Energy Trust of Oregon
Nest Thermostat Heat Pump Control
Pilot Evaluation

Prepared for Energy Trust of Oregon

Prepared by Apex Analytics LLC

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MEMO

Date: October 22, 2014
To: Board of Directors
From: Marshall Johnson, Residential Sector Manager, Existing Homes Program
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Subject: Staff Response to the Nest Thermostat Heat Pump Control Pilot Evaluation

The evaluation of the Nest thermostat heat pump control pilot showed that the Nest is a viable technology that received high marks from participants and achieved significant energy savings in homes heated with electric air source heat pumps. The realized electric savings are in line with engineering estimates for other advanced heat pump controls. Unlike other advanced heat pump controls, though, installation and setup of the Nest is much simpler and potentially less expensive. Although the pilot tested the Nest under ideal installation conditions by using a direct-install model, we believe that contractors, and in some cases homeowners, could be just as successful when paired with a simple, electronic verification process and customer support. There were some technical problems encountered early in the pilot, but these were quickly identified and resolved. In the end, the vast majority of pilot participants were happy with the Nest thermostat.

With the success of the pilot, the Existing Homes program is now planning to accelerate the deployment of the Nest and similar advanced thermostats in homes with heat pumps. The program currently offers an incentive for contractors to install advanced controls on existing heat pumps, which the Nest qualifies for, but this measure has not seen a lot of uptake. The program is working with PGE's contractor network to explore a variety of options to boost uptake of advanced thermostats with heat pumps. For instance, there is currently an incentive for contractors to install advanced controls with new, program qualifying heat pumps (≥0.9 HSPF) and there may be an opportunity to integrate advanced thermostats into this measure. A big expansion is coming in the form of a new incentive for contractor installed advanced controls with new, non-program qualifying heat pumps (<9.0 HSPF). This measure could provide substantial electric savings for less efficient new systems and could reach a large number of customers that might not otherwise be touched by the program.

An incentive for self-installed advanced thermostats for existing heat pump systems will be rolled out by the program beginning in 2015. Although self-install has a much lower cost, it may not always be successful, so some type of verification will be required along with follow up and technical support from the program or trade ally contractors. This type of incentive has the added benefit of potentially reaching a larger audience than contractor installs. Direct install by the program has also been discussed as a potential option to be deployed in strategic market niches.

Regardless of the delivery method, any future incentives for advanced thermostats should require customers to pay a portion of the cost, which will help limit participation to those who really want one and are willing to learn how to use it. This could potentially increase the average energy savings and customer satisfaction above what was observed in the pilot. Higher savings may also be realized by targeting electric customers that are more tech savvy and who have

more opportunity for savings, including those with higher annual usage, lower incomes, or that live in manufactured homes.

At the time of the pilot, the Nest was the only advanced thermostat that had the ability to adaptively lockout a heat pump's backup electric resistance heat based on weather conditions. However, with the rapid development of products in the advanced thermostat market, this is likely to change. The program should create a measure specification for advanced thermostats in heat pump applications and develop a process for vetting new products that have similar capabilities to the Nest and may provide comparable electric savings. Once there are clear criteria for products to qualify for the incentives, the measure can be expanded as new products become available.

The success of the Nest in heat pump homes got Energy Trust interested in whether advanced thermostats could produce energy savings in homes heated with gas furnaces. The opportunity for savings is lower with gas furnaces because they do not have a control challenge comparable to a heat pump's use of backup heat. However, there may still be some opportunity for savings in gas heated homes by setting back the temperature more frequently using strategies like automated schedule optimization, occupancy sensing, remote control, and feedback on energy use. A new pilot was launched in October 2014 to test 400 advanced thermostats in gas heated homes and determine the resulting gas savings and customer reactions. The Nest and Honeywell Lyric thermostats were selected for the pilot.

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1. Executive Summary

This report details the results of the implementation and evaluation of Energy Trust of Oregon's Nest Thermostat Heat Pump Control Pilot. The pilot ran from the fall of 2013 through the spring of 2014, covering one entire heating season. A total of 185 Nest thermostats were installed, free-of-charge, in participating air-source heat pump-heated homes. The primary goals of the evaluation were to determine if installing the Nest thermostat is a viable strategy for properly controlling central electric heat pump operation in residential settings, and how much electricity it saves during the heating season. In addition, the evaluation effort is being used to help determine how customers interact with the Nest thermostat, their level of satisfaction with the device, and its control of the comfort of their homes.

There were three primary components associated with this evaluation effort: staff interviews, participant surveys, and a billing analysis. Staff interviews were conducted with the goal of collecting insight and feedback from those staff members most familiar with the pilot and to supplement the program summary report compiled by the program implementation contractor, CLEAResult. Interviews were held with four members of CLEAResult, and one was held with a member of the Energy Trust team. There were two separate participant surveys administered to the entire population of Nest participants, one in January of 2014 (midpoint of the heating season), with a very high response rate (110 total completes, or 62%), and one at the end of the heating season for those who had completed the first survey (a 79% response rate). Participant surveys were conducted to understand participant usage, perceptions, satisfaction and reactions to the Nest device, as well as changes in these metrics over time as participants became more familiar with the devices . Finally, a billing analysis was performed to estimate the impacts of the Nest device on electric usage. The analysis was performed by Energy Trust evaluation staff and reviewed by Apex Analytics.

The key findings associated with this report include the following:

- The preliminary, weather-normalized, annual electric savings attributable to the Nest thermostat were 781 kWh per year or 4.7% of total electric usage and 12% of heating load. Compared to the predicted savings of 836 kWh per year, the realization rate was 93%. Further sub-group analysis showed some interesting trends (some of these findings were based on relatively low sample sizes and lacked statistical significance):
  - Portland Metro area homes, which tended to have more and younger occupants, realized the highest savings.
  - Manufactured homes, which tended to be smaller, have lower household income, and use less energy, appeared to have very high savings, nearly double the overall average.
  - Homes where the Nest thermostat replaced a programmable thermostat appeared to save more energy than homes where it replaced a non-programmable thermostat, providing a directional indicator that Nest's scheduling features may boost savings.

  - The lowest income category, which tended to have more manufactured homes and less education, had the largest percent savings of any subgroup that the team analyzed. This income category also had very large and significant differences in savings from the other two income categories.
  - The highest usage category, with the most opportunity for reduction, achieved the largest absolute electric savings, nearly double the overall average and statistically significant.
- There were successes and failures during the recruitment and installation phases of the pilot.
  - Site visits were conducted at 222 homes, resulting in 185 thermostat installations. Thirty-seven homes were disqualified on site due to various technical issues. Eleven of the 185 thermostats installed were removed at some point during the pilot period due to technical issues, and another 22 required a second visit to get them functioning properly.
  - The goal was to have 200 homes participate in the pilot; ultimately 174 homes had the Nest installed for the duration of the pilot study. Given that there were 1,589 participants selected as the treatment group population to recruit from, this translates to an achieved installation rate of 11%.
- Participants were very satisfied with the pilot study and the Nest device.
  - The satisfaction ratings with the installation process were overwhelmingly positive: over 90% of respondents indicated a satisfaction rating of either a 4 or 5 (out of 5).
  - Satisfaction with Nest thermostats was relatively high, as 79% of respondents in the first survey and 89% in the second provided satisfaction ratings of either 4 or 5 out of 5. Only 4% (three respondent's total) provided a rating score of 2 or below in the second survey compared to 9% (nine respondents total) in the first survey. Participants also felt increased comfort in their homes.
  - Over 60% of survey respondents in both the first-round survey (61%) and second-round survey (66%) described the temperature of their home to be either "somewhat more comfortable" or "much more comfortable" after installing the Nest thermostat. The percentage of survey respondents who felt the temperature was either "much less comfortable" or "somewhat less comfortable" decreased from 17% to 6% between the first and second surveys, suggesting that 1) the Nest thermostat participants learned how to better utilize the Nest thermostat features and functionality or 2) technical issues encountered during first survey had been resolved by the second survey.
- The most cited reason for participation in the Nest thermostat study was to lower energy bills, with 88% of respondents listing it among their top three reasons for participating. The next most frequent response provided was to save energy (49%), followed by increasing the comfort of the home (45%).
- The non-energy benefits of the Nest were perceived to be very large, as 34% of all respondents believed the Nest thermostat was worth the full retail price, even if no energy savings were realized. While the sample size is relatively small (at only 51 survey respondents who answered

this question), the results do suggest that many study participants place a good deal of value in the Nest thermostat's features, including remote access and automation.

- The vast majority, comprising 92% of all second survey respondents, found operating the Nest thermostat to be either "somewhat easy" or "very easy." Only 7% of second survey respondents found operating the Nest thermostat to be "somewhat difficult."
- The favorite aspect of the Nest thermostat was the energy savings (45% of all second survey respondents); the ability to control remotely (27%) and Nest's auto-learning feature (20%) were also popular aspects of the Nest thermostat.
- Some of the Nest thermostat features and functionality were used by most of the participants, though some features were used more frequently.
  - The Nest Leaf (94%), AutoSchedule (92%), Energy History (88%), and Early On (83%) features were frequently used by the study participants.
  - More than half of participants, in both the first- and second-round surveys, reported adjusting their thermostat with a smart phone or online, as well as using the filter reminder feature.
- In terms of the perceived usefulness of the various features, the AutoSchedule feature was perceived to be the most useful, with 81% of survey respondents in the first survey and 87% in the second survey reporting that the feature was either "somewhat useful" or "very useful." The Nest Leaf was the next most cited feature (81% first survey, 84% second survey), followed by the Energy History feature (74% first survey, 83% second survey).
- When the Nest thermostat was installed, the Heat Pump Balance function was preset to "Max Savings." Only a small minority of respondents (8% first survey, 13% second survey) reported changing this setting. Changing this setting has a negative impact on energy savings, as Nest Labs confirmed that backup heat runs approximately twice as much when the setting is not "Max Savings". Furthermore, Nest labs also confirmed that 14% of users switched off the Max Savings setting, which is in line with the 13% of the second survey sample.
- The AutoAway function, which minimizes heating when no one is home, was preset to "On" when the unit was installed. In both the first and second surveys, a minority of respondents, 19% and 20%, respectively, indicated changing this setting.

2. Introduction

The Energy Trust of Oregon (ETO) is an independent nonprofit organization dedicated to helping utility customers benefit from saving energy and generating renewable power. The Energy Trust was formed in March 2002, charged by the Oregon Public Utilities Commission with investing in cost-effective energy efficiency, helping to pay the above-market costs of renewable energy resources, delivering services with low administrative and program support costs and maintaining high levels of customer satisfaction. Customers of all four Oregon utilities – Portland General Electric, Pacific Power, NW Natural and

Cascade Natural Gas – pay a dedicated percentage of their utility bills to support a variety of energy-efficiency and renewable energy services and programs.

In the fall of 2014 the Energy Trust, as part of their energy efficiency efforts, decided to launch the Nest Thermostat Heat Pump Control Pilot. The Nest Pilot was proposed as a potential cost-effective alternative to Energy Trust's advanced heat pump controls measure, which was Energy Trust's first effort to achieve energy savings by preventing backup resistance heat at temperatures in which the heat pump compressor could effectively operate. In November 2014, the Energy Trust contracted with Apex Analytics LLC to conduct an evaluation of their Nest Pilot. This report documents the evaluation activities and results for this pilot and is organized into the following several key sections:

- The Introduction Section provides a brief introduction and the overall goals and objective for this report
- The Background Section provides an overview and details about the Nest thermostat and the Nest Pilot (including participant selection, recruitment, and thermostat installation)
- The Methodology Section provides detailed methodological and analytical approaches used for this evaluation
- The Findings Section provides the results from the various evaluation activities
- The Conclusions and Recommendations Section offers overarching highlights from the findings section and coalesces these findings into actionable recommendations

2.1 Evaluation Goals and Objectives

The primary goals of the evaluation are to determine if installing the Nest thermostat is a viable strategy for properly controlling central electric heat pump operation in residential settings, and to determine how much electricity it saves during the heating season. In addition, the evaluation effort is being used to help determine how customers interact with the Nest thermostat, their level of satisfaction with the device, and its control of the comfort of their homes. Ultimately, this evaluation is one component that will help determine whether the Nest thermostat can achieve cost-effective electric savings from heat pumps and should be incentivized through Energy Trust's Existing Homes program. The primary research questions are listed with their accompanying tasks in Table 1 below.

Table 1. Primary researchable questions and the associated tasks

Research Questions:	Task:
What was the achieved installation rate of Nest thermostats and what were the characteristics of participants and their homes?	CLEAResult report, Staff Interviews, Participant Survey
What is the staff/installer perspective on the pilot? Are there issues with eligibility or installation challenges (e.g., issues with	CLEAResult report, Staff Interviews, Participant Survey

eligibility, or Wi-Fi connection problems)? Do customers seem engaged and committed?	
How do customers use and interact with the thermostats? Which functions do they use?	Participant Survey
Are customers satisfied with the Nest thermostat and the comfort of their homes? Do customers seem engaged and committed?	Participant Survey
What do customers like or dislike about the Nest thermostat?	Participant Survey
Were customers motivated by the potential energy savings?	Participant Survey
Does the Nest thermostat cause customers to change their behavior? Does it reduce heat pump run time in customer homes? Does it reduce cutover to resistance heat?	Participant Survey and Billing Analysis
To what degree do customers change the efficiency/comfort settings in the Nest thermostat (control for the heat pump cutover) and what is the impact on energy savings?	Participant Survey and Billing Analysis
Which Nest functions appear to be the most important in saving energy?	Billing Analysis
How much energy does the Nest thermostat save when installed in homes with whole house electric heat pump systems?	Billing Analysis

3. Background

The Nest Pilot was conceived and implemented in the fall of 2013 by Energy Trust's Existing Homes program, which is operated by the program management contractor, CLEAResult. The Nest Pilot was proposed by CLEAResult as a potential cost-effective alternative to Energy Trust's advanced heat pump controls measure. The original heat pump advanced controls measure (HPAC, which transitioned from pilot to provisional status in January 2013) was Energy Trust's first effort to achieve energy savings associated with proper installation of an outdoor temperature sensor and setting the thermostat to lockout energy-intensive backup resistance heat at temperatures in which the heat pump compressor could effectively operate. Unfortunately, contractor uptake of the initial HPAC measure was low even though the market size is potentially large. Furthermore, the Northwest Energy Efficiency Alliance's 2005 analysis of heat pump performance, which served as the motivation for a heat pump control measure, showed that many residential HVAC contractors did not install proper heat pump controls (or did not set them properly) to switch over to backup resistance heat at the appropriate temperature.

At the time of the pilot study, the Nest thermostat was the only commercially available programmable thermostat that actually could be installed and lock out the resistance heat without the installation of an outside temperature sensor[1]. Furthermore, the Nest uses learning algorithms to optimize the compressor runtime so as to minimize the use of backup resistance heat which is more advanced feature than a straight lockout temperature threshold. There is also a behavioral component to the Nest that was assessed as a component of the pilot. The Nest thermostat has a heat pump balance point setting, which controls how frequently the heating system cuts over to backup resistance heat. The balance point was initially set by the installer to "Max Savings," to minimize reliance on backup heat to achieve the target temperature and participants were asked not to change this setting. However, customers can either go online or directly adjust the device and set this control for "Max Comfort," "Balance," or "Off[2]" and the Nest's tolerance for using the backup resistance heater changes accordingly. This set point may significantly impact the realized savings.

The Nest has a number of other potentially valuable energy management features, including the ability to learn the occupant's schedule and a motion sensor that detects if occupants are away. Additionally, the Nest thermostat has a dial that allows the user to interact with it similar to a manual thermostat. There are additional features that can be accessed using a smart phone-based application, or online, allowing homeowners to adjust their thermostat remotely and monitor how often their heat pump is

[1] Energy Trust anticipates that other thermostats that are coming to market may have this functionality too.

[2] When the heat pump balance is set to "off" a balance point temperature must be entered manually and Nest no longer attempts to optimize compressor versus backup heat run times. In this mode it acts exactly like a standard heat pump lockout control.

running. The following list details the additional potential energy saving features (with description) that the Nest thermostat offers:

- AutoAway: This function minimizes heating when no one is home. When the thermostat was installed, this function was turned on.
- Early On: This function starts heating or cooling early so the home will be at the requested temperature at the time specified.
- Filter Reminders: This function reminds the user to change their air filter based on how many hours their heating system has been running
- AutoSchedule: This function remembers what temperatures keep the user comfortable and creates a custom schedule for their home
- Energy History: This function allows the user to see exactly when their system was on and see a summary of their entire month's energy use
- Nest Leaf: The Nest "Leaf" appears when the user turns the Nest thermostat to a temperature that will save energy.

The Regional Technical Forum (RTF) has approved heat pump commissioning measures, but there is still significant uncertainty around the savings and cost effectiveness. Savings estimates for Energy Trust's heat pump advanced controls measure were developed by Ecotope and were applied to the Nest thermostat pilot[3]. The weighted average savings were estimated to be about 836 kWh per year in Climate Zone 1 and 1,541 kWh per year in Climate Zone 2. When installations are weighted 3:1 by climate zone to account for more projects expected in Climate Zone 1 than Climate Zone 2, the weighted average savings are 1,012 kWh. The measure is marginally not cost effective in Climate Zone 1 (the B/C ratio to two digits is .94), but promotion as a pilot only in Climate Zone 2 would be problematic due to scale. Furthermore, the unit may be found to be cost effective in Climate Zone 1 under alternative cost and savings scenarios.

The cost of the previous heat pump advanced control measure with the outdoor temperature sensor installation was approximately $400 for the thermostat and labor. The cost of the Nest thermostat and installation were approximately $600 per home for the purposes of this study (approximately $250 for the Nest thermostat and another $350 for the installation[4]). A direct-install implementation model was

[3] Ecotope report: REVISED Blessing Memo for Heat Pump Advanced Controls Pilot (HPAC) including web enabled thermostats

[4] This cost includes pilot and program costs that would not exist under a contractor direct install model. So, given a contractor incentive, plus fewer technical issues, the installation cost would likely be lower.

selected over an "open" contractor model in order to expedite thermostat installation prior to the start of the heating season and ensure best case scenario installations. Should the pilot be successful, expansion is possible through a contractor incentive, similar to the current heat pump advanced control measure, or through a retail incentive for self-install. A retail incentive could significantly reduce costs but may also impact the rate of successful installations. Costs may also go down over time due to competition and technology maturation.

The Nest thermostat has received a relatively significant amount of press and appears to be catching the attention of many electric utility programs. However, there are few utility-based studies available on realized energy savings. To assess the savings associated with Nest, Energy Trust attempted to recruit 200 homes randomly selected from a subset of previous other Energy Trust program participants to receive a free Nest thermostat (coupled with free installation) and compare their energy consumption to a comparison group selected from the same population of homes. To gather feedback regarding customer use and satisfaction with the Nest thermostat, Energy Trust also requested that participants complete two surveys. The pilot occurred during the duration of the 2013-2014 heating season, from November 2013 through May 2014. A more detailed description regarding the methodology and analysis used for this evaluation follows in the next section.

3.1 Participant Selection, Recruitment and Installation

Recruitment for the Nest Pilot Study began by selecting a list of potential candidate homes from previous Energy Trust program participants. The selection criteria for this list included a past Home Energy Review (HER) or free manufactured home service; a heat pump as the primary heat source with electric resistance heat backup; a single-family detached, site-built or manufactured home with no Energy Trust program activity for the last 12 months and a location along the I-5 corridor in Oregon. This selection process produced several thousand candidate homes, from which approximately 1,600 were randomly selected to be the sampling frame for the treatment group. The remaining 299 homes made up the comparison group. Neither CLEAResult nor Energy Trust contacted homes in the comparison group; these homes' energy usage was compared with the energy usage of the treatment group to help determine the savings associated with the Nest installation.

Participation requirements for the treatment group also included the following:

- No plans for a large remodel, weatherization, or heat pump upgrade during the study period
- Existing Wi-Fi connection
- Willingness to allow Nest Labs to share thermostat settings data with Energy Trust
- Willingness to participate in a study to test a new technology

Recruitment was initially conducted via randomized outbound phone calls to homes in the sampling frame. CLEAResult developed a list of qualifying questions to ensure eligibility as well as a standard voicemail message when calls went unanswered. As installations began and additional issues were identified, the list of qualifying questions was updated to better screen potential candidates.

After approximately six weeks of outbound calling, CLEAResult developed and mailed a recruitment letter to all remaining candidates in the sampling frame who had not spoken with a representative on the phone. The letter was mailed to approximately 1,400 homes and, similar to the talking points, explained the benefits of the study. Prominent on the letter was the value of the installation and contact information to call and schedule an appointment.

Together the outbound calling and the recruitment letter provided approximately 80% of targeted installations. To complete the remaining 20% of installations, in consultation with Energy Trust, CLEAResult reached beyond the initial treatment group to include homes that completed an online Home Energy Profile (HEP). Although the data collected by the HEP is slightly different than that collected during the HER, the data sets were similar enough to allow the same selection criteria to be applied. The resulting group of HEP candidates then received recruitment letters for installations beginning in December 2013.

CLEAResult field staff installed the thermostats starting in late Q3 of 2013. All Nest installations were completed in Q4 of 2013, so that energy usage during the 2013-2014 heating season could be evaluated in the spring. At the time of basic installation, the following activities also occurred:

- The heat pump balance point setting was set to “maximum savings.”
- The homeowner was instructed on how to adjust the other thermostat settings.
- CLEAResult developed standardized instructions to leave behind with the homeowner.

Before the installers arrived on site, CLEAResult sent out additional letters and placed calls to help educate the customers who had agreed to participate, explain the details (the what/why/how of the pilot study), and to ensure customer buy-in. These calls lasted at least 10 minutes. This was denoted as the “pre-education phase.”

For the installation, CLEAResult provided the installers with a “Nest On-Site Checklist,” which included the following items:

- Homeowner reviews and signs agreement
- Verify and gather site information
- Verify heat pump operation
- Power off heating equipment at breaker panel
- Remove old thermostat, put in Ziploc bag, and leave with homeowner
- Install Nest thermostat

- Power on heating equipment at breaker panel
- Affix electrical permit sticker to breaker panel
- Connect to the Internet (router name and Wi-Fi password needed)
- Verify equipment type, wiring, location, and temperature sensor accuracy
- Set heat pump balance to Maximum Savings
- Gather technical information
- Homeowner creates Nest account
- Link thermostat to Nest account
- Educate homeowner on controlling Nest
- Leave Nest packaging and information about Nest support with homeowner

CLEAResult also used a standardized data collection tool to gather the following information from the onsite visits:

- All data required to estimate home heat loss was collected.
- Capacity of the heat pump was recorded.
- Verification was made of heat pump fan and compressor functionality.

For the study comparison group, a random sample of 299 home comparison group members were selected from the same pool as the participants. The comparison group was not contacted or interviewed. Homes in the comparison group were confirmed to have not implemented any energy-saving measures in the past year, based on Energy Trust's tracking database.

Quality-control activities were greatly simplified due to pilot design. A single technician was able to complete the installation and collect on-site data, though as the study progressed it was deemed necessary to add a second installer to assist with installations. The second installer received complete training and background on the pilot to ensure he avoided issues (as described in detail later in this report) encountered by the initial installer early in the pilot.

4. Evaluation Methodology

There were three components, or primary data collection efforts, associated with this evaluation study: staff interviews, participant surveys, and a billing analysis. In addition to the three primary data collection efforts, the evaluation team also leveraged an existing summary report compiled by CLEAResult that detailed many of the findings associated with the implementation of the pilot. A more detailed discussion regarding the methodology used for data collection and analysis for the primary components is found below.

4.1 Staff Interviews

Apex 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. A draft interview guide was prepared for review by Energy Trust evaluation staff prior to finalizing it. Toward the end of the Nest Pilot Study, in April 2014, the evaluation team interviewed four CLEAResult key staff and one Energy Trust staff member. Each interview lasted approximately one hour. It was critical to debrief staff to get their perspectives on selection of the participant sample, installation and setup challenges, participant attrition, logistical and communication issues, customer reactions to the device, customer commitment to saving energy, and ideas for successful deployment of Nest in the market.

