runtime from the 2% of thermostats with heating fuel equal to liquid propane, fuel oil, or missing values under the natural gas savings total. Table 32 shows the mechanics of this calculation. To calculate the baseline heating runtime, the ITT runtime impact estimate is subtracted from the average observed heating runtime in the deployment period to estimate what runtime would have been absent Seasonal Savings. The 'Mean Days of Data' column represents the average number of days each thermostat had operating data in the final data set. These average values are slightly lower than the total number of days in the Seasonal Savings deployment from December 9, 2016 to May 31, 2017 (n=173).

Table 32: Post Period Runtime Baseline by Heating Fuel

Heating Fuel	Mean Daily Runtime	ITT Daily Runtime Impact	Mean Days of Data	# of ITT Thermostats	Heating Hours	ITT Opt-Ins
Fossil Fuel	3.36	-0.125	165	8,501	576.7	6,276
Electric	4.96	-0.125	167	643	848.4	440

The Evaluation Team opt-in counts by heating fuel match the Nest counts exactly, but the baseline heating hours are slightly lower. Table 33 shows the calculation of aggregate savings for the winter season. The number of ITT Opt-Ins with natural gas heat in Table 33 is lower than the number of fossil fuel ITT Opt-Ins in Table 32 because approximately 1% of the Pilot population had propane or fuel oil systems. The derivation of the values in the 'Equipment Size' column is discussed in detail in Section 6.4. It is interesting to note that the electric fan savings from homes with fossil fuel furnaces in the winter is greater than the average summer electric savings from AC reductions.

Table 33: Calculation of Participant Winter Energy Savings Impacts

Heating Fuel	ITT Opt-Ins	Runtime Reduction	Equipment Size (therm)	Equipment Size (kW)	Therms per ITT Opt-In with 90% CI	kWh per ITT Opt-In with 90% CI
Natural Gas	6,201	27.39	0.65	0.56	17.8 ± 3.7	15.3 ± 3.2
Electric	440	40.30	0	3.0	0	121 ± 25.4

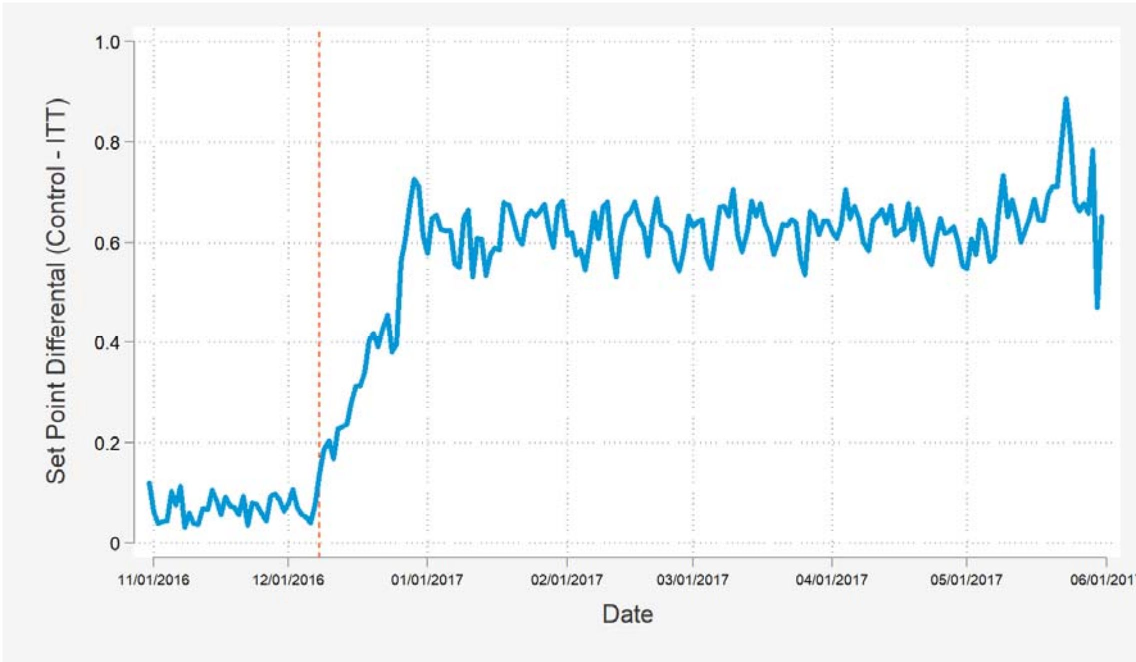
The aggregate energy savings for the winter season deployment are 110,404 therms of natural gas and 149,473 kWh.

6.6 Persistence

The Evaluation Team took a high-level look at savings persistence across the winter heating season only.[27] To gauge savings persistence, the Evaluation Team compiled average daily executed setpoint differentials between the ITT and control groups across the entire heating season. A review of the full seasonal differential is shown in Figure 23. The vertical red line represents the deployment of the Seasonal Savings algorithm. Visually, there is no indication of savings degradation for the duration of the heating season Pilot. The difference in executed setpoint hovers around 0.6 °F from early January 2017 to the end of May 2017. In theory, the modified setpoints of the ITT opt-in group will continue into the next heating season, unless the occupants adjust them. To determine to what extent the Seasonal Savings treatment persists across years, Energy Trust should request a comparison of setpoints and runtime from Nest for these two study groups at the outset of the winter 2017/2018 heating season.

[27] Due to a lack of summer cooling load and associated savings, the Evaluation Team focused our persistence analysis on heating season only.

Figure 23: Heating Season Setpoint Differentials between ITT and Control



7. Conclusions and Recommendations

Nest has developed, and Energy Trust offered, a turnkey energy savings service with the Seasonal Savings service. For participants, the service was easy to opt in and easy to adjust, where participants have control yet don't have to expend time or effort to deal with participation. Nest's package offering made it easy to implement with CLEAResult and Energy Trust staff. There were a few challenges, including marketing and communication mix-ups that were broadcast to participants; otherwise the Pilot ran flawlessly. The summer season showed very limited savings, given the lack of cooling load and the intermittent nature of that load, while the winter season showed robust energy savings that are likely to be cost effective, even with the one-year life of the measure. With respect to the measure's persistence, runtime data showed no evidence of savings decline over the season. Additionally, Nest thermostats are designed to maintain the Seasonal Savings schedule and setpoint settings going into the same season in the following year, provided participants do not override the settings and make additional adjustments. Ultimately, more time and research will be required to determine the actual year-over-year persistence of these settings. Customers showed strong Pilot satisfaction scores, though lower than those for the thermostat itself. There was a noticeable decrease in comfort in one-third of ITT opt-in participating homes that were aware of the Pilot, yet not everyone made adjustments or overrode the settings. The following conclusions and recommendation are based on the key findings presented throughout this report.

Delivery: Implementation, Opt-Ins, and Attrition

Feedback from staff interviews showed that the Pilot ran smoothly, with one potential communication error mixing up PGE's RushHour Rewards with the Seasonal Savings Pilot and an imperfect recruitment process that may have included a small number of non-Energy Trust partner utility customers. Participants opted in at a rate of approximately 80%, which is in line with other Seasonal Savings pilots that have been done (according to Nest staff). The summer offering had a lower effective opt-in rate, however, due to the lack of thermostats that met the technical criteria. Approximately one-fifth of those that opted in were not aware they had done so, and approximately half of those that did not opt in did not recall receiving an invitation. Attrition over the course of the Pilot was minimal, with less than 5% of the opt-in population.

Recommendation*: Overlap between RushHour Rewards and Seasonal Savings Pilot, as well as communication delivered to participants, should be vetted by Nest and coordinated with the active utility or program administrator partners. Future implementations to expand the Pilot can be planned using the effective opt-in rates noted in this report, but should also consider testing multiple modes of communication (e.g., email, phone, postal mail) as well as multiple invitations as a strategy to increase future opt-in rates. Energy Trust should either collaborate with Nest to identify solutions or consider partnering with the surrounding utilities in an attempt to resolve the issue with recruitment to overlapping non-participating utility customers, before larger deployment of the service is offered.*

Participant Experience: Usage, Feedback, and Satisfaction

Participants showed high satisfaction and comfort levels with the Nest thermostat across the survey strata, though reported lower satisfaction levels and lower levels of comfort with the changes to home temperature from the Seasonal Savings Pilot program.