4.2 Participant Surveys

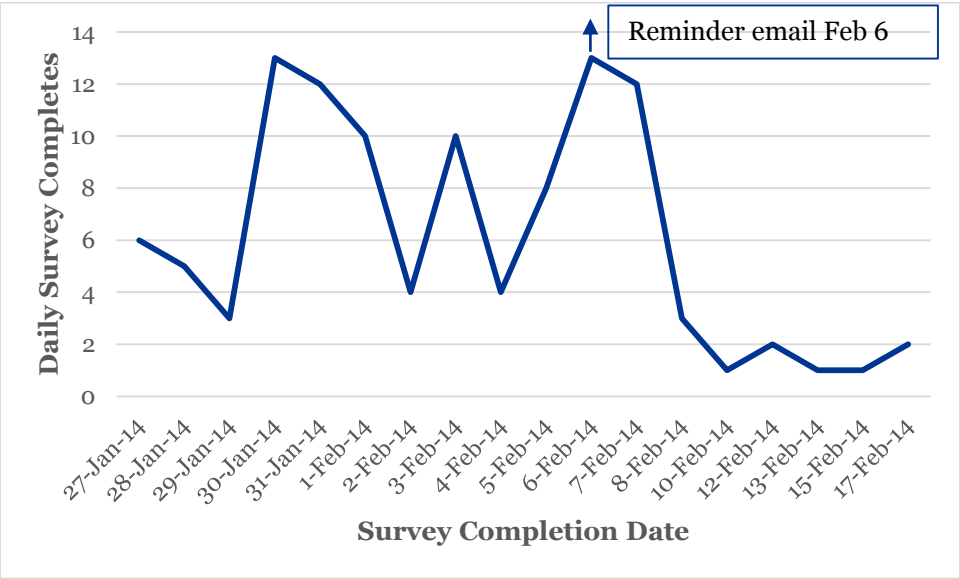
The evaluation team developed two survey instruments and fielded two rounds of surveys to obtain feedback from participants. A core set of questions remained consistent in both surveys to gauge whether participants changed their opinions of the device during the heating season. In addition, a number of the survey questions were similar to those used in other evaluations of smart thermostat initiatives so that the results could be compared. The team provided a draft of each survey instrument to Energy Trust evaluation staff for review prior to finalizing it.

The evaluation team decided, with Energy Trust support, to administer the survey via online web-based survey software. A web-based survey was deemed the best approach due to knowing that all participants had Internet access (a requirement for the Nest installation), and assuming that participants had at least some degree of familiarity with technology due to the high-tech nature of the Nest thermostat. The team had experience with, recommended using, and ultimately used Sogo Survey Software, an online tool that allows users to develop, administer, and analyze participant responses. After an initial draft survey instrument in Microsoft Word was reviewed and approved by Energy Trust, the team programmed the survey into the online survey tool and tested the functionality to ensure the invitations to take the survey were fully functional and that survey responses were properly saved to the system.

The first participant survey (Round 1 Survey – see Appendix B) was targeted for administration during the mid-heating season. Participant recruitment and actual implementation of the web survey occurred in late January 2014. This survey focused on customer motivations for participating in the pilot, installation and setup of the device, attitudes about the device, valued features of the thermostat, home comfort, use of the device, commitment to saving energy, and satisfaction with the pilot. The entire pilot participant population (at the time of recruitment N=177) was invited to take the first survey, whereas only those who completed the first survey (N=110) were selected to take the second survey.

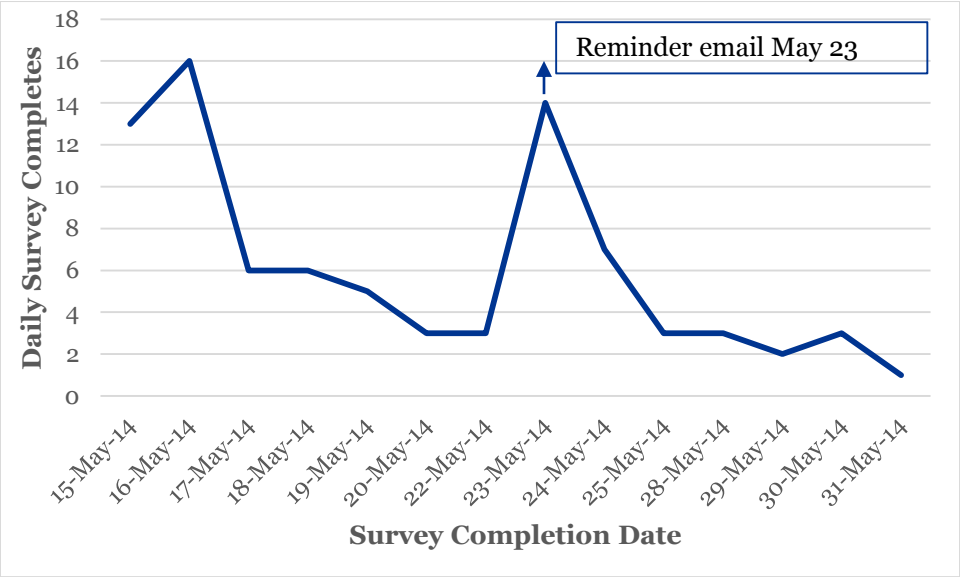
The evaluation team developed and mailed recruitment letters to enlist participants for both web survey efforts. In order to encourage customers to open the letters and trust the source of the online survey, the letters and envelopes displayed the Energy Trust logo, letters included personal salutations, and envelope addresses were handwritten, stamped, and delivered via U.S. Postal Service. After the letters were mailed, the team waited two weeks before sending a follow-up email to those participants who had not yet completed the survey to encourage them to take the survey. This follow-up email reminder proved to be very successful and helped push the number of survey completes well over the targeted goal of 70. A timeline of the number of completed Round 1 surveys is shown below in Figure 1.

Figure 1. Round 1 survey completes by date



The second participant survey (see Appendix C) was targeted for administration during the end of the heating season. The evaluation team recruited the same participants who responded to the Round 1 survey for a second survey in May 2014. The main objective of the second survey was to identify any changes in metrics relative to those collected during the first survey. In addition, the surveys explored which participant characteristics and behaviors might be related to the amount of energy savings and which features of the device might have the largest impact on savings. A timeline of the number of completed Round 2 surveys is shown below in Figure 2.

Figure 2. Round 2 survey completes by date



4.3 Billing Analysis

4.3.1 Data Sources

Energy Trust evaluation staff constructed the billing analysis data set using a number of data sources. Basic home characteristics and recent program participation information were retrieved from Energy Trust's FastTrack database for both participant and comparison homes. Detailed data elements captured at participant homes during the implementation of the pilot were also retrieved, including heat pump characteristics and information about the previous thermostat and Nest installation. Data from two surveys of Nest pilot participants was also collected and added to the analysis data set, contributing information on participant demographics and self-reported interaction with the Nest thermostat. Monthly electric usage data was retrieved from Energy Trust's utility database and matched to homes based on the USPS address barcode. Daily weather data from nearby weather stations was retrieved from NOAA and matched to homes based on zip code.

4.3.2 Electric Utility Data

Once electricity usage data was matched to the pilot homes, it was cleaned to facilitate analysis. The primary data cleaning tasks were to identify and remove duplicates, estimates, and readings with bad or suspect data. Duplicate readings were defined as readings taken at the same meter, on the same day, with the same value. When duplicate readings were identified where one value was equal to zero and the other was non-zero, the zero values were removed. If more than one non-zero reading was identified at the same meter on the same day, then the readings were flagged as bad data and later removed. In a given billing period, if an estimated meter reading was encountered, the team simply extended the billing period until the next actual reading and removed the estimate. For all readings, if a

billing period had fewer than 16 days or more than 66 days, it was assumed to contain bad data, and the reading was flagged and later dropped.

Some addresses had more than one electric meter associated with them. In these cases, multiple electric meters were aggregated together to obtain house-level electric usage. If all of the meter readings at an address were taken on the same day of the month, then the meter readings were simply summed together. However, a number of homes contained meters where readings were occasionally taken on different days of the month. To aggregate electric usage for these homes, the team first normalized the meter readings to a regular interval. This was accomplished by distributing the usage associated with each meter reading to the calendar months contained in the billing period, on a pro rata basis. Once meter-level usage data was assigned to a month in this way, meter-level data was summed to obtain the total monthly usage for each home. Monthly electric usage for all homes was divided by the number of days in each billing period to arrive at the average daily usage in kWh. This was used as the unit of analysis.

Annual electricity usage statistics for 2012 and 2013 were calculated for sites with at least nine readings in a given year. These are summarized in

Table 2. T-tests were performed to test for differences in annual usage between participant and comparison homes, but none were found, confirming that the two groups were comparable. Extreme outliers in 2012 annual usage were identified and flagged using histograms and distribution percentiles (Figures 3 and 4). Average monthly electric usage for 2012 and 2013 was also calculated and compared between participant and comparison homes (

Table 2). In a few isolated months, borderline significant differences in average monthly usage were identified between participant and comparison homes, but there was no clear pattern, and the differences may have been due to random fluctuations over time. Statistics for the change in annual electric usage at each home from 2012 to 2013 were calculated to identify homes that experienced large year-over-year changes. These are summarized in Table 3 and Figure 5. A t-test was performed to test the difference in the average year-over-year change between the participant and comparison groups, but none was found. Outliers in change in annual usage were identified and flagged using histograms and distribution percentiles.

Table 2. Average annual electricity usage in Nest pilot homes by year, 2012 and 2013

Year	Group	N	Mean	Std. Err.	Difference in Means	Std. Err. of Difference	p-value*
2012	Treatment	150	17,277	577	--	--	--
	Comparison	226	16,799	582	478	855	0.577
	Total	**376**	**16,990**	**418**	--	--	--
2013	Treatment	152	17,594	565	--	--	--
	Comparison	240	16,780	568	814	843	0.335
	Total	**392**	**17,096**	**411**	--	--	--

* Two sample t-tests assuming equal standard errors were used to calculate the p-value of the difference in means.

Figure 3. Histogram of average annual electricity usage in Nest pilot homes, 2012 and 2013

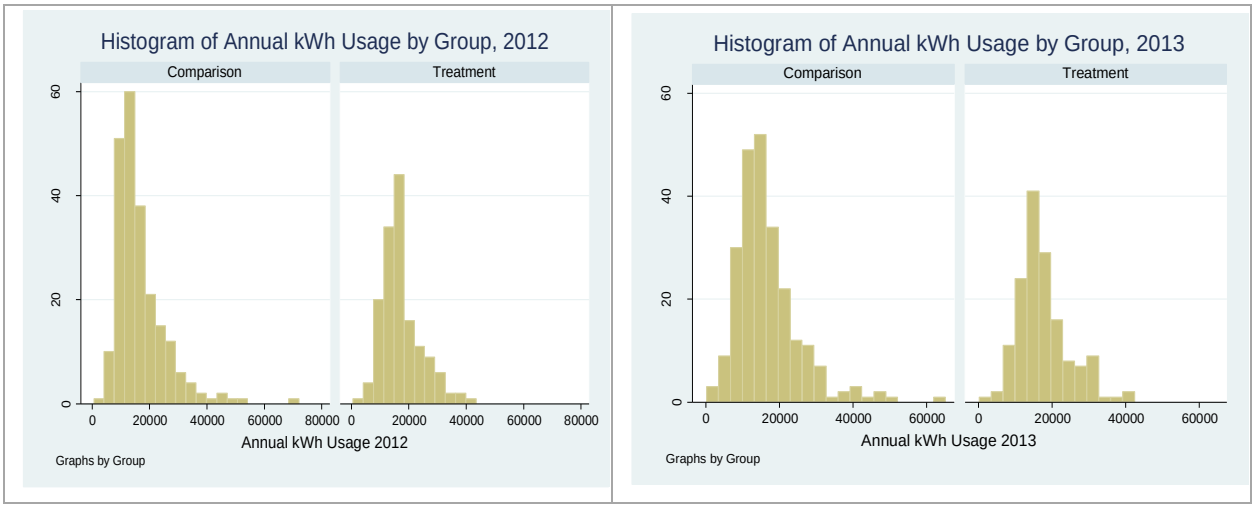


Figure 4. Average monthly electricity usage in Nest pilot homes, 2012 and 2013

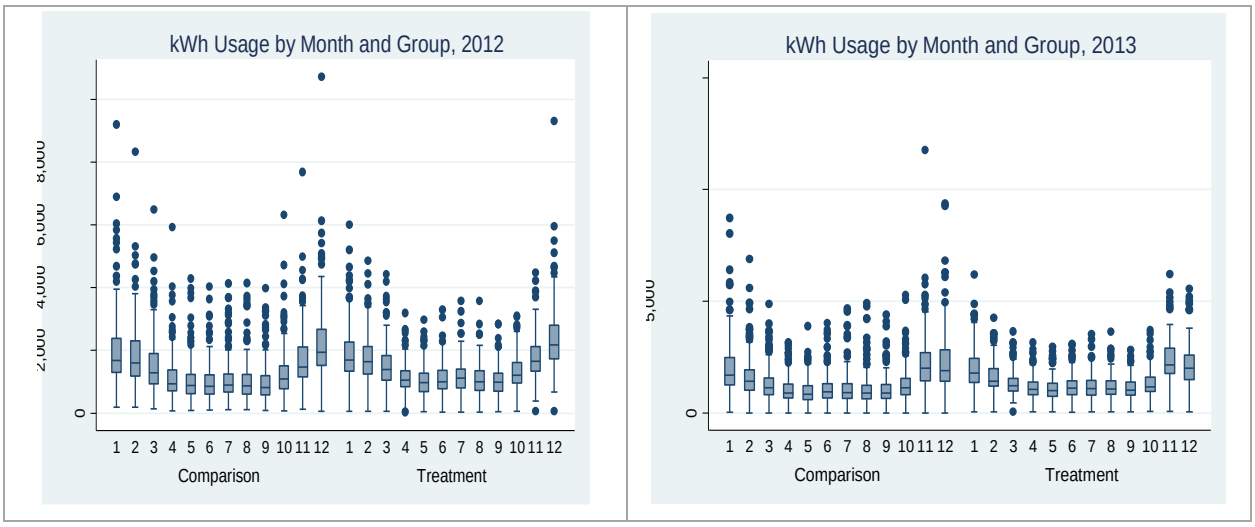
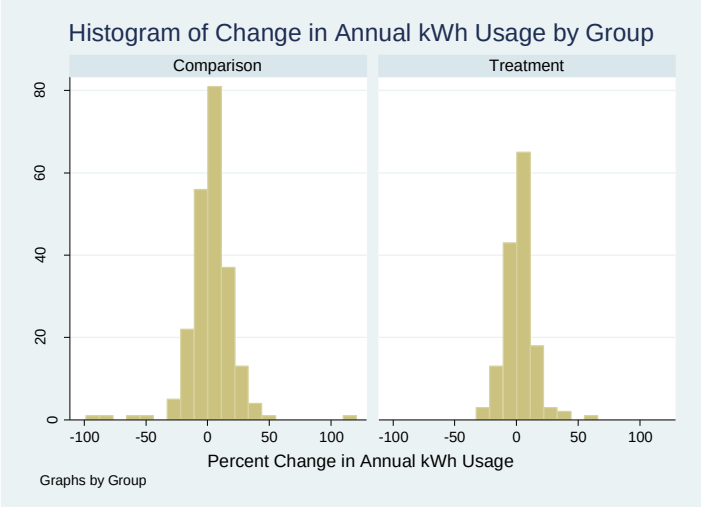


Table 3. Average percent change in annual electricity usage in Nest pilot homes from 2012 to 2013

Group	N	Mean	Std. Err.	Difference in Means	Std. Err. of Difference	p-value*
Treatment	148	+2.24%	0.98%	--	--	--
Comparison	224	+2.87%	1.20%	-0.63%	1.68%	0.708
Total	**372**	**2.62%**	**0.82%**	--	--	--

* Two sample t-tests assuming equal standard errors were used to calculate the p-value of the difference in means.

Figure 5. Histogram of percent change in annual usage from 2012 to 2013 by group



4.3.3 Attrition during Analysis

Nest pilot homes were removed from the analysis if they were not successfully matched to electric usage billing records. This was one of the largest sources of attrition in the analysis. Using Energy Trust project tracking data, a number of homes with solar PV systems were identified. These were removed from the analysis due to the difficulty in analyzing electric usage in net-metered homes with solar PV. Additionally, not all homes that were matched to electric billing data had a long enough time series of meter readings to be used in the analysis. Homes were removed if they did not have at least one reading prior to the pilot implementation period (before 8/12/2013) and at least one reading in the post-implementation period (after 12/15/2103). This also caused significant attrition. Energy Trust project tracking data was used to identify homes that received an Energy Trust incentive or service during the analysis period (1/1/2012 to 5/31/2014) that resulted in more than 300 kWh per year of electric savings. These homes were removed from the analysis, causing significant attrition. Next, homes were removed that did not have valid square-footage or year-built data. Outliers in electric use were excluded from the analysis if their 2012 annual usage was less than 1,000 kWh per year or greater than 55,000 kWh per year. In addition, homes that had large fluctuations in usage over the 2012 through 2013 timeframe were dropped from the analysis. These included sites with year-to-year increases in consumption of more than 100% or decreases of more than 50%. In addition to these criteria, homes were also excluded if the team had information that the Nest thermostat had been removed during the follow-up period (12/16/2013 to 5/31/2014).

Of the 177 homes that received a Nest thermostat in 2013, 122 had sufficient electric billing data and did not participate in other Energy Trust programs during the analysis period. After the oddities and outliers were removed there were 113 of these homes remaining, leaving 64% of the participant homes to be analyzed. Of the 299 comparison homes that were initially selected, 220 had sufficient electric billing data and did not participate in other Energy Trust programs during the analysis period. After the oddities and outliers were removed, 211 of these homes remained, leaving 71% of the comparison group homes to be analyzed. The sample attrition is summarized in Table 4**.**

Table 4. Sample attrition for Nest pilot homes

Phase of Analysis	Participants		Comparison	
	N	%	N	%
All Nest pilot sites	177	100%	299	100%
Sites matched to billing data	159	90%	251	84%
Sites removed with solar PV	154	87%	249	83%
Sites with sufficient valid billing data (1 or more records in both pre- and post-treatment periods)	145	82%	234	78%
Sites removed with Energy Trust projects between 1/1/2012 and 5/31/2014	122	69%	220	74%
Sites with valid square footage data	117	66%	215	72%
Sites with valid year built data	117	66%	215	72%
Outliers removed with low annual electric use (< 1,000 kWh per year)	116	66%	215	72%
Outliers removed with high annual electric use (> 55,000 kWh per year)	116	66%	214	72%
Outliers removed with large change in annual electric use (More than 100% increase or 50% decrease)	116	66%	211	71%
Sites removed where Nest uninstalled during follow up	113	64%	211	71%
Total sites available for analysis	113	64%	211	71%

4.3.4 Billing Analysis Methodology

To determine the preliminary[5] energy savings derived from using the Nest thermostat, a regression model of the Nest pilot homes was created using weather variables, home characteristics, time period, and treatment group to predict the outcome-variable, average daily electricity usage. Interaction terms were also added to the model to compare the pre- and post-pilot implementation periods between participant and comparison homes. The resulting "difference in differences" coefficients were used to calculate the average annual electricity savings attributable to the Nest thermostat.

The analysis time frame was from 1/1/2012 to 5/31/2014 and was separated into two parts: a pre-implementation period, defined as prior to 8/12/2013, and a post-implementation period, defined as after 12/15/2013. Billing periods that overlapped with pilot implementation were excluded from the analysis. The analysis dataset was organized into a longitudinal format with a series of repeated observations on each home representing the billing periods. Billing periods varied in length but were typically about one month. The data were unbalanced, with a different number of observations per home. Homes were excluded that did not have at least one observation in the pre-implementation period and one observation in the post-implementation period[6].

[5] This analysis is deemed preliminary due to only having a single heating-season worth of billing data. A more complete analysis will include a complete years' worth of billing data and may include PRISM-like methods.

[6] The final analysis dataset required at least five observations.

The home characteristic variables available for both the participant and comparison groups were square footage, year built, home type (site-built or manufactured), and geographic region. Average daily temperature data from the weather station nearest to each home was used to calculate the heating degree-days (HDD) and cooling degree-days (CDD) for each billing period. HDD variables were computed for reference temperatures ranging from 50 to 65°F. CDD variables were computed for reference temperatures ranging from 65 to 80°F. The HDD and CDD values were then divided by the number of days in each billing period to obtain average daily HDD and average daily CDD variables, so that the units were directly comparable to the average daily electricity usage. An indicator variable was created to show whether each observation in the series occurred in the pre-implementation or post-implementation period. Another variable indicated whether a home was part of the participant or comparison group.

Once the longitudinal data set was prepared, a first level of regression analysis was conducted in Stata/SE v12.1 (StataCorp LP, College Station, TX) to begin building a model that fit the data. A linear fixed-effects regression model was created, treating each observation as a repeated measurement on each home. The maximum likelihood method was selected to calculate the parameter estimates using an unstructured covariance matrix. Average daily electric usage was modeled as a function of average daily HDD and CDD with base 65, the pre/post-implementation flag, the participant/comparison group flag, and square footage. Interaction terms between the pre/post-implementation, participant/comparison group, and HDD variables were added to model the effect of the intervention between the participant and comparison homes — the difference in differences in electric usage. Once the basic fixed-effects model was created, random effects were added and their impact on the fit of the model was estimated using the likelihood ratio test. First, a random intercept term was added to model the clustering of observations within each home, which significantly improved the fit. Then a random slope term for HDD was added to model the relationship between HDD and usage for each home, which also significantly improved the fit. The following formula describes the resulting linear mixed effects model (using the 'mixed' procedure in Stata):

$$Usage_{ij} = \beta_0 + \beta_1 HDD_{ij} + \beta_2 CDD_{ij} + \beta_3 Group_i + \beta_4 Post_j + \beta_5 SqFt_i + \beta_6 Built_i + \beta_7 Group_i * Post_j + \beta_8 Group_i * HDD_{ij} + \beta_9 Post_j * HDD_{ij} + \beta_{10} Group_i * Post_j * HDD_{ij} + u_{0i} + u_{1i} HDD_{ij} + \epsilon_{ij}$$

Where:

$Usage_{ij}$ is the average daily electric usage for home i during billing period j,

β_0 is the fixed intercept for all homes,

HDD_{ij} is the Heating Degree-Days for home i during month j,

CDD_{ij} is the Cooling Degree-Days for home i during month j,

$Group_i$ $\{0,1\}$ is a dummy variable where 1 indicates that home i is part of the participant group,

$Post_j$ {0,1} is a dummy variable where 1 indicates that billing period j occurred during the follow-up period,

$SqFt_i$ is the square footage of home i,

$Built_i$ is the year that home i was built,

u_{0i} is the random intercept for site i and is independent from ϵ_{ij},

u_{1i} is the random slope coefficient of HDD for site i and is independent from ϵ_{ij},

ϵ_{ij} is the model error for site i during billing period j.

This model provides two key parameter estimates for computing savings: the interaction term coefficients β_7 and β_{10}. Together, these coefficients describe the difference between the treatment groups in their change in consumption from the pre- to post-implementation period for a given number of HDD, while controlling for CDD, square footage, and year built. In other words, the sum of these coefficients is the average daily electric savings. A linear combination of these two coefficients was computed (using Stata's 'lincom' command) to estimate the weather-normalized average annual electric savings attributable to the Nest thermostat:

$$Annual\ kWh\ Savings = 365 * \beta_7 + LRHDD_{Avg} * \beta_{10}$$

Where:

β_7 is the coefficient of the $Group_i * Post_j$ interaction term,

$LRHDD_{Avg}$ is the long-run average annual HDD for each weather station, derived from the Typical Meteorological Year 3 (TMY3) dataset and averaged over the sample sites,

β_{10} is the coefficient of the $Group_i * Post_j * HDD_{ij}$ interaction term.

Next, this model was re-run for different combinations of HDD and CDD reference temperatures. The resulting log likelihood, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) fit statistics were compared, and the model that best fit the data was selected. The best fit was achieved using a HDD reference temperature of 55°F and a CDD reference temperature of 70°F (Table 5). Although these reference temperatures are not standard, they fit the data better and produce savings estimates with a lower standard error than the typical reference temperatures.

Table 5. Nest model fit statistics for various HDD and CDD reference temperatures

Reference Temperatures	Log Likelihood[1]	AIC[2]	BIC[3]
HDD50 / CDD65	-25404.6	50839.2	50941.6
HDD50 / CDD70	-25379.9	50789.8	50892.3
HDD50 / CDD75	-25362.1	50754.2	50856.7
HDD50 / CDD80	-25370.1	50770.3	50872.7
HDD55 / CDD65	-25121.5	50273.0	50375.5
HDD55 / CDD70*	-25109.7	50249.4	50351.9
HDD55 / CDD75	-25118.5	50267.1	50369.5

Reference Temperatures	Log Likelihood[1]	AIC[2]	BIC[3]
HDD55 / CDD80	-25161.1	50352.2	50454.6
HDD60 / CDD65	-25155.8	50341.5	50444.0
HDD60 / CDD70	-25204.1	50438.1	50540.6
HDD60 / CDD75	-25270.0	50569.9	50672.4
HDD60 / CDD80	-25359.4	50748.7	50851.2
HDD65 / CDD65	-25298.5	50627.0	50729.5
HDD65 / CDD70	-25442.6	50915.2	51017.7
HDD65 / CDD75	-25585.6	51201.2	51303.6
HDD65 / CDD80	-25728.7	51487.5	51589.9

[1] A higher log likelihood value indicates a model that better fits the data.

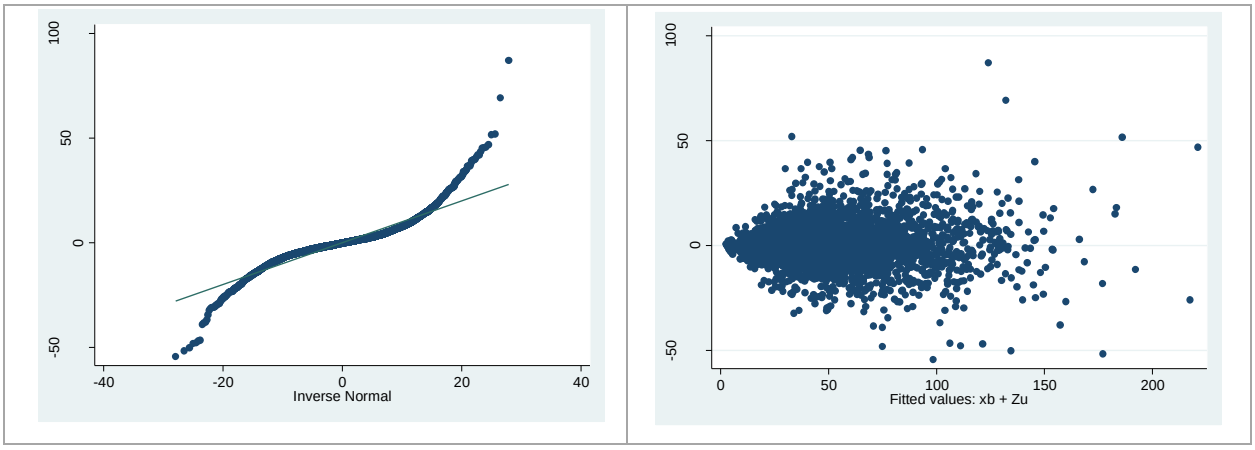
[2] Among a group of models fitting the same data, a lower AIC value indicates a preferable model.

[3] Among a group of models fitting the same data, a lower BIC value indicates a preferable model.

* HDD55 / CDD70 reference temperatures resulted in the best fit model.

To determine if there were any major issues with the model fit, the team created several residual plots. A look at the residual plots in Figure 6 reveals that the model residuals were not quite normally distributed but were pretty well randomly scattered with respect to the fitted values. The issues with the residuals appeared to be fairly minor and did not necessitate major changes or transformations to the model.

Figure 6. Residual plots for the best fit electricity usage model



5. Findings

The following findings are based on research conducted by CLEAResult, Apex Analytics, and Energy Trust. As mentioned previously, CLEAResult served as the implementer and designed the pilot for Energy Trust. Findings from CLEAResult's pilot summary report (the complete report can be found in Appendix D) are included throughout this section and supplemented with information compiled during Apex's interviews with implementation and program staff. Apex led the development and analysis of the staff and participant surveys and also assisted with compiling the analysis and results across the various actors and drafting this evaluation report. Energy Trust staff were responsible for and developed the energy savings estimates based on a billing analysis, with additional support and quality assurance reviews from both Apex and Nest Labs[7]. Each section below reviews the findings from each of the distinct primary researchable questions of the pilot study and leverages findings from each of the various pilot study sources to help inform the results.

What was the achieved installation rate of Nest thermostats, and what were the characteristics of participants and their homes?

According to CLEAResult staff, installation appointments were budgeted for 1.5 hours, which was more than sufficient for most homes. Each installation took between 45 minutes at a minimum to two hours for the most complicated installations, with the majority of installations taking approximately one hour. Some homes required revisits, where installers had to go through online setup of the Nest account and link the account with the thermostat. Some homes had slower speeds or connectivity issues since the Wi-Fi router location was far away, so those homeowners had to schedule another follow-up appointment. To maintain consistency and ensure that any disqualifying factors were identified before thermostats were installed, CLEAResult installers followed a standard set of procedures during each visit. According to the installers, the longest aspect of installation was connecting the Nest to the Wi-Fi signal. In general the hardware installation was a relatively straightforward process.

Educating the participant about the use of the Nest device was a critical component of the installation procedure. The education component was performed throughout the entire installation (approximately half-hour total time educating participant). The total time and level of interest varied by homeowner. The installer had an Energy Trust branded informational handout that was developed by CLEAResult, and within half an hour explained how to use the Nest. Participants' initial reaction to the Nest device during installation was overwhelmingly positive; as one of the primary installers noted, participants were "thrilled and genuinely happy to get the device installed." The question or concern most

[7] Nest Labs offered feedback on this report and provided supplemental participant usage data, including heat pump balance settings and run times for both the heat pump compressor and auxiliary heat system.

frequently raised during installation was whether they would still have heat if the Wi-Fi signal were lost in the home, with the response being affirmative, they would continue to have heat.

Achieved Installation Rate

The original recruitment plan for the pilot was to make outbound calls to the group of identified candidates and schedule installations from these calls. During the first month of recruitment, calls were made to 28% of candidates resulting in only 22% of needed installations. The two major barriers to recruiting were skepticism of people on the phone (concern this was a sales call or scam) and a lack of awareness of the Nest thermostat. Interestingly, CLEAResult reported that the vast majority of people did not know anything about the Nest and had never heard of a "smart thermostat."

The CLEAResult team ultimately decided to distribute an introductory letter that helped describe the pilot program to potential participants. After the letters were mailed, CLEAResult schedulers were able to say they were calling to follow up on the letter and ask if the candidate had thought about participating. Anecdotal accounts from schedulers suggest that the initial suspicion of the study was much lower after the letters were sent. Many candidates were still not interested in participating, but most had opened the letter and were now making an informed decision.

The total number of customers contacted to participate in the pilot was 1,589. Site visits were ultimately conducted at 222 homes, resulting in 185 thermostat installations. Thirty-seven homes were disqualified on site due to various technical issues. Eleven of the 185 thermostats installed were removed due to technical issues, and another 22 required a second visit to get them functioning properly. Therefore, out of the original 1,589 population to be recruited to participate in the pilot and serve as the treatment group in the billing analysis, there were ultimately 174 homes that had the Nest successfully installed, translating to an achieved installation rate of 11%. An overview of the recruitment, installation, and site visits is included below in Table 6.

Table 6. Nest Pilot Study recruitment, installation and site visits summary8

Date	Aug	Sep	Oct	Nov	Dec	Jan	Totals
CALLS							
Outbound	454	482	404				1,340
Inbound Calls		207	152				359
LETTERS							
Outbound Letters		1,410	690	337			2,437
Nests Originally Installed	**44**	**48**	**79**	**0**	**14**		**185**
Uninstalls		2		6		3	11
On-site DNQ	5	11	14	0	7		37
Re-visits			9	12	1		22
Total Site Visits:							**252**
Final Count of Installed Nests:							**174**

Characteristics of Participants and their Homes

CLEAResult collected the characteristics of participants' homes at the beginning of the pilot study, while participant demographic questions were included in the Round 1 participant survey. Table 7 through Table 9 provide a summary of Nest pilot data and characteristics of the participant and comparison group homes. Table 10 and Table 11 provide a summary of additional Nest participant information and survey responses, including heat pump characteristics and participant demographics.

Table 7: Summary of Nest pilot home characteristics

Group	N	Mean Square Footage	Mean Year Built	% Site Built
Participants	177	1,793	1979	84%
Comparison	299	1,793	1977	75%
Total	476	1,793	1978	78%

[8] Many of these summary points of contact are repeated attempts, total unique contacts was 1,589

Table 8: Nest pilot homes with solar PV system or a recent Energy Trust efficiency project*

Group	Solar PV[1]		Recent Projects[2]	
	N	% of Homes	N	% of Homes
Participants	6	3.4%	25	14%
Comparison	3	1.0%	15	5%
Total	9	1.9%	40	8%

* These homes are included in the total of 476 pilot homes listed above, but were later removed from analysis.

[1] Solar photovoltaic systems present on pilot homes that were installed at any point from 2002 to May 31, 2014, and received an incentive from Energy Trust.

[2] Home efficiency measures installed in pilot homes between 1/1/2012 and 5/31/2014 that saved a total of 300 or more kWh per year and received an incentive from Energy Trust.

Table 9: Geographic distribution of Nest pilot homes

Group	Portland Metro		Willamette Valley		Southern Oregon	
	N	% of Homes	N	% of Homes	N	% of Homes
Participants	104	59%	28	16%	45	25%
Comparison	150	50%	48	16%	101	34%
Total	254	53%	76	16%	146	31%

Table 10: Additional characteristics of Nest pilot participant homes (N=170)

Characteristic	Mean or % of Homes	Std. Dev.
Heat pump capacity (tons)	3	0.7
Heat pump backup heat power (kW)	15	4.0
Heat pump age (years)	12	7.9
Multi-stage heat pump	4%	--
Good or Average Wi-Fi Connection	95%	--
Prior thermostat was programmable	75%	--
Prior thermostat had backup heat lockout	6%	--
House Heat Loss Rate (UA)	531	172

Table 11: Summary of demographic information from Nest pilot participant survey (N=110)

Characteristic	N	% of Respondents
Education		
No College Degree	36	33%
College Degree	45	41%
Graduate Degree	28	26%
Income		
Less than $50,000	30	33%
$50,000 to $90,000	29	32%
$90,000+	32	35%
Children living in home		
No	83	76%
Yes	26	24%
Age		
Less than 50	30	29%
50 to 64	37	36%
65+	35	34%
Occupants		
1 person	16	15%
2 people	56	51%
3+ people	37	34%

What is the staff/installer perspective on the pilot? Are there installation challenges, issues with eligibility, or Wi-Fi connection problems?

Staff/Installer Perspective on Pilot

Staff members at both Energy Trust and CLEAResult overwhelmingly felt that the pilot was a worthwhile and successful endeavor. The speed with which the initial pilot design was proposed and then executed was unanimously the quickest that both teams had ever experienced, and the design of the pilot, with the direct-install component, was critical to the expeditious launch of the pilot in time for the winter heating season. Though the pilot did encounter some challenges, mostly centered on installation issues and flaws with the internal technical functioning of the Nest, staff members agreed that the quick response time, flexibility, and adaptability to resolve these issues proved to allay most participant frustration and fear about the functioning of the device. This is particularly evident in the high participant satisfaction ratings reviewed and discussed below in the report.

From proposed pilot concept to buy-in and kickoff, the project had fast-track development. Most of all, the pilot was a collaborative effort from start to finish, which required constant and effective

interaction, engagement, integrative reporting, and above all else, open communication, all while mitigating risks to participants. Staff agreed that this pilot has been one of the best-executed projects they have ever experienced.

All staff members interviewed felt that this pilot, if shown to provide reasonable energy savings, would be a valuable addition to the portfolio of programs offered by Energy Trust.

Installation Challenges

As mentioned above, there were challenges that were encountered during the installation of the Nest thermostats. These challenges can be grouped into the following categories: equipment eligibility, Wi-Fi router, and thermostat issues. There were 37 sites that were originally sampled but ultimately determined to not qualify to participate due to equipment eligibility, Wi-Fi compatibility, or other reasons, while another 11 sites had the Nest installed but required early removal of the device before the end of the pilot period[9]. Each of these challenges warrants a separate discussion, found below.

Equipment Eligibility

Even though every participant was asked if their home was heated by a heat pump, there were some issues early on of non-qualifying systems. The most common confusion was respondents reporting that their homes were heated by heat pumps, but they actually had electric furnaces with A/C. Several sites also had multiple heat pumps providing heat to multiple zones in the home, and one home was heated by a ground-sourced heat pump. After consultation with CLEAResult technical staff, it was determined that multiple systems and ground-sourced heat pumps introduced too many variables into the study. The screening questions were updated to emphasize that only homes heated with a single ducted, air-sourced heat pump would qualify for this study.

Wi-Fi and Routers

The Nest requires wireless Internet connectivity to receive local weather information, to allow for remote access, and to log data. Because of this, CLEAResult installers connected the Nest to Wi-Fi during each installation. One of the early problems encountered by the installers was that the homeowners were unsure of their wireless network passwords. When the installers reported this issue, CLEAResult staff amended the recruitment-and-installation phone battery to emphasize the need to have the Wi-Fi password available at the time of the appointment, effectively eliminating this issue. From the participant perspective, 11% of survey respondents noted a Wi-Fi-related issue during the installation process.

[9] An additional three participants requested that the Nest be removed at the end of the pilot study. These three were included for the billing analysis since they had the Nest installed for the duration of the heating season.

The second issue identified was the prevalence of mobile Wi-Fi hotspots as the main source of Internet access in homes. These devices, typically available from phone companies, are small portable devices that create a Wi-Fi network wherever they are located. While the Nest can connect to and work with these mobile hotspots, their portability introduces the potential for the Nest to periodically lose Internet connection when the hotspot is removed from the home. Because the Nest relies on a continuous Internet connection for weather information, CLEAResult decided that homes with mobile hotspots as the only source of Internet access would not qualify for this study.

The third Internet connectivity issue was routers that were not compatible with the Nest. From conversations with Nest technical support, CLEAResult learned that the thermostat requires the router to allow devices to go into a power-saving mode while remaining connected. The thermostat needs to enter this power-save mode to allow it to stay online while trickle-charging its battery. Unfortunately some of the most popular older routers do not support this power-save mode, and thus the Nest will not connect to them. In some cases updating router firmware can solve these issues, but in most cases the only way to install a Nest in these homes was for the homeowner to replace their router and reschedule the installation.

The final Wi-Fi/router issue was that connecting the thermostats to Wi-Fi was often difficult due to a lack of signal strength at the thermostat location. In some homes, low signal strength caused the installers difficulty in linking thermostats to the customers' Nest accounts in a timely fashion. In some instances, the thermostat would not update to the newest software version until a date and time determined by the Nest's auto-update schedule. When the installer could not connect the Nest account, a return visit was scheduled several days later to finish connecting the account.

Thermostat Issues

Early on in the pilot installation phase there were some Nest thermostat technical issues that were experienced by a not-insignificant group of the participants. The first set of problems came when a number of participants reported that their Nest thermostat was reporting higher temperatures than the actual ambient temperatures they were experiencing in the homes. This was followed up by a number of revisits, which resulted in a number of thermostats being replaced. Overall, approximately 5 to 7% of the pilot study thermostat sub-bases were found to be defective, although this was only applicable to the first generation of Nest units. The pilot installations were temporarily suspended until the issue was resolved with Nest labs.

After a consultation with technical staff at Nest to understand the defective sub-base issue mentioned above, it was discovered that the sub-bases had an issue that was most prevalent in thermostats

configured to heat pumps.[10] The installations were immediately stopped so that the issue could be properly resolved to avoid further installation of potentially faulty thermostats. The problem was with the field-effect transistors (FETs) used as the switches to power the HVAC relays. When these FETs fail, they fail in a partially open position, which creates the extra heat the thermostat senses. The problem in some cases provided a signal to the compressor relay but not to the indoor fan relay, which overheated some compressors and in one case caused a compressor to fail. Nest provided a number of sub-bases to the program in order to retrofit any thermostats that had an indication of a problem. Any thermostat that had a reported problem had its original sub-base replaced. Upon receiving the sub-bases the program began retrofitting problem thermostats with the new sub-bases.

With new sub-bases retrofitted into the remaining devices, the installations began again and is considered the "second" installation period. Upon the beginning of the second installation period a new problem was discovered. A number of the new sub-bases were not installing successfully. After a discussion with the same technical staff at Nest, the program discovered that the thermostat displays needed to be updated to a newer software version to be compatible with the new sub-bases. When a new sub-base was connected to a display with pre-version 3.5 software, the sub-base was "bricked" or rendered permanently inoperable. To prevent this issue, the thermostat displays were allowed to update by installing the original sub-base, connecting the Wi-Fi, waiting for the software auto update to run, then uninstalling and reinstalling the thermostat with the new sub-base before finalizing configuration.

An additional technical issue that arose during the installation phase was related to the wiring requirements between the Nest and the heat pump equipment. The heat pump requires at least five wires for control. Some newer heat pumps now have a communicating thermostat wherein the actual controlling of the system is done by a module located where the air handler is located. Therefore these systems only have two to four wires, and the thermostat effectively just functions as a remote control. This setup requires reconnecting wires directly to the system (effectively a complete system rewire), and systems like this require considerably more time and cost for the installation.

CLEAResult staff believed that since the program received mostly early Nest models with the sub-base issue, this issue was more pronounced for the pilot than it would be for the general population. The issue was potentially compounded by the heat pump issues discussed above. Furthermore, issues tended to be more pronounced for participants' homes due to demographics, especially the older, more technically challenged participants. The most common complaints or issues encountered by the participants were technical in nature. This was partly attributable to the elderly demographic who were challenged by issues like resetting Nest schedules, as they were unable to reprogram it.

[10] Nest staff contend that this was an unusually high failure rate and other studies and the general population of Nest users has not experience this level of failure rates.

CLEAResult staff spoke with Nest technical support staff and determined that the pilot had significantly more issues – mostly attributable to heat pumps – than typically occur with other types of heating systems (simple single-zone furnace or boiler-heated homes). The issues were also more pronounced because the pilot used the Nest as a heat pump advanced control. Nest reported that most users, with more basic single-zone furnace or boiler systems, often can complete the installation as a do-it-yourself install (no advanced HVAC skills required).

Nest technical support proved to be the most common, easiest, and reliable method for helping to resolve all of the issues mentioned above with the Nest thermostat. There were no logistical or communication issues with customers. The only issue that installers mentioned was that participant descriptions of problems were difficult to identify over the telephone. CLEAResult ultimately had to create a set of "if-this-then-that" guidelines to test if a complete replacement of a Nest unit was warranted.

How do customers use and interact with the thermostats? Which functions do they use?

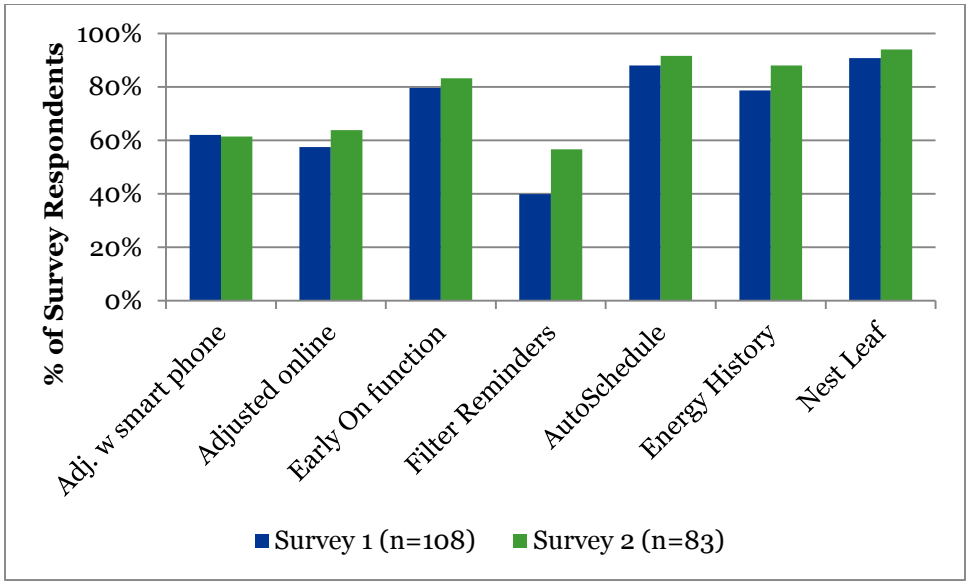
The Nest thermostat has numerous features and functionality. According to the survey results, the features that were most frequently used by the study participants were the Nest Leaf (94%), AutoSchedule (92%), Energy History (88%), and Early On (83%). Just under two-thirds of participants, in both the first and second surveys, reported adjusting the thermostat with a smart phone or online, as well as using the filter reminder feature (Figure 7).[11] Surprisingly, these results remain unchanged when analyzing the data with respect to age. For the "50-year-old and under" age demographic, slightly less than three-quarters of the respondents indicated adjusting the Nest thermostat either by smart phone or online. It should be noted that in the open-end response portion of the survey, multiple survey respondents specifically mentioned not knowing about the filter reminder feature and suggested the program provide participants with more information related to the Nest thermostat features.

The AutoSchedule feature was perceived to be the Nest thermostat's most useful feature, with 81% of survey respondents in the first survey and 87% in the second survey reporting that this was either

11 Filter reminders is a feature of the Nest thermostat that reminds the homeowner to change his or her air filter based on how many hours the heating system has been running.

"Somewhat Useful" or "Very Useful."[12] The Nest Leaf was the next most cited feature (81% first survey, 84% second survey), followed by the Energy History feature (74% first survey, 83% second survey).[13]

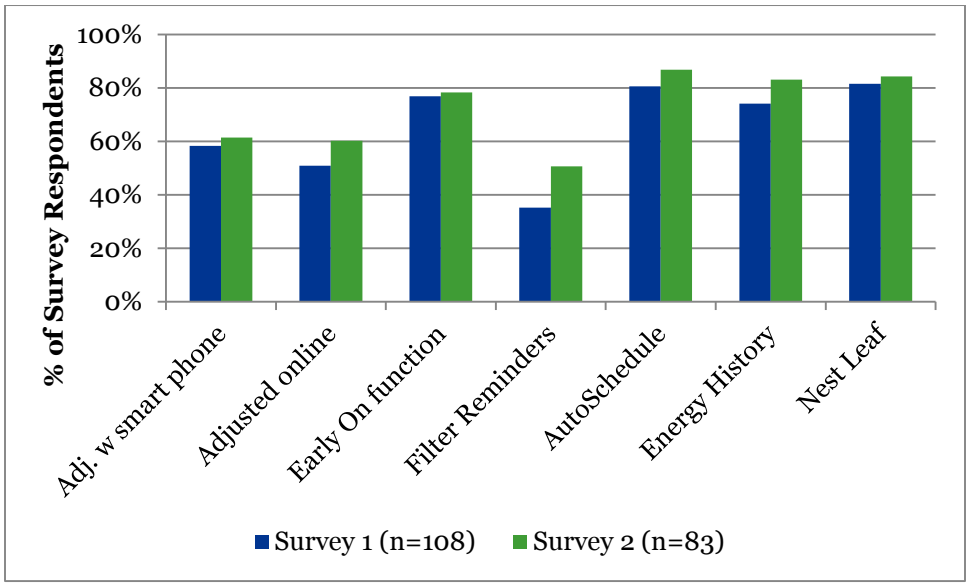
Figure 7. Percentage of survey respondents having used specific features



12 AutoSchedule is a Nest thermostat feature that remembers what temperatures keep the homeowner comfortable and creates a custom schedule for the home.

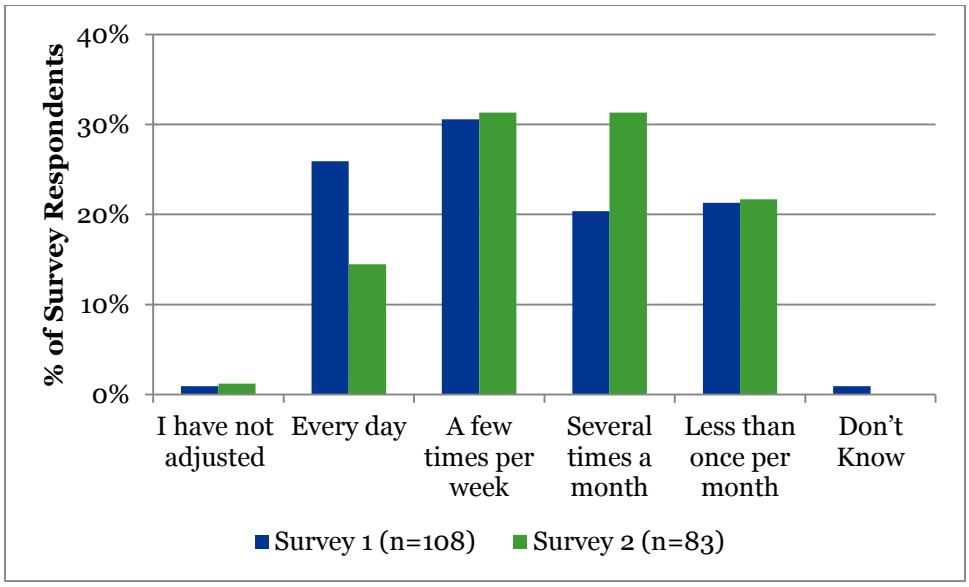
13 Energy History allows the homeowner to see exactly when the system was on and see an estimateof the entire month's heating and/or cooling energy use.

Figure 8. Percentage of survey respondents finding specific features somewhat or very useful



As seen in Figure 9, respondents tended to adjust the settings or use features from as frequently as every day to as little as less than once per month. An interesting trend that emerges from the data is the shift from adjusting settings and using features every day (12% point decrease) in the first survey to several times a month in the second survey (11% point increase). This trend is reinforced by the additional finding that 35% of the participants who responded to both surveys indicated a decreased frequency of adjusting settings or using features. This trend might represent a "novelty effect" with the thermostat that diminishes over time or could merely represent the participant's learning-curve to understand how to use the device.