Recommendation*: Energy Trust and other program administrators considering Seasonal Savings should make sure the marketing material and program communication highlight the lower bills and energy that participants save through the Seasonal Savings program. These savings were considered the primary drivers for participation and could help reduce the percentage of participants that opt out or make adjustments that reduce the potential savings.*

Summer Seasonal Savings

Cooling Season Validation

In general, the Evaluation Team's analysis confirmed the summer season findings presented in the Nest Report. However, the Evaluation Team made the following recommendations for future analysis (which were adopted for the heating season analysis).

Recommendation*:*

- *The runtime analysis should be the basis for any Seasonal Savings performance estimates. Analysis of executed setpoints is a useful secondary analysis to examine the magnitude and acceptance of the changes.*
- *The opt-in rate calculation should include only those devices with runtime data.*
- *Like the impact estimates, the scaling of the margin of error from per-ITT thermostat to per-Seasonal Savings participant should use the number of thermostats with data in the denominator of the opt-in rate (as opposed to the number targeted or randomized).*
- *In analyzing changes in setpoints, a longer timeframe (i.e., a month to six weeks) should be used to get a more stable measurement of the pre-deployment setpoint.*

Central AC and Heat Pump Connected Load

The Evaluation Team's connected load analysis results are generally consistent with the Nest connected load assumption of 2.88 kW, with each of the Evaluation Team's models returning a slightly higher estimate (see Table 34 below).

Table 34: Connected Load Summary

Connected Load Source	Connected Load (kW)
Monthly Billing Data (All Groups)	3.07
Monthly Billing (Weighted Mean of ITT Groups)	3.05
Interval Billing Data	2.93
Nest analysis	2.88
Evaluation Team Recommendation	**3.00**

Recommendation*: Considering the variance across the Evaluation Team's estimates and the limitations discussed previously, Apex recommends using a rounded connected load value of 3.0 kW per thermostat in the final savings estimates for the Seasonal Savings summer pilot. This analysis also found a limited amount of cooling use per air-conditioned home. Based on our estimates of less than 800 kWh/year of cooling usage per home, on average, we recommend that Energy Trust be very selective in pursuing strategies that target reducing AC usage as they are likely to face cost-effectiveness challenges.*

Winter Seasonal Savings

Heating Season Validation

The review of the RED heating season runtime impacts for the heating season were precise and extremely robust to model specification and dependent variable (runtime, therms, setpoint). The randomized groups also showed minimal differences in the pre-deployment period, which furthers bolsters the power of the runtime and energy savings analysis.

Recommendation*: The Evaluation Team recommends Energy Trust consider winter deployments for Seasonal Savings in the future as an effective way to capture heating savings. Unless permissions can be secured to gather utility billing data for all participants, the heating runtime analysis should be the primary impact evaluation method.*

Billing Analysis Energy Savings

The results of our heating season billing analysis were largely consistent with the Nest savings analysis. Because the billing analysis only includes survey respondents, there is both a larger statistical uncertainty from smaller sample size and the potential for selection bias.

Table 35 compares the per-opt-in thermostat impact estimates for the heating runtime model and two types of billing models. The point estimate for the runtime model is within the confidence interval of the other two models.

Table 35: Winter Season Gas Savings Model Comparison

Gas Savings Model	Therm Estimate	90% Lower	90% Upper
Thermostat Runtime Model	17.8	14.1	21.5
Billing Data Panel Regression	21.4	3.8	39.0
Individual Customer Billing Data Regression	32.8	13.8	51.8

Recommendation: *The gas billing analysis provides no evidence to contradict the RED analysis of thermostat runtime. The fact that an independent source of data produced results so close is a strong validation of the runtime model findings. The 18 therms per opt-in thermostat is our recommended winter savings for homes with fossil fuel heating systems.*

Savings Persistence

The Evaluation Team reviewed persistence by examining the runtime differential between the ITT and control groups throughout the entire season. There was no indication of any decline in savings (other than a general reduction in heating usage associated with milder spring temperatures) or significant attrition from participants by the end of each season. Furthermore, the Nest thermostat will continue to run the Seasonal Savings-based scheduling and setpoints during the following season, provided the participant does not override the settings.

Recommendation*: Energy Trust should assume no savings degradation across the currently assumed one-year measure life since runtime data showed consistent savings across the entire heating season. A follow-up analysis of the next (2017/2018) winter season runtime and setpoint differences between RED groups would provide some valuable insights into savings persistence greater than a year, provided additional Seasonal Savings deployments aren't layered on top of the winter 2016/2017 algorithm.*

Impact Estimates per Opt-In Thermostat

Table 36 summarizes the average impacts per opt-in thermostat by season and equipment type.

Table 36: Pilot Impact Summary per Opt-In Thermostat

Season	Percent Runtime Reduction	Equipment	Electric Savings (kWh)	Gas Savings (therms)
Summer Cooling	0.81%	CAC/HP	4	0
Winter Heating	4.75%	Gas Furnace	15	18
Winter Heating	4.75%	Heat Pump	121	0

Recommendation*: The per-unit savings from future deployments of Seasonal Savings will depend on when in the season the algorithm is deployed and the weather conditions of the specific season.*

However, the values shown in Table 36 *are reasonable planning assumptions based on the results of the Pilot evaluation.*

8. Appendices

A. Staff Interview Guide

Name:	Agency: Energy Trust / CLEAResult
Title:	Participant Phone:
Survey Completion Date:	Interviewer

A.1 Introduction

Hi, thank you for taking some time out of your schedule to meet with me. My name is [**name**], and as you know, my firm, Apex Analytics, was hired by Energy Trust of Oregon to evaluate the Nest Seasonal Savings Pilot. As part of this evaluation, we are surveying Pilot participants (and non-participants) and Energy Trust staff to understand what has worked well, what could be improved upon and what the prospects are for the Seasonal Savings program to be offered to a larger audience.

These interviews are meant to document your experiences so that future program implementers can learn and build upon your knowledge. Your responses will be reported in aggregate and your name will not be associated with any specific responses.

Before we get started, do you have any questions for me?

Q1. Will you briefly describe your role at [COMPANY]? What are/were your responsibilities with the Seasonal Savings Pilot?

Q2. What, if any, experience do you have with the Nest thermostat, prior to being involved with this pilot?

Q3. What, if any, research did you perform to understand the Nest thermostat and seasonal savings during the initial development of this pilot?

Q4. What level of communication was held between staff at Nest to discuss and learn about the Pilot?

Q5. Please describe any lessons learned from previous thermostat pilots that informed this pilot.

A.2 Customer Interactions

I want to talk briefly about your interactions with the participants following the recruitment process.

Q6. Based on your experience with this pilot, what do you think is the biggest barrier for customers to opt-in to the pilot?

   a. What could be done to overcome this/these barrier(s)?

Q7. Based on your experience with this pilot, what do you think is the biggest barrier for customers to successfully engage with the savers function and to generate savings?

   a. What could be done to overcome this/these barrier(s)?

A.3 Closing

Q8. How has the communication and coordination gone with Nest? Have there been any issues between the organizations? (What were they? How have they been resolved?)

Q9. What aspects of the pilot worked particularly well?

Q10. Would you consider this pilot a success? Based on what factors?

Q11. What aspects of the pilot have been challenging?

Q12. What do you think the prospects are for the pilot being rolled out on a larger scale, given the opt-in and low summer savings realization rates?

Q13. What suggestions would you have for other programs considering a seasonal savings pilot? (lessons learned)

   a. Recruitment?
   b. Opt-in?
   c. Engagement?

Q14. Are there additional comments or concerns you would like to share?