Figure 9. Frequency of adjusting settings or using features



To what degree do customers change the efficiency/comfort settings in the Nest thermostat (control for the heat pump cutover), and what is the impact on energy savings?

One prominent feature of the Nest thermostat is the Heat Pump Balance function that minimizes how often resistance backup heat is called. The settings for this function are Maximum Comfort, Maximum Savings, Balance, or off. Energy Trust attempted to get more information from Nest about the settings and their use and adjustments (since Nest, via the wireless connection, is able to collect this information from users). This would have avoided having to ask customers and rely on their recall, as was done in this study during the two surveys. At present Nest has not been willing to share the data with Energy Trust but that could change in the future. This would allow a more accurate representation of the impacts of the various usage features and how they are associated with energy savings.

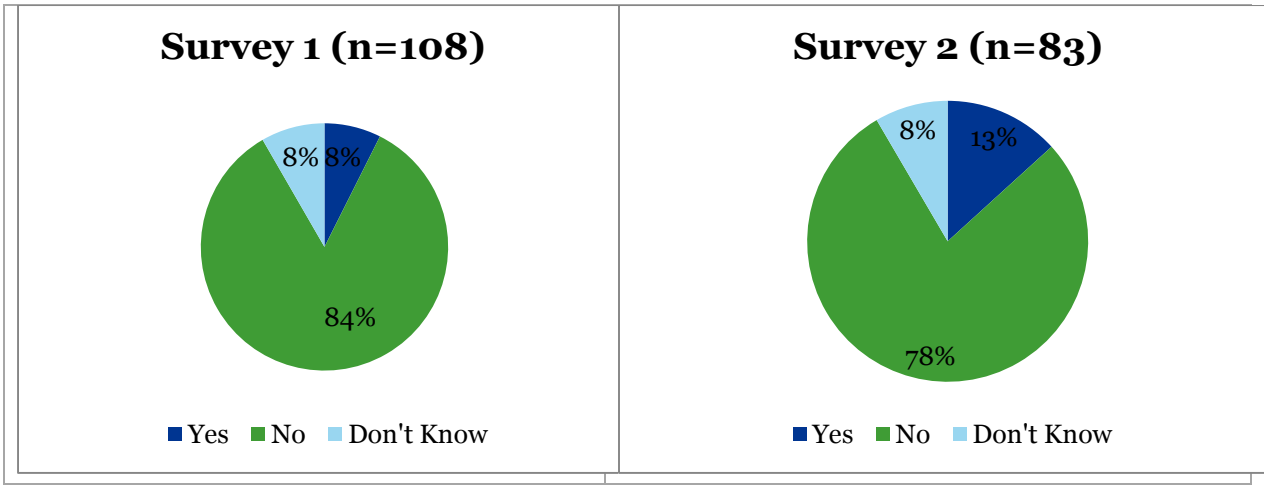
When the Nest thermostat was installed it was preset to Maximum Savings. As seen in Figure 10, there were very few participants (8% first survey, 13% second survey) reported changing this setting. Usage data from Nest Labs shows that by the end of the heating season, 14% of participants had a different heat pump balance setting than Max Savings. This supports and is in line with the survey findings. However, 21% of participants did change this setting at some point during the heating season, but many changed it back to Max Savings. Six respondents who indicated not changing the heat pump balance setting in the first survey did report changing it in the second survey. Due to the low number of participants who indicated having adjusted the heat pump balance setting of the Nest thermostat, and

without the actual setting data available from Nest Labs, the team was unable to statistically determine the energy savings impact this may have had.

For the small percentage of participants who did change the setting of the Heat Pump Balance function, two-thirds of them changed the setting to "balance". Two of the eight participants who reported changing the setting in the first survey indicated that they turned off the feature, a response not seen in the second survey. A common response for why the participant changed the setting revolved around the house being too cold, particularly during brief periods of extreme cold.

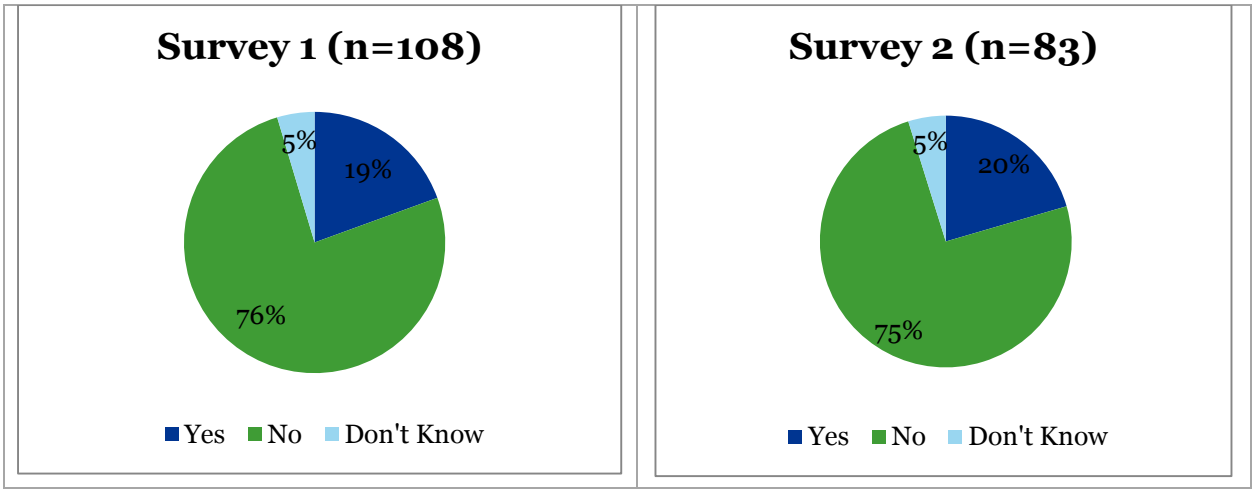
Energy Trust received, towards the end of finalizing the analysis and this report, an analysis performed by analysts at Nest Labs. This analysis reviewed heat pump and compressor run times for participants who kept their thermostat set to "Max Savings" and benchmarked these participants against those who changed the setting to something other than "Max Savings". This analysis showed that the backup heat ran twice as often when the heat pump balance setting was changed from Max Savings (15.4% versus 7.7%), while the average indoor temp remained the same. According to data from Nest Labs, participants used their heat pump's backup resistance heater twice as frequently when they set the heat pump balance away from Max Savings. Unfortunately the evaluation team does not have sufficient usage and other settings detail to infer how much savings the Max Savings feature provided and ultimately what portion of savings were due to the heat pump balance relative to other features.

Figure 10. Did participants change Heat Pump Balance function settings?



Another main feature of the Nest thermostat is the AutoAway function that minimizes heating when no one is home. When the Nest thermostat was installed, this feature was preset to on. In both the first (19%) and second (20%) surveys, less than one-quarter of respondents indicated changing this setting (Figure 11). Five participants went from not adjusting the setting in the first survey to altering it in the second survey. Conversely, two participants adjusted it in the first survey and did not adjust it in the second survey. For those who did adjust the setting, the main reason for doing so involved the house being too cold because the Nest thermostat was engaging in AutoAway while people were present in the house. Additionally, three respondents in the first survey and two in the second survey also mentioned adjusting the setting prior to leaving the house for an extended period of time. Similar to the Heat Pump Balance analysis, due to the low number of participants who indicated having adjusted the AutoAway setting of the Nest thermostat, and without the actual setting data available from Nest Labs, the team was unable to statistically determine the energy savings impact this may have had.

Figure 11. Did participants change AutoAway function settings?

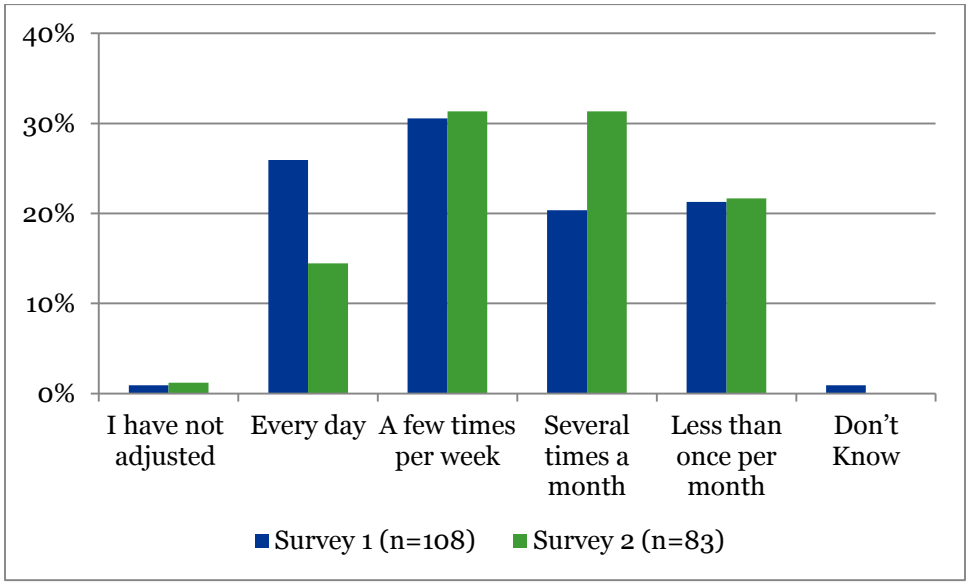


Does the Nest thermostat cause customers to change their behavior?

During the first survey, 26% of survey respondents noted adjusting the Nest thermostat every day, a response that then noticeably decreased to 14% in the second survey (Figure 12), suggesting that study participants were taking fuller advantage of, and were more pleased with, the Nest thermostat's auto-learning behavior, effectively interacting less with the Nest thermostat. Interestingly, the associated percentages for adjusting the thermostat a few times per week and less than once a month remained

relatively unchanged between the two surveys, but the percentage of survey respondents adjusting the Nest thermostat several times a month increased from 20% to 31%.[14]

Figure 12. Frequency of adjusting Nest settings or using Nest features



Regarding their previous thermostat, 73% of survey respondents indicated that they had programmable thermostats, leaving the remaining 27% with manual thermostats. These responses are reliable as they were validated against the installers' documentation of the existing (old) thermostat at the time of installation and were all correctly specified. As seen in Figure 13, prior manual thermostat users were very committed to manually adjusting the thermostats' settings/temperature, with 79% stating that they did so every day. The remaining survey respondents were equally distributed between altering the manual thermostat a few times a week, several times a month, and a few times a year. Eighty-five percent of survey respondents who previously had a programmable thermostat noted that their prior thermostat was set to change temperatures throughout the day, with 11% keeping the temperature at a constant setting and 4% unsure of their prior thermostat's setting (Figure 14).

14 A caveat to these findings is that the question did not distinguish between adjusting settings (i.e. temperature) and the use of features (i.e. remote access, energy history, etc.). Consequently, it is plausible that the high percentage observed in the first survey for everyday setting adjustment or feature usage stems in part from a "novelty effect" – participants engaging with the Nest because it is a new technology in the home, not necessarily to adjust the temperature of the home.

Figure 13. Frequency of adjusting setting on previous manual thermostat

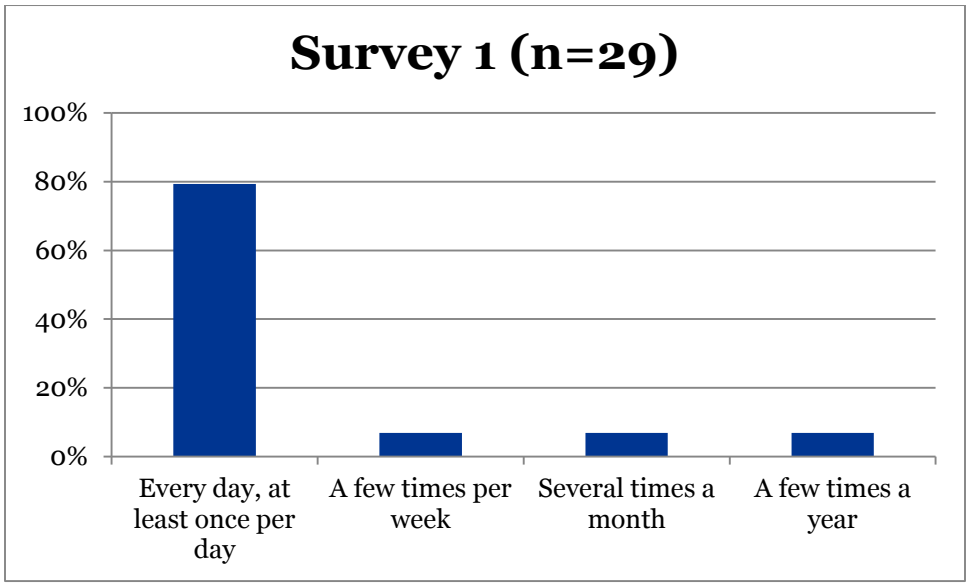
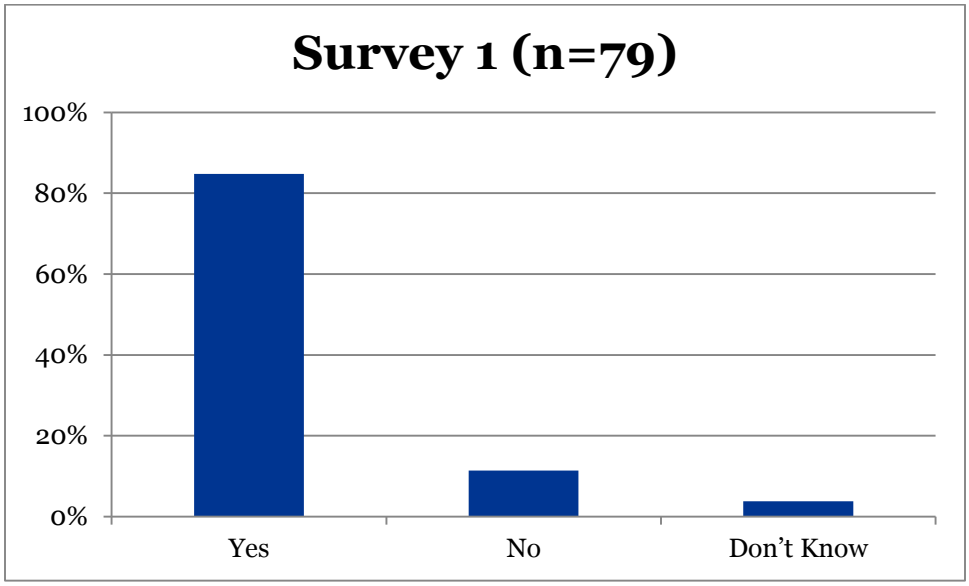


Figure 14. Was previous programmable thermostat actually programmed?

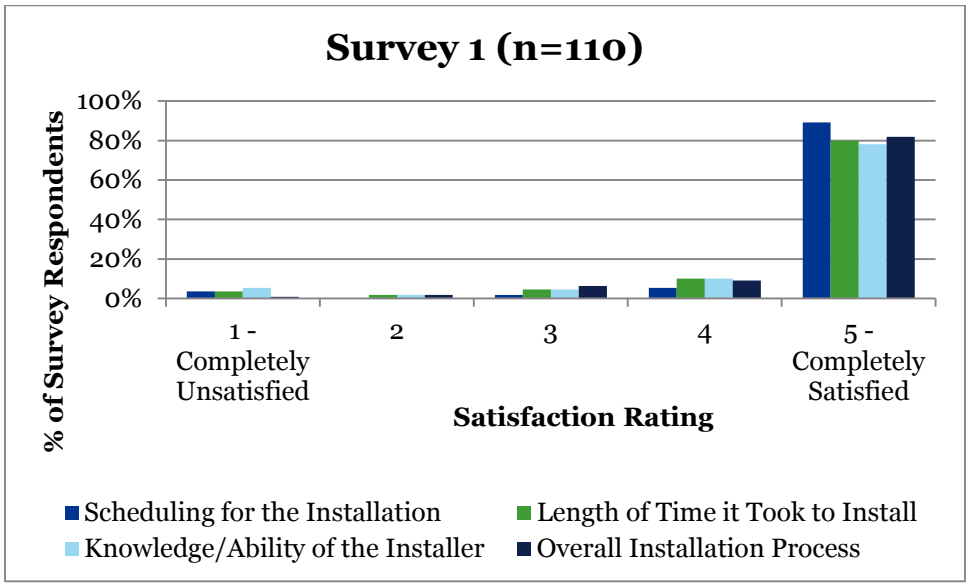


Are customers satisfied with the Nest thermostat and the comfort of their homes since installation of the Nest? Do customers seem engaged and committed to saving energy?

Customer Satisfaction

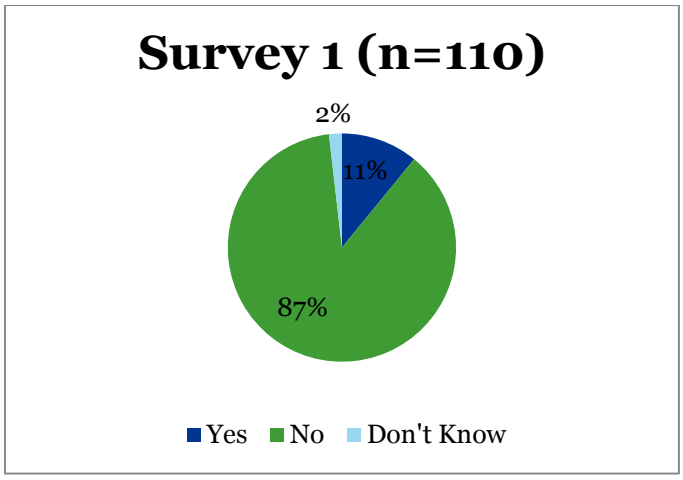
The satisfaction ratings provided by the survey respondents about the installation process were overwhelmingly positive: Over 90% of respondents indicated a satisfaction rating of either a 4 or 5 out of 5 for the scheduling of the installation, length of time to install, and their overall rating of the installation process (Figure 15). Only the knowledge/ability of the installer was under the 90% value for ratings of a 4 or 5 at 88%, which is still a high indication of participant satisfaction.

Figure 15. Satisfaction related to installation of the Nest thermostat



The majority of survey respondents (87%) indicated not having any issues with the connectivity of the Nest thermostat to the household Wi-Fi network during the installation process (Figure 16). For the 12 survey respondents (11%) who did report an issue, five specifically mentioned compatibility issues with the wireless router, while the remaining seven responses varied from adjusting the firewall settings to rebooting the router and changing the Wi-Fi password.

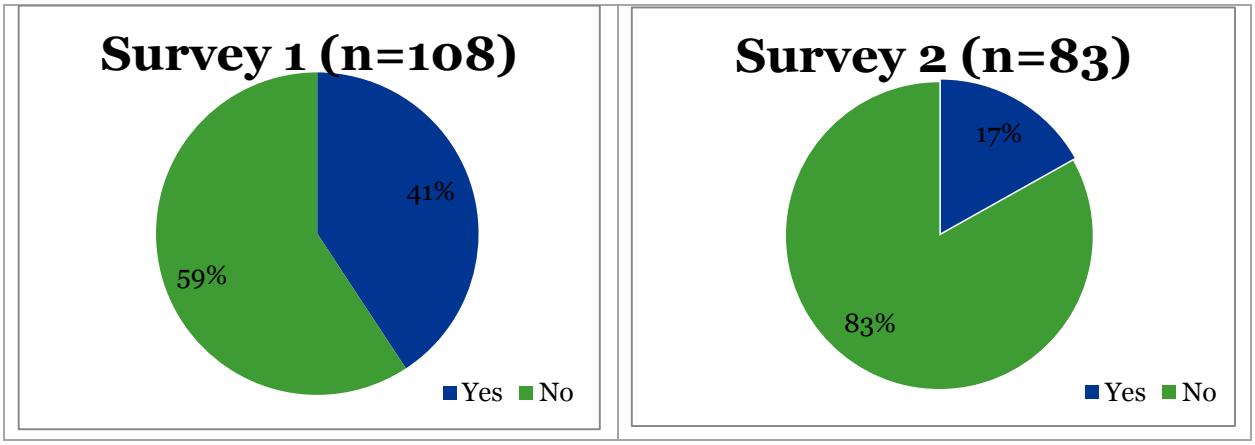
Figure 16. Wi-Fi network connection issues during installation



As for other problems that arose during the installation process, 11% of survey respondents noted an issue. Of those reporting an issue, 75% were related to hardware issues, most commonly that the wiring needed fixing.

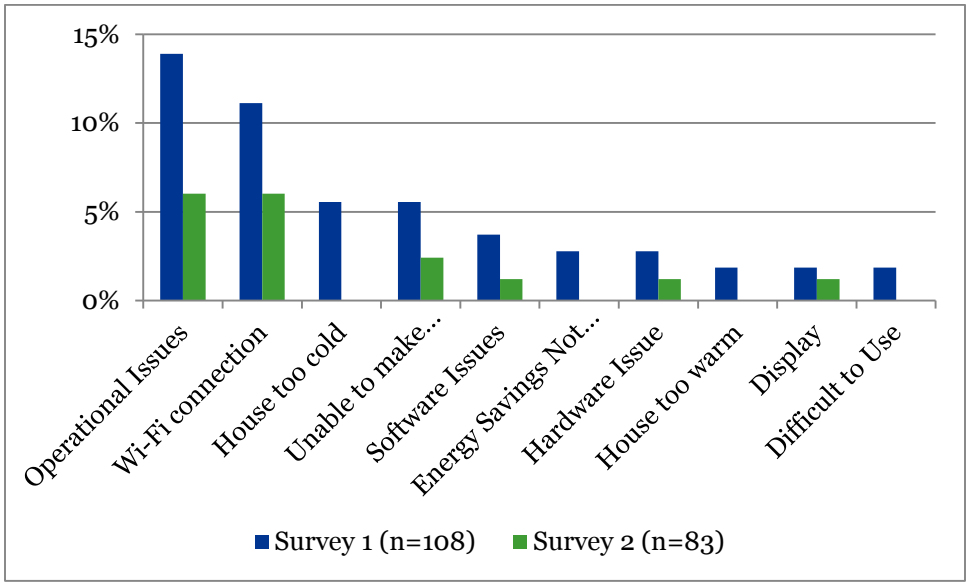
Aside from installation issues, 41% of respondents in the first survey and 17% in the second reported having additional issues with their Nest thermostat (Figure 17). Only 7 of the 83 survey respondents (8%) who took both rounds of the survey noted additional issues (apart from installation) in both surveys.

Figure 17. Additional Non-Installation issues with Nest thermostat



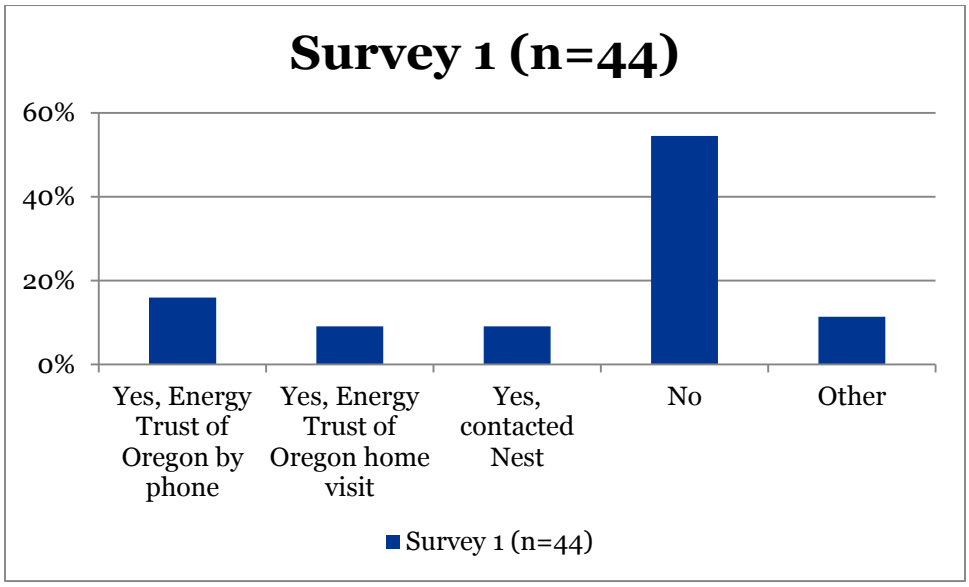
In terms of specific issues with the Nest thermostat, 14% of all Round 1 survey respondents reported operational issues with the thermostat (operational being able to properly operate/control the thermostat), followed by 11% stating Wi-Fi connection issues (Figure 18). These same two issues were atop the second survey findings, with 6% of all Round 2 survey respondents mentioning each issue. The array of additional issues is substantially less in the second round of survey responses, perhaps indicative that the study participants learned how to better use the Nest thermostat and alleviate some of the concerns noted during the first survey.