B. Summer Participant Survey – Opt-in Group

*** Required Information**

page 1

1. To proceed with this brief survey, please enter your:

(a) Home street address (example: 1234 Main Street) and
(b) 5-digit zip code (example: 97201)

of where your Nest thermostat is installed:

* (a) Street Address

____
____

* (b) Zip Code

____
____

*** 2. How long has your Nest thermostat been installed in your home?** (Select one option)

- ◯ Less than three months
- ◯ Three to six months
- ◯ Over six months but less than a year
- ◯ One year or longer
- ◯ Not sure / Don't know

*** 3. Is the temperature in your home generally more or less comfortable now than before you installed the thermostat?** (Select one option)

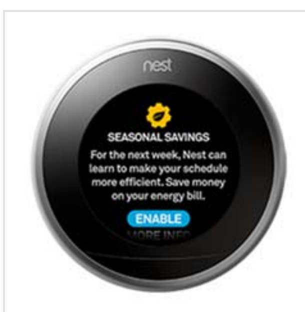
- ◯ Much more comfortable

- Somewhat more comfortable
- Equally comfortable
- Somewhat less comfortable
- Much less comfortable
- Not sure / Don't Know

*** 4. Please rate your overall satisfaction with your Nest thermostat on a 5-point scale where 5 is very satisfied and 1 is not at all satisfied?** (Select one option)

- 1 - Not at all satisfied
- 2
- 3
- 4
- 5 - Very Satisfied
- Not sure / Don't Know

page 2



*** 5. In mid-July, you should have received an invitation to enable the Seasonal Savings feature on your Nest thermostat. The invitation looked like the image above. Do you recall enabling Seasonal Savings on your Nest?** (Select one option)

- ○ Yes
- ○ No

*** 6. Please select any of your primary motivations for participating in Nest's Seasonal Savings program from the following list.** [Answer this question only if answer to Q#5 is Yes]

- ☐ Save Energy
- ☐ Lower my bills
- ☐ Environmental concerns
- ☐ Increase the comfort of my home
- ☐ Ease of participation
- ☐ Other (Please specify) ______________

*** 7. Your Nest thermostat automatically made small adjustments to your temperature settings after you enabled the Seasonal Savings. Did you leave the settings alone or did you manually override them afterwards by changing the thermostat temperature?** (Select one option) [Answer this question only if answer to Q#5 is Yes]

- ○ I left my thermostat alone - I did not change the temperature settings after enabling Seasonal Savings
- ○ I overrode some of the temperature settings after enabling Seasonal Savings – I found some of the adjusted settings uncomfortable

- ○ I overrode all of the temperature settings after enabling Seasonal Savings – I found the adjusted settings uncomfortable
- ○ Not sure / Don't know

*** 8. After you opted-in to the Seasonal Savings program, did you notice any changes to the temperature in your home?** (Select one option) [Answer this question only if answer to Q#5 is Yes]

- ○ Yes
- ○ No

*** 9. Did the changes to the temperature in your home make it more or less comfortable than before you enabled Seasonal Savings?** (Select one option) [Answer this question only if answer to Q#8 is Yes]

- ○ Much more comfortable
- ○ Somewhat more comfortable
- ○ Equally comfortable
- ○ Somewhat less comfortable
- ○ Much less comfortable
- ○ Not sure / Don't Know

*** 10. Please rate your overall satisfaction with the Nest Seasonal Savings program on a 5-point scale where 5 is very satisfied and 1 is not at all satisfied?** (Select one option) [Answer this question only if answer to Q#5 is Yes]

- ○ 1 - Not at all satisfied

- ○ 2
- ○ 3
- ○ 4
- ○ 5 - Very Satisfied
- ○ Not sure / Don't Know

11. Is there anything else that you would like us to know about your Nest thermostat or the Seasonal Savings program?

____

____

page 3

12. How many people currently live in your home? (Select one option)

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7
- ○ 8
- ○ 9

- ○ 10+

13. Has the number of people living in your home changed over the past year? (Select one option)

- ○ No
- ○ Yes: Added 1 Occupant
- ○ Yes: Added 2 Occupants
- ○ Yes: Added 3 Occupants
- ○ Yes: Added 4+ Occupants
- ○ Yes: Lost 1 Occupant
- ○ Yes: Lost 2 Occupants
- ○ Yes: Lost 3 Occupants
- ○ Yes: Lost 4 Occupants

14. What is the approximate square footage of your home? (Select one option)

- ○ Less than 500 square feet
- ○ Between 500 and 999 square feet
- ○ Between 1,000 and 1,999 square feet
- ○ Between 2,000 and 2,999 square feet
- ○ Between 3,000 and 3,999 square feet
- ○ Over 4,000 square feet

15. Please select the cooling system you have in your home (Select one option)

- ◯ Central air conditioning system
- ◯ Central heat pump system
- ◯ Ductless mini-split heat pump(s)
- ◯ Other (Please specify) __________

16. Does your Nest thermostat control ALL of the cooling in your home, or are there other cooling zones NOT controlled by your Nest? (Select one option)

- ◯ My Nest controls ALL cooling in my house
- ◯ There are other cooling zones not controlled by my Nest
- ◯ Not sure / Don't know

page 4

17. As a reminder, by completing this survey you have qualified to be entered into a drawing to win a free Nest cam. If you would like to be considered for the drawing, please enter your name and email address below.**

(a) Full name

____
____

(b) Email address

____
____

**** Nest Cam drawing is offered exclusively by Apex Analytics and neither Nest nor Energy Trust are involved with the drawing. Full terms and conditions for this drawing can be found at the following URL: Terms and Conditions. Odds of winning depend on the number of respondents. All Nest owners that complete the survey are eligible for the drawing. NO PURCHASE OR PAYMENT OF ANY KIND IS NECESSARY TO ENTER OR WIN. Drawing void where prohibited by law. Subject to applicable federal, state, and local laws. Apex Analytics will randomly select a winner after the survey closes. Prize will be one of five Nest Cams. MSRP of $199. Winner will be contacted via email immediately after the drawing.**

Questions? Problems? Stuck? Call Noah Lieb at Apex Analytics to receive survey support - 303.590.9888 ext 103.

C. Winter Participant Survey – Control Group

Nest Thermostat Survey

*** Required Information**

page 1

1. To proceed with this brief survey, please enter your:

(a) Home street address (example: 1234 Main Street) and
(b) 5-digit zip code (example: 97201)

of where your Nest thermostat is installed.

* (a) Street Address

____
____

* (b) Zip Code

____
____

*** 2. How long has your Nest thermostat been installed in your home?** (Select one option)

- ○ Less than three months
- ○ Three to six months
- ○ Over six months but less than a year
- ○ One year or longer
- ○ Not sure / Don't know

*** 3. Is the temperature in your home more or less comfortable now than before you installed the thermostat?** (Select one option)

- ○ Much more comfortable

- ○ Somewhat more comfortable
- ○ Equally comfortable
- ○ Somewhat less comfortable
- ○ Much less comfortable
- ○ Not sure / Don't Know

*** 4. Please rate your overall satisfaction with your Nest thermostat on a 5-point scale where 5 is very satisfied and 1 is not at all satisfied?** (Select one option)

- ○ 1 - Not at all satisfied
- ○ 2
- ○ 3
- ○ 4
- ○ 5 - Very Satisfied
- ○ Not sure / Don't Know

5. How many people currently live in your home? (Select one option)

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7
- ○ 8
- ○ 9
- ○ 10+

6. Has the number of people living in your home changed over the past year? (Select one option)

- ○ No
- ○ Yes - Added 1 Occupant
- ○ Yes - Added 2 Occupants
- ○ Yes - Added 3 Occupants
- ○ Yes - Added 4+ Occupants
- ○ Yes - Lost 1 Occupant
- ○ Yes - Lost 2 Occupants
- ○ Yes - Lost 3 Occupants
- ○ Yes - Lost 4+ Occupants

7. What is the approximate square footage of your home? (Select one option)

- ○ Less than 500 square feet
- ○ Between 500 and 999 square feet
- ○ Between 1,000 and 1,999 square feet
- ○ Between 2,000 and 2,999 square feet
- ○ Between 3,000 and 3,999 square feet
- ○ Over 4,000 square feet

8. Please select the heating system you have in your home (Select one option)

- ○ Gas furnace
- ○ Gas boiler
- ○ Electric furnace
- ○ Heat pump (air or ground source)
- ○ Other (Please specify) __________

9. Does your Nest thermostat control ALL of the heating in your home, or are there other heating zones NOT controlled by your Nest? (Select one option)

- ◯ My Nest controls ALL heating in my house
- ◯ There are other heating zones not controlled by my Nest (e.g. gas fireplace)
- ◯ Not sure / Don't know

10. As a reminder, by completing this survey you have qualified to be entered into a drawing to win a free Nest cam. If you would like to be considered for the drawing, please enter your name and email address below.**

(a) Full name

____
____

(b) Email address

____
____

**** Nest Cam drawing is offered exclusively by Apex Analytics and neither Nest nor Energy Trust are involved with the drawing. Full terms and conditions for this drawing can be found at the following URL: Terms and Conditions. Odds of winning depend on the number of respondents. All Nest owners that complete the survey are eligible for the drawing. NO PURCHASE OR PAYMENT OF ANY KIND IS NECESSARY TO ENTER OR WIN. Drawing void where prohibited by law. Subject to applicable federal, state, and local laws. Apex Analytics will randomly select a winner after the survey closes. Prize will be one of five Nest Cams. MSRP of $199. Winner will be contacted via email immediately after the drawing.**

Questions? Problems? Stuck? Call Noah Lieb at Apex Analytics to receive survey support - 303.590.9888 ext 103.