Figure 18. Specific issues with Nest thermostat



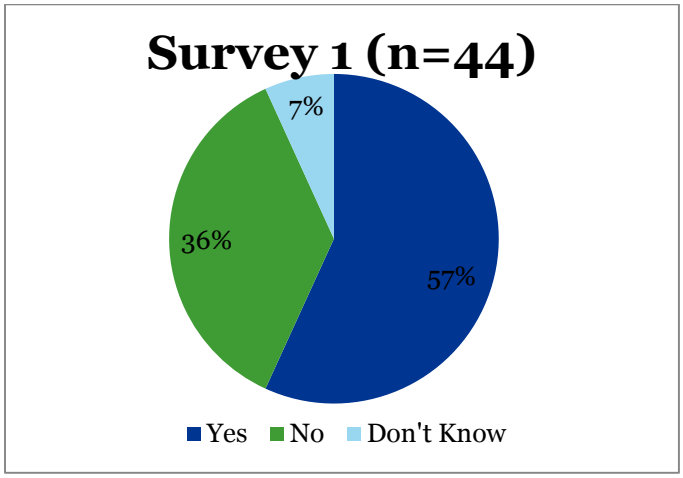
A somewhat surprising finding is the lack of assistance sought by study participants experiencing Nest thermostat issues, with only 45% of first survey respondents that experienced issues seeking assistance from either Energy Trust of Oregon (25%), Nest (9%), or other support (11%), ranging from searching online forums to asking family and friends (Figure 19).

Figure 19. Support to resolve Nest thermostat issues



Over half of survey respondents with reported Nest thermostat issues (57%) reported that their issues had been resolved at the time of the first survey (Figure 20). By the second survey, only three participants out of the total respondent sample (or slightly less than 3%) indicated that they still had issues that were not resolved.

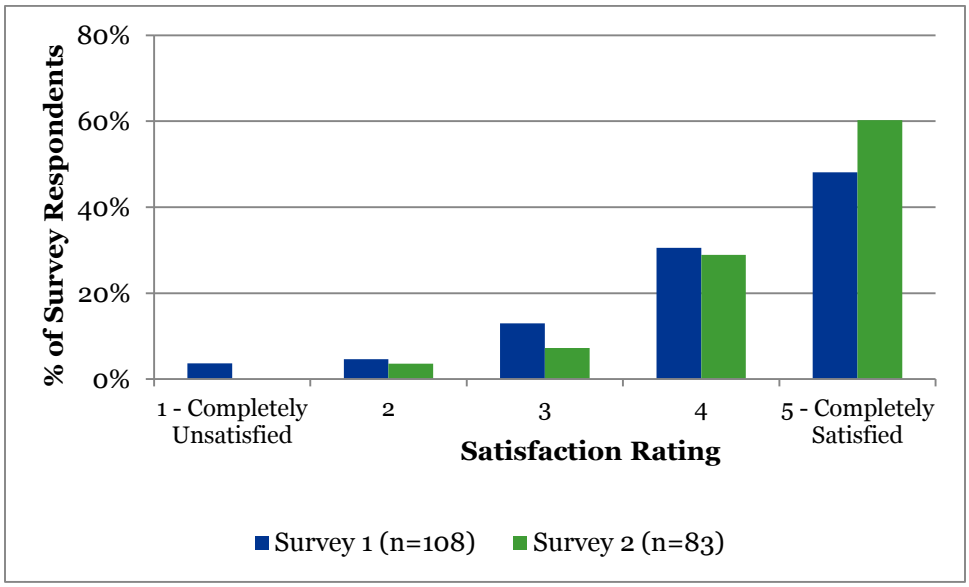
Figure 20. Resolution of Nest thermostat issues



Overall satisfaction with Nest thermostats was high, as 79% of responds in the first survey and 89% in the second provided satisfaction ratings of either 4 or 5. Another key finding from the second survey was that only 4% (three total) of survey respondents indicated a rating score of 2 or below, compared to 9% (nine total) from the first. For the three respondents unsatisfied with the Nest thermostat in the

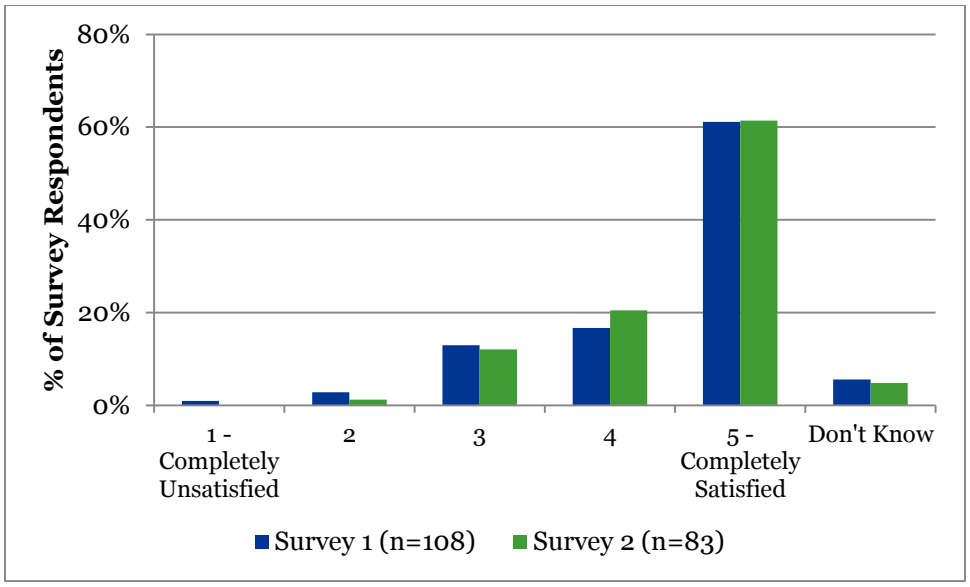
second round, one commented that their bills increased and the heat turned on in the middle of the night, another also noted the heat turning on in the middle of the night, and the third was displeased due to not seeing any energy savings on the heating bill, while also being colder in the house.

Figure 21. Satisfaction rating of Nest thermostat



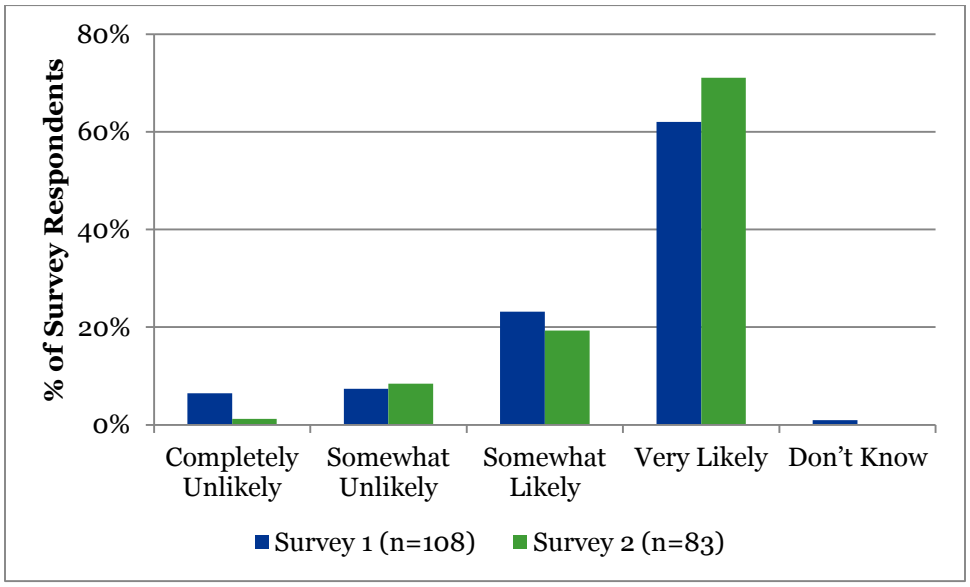
Unlike the satisfaction findings of the Nest thermostat, where responses differed between the first and second surveys and arguably provided some meaningful insight, the results for both survey rounds for the satisfaction level related to participation in the Nest thermostat study were very similar (Figure 22). The number of survey respondents reporting a 4 or 5 rating in the first survey was 78%, and 81% in the second survey. For those survey respondents who provided a satisfaction rating of a 1 or 2 in the first survey, two survey respondents related their answer back to their dissatisfaction with the Nest thermostat itself, and one tied it back to their disappointment in not realizing savings on the heating bill. The one survey respondent from the second survey who gave a satisfaction rating of 2 found that the survey was not intuitive and due to a web page issue, had to restart the online survey.

Figure 22. Satisfaction rating of participation in Nest thermostat study



Reflective of the satisfaction ratings noted above, 85% of the first survey respondents and 90% of the second survey respondents stated they were either "somewhat likely" or "very likely" to recommend the Nest thermostat to a friend or family member. For respondents common to both survey rounds, 22% displayed an increased likelihood to recommend from the first to second survey, compared to just 7% who decreased their likelihood to recommend, with the remainder staying unchanged in their responses.

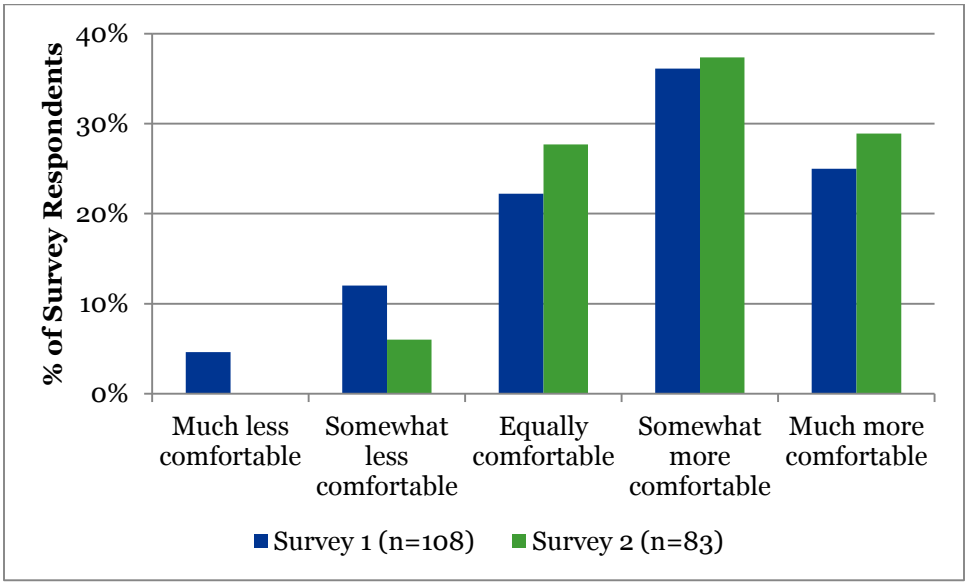
Figure 23. Likelihood to recommend Nest thermostat



Comfort of Participant Homes

Over 60% of survey respondents in both the first (61%) and second survey (66%) described the temperature of their home to be either "somewhat more comfortable" or "much more comfortable" after installing the Nest thermostat. An interesting and positive finding is that the percentage of survey respondents who felt the temperature was either "much less comfortable" or "somewhat less comfortable" decreased from 17% to 6% between the first and second surveys, suggesting that the Nest thermostat participants learned how to better utilize the Nest thermostat features and functionality. This is further supported by the fact that of survey respondents in both rounds, 14% indicated that their home temperature comfort level increased, compared to 7% who experienced a decreased comfort level (Figure 24).

Figure 24. Comfort of home temperature compared to pre-Nest thermostat period



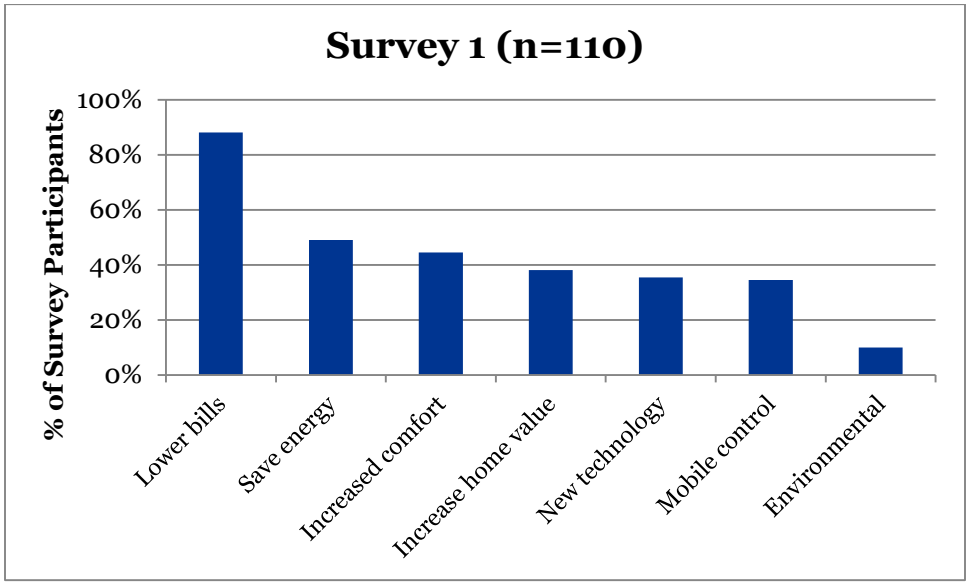
Are Customers Engaged and Committed to Saving Energy?

According to the staff interviews, participants were very engaged and committed to saving energy. As one installer – who installed the majority of the thermostats – stated: "Participants were thrilled and genuinely happy to have the Nest installed." Probably the most telling of all indicators related to participant engagement was the extremely high response rate for the participant surveys. Overall, participation in the survey was very high, with 110 out of 177 total Nest thermostat participants responding (62% response rate). For the second survey, 85 out of the 107 eligible participants

responded to the survey (79% response rate).[15] These are the highest survey response rates of any program the Apex team has ever experienced.

As seen in Figure 25, the most cited reason for participation in the Nest thermostat study was to lower energy bills, with 88% of respondents listing it among their top three reasons for participating. The next most frequent response provided was to save energy (49%), followed by increasing the comfort of the home (45%).

Figure 25. Reasons for Nest thermostat study participation



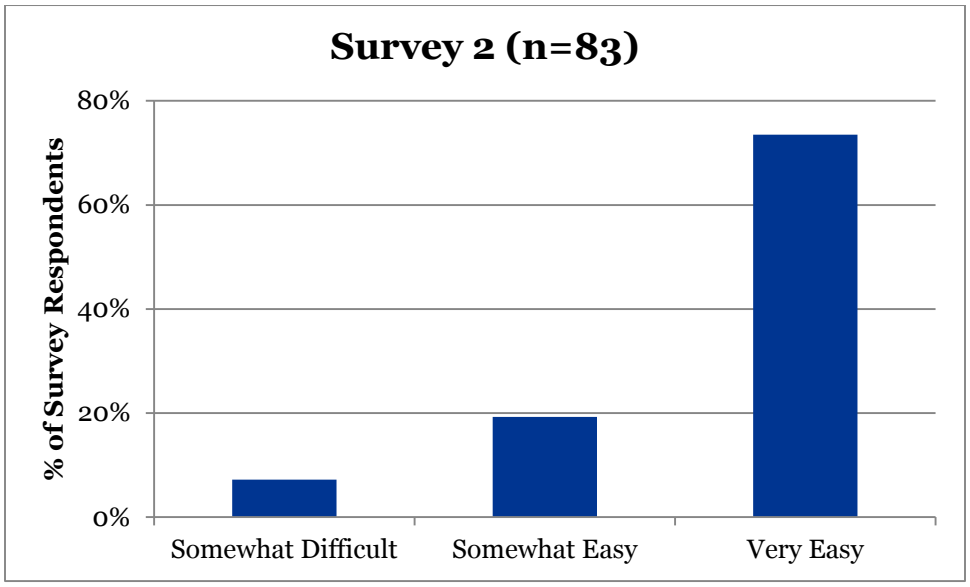
Survey respondents provided three reasons for participation, grand total sums to 300%.

What do customers like or dislike about the Nest thermostat?

The vast majority, comprising 92% of all second survey respondents, found the Nest thermostat operation to be either "somewhat easy" or "very easy," with only 7% of second-round survey respondents finding the Nest thermostat operation to be "somewhat difficult" (Figure 26).

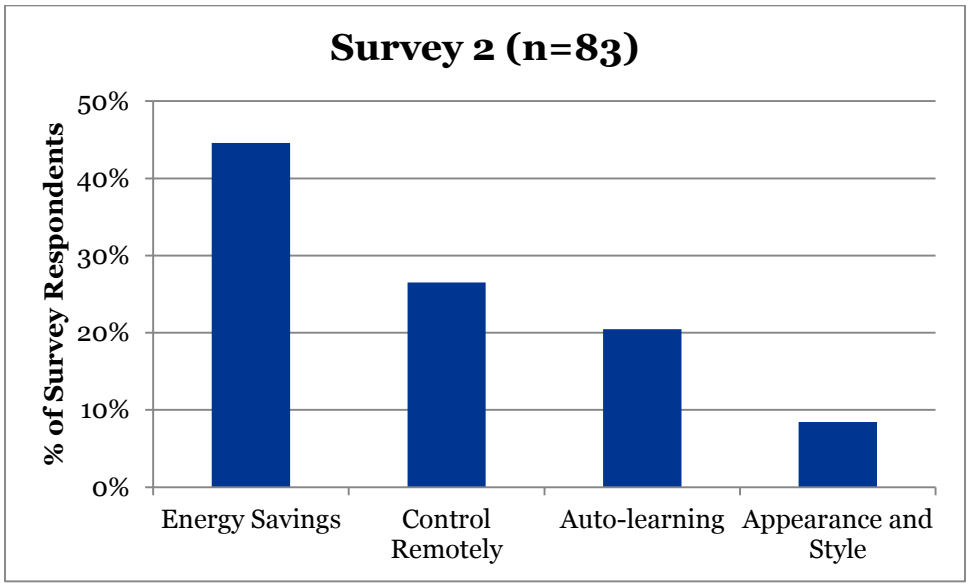
[15] While 110 participants responded to the first survey, three noted that their Nest thermostat had been removed. This resulted in 107 eligible participants for the second survey.

Figure 26. Ease of Nest thermostat operation



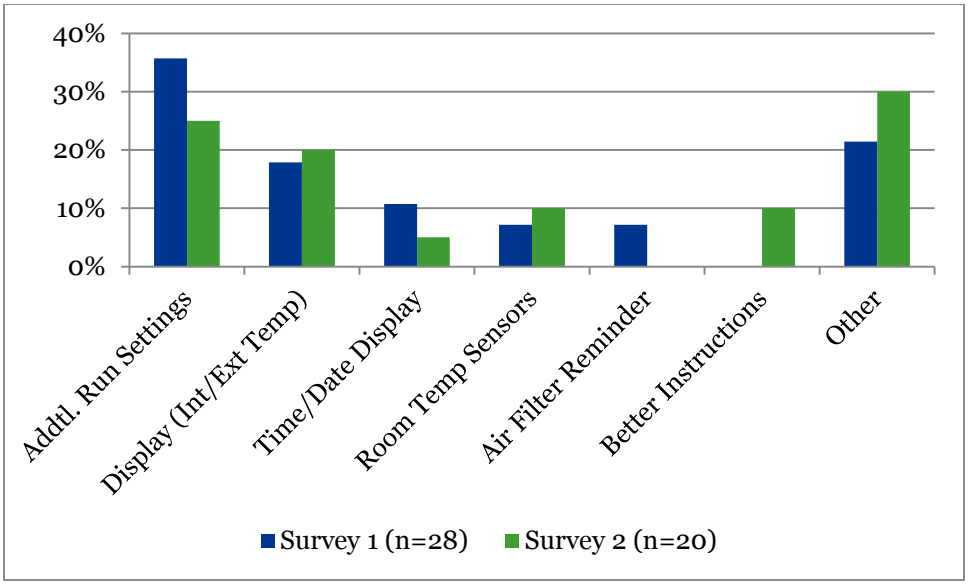
When asked about their favorite aspect of the Nest thermostat, participants' top response was the energy savings (45% of all second survey respondents, Figure 27). The ability to control remotely (27%) and Nest's auto-learning feature (20%) were also popular aspects of the Nest thermostat. Aside from the functionality of Nest and its energy savings potential, 8% of survey respondents most appreciated the thermostat for its aesthetics.

Figure 27. Favorite aspect of Nest thermostat



Around a quarter of survey respondents in both the first (28%) and second (24%) survey rounds expressed a desire for additional Nest thermostat functions. Additional run settings – meaning the ability to control the timing and scheduling for heating – 36% first survey, 25% second survey) was the most desired additional feature, followed by the ability to display the actual current temperature, primarily the outdoor temperature (18% first survey, 20% second survey). Some responses also demonstrated a lack of understanding of the Nest features; for example, 7% of first-round survey respondents recommended air filter reminders, a feature that Nest already offers. In addition to the general categories of additional features wanted, respondents also mentioned "other" features such as having the Nest thermostat interface with the utility company to show real-time usage statistics, increased security due to hacking concerns, and a humidity indicator.

Figure 28. Additional Nest thermostat functions wanted



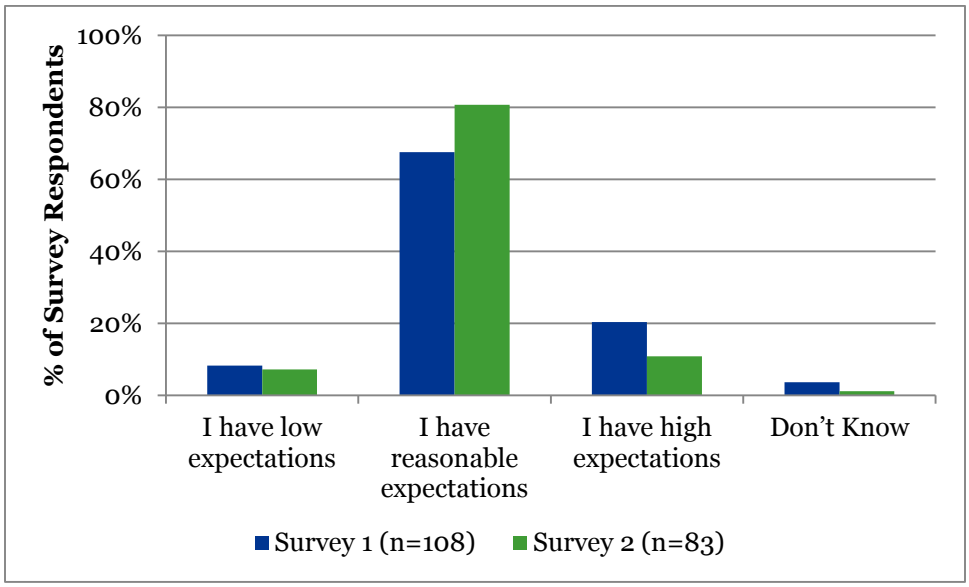
Were customers motivated by the potential energy savings?

Participants were absolutely motivated by the potential energy savings. As seen and discussed previously at the beginning of the findings section (in Figure 25 above), the most cited reason for participation in the Nest thermostat study was to lower energy bills, with 88% of respondents listing it among their top three reasons for participating. The next most frequent response provided was to save energy (49%), followed by increasing the comfort of the home (45%).

Higher energy savings expectations were seen in the first survey, with 20% of survey respondents indicating that they had high savings expectations associated with the Nest thermostat installation, compared to 11% in the second survey (Figure 29). Of those participants who answered both the first

and second survey, 11% had increased savings expectations between the two surveys and 20% had decreased savings expectations, with the remaining survey respondents noting the same energy savings expectations in both surveys.

Figure 29. Energy savings expectations



As the Nest thermostat – in the absence of the Energy Trust incentive – is a fairly substantial investment at approximately $250, study participants were asked whether or not they felt this full retail price was justified. Over half of the second survey respondents (62%) believed that the full retail price was warranted, with 36% feeling that the price was too high for the product (Figure 30). A noteworthy finding related to the respondents' perceived value of the Nest thermostat is presented in Figure 31, where the percentage of survey respondents finding the $250 price reasonable is analyzed with regard to household income. Interestingly, households with incomes of less than $50,000 made up the group with the highest percentage (79%) of survey respondents indicating that the $250 Nest thermostat was a justifiable price, followed by households with incomes above $90,000 (65%), the group one would imagine would be most willing to pay the high price. However, these differences across income group are not statistically significant.[16]

[16] While not statistically significant (p-value = 0.24), it would be very difficult to detect significant differences in such a small sample (n=69), so there may be important difference here.

Figure 30. Does the $250 Nest thermostat price tag make sense?

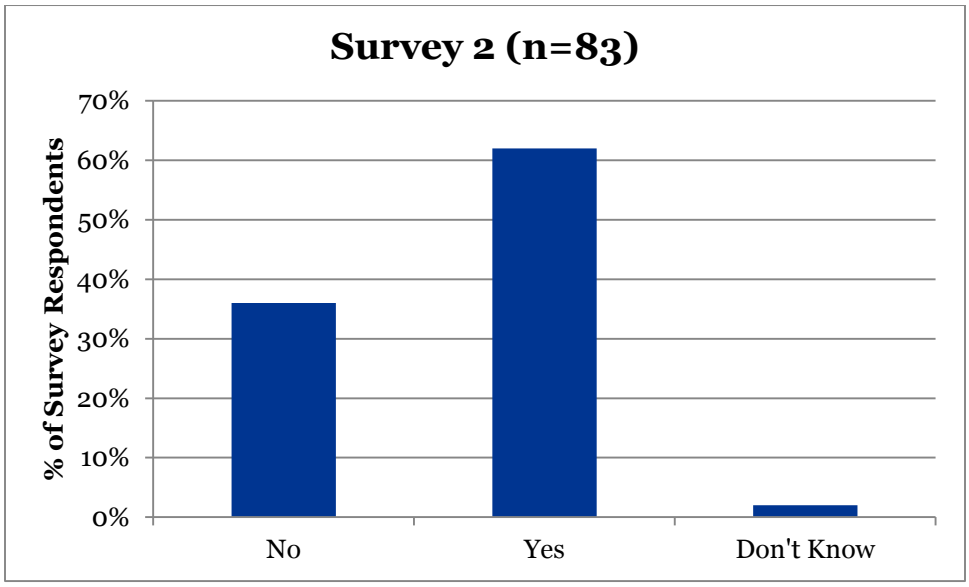
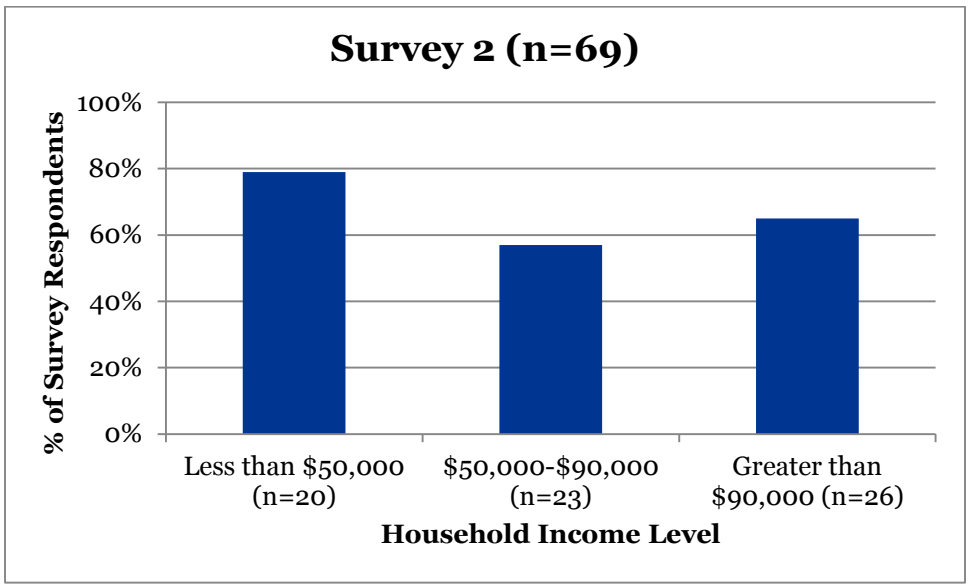


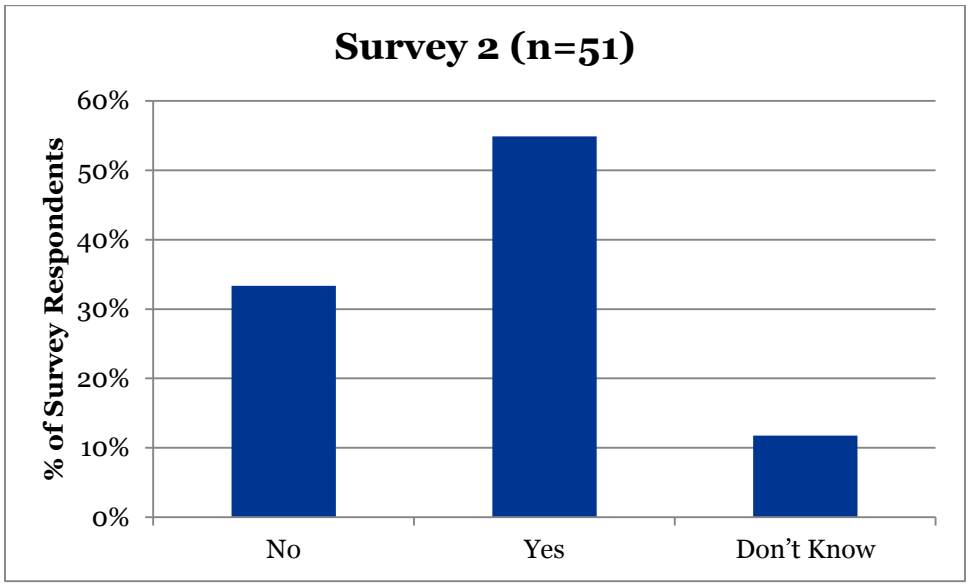
Figure 31. Respondents who feel the $250 price tag makes sense, by household income level



As a follow-up to the question about the Nest thermostat price, survey respondents who believed the full retail price was reasonable were asked whether that sentiment held true if zero energy savings were associated with the Nest thermostat. Fifty-five percent of those survey respondents (or 34% of all respondents) stated that the Nest thermostat was worth the full amount even if no energy savings were realized, with one-third of survey respondents not finding the Nest thermostat worth $250 once the

energy savings were removed from the equation. While the sample size is relative small at only 51 survey respondents, the results do suggest that study participants place a good deal of value in the Nest thermostat features, including remote access and automation.

Figure 32. Nest thermostat worth $250 with zero energy savings



Realized Energy Savings Results for the Nest Pilot

One of the primary objectives of this study was to determine the heating-based electric energy savings associated with the installation of the Nest thermostat. The questions that were originally posed in relation to energy savings included the following:

- Does Nest reduce heat pump run time in customer homes? Does it reduce cutover to resistance heat?
- Under ideal installation conditions, how much energy does the Nest thermostat typically save when installed in homes with whole-house electric heat pump systems?
- Which Nest functions appear to be the most important in saving energy?

The following section includes answers to these questions and provides insight into the billing analysis that was used to estimate the energy savings.

Overall Nest Pilot Savings Results

Using the best fit model described above, the 326 homes available for analysis (113 participant and 211 comparison homes) provided 6,845 observations for analysis. There was an average of 21 observations

per home with a minimum of five and a maximum of 23. The preliminary[17] overall, weather-normalized, annual electric savings attributable to the Nest thermostat were 781 kWh per year or 4.7% of annual electric use (Table 12). The team did not have a complete annual billing cycle to be able to pinpoint the participant-specific heating load though as a proxy the team leveraged a recent NEEA/Ecotope metering study to approximate the participant base heating load. [18] Savings are approximately 12% of the annual heating load, using the RBSA's regional estimate for heating load in electric heated homes of 38% of annual usage. Compared to the predicted savings of 836 kWh per year, the savings realization rate was 93%. However, the team learned from the implementation report and the participant surveys that many participants experienced technical issues with the Nest thermostat or could not figure out how to use the device properly. If homes that experienced these types of issues were removed from the analysis, the savings would likely be higher.

Table 12. Preliminary Nest weather-normalized annual electric savings.

Annual Savings (90% CI)	Std. Err.	p-value	Annual Usage	% Savings (90% CI)	Realization Rate
781 (316, 1246)	256	0.012	16,569	4.7% (1.9, 7.5)	93%

Model Sensitivity Analysis

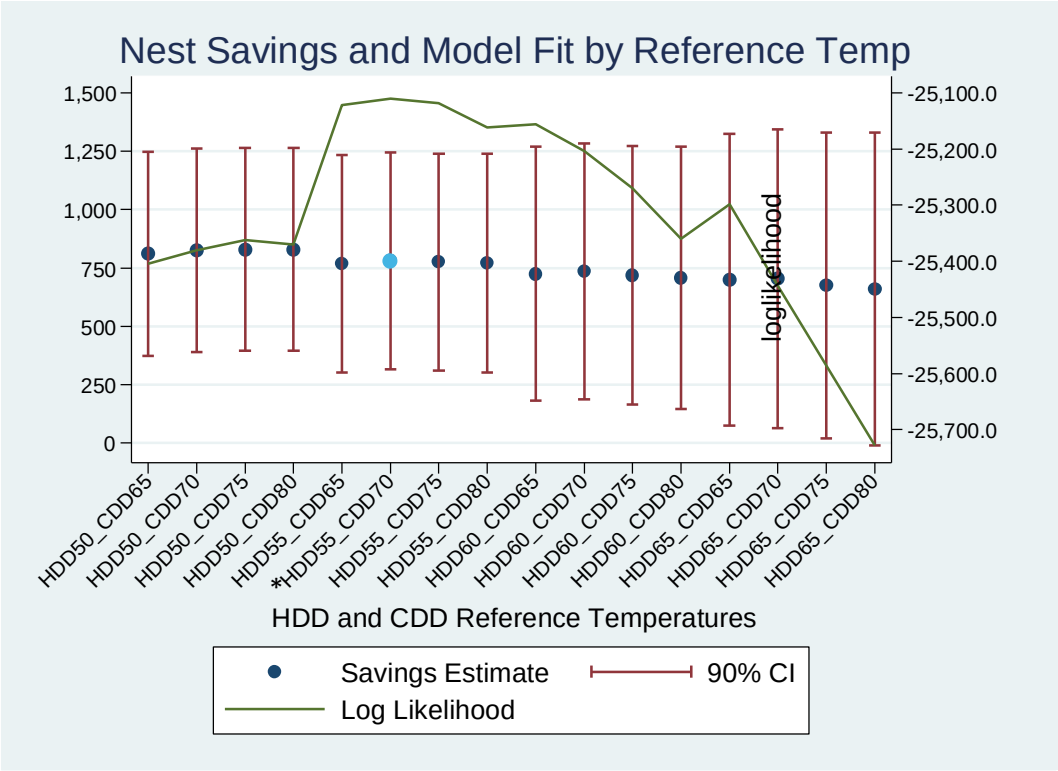
As described above in the Billing Analysis Methods section, the team tested models with a variety of HDD and CDD reference temperatures and ultimately selected the one with the best fit statistics. However, the team was concerned that the savings estimate might be sensitive to model specification. To test this, the team calculated the annual savings, using the method described above, for HDD reference temperatures from 50 to 65°F on five-degree intervals and for CDD reference temperatures from 65 to 80°F on five-degree intervals.

Figure 33 compares the savings estimates resulting from each model along with the 90% confidence intervals and log likelihood of each model. It clearly shows that the reference temperatures did not dramatically influence the savings estimates.

[17] A more robust estimate will be obtained after a full year of post-pilot billing data is available and can compare full years of data and even look at house level weather normalization (using PRISM-like methods).

[18] Ecotope, April 2014; *Residential Building Stock Assessment: Metering Study* - http://neea.org/docs/default-source/reports/residential-building-stock-assessment--metering-study.pdf?sfvrsn=6, page 101, table 81.

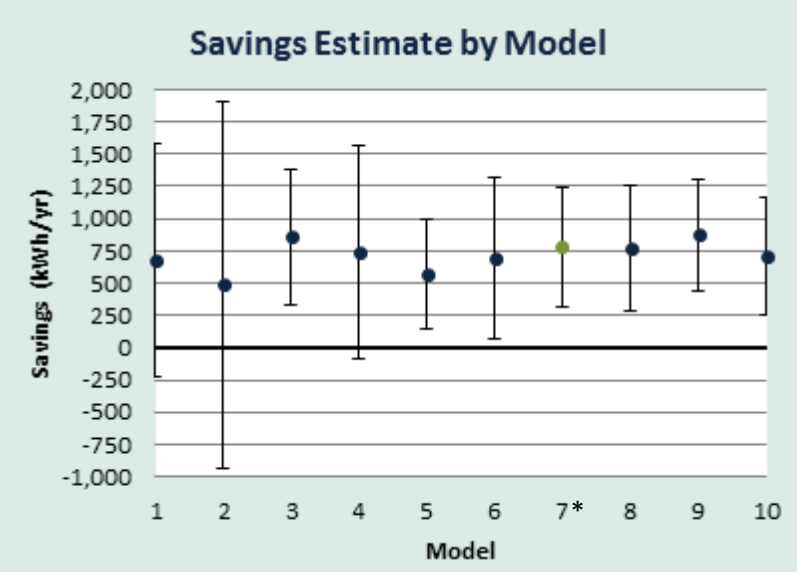
Figure 33. Nest pilot annual electric savings and model fit by HDD and CDD reference temperature.



* The best fit model, using HDD with base temperature 55 and CDD with base temperature 70. The savings estimate from this model is indicated with a light blue circle on the graph.

The Team also used a variety of models with less complex random effect structures and fewer interaction terms to estimate the savings. We also re-estimated the savings using the best fit model but included all of the outliers that had previously been removed. The savings estimates and 90% confidence intervals resulting from these different models are summarized in Figure 34 . Model 1 is a fixed-effects model, with HDD and CDD using a base temperature of 65 without any weather interaction terms. Model 2 is a fixed-effects model using a base temperature of 65 that includes weather interactions. Models 3 and 4 are mixed-effects models with random intercepts using a base of 65, excluding and including weather interaction terms, respectively. Models 5 and 6 are mixed-effects models with random slopes and intercepts using a base of 65, excluding and including weather interactions, respectively. Model 7, shown in green, is the best fit model, using HDD of base 55 and CDD of base 70. Model 8 is identical to Model 7 except that it includes all of the outliers. Although there is some variability in the savings estimates, the range is fairly narrow, and the estimate from the best fit model is near the middle of that range.

Figure 34. Nest pilot annual electric savings by model specification.



* The best fit model. The savings estimate from this model is indicated with a green circle on the graph.

Subgroup Analysis

The next level of analysis was to determine if the team could identify differences in the magnitude of savings for different subgroups of participants. It was hypothesized that participant demographics, prior thermostat features, heat pump characteristics, home characteristics, and the way in which participants used the Nest thermostat would impact the level of observed savings. Using variables described earlier from Energy Trust's project-tracking database and collected during installation site visits and participant surveys, the team was able to analyze annual electric savings for different subgroups. For variables where the team had information for both the participant and comparison homes, the team compared each participant subgroup to its corresponding comparison subgroup. However, in most cases the team did not have additional information about the comparison homes, and the analysis was done by splitting the participant group into subgroups and comparing each subgroup against the entire comparison group of 211 homes. This method has the downside of introducing error into the savings analysis by making the comparison group less representative of each participant subgroup. However, since each subgroup uses the same comparison group, the savings estimates are more similar to one another, and the error that is introduced will tend to bias the between-group differences towards zero.

There are several caveats to the subgroup analyses presented here. The subgroups were often very small, so apparent differences in savings may not have been meaningful or statistically significant. The participant group was divided up in many different ways to make a large number of comparisons. As a result, it is entirely possible that some of the apparent differences arose entirely by chance. We tried to

mitigate this risk by testing only differences where there was a theory to support a potential difference in savings. The analyses of various Nest features used by participants were based on self-reported survey data and were subject to response error. Therefore, the subgroups analyzed may not accurately reflect the actual use of the device by the participants.

Table 13 illustrates the correlations between selected participant characteristics used to create the subgroups analyzed in this section. Many of the subgroup variables the team analyzed were correlated with one another and may be correlated with unmeasured variables. Thus, the apparent differences in savings between subgroups may not have been a result of the subgroups; the subgroups may simply have been correlated with other factors that affected savings. As a result of these limitations, the team cannot draw too many hard conclusions about differences in savings based on the following subgroup analyses.

Table 13. Pearson correlations between selected participant characteristic variables.

Variable R-value p-value n	Age	Ed.	Inc.	Occs.	Chldn.	kWh	Sq. ft.	Const.	Prgm.	Lockout
Age	1 64									
Education	-0.174 0.168 64	1.000 68								
Income	-0.222 0.111 53	0.325 0.014 57	1.000 57							
Occupants	-0.472 0.000 63	0.236 0.055 67	0.209 0.123 56	1.000 68						
Children *0 = No* *1 = Yes*	-0.504 0 63	0.154 0.213 67	0.089 0.512 57	0.673 0.000 67	1.000 68					
Annual kWh	0.005 0.967 64	-0.137 0.265 68	-0.011 0.934 57	0.297 0.014 68	0.069 0.575 68	1.000 306				
Square feet	-0.062 0.625 64	0.069 0.575 68	0.047 0.730 57	0.164 0.181 68	0.248 0.041 68	0.540 0.000 306	1.000 324			
Construction *0 = Mfd.* *1 = Site built*	-0.176 0.164 64	0.244 0.045 68	0.314 0.017 57	0.295 0.015 68	0.173 0.158 68	0.260 0.000 306	0.288 0.000 324	1.00 324		
Prior program *0 = No* *1 = Yes*	0.124 0.333 63	0.024 0.849 67	0.078 0.567 56	-0.085 0.492 67	-0.156 0.208 67	0.181 0.060 109	0.250 0.008 110	0.430 0.000 110	1.00 110	
Prior lockout *0 = No* *1 = Yes*	-0.003 0.981 63	-0.325 0.007 67	-0.191 0.159 56	-0.020 0.876 67	0.046 0.713 67	0.028 0.774 109	-0.080 0.409 110	0.140 0.143 110	0.170 0.068 110	1.00 110

Participant and Comparison Subgroups

Savings by Region

The geographic location of every participant and comparison home was obtained from the housing characteristics data in Energy Trust's project-tracking database, FastTrack. Participant and comparison subgroups were created based on typical geographic regions used by Energy Trust. Homes located in Multnomah, Washington, Clackamas, Yamhill, and Columbia counties were grouped into the Portland Metro region. Homes located in Benton, Linn, Marion, and Polk counties were grouped into the Willamette Valley. Douglas, Josephine, and Jackson county homes were grouped into Southern Oregon. Each subgroup was analyzed separately. Savings results by region are summarized in Table 14.

The differences in savings by region were fairly striking. Portland Metro area homes, which tended to have more and younger occupants, realized the highest savings, at 7.3%, nearly double the overall average of 4.7%. These savings were highly significant, although the error band was relatively wide and overlapped with the other regions. Savings in Willamette Valley homes were essentially zero, with large relative error. Southern Oregon homes appeared to achieve modest savings, but with a low sample size and large relative error, they were not statistically different from zero.

Table 14. Nest weather-normalized annual electric savings by geographic region.

Region	Participant N / Comparison N	Annual Savings (90% CI)	Std. Err.	p-value	Annual Usage	% Savings (90% CI)	Realization Rate
Portland Metro	57 / 104	1,269 (567, 1971)	387	0.008	17,383	7.3% (3.3, 11.3)	152%
Willamette Valley	23 / 34	104 (-879, 1087)	543	0.852	14,866	0.7% (-5.9, 7.3)	12%
Southern Oregon	33 / 73	460 (-328, 1247)	435	0.315	17,039	2.7% (-1.9, 7.3)	55%

These results suggest that Portland Metro area participants were somewhat more successful in saving energy during the pilot.

Savings by Construction Type

The construction type of every participant and comparison home was obtained from the housing characteristics data in Energy Trust's project-tracking database. Participant and comparison subgroups were created based on whether a home was manufactured or built on site, and each subgroup was analyzed separately. Savings results by construction type are summarized in Table 15. Manufactured homes, which tended to be smaller, lower income, and use less energy, appeared to have very high savings, at 8.7% of electricity usage, more than double the overall average. These savings were

statistically significant, but the error band was relatively wide and overlapped with site-built homes. The large percent savings was also partly due to a lower baseline annual usage among manufactured homes.

Table 15. Nest weather-normalized annual electric savings by home construction type.

Construction Type	Participant N / Comparison N	Annual Savings (90% CI)	Std. Err.	p-value	Annual Usage	% Savings (90% CI)	Realization Rate
Manufactured	21 / 54	1,172 (470, 1874)	388	0.013	13,521	8.7% (3.5, 13.9)	140%
Site-built	92 / 157	669 (105, 1232)	311	0.057	17,532	3.8% (0.6, 7.0)	80%

These results suggest that participants in manufactured homes were somewhat more successful in saving energy during the pilot.

Savings by Electricity Usage

The baseline annual electricity usage of every participant and comparison home was calculated from the monthly utility billing data. Three electric use categories roughly equal in number of sites were created: homes using less than 13,000 kWh per year, homes using from 13,000 to 18,000 kWh per year, and homes using 18,000 or more kWh per year. Participant and comparison homes were assigned to these subgroups based on their annual usage, and each subgroup was analyzed separately. Savings results by electricity usage category are summarized in Table 16. Not surprisingly, the highest usage category, with the most opportunity for reduction, achieved the largest electric savings at 8.2%, which was nearly double the overall average and statistically significant. However, the error bands were relatively wide and overlapped with the other usage categories. High users tended to be larger, site-built homes with more occupants. The lowest usage category had essentially zero savings, while the middle category saw modest but insignificant savings of 1.8%.

Table 16. Nest weather-normalized annual electric savings by annual electricity usage.

Electricity Usage Category	Participant N / Comparison N	Annual Savings (90% CI)	Std. Err.	p-value	Annual Usage	% Savings (90% CI)	Realization Rate
Less than 13,000 kWh	32 / 79	-60 (-619, 498)	308	0.848	10,022	-0.6% (-6.2, 5.0)	-7%
13,000 to 18,000 kWh	46 / 62	267 (-330, 864)	329	0.437	15,125	1.8% (-2.2, 5.7)	32%
18,000+ kWh	34 / 53	1,984 (678, 3289)	720	0.020	24,233	8.2% (2.8, 13.6)	237%

These results indicate that homes with higher electric use were somewhat more successful in saving energy during the pilot. This effect appears to be graded.

Participant Subgroups

Savings by Participant Age

Participant age data was derived from the participant survey. This subgroup analysis was limited to those who responded to the survey question about age; 103 of the 177 participants responded to this question, and sample attrition brought that down to just 64 participants (36%) who could be analyzed. Three age categories of roughly equal numbers of participants were created: less than 50 years old, 50 to 64 years old and 65 or more years old. Each of the participant subgroups were then analyzed against the entire comparison group. Savings results by age category are summarized in Table 17. During the implementation of the pilot, it was hypothesized that elderly participants, who were associated with lower occupancy and fewer children, might have lower savings due to less aptitude with technology. The savings results appeared to bear that out, with the oldest age group seeing a slight, although insignificant, increase in electric use. The lowest age group had modest but insignificant savings, at 2.8%. The middle age group seems to have achieved the highest savings, at 7.0%, which was borderline statistically significant. However, the precision of this savings estimate was very low, and the error bands overlapped with the other subgroups.

Table 17. Nest weather-normalized annual electric savings by reported participant age (Comparison N=211).

Age Category	Participant N	Annual Savings (90% CI)	Std. Err.	p-value	Annual Usage	% Savings (90% CI)	Realization Rate
Less than 50	21	471 (-503, 1444)	537	0.401	16,878	2.8% (-3.0, 8.6)	56%
50 to 64	20	1,123 (148, 2097)	538	0.063	15,941	7.0% (0.9, 13.2)	134%
65+	23	-84 (-920, 753)	461	0.860	16,998	-0.5% (-5.4, 4.4)	-10%

These results suggest that elderly participants were somewhat less successful in saving energy during the pilot.

Savings by Participant Income

Participant household income data was derived from the participant survey. This subgroup analysis was limited to those who responded to the survey question about income; 91 of the 177 participants responded to this question, and sample attrition brought that down to just 57 participants (32%) who could be analyzed. Three income categories of roughly equal numbers of participants were created: less than $50,000, $50,000 to $90,000, and $90,000 or more. Each of the participant subgroups were then analyzed against the entire comparison group. Savings results by income category are summarized in Table 18. The lowest income category, which tended to have more manufactured homes and less education, had the largest percent savings of any subgroup that the team analyzed, at 11.1%. This income category also had very large and significant differences in savings between the other two income

categories. In contrast, the middle income category saw an increase in electric use, although this was insignificant, and the high income category had savings of essentially zero.

Table 18. Nest weather-normalized annual electric savings by reported participant income (Comparison N=211).

Income Category	Participant N	Annual Savings (90% CI)	Std. Err.	p-value	Annual Usage	% Savings (90% CI)	Realization Rate
Less than $50,000	20	1,654 (779, 2530)	483	0.007	14,944	11.1% (5.2, 16.9)	198%
$50,000 to $90,000	20	-458 (-1463, 548)	555	0.429	18,708	-2.4% (-7.8, 2.9)	-55%
$90,000+	17	-15 (-1046, 1017)	569	0.980	14,755	-0.1% (-7.1, 6.9)	-2%

These results strongly indicate that homeowners with less than $50,000 per year of income were more successful in saving energy during the pilot.