D. Nest Seasonal Savings Impacts in Oregon: Summer 2016[28]

D.1 Intro

On July 13, 2016, Nest launched its summer Seasonal Savings algorithm targeted at 6,353 thermostats in Oregon under contract from the Energy Trust of Oregon. This report summarizes the estimated cooling impacts of Seasonal Savings on these homes.

D.2 Participation

A total of 12,632 thermostats were identified in the target population of Nest customers. This group was randomly split into treatment and control groups using a stratified sampling of structures at the zip code level. The split resulted in 6,353 thermostats in the participant group and 6,279 thermostats in the control group. The Seasonal Savings algorithm requires a thermostat to be running a cooling schedule in order to qualify for participation. Overall 3,495 of the thermostats (55%) qualified to participate and 2,858 (45%) did not qualify. Half of the not-qualified group (22% of total) did not have an air conditioner controlled by the thermostat. Overall, 2,790 thermostats opted to participate -- 80% of those that qualified.

D.3 Savings Analysis

The impact of seasonal savings was assessed using two approaches -- an analysis of changes in the schedules and setpoints and an analysis of cooling system runtime. The randomized control group provided the opportunity to employ a true experimental design in the analysis by comparing the impacts for the entire targeted participant group (including those that did not qualify or did not opt-in) to the entire control group. This evaluation approach is called a Randomized Encouragement Design (RED).

An RED eliminates self-selection bias, but the interpretation of results is slightly different because it estimates the impact of being in the participant group -- not of actually participating. For example, if the average savings were 4% per participant and there was a 50% participation rate then the analysis would find 2% savings. The RED analysis should provide an unbiased estimate of savings per targeted customer and therefore aggregate savings, but any estimate of savings per opt-in participant requires accounting for the participation rate and does not provide the same level of protection against bias.

[28] This appendix is the memo provided by Nest on January 6, 2017 to the Energy Trust of Oregon for the summer savings analysis.

D.3.1 Setpoints Analysis

The setpoints based analysis involved assessing the change in each customer's cooling setpoints from the day the algorithm launched (July 13, 2016) through the end of October 2016. For each day for each thermostat, the average scheduled setpoint was compared to the average setpoint from the week prior to the algorithm launch (matching on day of week).

The changes in thermostat schedules are shown in Figure 1 for the participants that opted in and for the control group. The graph shows a 7 day moving average. The shading on the right side indicates the period when fewer than 75% of opt-in participant thermostats were still in cooling mode. The graph ends on October 1st -- the last day where at least 50% of participant thermostats were still in cooling mode.

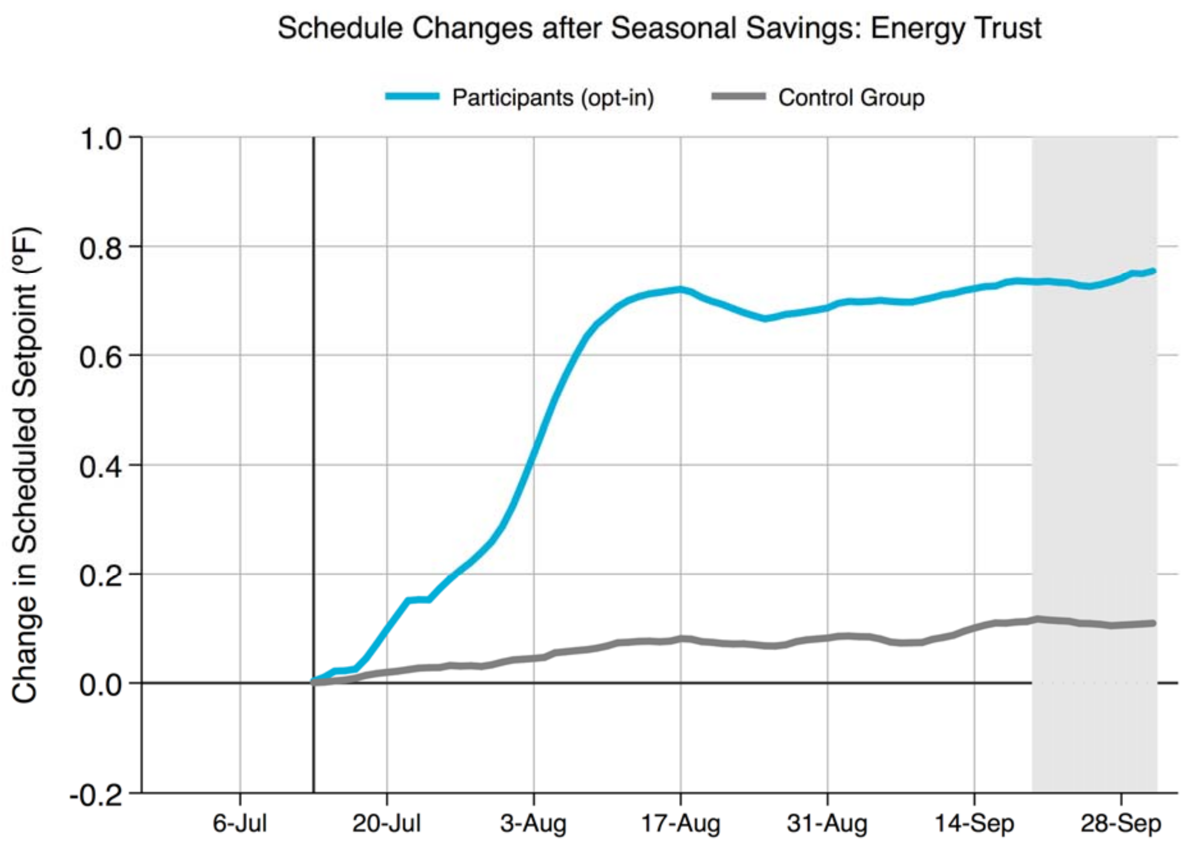


Figure 1. Changes in Scheduled Cooling Setpoints

The graph clearly illustrates the impact of the Seasonal Savings algorithm deployment on the cooling schedule setpoints of participants -- showing an average increase of about 0.7°F about four weeks into the deployment. These changes generally persisted throughout the remainder of the cooling season. The graph also shows a small increase in cooling setpoints for the control group of about 0.1°F.

Figure 1 is designed to illustrate the direct impact of the algorithm on the schedules of participants but it does not show the net schedule changes accounting for the RED design. In addition, the simple comparison of schedules over time does not reflect how cooling loads vary over time. To address these issues, the net change in schedules was analyzed by comparing the change in scheduled setpoints for the entire target population to the change in the control group using a runtime-weighted Difference-in-Difference (DiD) estimator. The DiD calculation was performed using a weighted linear regression with the dependent variable being the change in scheduled setpoint for each date for each thermostat. The sole explanatory variable was a treatment target population indicator variable. Each observation was weighted by the daily cooling runtime and standard errors were calculated that accounted for the clustering of observations within thermostats.

This DiD RED analysis found a net setpoint change of 0.33°F (± 0.03°F 90% confidence interval) per target group participant over the season. A prior Nest analysis of the relationship between setpoints and runtime by climate region estimated a 7.1% average cooling savings per degree change in setpoint for the marine-climate dominated Oregon. Applying this savings estimate to the schedule changes results in an estimated 2.3% cooling savings per target participant. If one assumes that all savings resulted from the opt-in group and rescales the estimate to reflect the opt-in rate, then the savings per opt-in participant are estimated at 5.3% (± 0.5%) of cooling usage.

This 5.3% savings estimate depends strongly on the prior estimate of 7.1% cooling savings per degree change in setpoint. That estimate is especially uncertain in a very mild cooling climate such as Oregon -- where many customers may treat their cooling systems more like on/off devices than relying on scheduled setpoints. To partly address this issue, the analysis was repeated using actual executed setpoints including the impact of manual adjustments and away mode. The estimated net impact declined to 0.24°F, implying cooling savings of 1.7% per targeted participant and 3.9% (± 0.6%) per opt-in participant.

The preceding analysis provides for a sound and fairly precise estimate of the changes in setpoints achieved by Seasonal Savings. But the actual cooling energy savings provided by these changes has greater uncertainty due to variability in how setpoint changes actually affect cooling energy usage. To address this issue, the impact of Seasonal Savings on cooling runtime was directly analyzed using regression modeling.

D.3.2 Regression Analysis of Runtime

The runtime analysis modeled daily cooling runtime as a function of cooling degree days (CDD65), participation group, and post treatment variables and their interactions. The primary model was fit using the RED approach and included thermostat-specific fixed effects. Regression modeling details are provided in the appendix that also includes excerpts from the statistics software output and the command file used to generate the results.

This regression analysis estimated net cooling savings per opt-in participant of 0.9% (± 3.4%). The wide confidence interval indicates that the impacts were too small to measure very accurately for this size sample in this context -- cooling in a very mild climate.

The 0.9% savings estimate per opt-in participant from the runtime analysis appears considerably smaller than the 3.9% estimated from the setpoints analysis, but the difference is not statistically significant. In addition, in absolute terms, the difference works out to less than 15 kWh in savings per participant.

D.3.3 Converting Runtime into kWh Savings

To convert percent savings to kWh savings requires an estimate of the kWh cooling usage over the period. The cooling runtime for the period from the day of deployment (July 13, 2016) through the end of October 2016 averaged 156 hours for the target participant group and 238 hours for the opt-in group. This large difference was expected since the qualification process excluded customers who didn't use cooling. The average connected load of the participant air conditioners was estimated as 2.88 kW based on a Nest internal sizing estimation algorithm. This value is consistent with the 2.9 ton average air conditioner size from the RBSA data provided by CLEAResult.

Based on the 2.88 kW value, post-deployment cooling usage averaged 449 kWh for the target population and 686 kWh for the opt-in participants. The estimated savings can then be calculated as 4 kWh for the runtime analysis and 17 kWh for the setpoints analysis.

D.4 Summary and Conclusions

The table below summarizes the results of the analysis.

	Results per Target Population		Results per Opt-In		
Method	Setpoint Change	% Cooling Savings	Setpoint Change	% Cooling Savings	kWh
Scheduled Setpoints	0.33	2.3%	0.75	5.3%	24
Actual Setpoints	0.24	1.7%	0.54	3.9%	17
Runtime Regression		0.4%		0.9%	4

Seasonal Savings provided measurable changes in cooling schedules and actual setpoints that are consistent with a 3.9% reduction in cooling usage, which equalled about 17 kWh per opt-in participant during this past summer. The regression analysis of cooling runtime estimated savings of 0.9% of cooling use, equal to about 4 kWh per opt-in participant. The difference between these estimates is not statistically significant due to fairly wide uncertainty bounds for the runtime estimate. It's unclear which estimate should be considered more reliable, so Nest recommends averaging the two -- which rounds to 11 kWh per opt-in participant. Based on this value, the aggregate savings are estimated at 29,431 kWh.

It should be noted that some persistence of savings in future cooling seasons is likely due to the more efficient schedules. Those future savings have not been included in this analysis. If the post-deployment savings of 11 kWh are scaled to the average annual cooling degree days, the estimated cooling savings would be 16 kWh per opt-in participant.

D.5 Appendix

This appendix contains some additional technical details about the data analysis and also includes excerpts from a log of outputs from the Stata script that performed the analysis. The data set and accompanying Stata .do file are being shared separately.

The specification of the regression model of runtime is a fairly straightforward approach to estimating impacts along the lines of methods commonly used to analyze utility billing data -- including cooling degree days (base 65) and indicator variables for the treatment group, the post period and interactions between these terms. The specific modeling command used in Stata was:

```
xtreg  coolontime dd dd_treatx post post_treatx post_dd post_dd_treatx, fe cluster(sn)
```

Where treatx indicates intent to treat. Savings were then estimated based on the post_treatx and post_dd_treatx variables.

A wide range of alternative degree day base temperatures were tried and the best fit was found using CDD60 -- a surprisingly low value. This value resulted in slightly higher estimated savings of 1.2% per opt-in rather than the 0.9% using when CDD65. The reported model used the more conventional CDD65 instead because the pooled approach can lead to a lower CDD base temperature than typical usage patterns and also because CDD65 is more commonly used. But an argument could be made either way.

An alternative model was also fit -- one that included date fixed effects in addition to thermostat fixed effects. One advantage of this alternative specification is that all terms except a post treatment indicator variable could be dropped from the model. The resulting savings estimate was indistinguishable from the primary model estimate (less than a <4% relative difference) implying that either approach could be used.

Stata log excerpts -- setpoints and runtime based analysis

```
seasonalsavings_summer16_etomodel.do

. noi tab participation  if perserial==1 & treatx==1

  participation |      Freq.     Percent        Cum.
----------------+-----------------------------------
Did Not Qualify |      2,858       44.99       44.99
 Did Not Accept |        705       11.10       56.08
       Accepted |      2,790       43.92      100.00
----------------+-----------------------------------
          Total |      6,353      100.00
```

```
. * Executed setpoints reduction
. reg dt_set treatx [aw=coolontime] if  post==1 & dt_setgt5==0, cluster(sn)
(sum of wgt is   1.7861e+06)

Linear regression                                      Number of obs =  389959
                                                       F(  1,  7895) =  120.94
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.0083
                                                       Root MSE      =  1.2994

                                  (Std. Err. adjusted for 7896 clusters in sn)
------------------------------------------------------------------------------
             |               Robust
      dt_set |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      treatx |   .2378819   .0216309    11.00   0.000     .1954796    .2802841
       _cons |  -.2038401   .0145018   -14.06   0.000    -.2322674   -.1754128
------------------------------------------------------------------------------

. * runtime regression analysis
. noi xtreg  coolontime dd dd_treatx post post_treatx post_dd post_dd_treatx, fe cluster(sn)

Fixed-effects (within) regression               Number of obs      =   1710128
Group variable: sn                              Number of groups   =     11829

R-sq:  within  = 0.3626                         Obs per group: min =         1
       between = 0.0290                                        avg =     144.6
       overall = 0.2549                                        max =       153

                                                F(6,11828)         =   2963.93
corr(u_i, Xb)  = -0.0104                        Prob > F           =    0.0000

                                  (Std. Err. adjusted for 11829 clusters in sn)
--------------------------------------------------------------------------------
               |               Robust
    coolontime |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------+----------------------------------------------------------------
            dd |   .3837325   .0044323    86.58   0.000     .3750445    .3924205
     dd_treatx |  -.0056386   .0062214    -0.91   0.365    -.0178335    .0065564
          post |  -.1951449   .0105493   -18.50   0.000    -.2158232   -.1744666
   post_treatx |  -.0018497   .0143702    -0.13   0.898    -.0300177    .0263182
       post_dd |   .0109107   .0027109     4.02   0.000     .0055968    .0162246
post_dd_treatx |  -.0018373   .0038803    -0.47   0.636    -.0094433    .0057687
         _cons |   .9129218   .0073247   124.64   0.000     .8985641    .9272794
---------------+----------------------------------------------------------------
       sigma_u |   1.810264
       sigma_e |  2.1246488
           rho |  .42061052   (fraction of variance due to u_i)
--------------------------------------------------------------------------------
```

```
. * calculate percent savings accounting for the fact that baseline use would have been higher by
      amount of savings
. nlcom -(_b[post_treatx]+`postddtreat'*_b[post_dd_treatx])/(-
      (_b[post_treatx]+`postddtreat'*_b[post_dd_treatx])+`cooluse_target')

       _nl_1:  -(_b[post_treatx]+2.278523607865907*_b[post_dd_treatx])/(-
      (_b[post_treatx]+2.278523607865907*_b[post_dd_treatx])+1.584322804800829)

------------------------------------------------------------------------------
  coolontime |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _nl_1 |   .0037954   .0091307     0.42   0.678    -.0141004    .0216911
------------------------------------------------------------------------------


Model                      save_hrs se   %Save   +/- %Save  base_hrs     HoursSave  kWh/unit kWhAgg
Target v Control (ITT)      0.006  0.015  0.38%  +/- 1.50%    1.590          0.6     1.7
      10,800
ITT per Opt-In ( 43.9%)     0.014  0.033  0.86%  +/- 3.42%    2.234          1.3     3.9
      10,800

Post deployment cooling usage
Group      CDD    Days  RuntimeHrs  kWh      Agg kWh
Target     251    110       156     448      2,845,658
Opt-In     251    110       238     685      1,910,743

ITT Net Schedule Setpoints Impact per offered =0.330 +/-0.031
   Savings per Offered= 2.34%  +/- 0.22% (90% ci)

ITT Net Schedule Setpoints Impact per Opt In =0.751 +/-0.070
   Savings implied per Opt-In= 5.33%  +/- 0.50% (90% ci)   (Opt-in Rate= 43.9%)

ITT Net Executed Setpoints Impact per offered =0.238 +/-0.036
   Savings per Offered= 1.69%  +/- 0.25% (90% ci)

ITT Net Executed Setpoints Impact per Opt In =0.542 +/-0.081
   Savings implied per Opt-In= 3.85%  +/- 0.58% (90% ci)
   kWh Savings: Opt-In = 17.2    Aggregate Savings=    48,062
```