Savings by Participant Education Level

Participant education data was derived from the participant survey. This subgroup analysis was limited to those who responded to the survey question about education; 109 of the 177 participants responded to this question, and sample attrition brought that down to 68 participants (38%) who could be analyzed. Three education categories of roughly equal numbers of participants were created: less than a college degree, college degree, and graduate degree. Each of the participant subgroups were then analyzed against the entire comparison group. Savings results by education level are summarized in Table 19. The highest education category, which tended to have more site-built homes, higher income, and more occupants, saw a relatively large but insignificant increase in electric usage of 4.5%. In contrast, the middle and lower education categories had slightly higher savings than the overall average, at 5.6% and 6.1%, respectively. These were borderline statistically significant, although the error bands were relatively wide and overlapped with the high education category.

Table 19. Nest weather-normalized annual electric savings by reported participant education (Comparison N=211).

Education Level	Participant N	Annual Savings (90% CI)	Std. Err.	p-value	Annual Usage	% Savings (90% CI)	Realization Rate
Less than college degree	21	1,070 (159, 1980)	502	0.059	17,470	6.1% (0.9, 11.3)	128%
College degree	28	944 (126, 1762)	451	0.063	17,002	5.6% (0.7, 10.4)	113%
Graduate degree	19	-692 (-1658, 274)	533	0.223	15,271	-4.5% (-10.9, 1.8)	-83%

These results suggest that participants with less education were more successful in saving energy during the pilot.

Savings by Number of Occupants

Data on occupants per home was derived from the participant survey. This subgroup analysis was limited to those who responded to the survey question about number of occupants; 109 of the 177 participants responded to this question, and sample attrition brought that down to 68 participants (38%) who could be analyzed. Three categories roughly equal in number of occupants were created: one person, two people, and three or more. Each of the participant subgroups were then analyzed against the entire comparison group. Savings results by number of occupants are summarized in Table 20. One-person households, which were associated with more elderly participants, lower education, more manufactured homes and lower electric usage, saw an increase in their electric usage of 7.6%, although this was not statistically significant. Households with two and three or more occupants saw savings of 4.5% and 3.7%, respectively, close to the overall average. However, these were not statistically significant and had wide confidence intervals that overlapped somewhat with one-person households.

Table 20. Nest weather-normalized annual electric savings by reported number of occupants (Comparison N=211).

# of Occupants	Participant N	Annual Savings (90% CI)	Std. Err.	p-value	Annual Usage	% Savings (90% CI)	Realization Rate
1 person	11	-846 (-2045, 352)	661	0.230	11,189	-7.6% (-18.3, 3.1)	-101%
2 people	33	769 (35, 1502)	405	0.087	17,229	4.5% (0.2, 8.7)	92%
3+ people	24	631 (-288, 1551)	507	0.242	17,241	3.7% (-1.7, 9.0)	76%

These results suggest that homes occupied by one person were less successful in saving energy during the pilot.

Savings by Children Living at Home

Data on children under the age of 18 living at home was derived from the participant survey. This subgroup analysis was limited to those who responded to the question about children; 109 of the 177 participants responded to this question. This was reduced to 68 participants (38%) who could be analyzed after sample attrition. Participant subgroups were created based on whether children were living at home or not and analyzed against the entire comparison group. Savings results by children are summarized in Table 21. Participant homes with no children, which tended to be smaller and have fewer, older occupants, achieved higher savings than homes with children (4.1% vs. 0.9%), which was borderline statistically significant. Although savings for homes with children appeared to be very low, the error bands were wide and overlapped with the no-children group. This finding goes counter to the savings results by number of occupants and may be a random fluctuation due to the small number of participants with children at home.

Table 21. Nest weather-normalized annual electric savings by children reported living at home (Comparison N=211).

Children*	Participant N	Annual Savings (90% CI)	Std. Err.	p-value	Annual Usage	% Savings (90% CI)	Realization Rate
No children	50	671 (62, 1280)	336	0.074	16,343	4.1% (0.4, 7.8)	80%
Children at home	18	159 (-898, 1216)	583	0.791	17,326	0.9% (-5.2, 7.0)	19%

* Children were defined in the participant survey as anyone under the age of 18 living in the home.

These results suggest that participants with no children at home were somewhat more successful in saving energy during the pilot, although this could be a random fluctuation due to the small sample of homes with children.

Savings by Prior Thermostat Type

Information on the type of thermostat previously used in participant homes was obtained from the housing characteristics data collected during the installation site visits. This data was available for 171 of 177 participant homes, which was reduced to 110 homes (62%) that could be analyzed after sample attrition. Participant subgroups were created based on whether the prior thermostat was programmable or not and then analyzed against the entire comparison group. Savings results by prior thermostat type are summarized in Table 22. Interestingly, homes where the Nest thermostat replaced a programmable thermostat appeared to save more energy than where it replaced a non-programmable thermostat. It is well established that standard programmable thermostats are often not programmed or not programmed to save energy. In addition, homes with prior programmable thermostats tended to be larger, site-built homes with higher energy use. The prior programmable thermostat group saved an average of 6.5%, which was statistically significant and higher than the overall average. Even though the savings for the prior non-programmable thermostat group were less than half this much (2.9%), the error bands between the two estimates overlapped.

Table 22. Nest weather-normalized annual electric savings by prior thermostat type (Comparison N=211).

Prior Thermostat Type	Participant N	Annual Savings (90% CI)	Std. Err.	p-value	Annual Usage	% Savings (90% CI)	Realization Rate
Not programmable	28	423 (-384, 1230)	445	0.365	14,656	2.9% (-2.6, 8.4)	51%
Programmable	82	1,151 (621, 1681)	293	0.003	17,619	6.5% (3.5, 9.5)	138%

These results suggest that participants who previously had a programmable thermostat were somewhat more successful in saving energy during the pilot.

Savings by Use of Smart Phone App

Information on participants' use of the Nest smart phone app to adjust the thermostat remotely was derived from the participant survey. The sample for this subgroup analysis was limited to those who responded to the survey question about smart phone use; 110 of the 177 participants responded to this question, which was reduced to 71 participants (40%) who could be analyzed after sample attrition. Participant subgroups were created based on whether the smart phone app was reportedly used to adjust the thermostat or not and then analyzed against the entire comparison group. Savings results by use of the smart phone app are summarized in Table 23. Participants who reported using the app to adjust their thermostat achieved higher electric savings than those who did not use it (4.0% vs. 0.1%), although the error bands of the savings estimates overlapped. Participants who reported using the app had savings that were near the overall average. Those who did not use the app had essentially zero savings.

Table 23. Nest weather-normalized annual electric savings by reported use of smart phone app to adjust thermostat (Comparison N=211).

Use of Smart Phone App	Participant N	Annual Savings (90% CI)	Std. Err.	p-value	Annual Usage	% Savings (90% CI)	Realization Rate
Did not use feature	20	314 (-618, 1246)	514	0.555	16,587	1.9% (-3.7, 7.5)	38%
Used feature	49	661 (33, 1288)	346	0.085	16,641	4.0% (0.2, 7.7)	79%

These results suggest that participants who used the smart phone app to adjust their thermostat were more successful in saving energy during the pilot.

Savings by Use of Filter Reminders

Information on participants' use of Nest filter reminders was derived from the participant survey. The sample for this subgroup analysis was limited to those who responded to the survey question about filter reminders; 110 of the 177 participants responded to this question, which was reduced to 71 participants (40%) who could be analyzed after sample attrition. Participant subgroups were created based on whether filter reminders were reportedly used or not and then analyzed against the entire comparison group. Savings results by use of the filter reminders are summarized in Table 24. There appears to be a large and significant difference between these two subgroups. Participants who reported using the filter reminders had large, statistically significant savings, at 7.1%, nearly twice the overall average. Participants who reported not using this feature experienced an increase in electric usage, although this was not statistically significant.

Table 24. Nest weather-normalized annual electric savings by reported use of filter replacement reminders (Comparison N=211).

Use of Filter Reminders	Participant N	Annual Savings (90% CI)	Std. Err.	p-value	Annual Usage	% Savings (90% CI)	Realization Rate
Did not use feature	30	-266 (-1040, 508)	427	0.547	16,132	-1.7% (-6.4, 3.1)	-32%
Used feature	39	1,211 (510, 1911)	387	0.011	16,976	7.1% (3.0, 11.3)	145%

These results strongly indicate that participants who used the filter reminders were more successful in saving energy during the pilot.

Savings by Prior Thermostat's Backup Heat Lockout Capability

Information on the backup resistance heat lockout capability of the thermostat previously used in participant homes was obtained from the housing characteristics data collected during the installation site visits. No information was available on whether the lockout was properly functioning or set at the recommended temperature. Participant subgroups were created based on whether the prior thermostat had the capability to lock out the heat pump's backup heat source or not and then analyzed against the entire comparison group. Unfortunately, the team was unable to analyze the difference between these subgroups due to the small number of participants, after sample attrition, who reported having a prior thermostat with lockout capability (n=9; 5%).

Savings by Balance Point Setting

Information on whether participants changed the Nest thermostat's heat pump balance point was derived from the participant survey. The heat pump balance point controls the degree to which the Nest attempts to avoid using the electric resistance backup heat. During installation, each device was set to "Max Savings" to effectively lock out the backup heat as much as possible and maximize the energy savings. However, even though participants agreed not to alter this setting, it can be changed by the user, so the team asked participants if they did this. The Team believed that the backup heat lockout capability of the Nest thermostat was one of the core features that would enable it to save energy in heat pump homes. Unfortunately, the team was unable to analyze the impact of this feature due to the small number of participants, after sample attrition, who reported changing the heat pump balance point (n=8; 5%). However, preliminary data obtained directly from Nest Labs showed that participant backup heat run times doubled when the Max Savings heat pump balance settings were changed to a different (non-Max Savings) setting.

Savings by Use of AutoAway

Information on the use of the Nest thermostat's AutoAway feature was derived from the participant survey. The device's default setting was to employ its onboard motion sensor to detect when occupants were away and automatically set the temperature back accordingly. However, the AutoAway feature can be turned off, so the team asked participants if they did this. The sample for this analysis was limited

to those who responded to the survey question about using AutoAway; 110 of the 177 participants responded to this question, which was reduced to 69 participants (39%) who could be analyzed after sample attrition. Participant subgroups were created based on whether AutoAway was reportedly turned off or not and then analyzed against the entire comparison group. This comparison was limited due to the small sample of participants, after sample attrition, who turned off AutoAway (n=15). With that limitation in mind, it appears that participants who reported keeping this feature turned on had higher savings than those who reported turning it off (4.0% vs. 1.9%), but the difference was not significant. Savings results by use of the AutoAway feature are reported in Table 25**.**

Table 25. Nest weather-normalized annual electric savings by reported use of AutoAway (Comparison N=211).

AutoAway Setting	Participant N	Annual Savings (90% CI)	Std. Err.	p-value	Annual Usage	% Savings (90% CI)	Realization Rate
Kept feature turned on	54	637 (36, 1238)	331	0.084	16,567	3.8% (0.2, 7.5)	76%
Turned feature off	15	269 (-805, 1343)	593	0.659	16,810	1.6% (-4.8, 8.0)	32%

6. Conclusions and Recommendations

The Nest Pilot Study was very successful on a number of key aspects: the speed of pilot inception through implementation, high participant satisfaction ratings, and robust electric energy savings. The pilot did suffer some setbacks, including technical and logistical issues and a small but vocal minority of participants who were dissatisfied with the thermostat. The quick response time, flexibility, and adaptability to resolve these issues proved to allay most participant frustration about the functioning of the device. This is particularly evident in the high participant satisfaction ratings reviewed and discussed above in the Findings section of this report. Over 90% of respondents indicated a satisfaction rating of either a 4 or 5 for the scheduling of the installation, length of time to install, and their overall rating of the installation process. Satisfaction related to the thermostat itself was also very positive, with 89% (from the second survey) providing a rating of 4 or 5. Similarly, 81% of the second survey respondents reported a 4 or 5 rating for the Nest thermostat study overall.

Staff members at both Energy Trust and CLEAResult overwhelmingly felt that the pilot was a worthwhile and successful endeavor. The speed with which the initial pilot design was proposed and then executed was unanimously the quickest that both teams had ever experienced. All staff members interviewed felt that this pilot, if shown to provide reasonable energy savings, would be a valuable addition to the portfolio of programs offered by Energy Trust. The following section summarizes and distills the findings contained in this report and offers recommendations to assist Energy Trust in its efforts to launch an expanded advanced thermostat incentive for electric heat pumps and for other future pilot studies.

Energy Savings and Realization Rate

Nest pilot participants achieved significant electricity savings, at 781 kWh per year on average, or 4.7% of annual electric usage. This translates to a 93% realization rate compared to the working savings estimate of 836 kWh per year and is a relatively strong savings finding, especially given that there were many installation and technical difficulties with the Nest throughout the pilot described above. Furthermore, this pilot study focused exclusively on electric heating savings and did not attempt to assess the additional potential savings associated with the summer cooling season.

Further analysis showed that these savings were not achieved uniformly by all participant homes in the pilot. Large differences appeared in the amount of savings realized between subgroups:

- Homes in the Portland Metro area appeared to have somewhat higher savings than those in Southern Oregon or the Willamette Valley.
- Manufactured homes appeared to have somewhat higher savings than single-family homes.

- As expected, homes with high electric usage had the highest savings, with the highest usage category achieving an impressive 1,785 kWh per year, or 7.3%.
- Elderly participants appeared to have essentially zero savings, which is in line with feedback and anecdotal evidence the team received during the pilot. The middle age category (50 to 64) had the highest level of savings.
- Surprisingly, the lowest income and education categories had higher savings than their more affluent and more educated counterparts. In fact, the lowest income group had the highest percent savings of any subgroup in our analysis, at 11.1% (1,654 kWh).
- Single-person households, which were associated with more elderly participants, appeared to experience a large increase in electric usage during the pilot. Participants with children living at home appeared to achieve slightly lower-than-average savings.

Homes where the Nest replaced a programmable thermostat were expected to save slightly less energy, but that was not the case. Participants who started out with a programmable thermostat saved more energy than those who did not. The Nest's other energy-saving features appeared to be relatively important to energy savings. Participants who reported keeping the AutoAway feature on, using the smart phone app to adjust their thermostat, and making use of the filter reminders all achieved somewhat higher energy savings than their counterparts. Due to sample size limitations, the team was unable to analyze the impacts of two potentially important factors that could reduce Nest thermostat savings: there were too few participant homes that either changed the heat pump balance point or had a prior thermostat with backup heat lockout capability to analyze any differences in savings for these groups. Fortunately, Nest Labs provided participant usage data that showed backup heat run times doubled for those participants that adjusted the heat pump balance setting away from "Max Savings", though the team was unable to attribute specific energy savings to this feature.

The Nest pilot ensured the best possible thermostat installation scenario, with site visits and ongoing support. However, there were some technical issues, discussed throughout this report, which may have eroded the realized energy savings in some cases. In addition, the method that was used to identify participants, including providing a free thermostat, may have resulted in many participants obtaining a Nest who would not normally have bought one. This may have created a group of participants who were mismatched to the technology and were not ideal candidates to receive a Nest, further reducing the observed savings. In the future, if the technical issues can be resolved and the thermostats find their way to customers who are better suited to them and can more effectively use them, then the average energy savings could increase.

Although the team is confident in the overall savings estimate from this analysis, there are a few concerns that remain. The amount of follow-up time for the analysis was relatively short. Most homes only had post-implementation data available from January through April of 2014 at the time of the analysis. We plan to rerun this analysis and update the savings numbers once there is a full year of

follow-up data available. We have some reservations about the reliability of the results from the subgroup analyses. Each subgroup comparison began with a relatively small sample of pilot homes and cut it into even smaller pieces to analyze. With such small samples to work with and so many comparisons that the team was interested in, there may have been random fluctuations in the data that resulted in observing spurious differences. Finally, using linear mixed-effects regression models to weather-normalize utility data and estimate savings is a new technique for Energy Trust, and while the team followed recommended best practices, this method has not yet been fully vetted against our standard billing analysis methods.

***Recommendation**: The results of the billing analysis should be adopted as the default deemed savings expected from the installation of the Nest thermostat in heat pump-heated homes when directly installed by program staff. The direct install aspect of this pilot may contribute to higher savings due to both the expert installation (higher quality control and expertise) and the educational component of the installation process. Though some of the subgroup analysis did show significant differences and should be used to help with future program design, the use of and reporting of the savings associated with the subgroups should be made cautiously to avoid placing too much emphasis on these findings, due to the lack of precision and statistical significance with some of the results. As an example, the robust savings associated with income-qualified households could be used to help target or include the Nest thermostat as part of an income-qualified program.*

Implementation

One issue that the implementation contractor, CLEAResult, encountered during the launch of this pilot was the integrity of the FastTrack database site information. The sites of every home on the candidate list should have been eligible to receive a Nest. However, some homes on the list for the treatment group either did not have a heat pump or used a non-qualifying fuel source as their supplementary heat (e.g., wood). Because the comparison group was not contacted in any way during the study, there is no way to verify that all sites have heat pumps. This introduces the possibility that the comparison group is not identical to the treatment group and may provide a less-than-perfect comparison.

Another issue CLEAResult encountered during the implementation of this pilot was the low response and participation rate. During the initial recruitment calls, CLEAResult reported that “During this [recruitment] time period, it was reported that the two major barriers to recruiting were skepticism of people on the phone making offers and a lack of knowledge of the Nest. When people answered the phone, they were often skeptical that we were trying to sell or scam them, and were hesitant to agree to participate. The vast majority of people also did not know anything about the Nest and had never heard of a ’smart thermostat’”.

***Recommendation**: In planning future studies, CLEAResult's experience with this pilot suggests that the following improvements:*

- *Data that are collected and compiled for the FastTrack database should receive a series of quality control measures and cross-checks to ensure that the data are accurate and valid, especially when they may be used for future planning and evaluation efforts*
- *Letters followed up by phone calls is a better approach than outbound calling alone because it makes the calls "warm" and allows motivated candidates to sign up on their own. In Apex's own experience the team have found this to be true and used this exact approach to recruit for the online surveys*.

Recruitment, Participation, and Installation Rates

The Nest Pilot experienced a fairly high attrition rate during the recruitment and installation process. There were a number of challenges that were unforeseeable but some issues that should have been expected and integrated as part of the pilot. These issues are related to the successful installation of the Nest thermostats – this includes disqualified participants (due to equipment incompatibility), Wi-Fi logistical issues (lack of password, weak signal strength), hardware (defective sub-bases, wiring requirements), and participant confusion about the presence of a heat pump system. Furthermore, the participant sample was deemed to be over-representative of an elderly population (this is often termed a "sample of convenience" due to the majority of the recruitment having occurred during the middle of the day), which made some of the installation and technical issues more pronounced.

***Recommendation**: To best avoid these recruitment and installation issues in the future, the critical breaking points of the pilot should be well understood and researched with plans in place to avoid their occurrence. "Breaking points" can be mapped at the onset of any pilot and can be researched using web-based queries, communicating directly with manufacturers and contractors of the measures to be installed, and reaching out to any other program administrator or utility that has offered a comparable program. Hindsight is 20/20, but in the haste to launch the pilot there should have been some amount of time and resources committed to this research. As an example, the sub-base issue was well documented going back to early 2013 using a simple web-search for "Nest installation issues" or "Nest heat pump installation."*

Regarding recruitment issues, Energy Trust should ensure that any future recruitment will reach a broader population of household and demographics, and Energy Trust should be proactive with recruitment (recruit during different times and days of the week to avoid convenience samples).

To help alleviate any participant frustration with the use of the Nest device and adjustments to the settings, Energy Trust should provide a troubleshooting guide to the most common issues encountered during this pilot, let participants know who to contact, and make it clear that support will be

immediately available. Energy Trust should also ensure that study participants are aware of the support available to them, as it appears that encountering some initial difficulties is fairly typical. As it was administered during this pilot, the installation process should continue to provide ample time to attempt to educate the study participants as much as possible.

Participant Usage, Feedback, and Satisfaction

As noted above, the team was unable to directly link specific Nest features with energy savings, though it was clear from the results that those participants who tended to use the features had considerably higher savings compared to those participants who did not use any features. A minority of study participants reported changing the setting of two prominent Nest thermostat features: Heat Pump Balance (8% Survey 1, 13% Survey 2) and AutoAway (19% Survey 1, 20% Survey 2). Nest Labs provided usage data corroborated this finding, showing that 14% of participant thermostats were set to something other than Max Savings by the end of the heating season. Additionally, a smaller than expected portion of survey respondents stated that they adjusted the Nest thermostat by smart phone (62% Survey 1, 61% Survey 2) or online (57% Survey 1, 64% Survey 2).

The most cited reason for participation in the Nest thermostat study was to lower energy bills, with 88% of respondents listing it among their three reasons for participating. The next most frequent response provided was to save energy (49%), followed by increasing the comfort of the home (45%). The favorite aspect of the Nest thermostat was the energy savings (45% of all second survey respondents), while the ability to control remotely (27%) and Nest's auto-learning feature (20%) were also popular aspects of the Nest thermostat. Some of the Nest thermostat features and functionality were frequently used by study participants, such as the Nest Leaf (94%), AutoSchedule (92%), Energy History (88%), and Early On (83%). Other Nest features were not: over a third of participants, in both the first- and second-round surveys, reported not adjusting the thermostat with a smart phone or online, as well as not using the filter reminder feature.

In terms of the perceived usefulness of the various features, the AutoSchedule feature was perceived to be the most useful, with 81% of survey respondents in the first survey and 87% in the second survey reporting that the feature was either "Somewhat Useful" or "Very Useful." The Nest Leaf was the next most cited feature (81% first survey, 84% second survey), followed by the Energy History feature (74% first survey, 83% second survey). Some participants who responded to the survey were evidently not even aware of the features, since they added recommendations that Nest incorporate the very features that already exist.

Every data collection resource used for this study corroborated the same finding: that participants were absolutely motivated to participate due to the potential energy savings.[19] Installation field staff indicated that this was the number one reason for the participants to have signed up, while the participant surveys were unanimously in agreement that the potential energy savings (associated with lower energy bills) was the most important attribute of the thermostat. The most cited reason for participation in the Nest thermostat study was to lower energy bills, with 88% of respondents listing it among their three reasons for participating. The next most frequent response provided was to save energy (49%), followed by increasing the comfort of the home (45%).

Participants also felt increased comfort in their homes. Over 60% of survey respondents in both the first-round survey (61%) and second-round survey (66%) described the temperature of their home to be either "somewhat more comfortable" or "much more comfortable" after installing the Nest thermostat. The percentage of survey respondents who felt the temperature was either "much less comfortable" or "somewhat less comfortable" decreased from 17% to 6% between the first-round and second-round surveys. Related to this finding is the change in the adjustment of settings and usage of features by study participants, with a 12% point decrease from survey one to survey two in daily interaction with the thermostat, offset by an 11% point increase over the same time frame for monthly interaction with the thermostat. Both of these findings suggest that the Nest thermostat study participants learned how to better utilize the Nest thermostat features and functionality. The findings also suggest that the Nest thermostat itself got better at identifying the households' preferences and behavior.

In spite of the importance of energy savings to participants, the non-energy benefits associated with the Nest were very high: Over 34% of all respondents believed the Nest thermostat was worth the full retail price (~$250) even if no energy savings were realized. While the sample size is relatively small at only 51 survey respondents, the results do suggest that study participants place a good deal of value in the Nest thermostat features, including remote access and automation. The high-level of value the participants placed on the Nest are also supportive of the high satisfaction ratings the users provided, including the following:

- The installation process satisfaction ratings were overwhelmingly positive: over 90% of respondents indicated a satisfaction rating of either a 4 or 5 (out of 5).
- Satisfaction with Nest thermostats was high, as 79% of respondents in the first survey and 89% in the second provided satisfaction ratings of either 4 or 5. Only 4% (three total) of survey respondents indicated a rating score of 2 or below, compared to 9% (nine total) from the first survey.

[19] Note, however, that Nest Pilot participants were previous Energy Trust participants whose installation of Nest was prompted by Energy Trust. A market based program may not have the same motivations.

- Participation in the survey was very high, with 110 out of 177 total Nest thermostat participants responding (62% response rate). For the second survey, 85 out of the 107 eligible participants responded to the survey (79% response rate). These are the highest survey response rates of any program the Apex team has ever experienced.
- Almost half of the first-round survey respondents (41%) experienced issues outside of the installation process, with operational issues and Wi-Fi connection being the most frequently cited issues. At the time of the second survey, the number of survey respondents encountering issues decreased to 17%. Around half of the survey respondents experiencing issues sought assistance from either Energy Trust or Nest.