E. Nest Seasonal Savings Impacts in Oregon: Winter 2016-2017[29]

E.1 Intro

On December 8, 2016, Nest launched its winter Seasonal Savings algorithm targeted at 9,745 thermostats in Oregon under contract from the Energy Trust of Oregon. This report summarizes the estimated heating impacts of Seasonal Savings on these home

Seasonal Savings is a software algorithm that offers customers an opportunity to make their heating schedules more efficient through a series of very small adjustments to the scheduled temperatures over a three week period. The algorithm results in more energy efficient heating schedules going forward. Customers are offered the program on their thermostat and through the Nest phone app and must opt-in to participate. This report summarizes the estimated heating impacts of Seasonal Savings in Oregon.

E.2 Participation

A total of 16,163 thermostats were identified in the target population of Oregon Nest customers. The target population was randomly split into treatment and control groups using a stratified sampling of structures at the zip code level with a 60%/40% split between treatment and control. The split resulted in 9,745 thermostats in the target treatment group and 6,418 thermostats in the control group.

The algorithm was deployed in December 8, 2016 and overall 88% of the 9,745 target thermostats qualified to participate (i.e., were online and running a heating schedule) and 78% of the qualified thermostats had the customer opt to participate. In total, 6,746 thermostats opted to participate in the Seasonal Savings event, equal to 69% of the target population. These 6,746 thermostats were located in 6,302 homes (an average of 1.07 thermostats per home)

E.3 Savings Analysis

Seasonal Savings makes changes to customer heating schedules which then leads to more efficient heating setpoints which then leads to a reduction in heating system runtime hours. This evaluation assesses each of these impacts.

The impact of seasonal savings was assessed using two approaches -- an analysis of changes in the schedules and setpoints and an analysis of heating system runtime. The randomized control group provided a true experimental design for the evaluation -- comparing the impacts

[29] This appendix is the memo provided by Nest on September 11, 2017 to the Energy Trust of Oregon for the winter savings analysis.

for the entire targeted participant group (including those that did not opt-in) to the entire control group. This evaluation approach is called a Randomized Encouragement Design (RED).

An RED eliminates self-selection bias but it directly estimates the impact of being in the target participant group -- not the impact of actually participating. To estimate the savings per opt-in, the RED results are adjusted for the opt-in rate. For example, if the RED analysis found 2% savings from being in the target group and there was a 50% participation rate then the estimated savings per opt-in customer would be 4% (2% / 50% = 4%).

Setpoints Analysis

The setpoints based analysis involved assessing the change in each customer's heating setpoints from the day the algorithm launched (December 8, 2016) through the end of April 2017. The daily average scheduled thermostat setpoints for the target population and control group are shown in Figure 1.

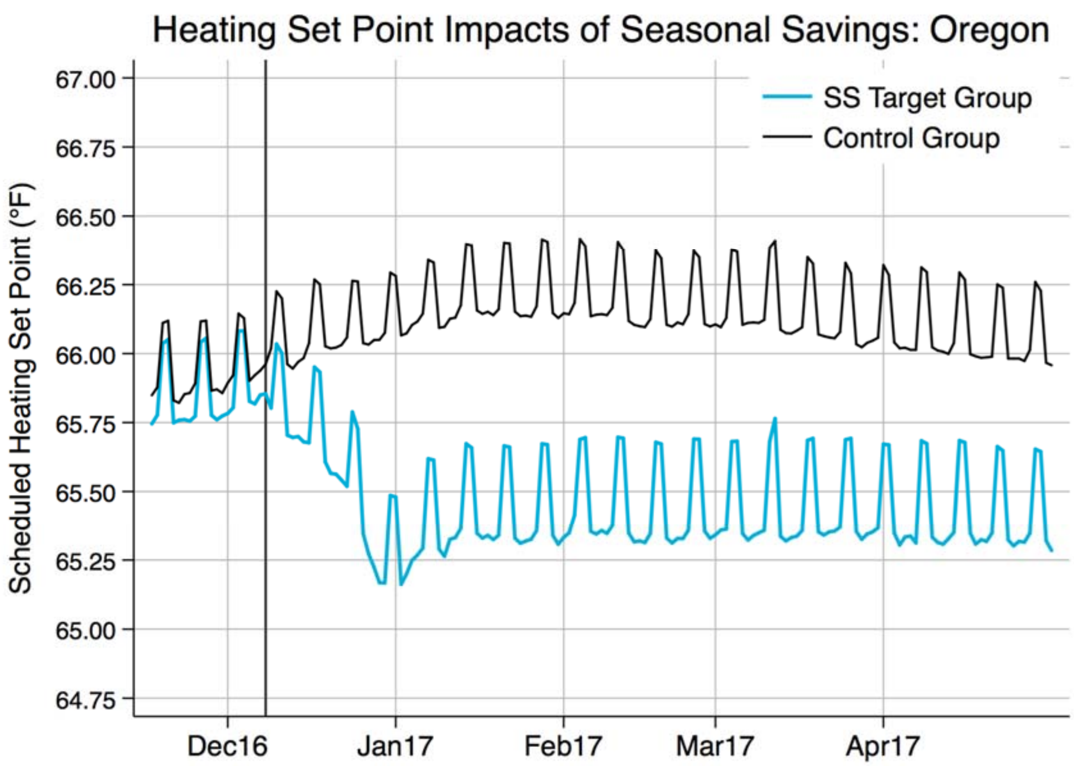


Figure 1. Scheduled Heating Setpoints over the season

The vertical line indicates the date the algorithm was deployed. The up and down pattern is largely due to differences between weekends and weekdays. The graph clearly shows the three week period of small schedule adjustments made by Seasonal Savings.

The difference between the groups appears to taper a little over the season showing some potential takeback effect.   Figure 2 directly plots the difference between the two lines in Figure 1 -- providing a better illustration of the schedule impacts. Seasonal Savings has a clear impact during deployment and there appears a modest degradation in savings.

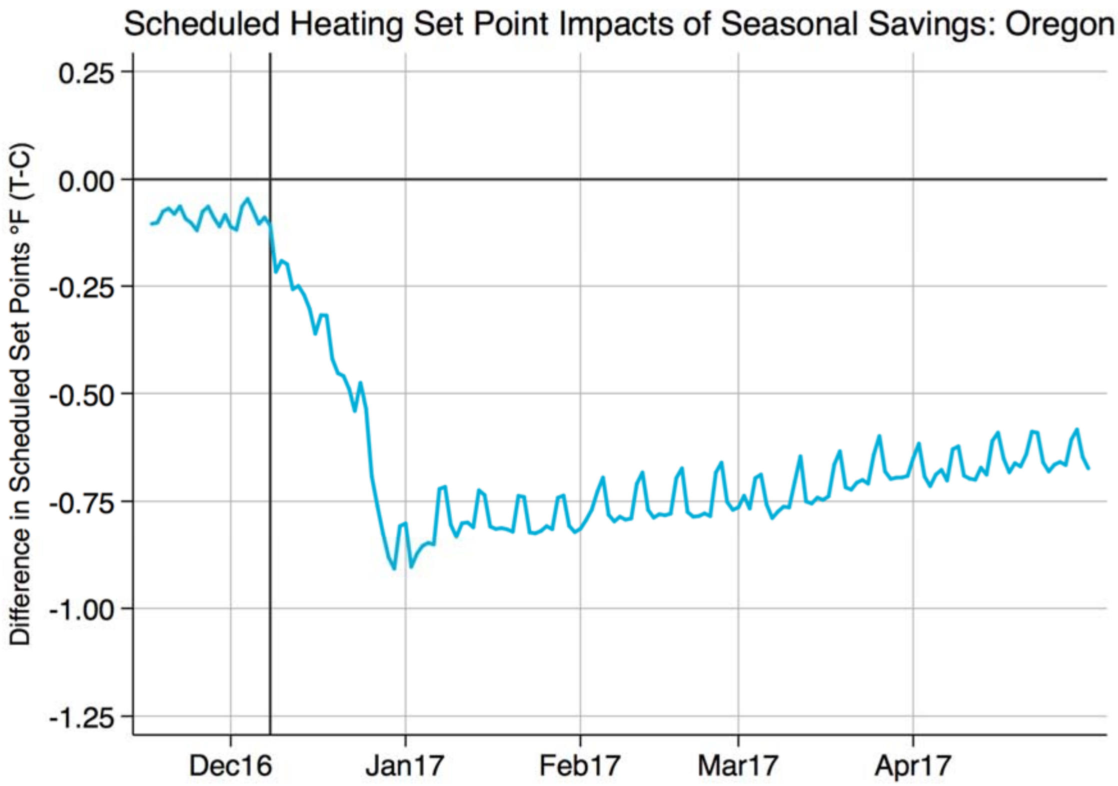


Figure 2. Difference in Scheduled Setpoints: Target Treatment Group minus Control Group

Seasonal Savings directly affects customer setpoint schedules, but the setpoints that are actually executed often differ from the schedule due to either manual adjustments (via dial or app or web) or to the auto-away feature based on occupancy detection of the Nest Learning Thermostat.

Figures 3 and 4 repeat the graphs in figures 1 and 2 but using the actual executed setpoints. The data are noisier but the impacts from the algorithm are still clear and there no longer seems to be any degradation of impacts over the season.

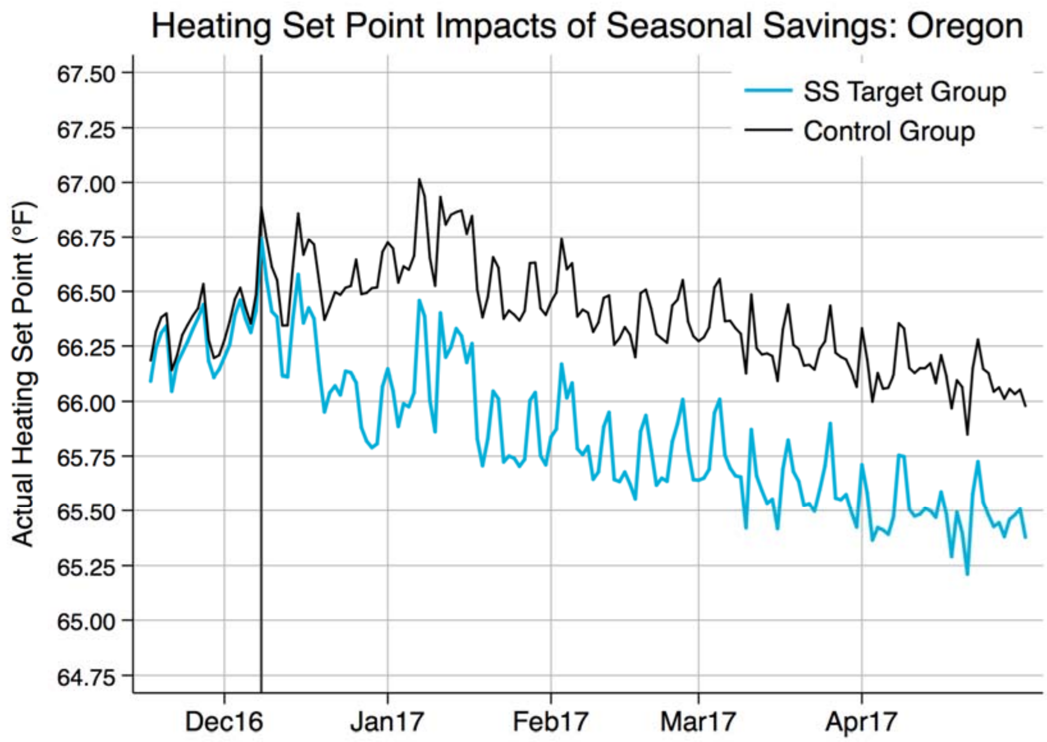


Figure 3. Actual Heating Setpoints over the season

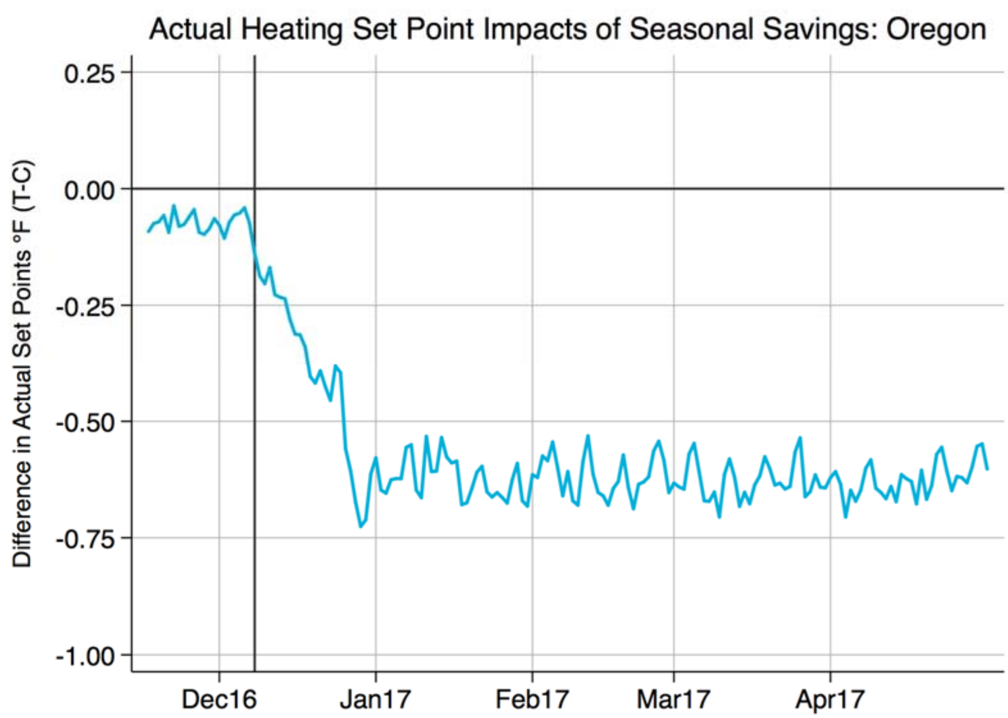


Figure 4. Difference in Actual Setpoints: Target Treatment Group minus Control Group

The net change in setpoints during the season was quantified using a regression analysis of setpoints with both thermostat and date fixed effects. The model estimated the net impact on the entire target group. The impact per opt-in customer was then calculated by dividing this result by the opt-in rate. The analysis found a net reduction in scheduled setpoints of 0.62°F per targeted participant, equal to 0.83°F per opt-in (74% opt-in rate for customers in the analysis). For executed setpoints, the reduction averaged 0.52°F per targeted participant and 0.69°F (±0.05°F) per opt-in participant.

The impact of setpoint changes on heating runtime was estimated at 6.4%/°F using a regression model of heating runtime hours as a function of outdoor temperature and actual heating setpoint using data for all target and control customers. An alternative estimate was calculated based on the physics of heat loss, as equal to the percent change in the average indoor - outdoor temperature difference during the season per degree, adjusted for the temperature increase created by solar and internal heat gain. This calculation estimated heating savings of 1/(24.4-9.3) = 6.7%/°F -- nearly identical to the statistical estimate. Based on these two estimates, the 0.69°F reduction in average executed setpoint is estimated to save 4.5% of heating usage per opt-in customer.

Analysis of Runtime

The heating runtime recorded by the thermostats can also be used to more directly assess the impacts produced by Seasonal Savings. Figure 5 shows the daily heating runtime averaged by week for the target participant group and the matched controls.

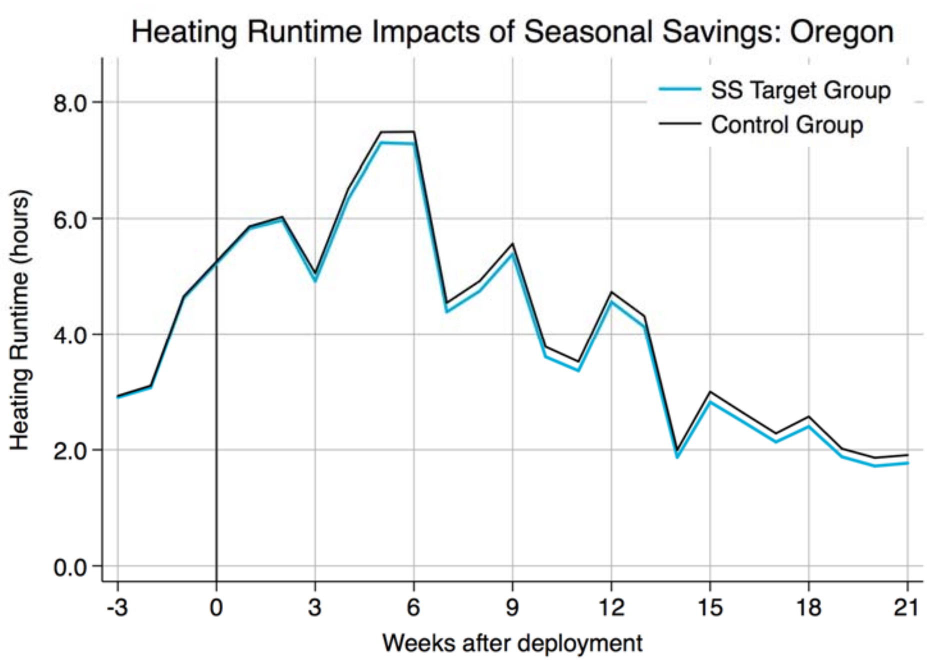


Figure 5. Average Daily Heating Runtime by week: Target and Control Groups

The heating runtime is nearly identical for the two groups in the three weeks prior to the deployment and then the participant runtime becomes noticeably lower than the controls -- the blue line drops below the black line. Figure 6 directly plots the difference in average daily heating runtime between the two groups -- i.e., the difference between the two lines of Figure 5.

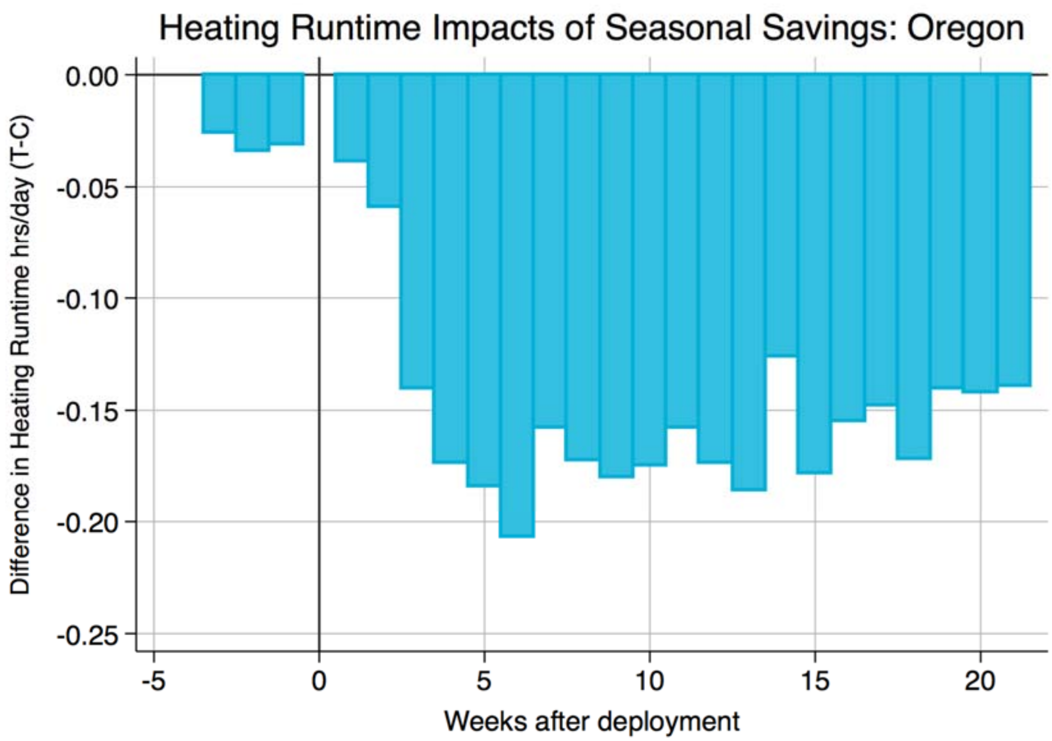


Figure 6. Difference in Average Daily Heating Runtime: Target minus Control Group

The difference in heating runtime is quite small prior to the Seasonal Savings deployment but then grows sharply over the next few weeks as the algorithm deploys and then levels out at about 0.15 hours/day. Comparing this value to the average hourly runtimes shown in Figure 5 indicates about a 3%-4% reduction in average runtime for the full target population.

The impacts shown in Figure 6 can be better quantified using regression analysis similar to methods commonly employed to analyze utility meter data. The primary regression model followed a common specification -- fitting daily heating runtime as a function of heating degree days (HDD base 60F); and indicator variables for the target group and the post-treatment period and including all interactions between variables as well as thermostat fixed effects[30].

The primary dataset (extended from the original report to include May 2017) included 3,082,623 daily observations from 9,144 target participants and 6,024 control customers.

[30] The Stata command was: `xtreg heat_hrs dd ddXtreat post postXtreat postXdd postXddXtreat, fe  cluster(serial_number)`

The degree day analysis estimated net heating savings of 4.75% ±0.95% -- nearly identical to the 4.5% estimated from the setpoints analysis. Alternative model specifications were also explored including a model of post-deployment data that used pre-deployment runtime as an explanatory factor and date fixed effects which estimated nearly identical savings of 4.86% ±0.92%. Although the post-only model provided a slightly smaller standard error, the degree day model results are considered to provide the best estimates of program impacts because of its greater similarity to common program evaluation methods and because it was the planned evaluation method and was employed in the prior summer analysis.

Energy Savings

The estimated percent heating savings were converted to energy savings based on the actual heating runtime of the participants during the period (December 8, 2016 through May 31, 2017) and using estimated heating system input rates of 70 kBtu/hr for gas heating systems with 560W of electric use (air handler plus other electronics), and 3 kW for heat pumps. The results of these calculations are shown in the table below.

Table 1. Energy Savings Summary

		Runtime Hours		Energy Savings per opt-in		Aggregate Energy Savings	
Heat Type	# opt-in	Post Period baseline	Saved	therms	kwh	therms	kWh
Gas	6,276	589	28	20	16	122,810	98,248
Heat Pump	440	886	42	0	126	0	55,570
Total	6,716					122,810	153,818

Gas heated homes that opted to participate in Seasonal Savings are estimated to have saved 28 hours of furnace runtime which equals 20 therms of natural gas and 16 kWh of electricity (primarily from reduced air handler power use). About 7% of the participants had heat pumps and are estimated to have reduced runtime by 42 hours which equals 126 kWh over the season. Aggregate savings were 122,810 therms of natural gas and 153,818 kWh of electricity.

These savings results do not include any savings achieved after May 2017 (i.e., no persistence into the following heating season) -- a full accounting of savings would likely result in a larger total impact.

*Note: This study is specific to the Seasonal Savings program deployed by Nest for eligible, participating Oregon customers during the 2016-17 heating season. The results found herein do not necessarily represent expected results from the Seasonal Savings program under different conditions.

F. Participant Survey Recruitment Email

EMAIL 1/EMAIL 2
SUBJECT:
Tell us how you like Seasonal Savings. You could win a Nest Cam.

HEADLINE
How'd it go?

This past summer, Nest worked with Energy Trust of Oregon (ETO) to offer you Seasonal Savings.

And we want to know: Did you try it? How'd it go?

Tell us with a quick 5-minute survey. We'll use your insights to make these programs better and easier for you next season. ETO will enter you into a drawing to win one of five Nest Cams (https://nest.com/camera/meet-nest-cam/) after completing the survey.

TAKE OUR SURVEY

EMAIL 3

SUBJECT:
Tell us how you like your Nest Thermostat. You could win a Nest Cam.

HEADLINE
XXX

Nest is working with Energy Trust of Oregon (ETO) to learn about your experiences with your Nest Thermostat.

And we want to know: How do you like it?

Tell us with a quick 5-minute survey. ETO will use your insights to improve programs that help utility customers save energy and money. ETO will enter you into a drawing to win one of five Nest Cams (https://nest.com/camera/meet-nest-cam/) after completing the survey.

TAKE OUR SURVEY

Nest Cam Indoor image