***Recommendation**: Advocate, encourage, and educate participants on the use and usefulness of the various features. Provide study participants widely available additional educational materials found on Nest Labs website that highlight the features and functionality of the Nest thermostat. Nest Labs dedicated web page containing detailed directions could be extremely beneficial for study participants not familiar with the technology and should be directed to make use of it. Make an effort to ensure that study participants are fully aware of the Nest thermostat's features and functionality from the onset and how those are likely to impact the house's temperature, comfort, and energy savings. Finally, provide potential participants with some of the findings from this report to help sell the program: Participants can expect significant energy savings, resulting in reduced electric bills (provide approximate dollars-per-year saved), the majority of past participants experienced increased comfort, and using the various energy-saving features of the Nest should maximize energy savings.*

Prospects for the Nest Pilot being rolled out to larger audience

***Recommendation:** The prospects for the advanced learning thermostat, one that is capable of adaptive lockout control, being rolled out to a larger audience were dependent on the participant satisfaction, realized savings associated with the thermostat, and the potential alternative delivery approaches that could reduce the overall installed cost of the measure, with the latter two being critical factors when performing cost-effectiveness analysis. This study has shown that the Nest thermostat, when used as an alternative approach to an outdoor thermometer controlling the lockout of resistance backup heat, can offer considerable energy savings. Currently, no other advanced thermostats on the market have the features Nest has that make it suitable for this pilot: adaptive lockout controls, the "time to temperature" or "Early On" features that Nest has, which allow it to learn how much time it takes to warm up a house under various current and expected outdoor temperatures. Therefore the Nest thermostat prevents expensive resistance heat from running, by using algorithms to optimize energy use under given weather conditions. It is this "smart algorithm" feature of the Nest that makes it so attractive for a program like this.*

During this pilot study most of the technical, logistical, and participant-related challenges have been overcome, while participant-level interest and satisfaction with the Nest device was very high. The team therefore believes that the Nest thermostat, provided it can meet Energy Trust's cost-effectiveness requirements, is an attractive and viable candidate for being rolled out to a larger audience and implemented on a larger scale for homes with heat pumps.

7. Appendices

A. Staff Interview Guide

Name:	Agency: ETO / 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 Thermostat Study. As part of this evaluation, we are surveying study participants, Energy Trust Staff, and implementation staff to understand what has worked well, what could be improved upon and what the prospects are for an expanded rollout of the Nest thermostat.

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 [AGENCY]? What are/were your responsibilities with the Nest Thermostat Study?

Q2. What, if any, experience do you have with NEST thermostats, prior to being involved with this pilot?

A.2 Installation Experiences [CLEAResult Only]

I have read through the Nest Research Wrap-Up Report, which summarizes many of the challenges experienced during the recruitment and installation parts of this pilot. However, there are a few pieces I would like to discuss in more depth.

Q3. First, how long did the installation process usually take (per home, on average)?

a. What were the least and most amounts of time you spent in a home (min/max)?

Q4. How much time was generally spent on educating the customer on the Nest Thermostat?

a. What topics do you discuss during the education component of the visit?
   i. Do you have specific handouts you provide? If so, can we get copies?
   ii. Is there an outline or checklist you follow for customer education?

b. What questions did you most often hear during installation?
c. What were the most common reactions toward the device?

Q5. [IF NOT ADDRESSED ABOVE] I understand that you set the NEST thermostat to the *Max Savings* setting during installation. Did you educate the customer on this setting? Did you review the energy benefits of this feature? What was the general response to this feature?

Q6. What generally took the most time during your installation visit?
a. What made a visit particularly difficult or time consuming?

According to the Nest Research Wrap-Up Report, there were a fair number of technical challenges during installation, such as thermostat wiring issues, internet connectivity, and heat pump compatibility.

Q7. What do you consider the most problematic *technological* issue(s) associated with the NEST thermostat? (i.e. issues internal to the Nest, such as sub-base issues, Wi-Fi router incompatibility, heat pump incompatibility, etc.).

Q8. What do you consider the most problematic customer issue(s) you encountered during installation? (i.e. issues that had more to do with the customer and their home such as lost Wi-Fi passwords, old heat pump not performing well to begin with, not tech savvy, etc.)

Q9. [IF IC HAS PREVIOUS EXPERIENCE WITH NEST THERMOSTATS, Q2] Based on your previous experience with Nest thermostats, are these issues common for the NEST technology, or were these issues particularly pronounced for the ETO participant homes?
a. [IF MORE COMMON IN PILOT THAN IN OTHER EXPERIENCES] Why do you think this group [of participants] experienced more challenges than others? [IF NOT MENTIONED, PROBE FOR HOMES WITH HEAT PUMPS VS. FURNACES AND/OR AC]
b. Were these issues particular to heat pump users, or would they be present with any heat source?

Q10. What were the best resources for solving these problems? (i.e. internet groups, calls to the manufacturer, manufacturer provided documentation, etc.)

Q11. I understand that NEST made a number of changes to the technology and sub-base due, in part, to the issues encountered during this pilot. Can you please describe what issues NEST was able to address?
a. Do you think these updates will enable future thermostats to be more successful for heat pump applications? Or are there significant issues that still need to be overcome to make this technology viable?

Q12. Do you have any suggestions on how to more effectively screen for/identify homes that would be good candidates for this technology?

a. Are there specific questions you could ask over the phone that would screen for good candidates? (What are they?)
b. Are there specific indicators at a home that could quickly identify/screen for good candidates? (What are they?)

Q13. Were there any logistical or communications issues between you and the participants, and, if so, can you please describe?

A.3 Customer Interactions

I want to talk briefly about your interactions with the customers during the recruitment and installation process.

Q14. Have you received ongoing calls/concerns from pilot participants after these initial installation issues were resolved?

a. Approximately how many?
b. What are the most common concerns/complaints?
c. Can you provide documentation on these calls? (how many, resolutions, etc.)

Q15. What has been the most effective method of communicating with the program participants? (phone, email, postal mail)

Q16. [CLEAResult Only] During your home visits, what were the customer's attitudes toward the device?

a. Did customers seem engaged and committed to saving energy?
b. Were most customers comfortable using the device, or was it too confusing/high tech for widespread use?
c. Were there feature/settings that excited customers? (which ones?)
d. Were there features/settings that customers did not want? (which ones?)

Q17. Based on your experience with this pilot, what do you think is the biggest barrier for customers to purchase and/or use the NEST thermostat (for the market in general, not just these particular participants).

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

A.4 Closing

Q18. How has the communication and coordination gone with [FOR CLEARESULT READ: Energy Trust; FOR ETO READ: CLEAResult]? Have there been any issues between the firms? (What were they? How have they been resolved?)

Q19. What aspects of the pilot went particularly well?

Q20. What aspects of the pilot have been challenging?

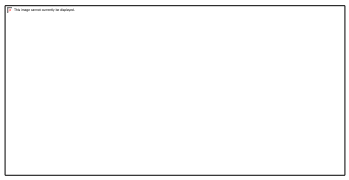
Q21. What do you think the prospects are for the Nest being rolled out on a larger scale given the current state of the technology and interest in the market?

a. What would the most successful incentive structure be for doing this (rebate at store, contractor incentive, customer incentive, direct install, something else)?

Q22. What suggestions would you have for other utilities/agencies considering a NEST thermostat incentive? (lessons learned/pitfalls/target markets/etc)

Q23. Any additional comments or concerns you would like to share?

B. First Participant Survey



Nest Thermostat Study Participant Survey

*** Required Information**

page 1

Hello, and welcome to Energy Trust of Oregon's Nest Thermostat Study participant survey. Your feedback will help Energy Trust evaluate new products and services to save utility customers energy and money. As a valued participant in this pilot study, we would like to hear about your experiences with the Nest technology, both during the installation process and during your first few months of use. The information you provide will be kept confidential to the extent permitted by law. We will report all responses in aggregate and will not attribute any comments to you. As an added incentive, if you complete the survey by February 7, 2014 will be entered into a drawing for an Apple iPad Air*. Energy Trust has contracted with Apex Analytics to administer this survey. If you are having trouble with the survey, please call Noah Lieb of Apex Analytics at 303- 590-9888. *Odds of winning depend on the number of responses; there are only 180 participants being invited to complete the survey. Apple is not involved with nor do they endorse this study. All Nest study participants that complete the survey are eligible for the contest. Apex Analytics will randomly select a winner around February 14, 2014. Prize is one Apple iPad Air, 16GB. MSRP of $499. Winner will be contacted via mail, email, and/or phone immediately after the drawing.

page 2

*** To continue taking the survey please enter your login ID provided in the invitation letter below:** (Enter your answer in "@######@" format where @ is character and # is number)

_____

_____

page 3

Q1. There are a number of potential reasons for participating in the Nest Thermostat Study. Please select your top three motivations in order of importance, from the following drop down menus.

*	1 - Motivation (Select one option)
	○ Save Energy ○ Lower my bills ○ Try new technology ○ Increase the value of my home ○ Environmental concerns ○ Increase the comfort of my home ○ Ability to control thermostat from mobile device
*	2 - Motivation (Select one option)
	○ Save Energy ○ Lower my bills ○ Try new technology ○ Increase the value of my home ○ Environmental concerns ○ Increase the comfort of my home ○ Ability to control thermostat from mobile device
*	3 - Motivation (Select one option)
	○ Save Energy ○ Lower my bills ○ Try new technology ○ Increase the value of my home ○ Environmental concerns ○ Increase the comfort of my home ○ Ability to control thermostat from mobile device

Q2. On a scale from 1 to 5, where 1 is completely unsatisfied, and 5 is completely satisfied, how satisfied are you with the following aspects of installation?

Select satisfaction rating below

	1 - Completely Unsatisfied	2	3	4	5 - Completely Satisfied	Don't Know
*(a) Scheduling for the installation (Select one option)	○	○	○	○	○	○
*(b) Length of time it took to install (Select one option)	○	○	○	○	○	○
*(c) Knowledge/ability of the installer (Select one option)	○	○	○	○	○	○

*** Q3 a). Were there any issues connecting the thermostat to your Wi-Fi network?** (Select one option)

- ○ Yes
- ○ No
- ○ Don't Know

Q3 b). What was the issue? [Answer this question only if answer to Q#4 is Yes]

_____
_____

*** Q4 a). Were there any other issues with installing or setting up the thermostat?** (Select one option)

- ○ Yes
- ○ No
- ○ Don't Know

Q4 b). What was the issue? [Answer this question only if answer to Q#6 is Yes]

_____
_____

*** Q5 a). On a scale from 1 to 5, where 1 is completely unsatisfied and 5 is completely satisfied, how satisfied were you with the overall installation process for the Nest thermostat?** (Select one option)

- ○ 1 - Completely Unsatisfied
- ○ 2
- ○ 3
- ○ 4
- ○ 5 - Completely Satisfied
- ○ Don't Know

Q5 b). Why are you unsatisfied with the overall installation process? [Answer this question only if answer to Q#8 is 1 - Completely Unsatisfied OR 2]

_____
_____

*** Q6. Is your Nest thermostat still installed?** (Select one option)

○ Yes	Go to Page No. 5
○ No	Go to Page No. 4
○ Don't Know	Go to Page No. 5

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Q7. Why was your Nest thermostat removed?

_____
_____

Go to Page No. 11

If Did Not Answer Then Go to Page No. 11

page 5

*** Q7 a). Have there been any issues or complications with your use of the thermostat? This includes any challenges not related to the initial installation.** (Select one option)

- ○ No, I have not had any issues with the use of my thermostat
- ○ Yes, I have had issues with the use of my thermostat
- ○ Don't Know

*** Q7 b). What was the problem?** [Answer this question only if answer to Q#12 is Yes, I have had issues with the use of my thermostat]

- ☐ House has been too cool
- ☐ House has been too warm
- ☐ Unable to make adjustments
- ☐ Wi-Fi connection issues
- ☐ Don't Know
- ☐ Other please specify _____

*** Q7 c). Did you receive assistance from an Energy Trust program representative to resolve the issue?** (Select one option) [Answer this question only if answer to Q#12 is Yes, I have had issues with the use of my thermostat]

- ○ No, I did not receive help from a program representative
- ○ Yes, a program representative assisted me over the phone
- ○ Yes, a program representative or contractor came to my home to address the problem
- ○ Don't Know
- ○ Other, please specify _____

*** Q7 d). Has the problem been resolved?** (Select one option) [Answer this question only if answer to Q#12 is Yes, I have had issues with the use of my thermostat]

- ○ Yes
- ○ No
- ○ Don't Know

page 6

*** Q8 a). The Nest thermostat has a "Heat Pump Balance" function that minimizes how often you use back-up heat. The settings for this function are Maximum Comfort, Maximum Savings, Balance, or off. When the thermostat was originally installed, this function should have been set to Maximum Savings mode. Have you adjusted this setting since your thermostat was installed?** (Select one option)

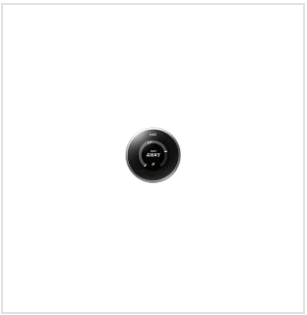
- ○ Yes
- ○ No
- ○ Don't Know

Q8 b). Why did you change this setting? [Answer this question only if answer to Q#16 is Yes]

_____
_____

*** Q8 c). What have you changed this setting to?** (Select one option) [Answer this question only if answer to Q#16 is Yes]

- ○ Maximum Comfort
- ○ Balance
- ○ Turned it off
- ○ Don't know



*** Q9 a). The Nest thermostat has an "AutoAway" function that minimizes heating when no one is home. When the thermostat was installed, this function should have been turned on. Have you adjusted this setting since your thermostat was installed?** (Select one option)

- ○ Yes
- ○ No
- ○ Don't Know

Q9 b). Why did you change this setting? [Answer this question only if answer to Q#19 is Yes]

_____
_____

page 7

Q10. Which other functions have you found useful on your Nest thermostat?

.

	I have not used this function	Very Useful	Somewhat Useful	Not Very Useful	Not At All Useful	Don't Know
*(a) Adjusted thermostat with smart phone (Select one option)	○	○	○	○	○	○
*(b) Adjusted thermostat online (Select one option)	○	○	○	○	○	○
*(c) Early On: Nest thermostat starts heating or cooling early so your home will be at the requested temperature at the time specified (Select one option)	○	○	○	○	○	○
*(d) Filter Reminders: Nest thermostat reminds you to change your air filter based on how many hours your heating system has been running (Select one option)	○	○	○	○	○	○
*(e) AutoSchedule: Nest thermostat remembers what temperatures keep you comfortable and creates a custom schedule for your home (Select one option)	○	○	○	○	○	○
*(f) Energy History: see exactly when your system was on and see a summary of your entire month's energy use (Select one option)	○	○	○	○	○	○
*(g) Nest Leaf: the Nest Leaf appears when you turn the Nest thermostat to a temperature that will save energy (Select one option)	○	○	○	○	○	○

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*** Q11. How often do you adjust settings or use features of the Nest thermostat?** (Select one option)

- ○ Every day
- ○ A few times per week
- ○ Several times a month
- ○ Less than once per month
- ○ I have not adjusted settings or used the features of my Nest thermostat
- ○ Don't Know

Q12. What is your favorite aspect of the Nest thermostat?

_____
_____

*** Q13. What additional functions, if any, would you like to see on your Nest thermostat?** (Select one option)

- ○ There are no additional functions I would like to see on the Nest thermostat
- ○ I would like to see the following functions on the Nest thermostat:
- ○ Don't Know

Please list additional functions you would like to see on the Nest thermostat. [Answer this question only if answer to Q#24 is I would like to see the following functions on the Nest thermostat:]

_____
_____

page 9

*** Q14 a). Was your previous thermostat a programmable thermostat?** (Select one option)

- ○ Yes
- ○ No
- ○ Don't Know

*** Q14 b). How often did you manually adjust the temperature on your old thermostat (like lowering at night or while at work during the day)?** (Select one option) [Answer this question only if answer to Q#26 is No]

- ○ Every day, at least once per day
- ○ A few times per week
- ○ Several times a month
- ○ A few times a year (for example, when leaving town)
- ○ Less than once per year
- ○ I did not adjust my previous thermostat, it was set to a constant temperature
- ○ Don't Know

*** Q14 b). Was your programmable thermostat set to change the temperature at different times of the day (like lowering at night, or while at work during**

the day), or was it set to run at a constant temperature? (Select one option) [Answer this question only if answer to Q#26 is Yes]

- ○ Yes, I programmed my previous thermostat for different temperatures during the day
- ○ No, I did not program my previous thermostat, it was set to a constant temperature
- ○ Don't Know

page 10

*** Q15. Is the temperature in your home more or less comfortable now than before you installed the Nest thermostat?** (Select one option)

- ○ Much more comfortable now
- ○ Somewhat more comfortable now
- ○ Equally comfortable now
- ○ Somewhat less comfortable now
- ○ Much less comfortable now
- ○ Don't Know

*** Q16 a). On a scale from 1 to 5, where 1 is completely unsatisfied and 5 is completely satisfied, how satisfied are you overall with your Nest thermostat?** (Select one option)

- ○ 1 - Completely Unsatisfied
- ○ 2

- ○ 3
- ○ 4
- ○ 5 - Completely Satisfied
- ○ Don't Know

Q16 b). Why are you unsatisfied with your Nest thermostat? [Answer this question only if answer to Q#30 is 1 - Completely Unsatisfied OR 2]

_____
_____

*** Q17 a). On a scale from 1 to 5, where 1 is completely unsatisfied and 5 is completely satisfied, how satisfied are you overall with the Nest Thermostat Study?** (Select one option)

- ○ 1 - Completely Unsatisfied
- ○ 2
- ○ 3
- ○ 4
- ○ 5 - Completely Satisfied
- ○ Don't Know

Q17 b). Why are you unsatisfied with the Nest Thermostat Study? [Answer this question only if answer to Q#32 is 1 - Completely Unsatisfied OR 2]

_____
_____

*** Q18. Based on your experience to date with the Nest thermostat, how likely are you to recommend this technology to a friend or family member?** (Select one option)

- ○ Very Likely
- ○ Somewhat Likely
- ○ Somewhat Unlikely
- ○ Completely Unlikely
- ○ Don't Know

*** Q19. Which of the following statements best represents your expectations for energy savings as a result of the Nest thermostat?** (Select one option)

- ○ I have high expectations (I expect to save lots of energy)
- ○ I have reasonable expectations (I expect there will be some savings, but not huge)
- ○ I have low expectations (I do not expect there will be any noticeable savings)
- ○ Don't Know

page 11

There are just a few final questions for statistical purposes.

Q20. In what year were you born? (4 digit year, YYYY) (Enter a value between 1900 and 1996)

_____
_____

Q21. What is your ethnicity? Do you consider yourself to be…

- ☐ White or Caucasian
- ☐ Hispanic or Latino
- ☐ Black or African-American
- ☐ American Indian
- ☐ Pacific Islander
- ☐ Asian (Chinese, Japanese, Indian, Malaysian, Vietnamese, Cambodian)
- ☐ Refused
- ☐ Other, please specify _____

Q22. What is the highest level of education you have completed so far? (Select one option)

- ○ Non-high school graduate
- ○ High school graduate or equivalent (e.g., GED)
- ○ Attended some college, no degree (includes junior/community college)
- ○ Associates degree
- ○ Bachelors degree

- ○ Graduate or Professional degree
- ○ Refused
- ○ Other, please specify _____

Q23. Which range best describes your total household income in 2013 before taxes? (Select one option)

- ○ Less than $10,000
- ○ $10,000 to less than $20,000
- ○ $20,000 to less than $30,000
- ○ $30,000 to less than $50,000
- ○ $50,000 to less than $70,000
- ○ $70,000 to less than $90,000
- ○ $90,000 to less than $110,000
- ○ $110,000 to less than $150,000
- ○ $150,000 to less than $200,000
- ○ Greater than $200,000
- ○ Refused

Q24. How many people live in your home full-time? (Select one option)

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7
- ○ 8
- ○ 9
- ○ 10+
- ○ Refused

Q25. Of those that live in your home full-time, are any under 18 years of age?
(Select one option)

- ○ Yes
- ○ No
- ○ Refused

Q26. Are there any other items or issues you would like Energy Trust to be aware of so they can work to improve their program offerings in the future?

_____

_____

C. Second Participant Survey

Nest Thermostat Study Participant Survey

*** Required Information**

page 1

Thank you again for participating in Energy Trust of Oregon's Nest Thermostat Study. Now that a full winter season is behind us, we would like to understand your overall experience with the Nest thermostat and whether your likes/dislikes of the device have changed since you responded to our first survey. To provide us with additional feedback, we would like you to take another short survey. This is the second and final survey we are requesting participants to take. The information you provide will be kept confidential to the extent permitted by law. We will report all responses in aggregate and will not attribute any comments to you. As an added incentive, if you complete the survey by May 30, 2014 will be entered into a drawing for an Apple iPad Air*. Energy Trust has contracted with Apex Analytics to administer this survey. If you are having trouble with the survey, please call Noah Lieb of Apex Analytics at 303-590-9888. *Odds of winning depend on the number of responses; there are only 107 participants eligible to complete the survey. Apple is not involved with nor do they endorse this study. All Nest study participants that complete the survey are eligible for the contest. Apex Analytics will randomly select a winner around June 5, 2014. Prize is one Apple iPad Air, 16GB. MSRP of $499. Winner will be contacted via mail, email, and/or phone immediately after the drawing.

page 2

*** To continue taking the survey please enter your login ID provided in the invitation letter below:** (Enter your answer in "@######@" format where @ is character and # is number)

_____

_____

page 3

*** Q1. Is your Nest thermostat still installed?** (Select one option)

○ Yes	Go to Page No. 5
○ No	Go to Page No. 4
○ Don't Know	Go to Page No. 5

page 4

Q1 a). Why was your Nest thermostat removed?

_____

_____

Go to Page No. 11

If Did Not Answer Then Go to Page No. 11

page 5

*** Q2 a). During the last survey, we asked about any installation or early challenges with the NEST thermostat. Have you experienced any additional issues or complications while using the thermostat that were not mentioned in the previous survey? This includes any challenges not related to the initial installation.** (Select one option)

- ○ No, I have not had any additional issues with the use of my thermostat
- ○ Yes, I have had additional issues with the use of my thermostat
- ○ Don't Know

*** Q2 b). What was the problem?** [Answer this question only if answer to Q#4 is Yes, I have had additional issues with the use of my thermostat]

- ☐ House has been too cool
- ☐ House has been too warm
- ☐ Unable to make adjustments
- ☐ Wi-Fi connection issues
- ☐ Don't Know
- ☐ Other please specify _____

*** Q2 c). Did you receive assistance from an Energy Trust program representative to resolve the issue?** (Select one option) [Answer this question only if answer to Q#4 is Yes, I have had additional issues with the use of my thermostat]

- ○ No, I did not receive help from a program representative
- ○ Yes, a program representative assisted me over the phone
- ○ Yes, a program representative or contractor came to my home to address the problem
- ○ Don't Know
- ○ Other, please specify _____

*** Q2 d). Did you receive assistance from a Nest Labs customer service representative to resolve the issue?** (Select one option) [Answer this question only if answer to Q#4 is Yes, I have had additional issues with the use of my thermostat]

- ○ No, I did not receive help from a Nest representative
- ○ Yes, a Nest Labs representative assisted me online
- ○ Yes, a Nest Labs representative assisted me over the phone
- ○ Don't Know

*** Q2 e). Has the problem been resolved?** (Select one option) [Answer this question only if answer to Q#4 is Yes, I have had additional issues with the use of my thermostat]

- ○ Yes
- ○ No
- ○ Don't Know

page 6

*** Q3 a). The Nest thermostat has a "Heat Pump Balance" function that minimizes how often you use back-up heat. The settings for this function are Maximum Comfort, Maximum Savings, Balance, or off. When the thermostat was originally installed, this function should have been set to Maximum Savings mode. Have you adjusted this setting since your thermostat was installed?** (Select one option)

- ○ Yes
- ○ No
- ○ Don't Know

Q3 b). Why did you change this setting? [Answer this question only if answer to Q#9 is Yes]

_____
_____

*** Q3 c). What have you changed this setting to?** (Select one option) [Answer this question only if answer to Q#9 is Yes]

- ○ Maximum Comfort
- ○ Balance
- ○ Turned it off
- ○ Don't know

*** Q4 a). The Nest thermostat has an "AutoAway" function that minimizes heating when no one is home. When the thermostat was installed, this function should have been turned on. Have you adjusted this setting since your thermostat was installed?** (Select one option)

- ○ Yes
- ○ No
- ○ Don't Know

Q4 b). Why did you change this setting? [Answer this question only if answer to Q#12 is Yes]

_____
_____

page 7

Q5. Which other functions have you found useful on your Nest thermostat?

.

	I have not used this function	Very Useful	Somewhat Useful	Not Very Useful	Not At All Useful	Don't Know
*(a) Adjusted thermostat with smart phone (Select one option)	○	○	○	○	○	○
*(b) Adjusted thermostat online (Select one option)	○	○	○	○	○	○
*(c) Early On: Nest thermostat starts heating or cooling early so your home will be at the requested temperature at the time specified (Select one option)	○	○	○	○	○	○
*(d) Filter Reminders: Nest thermostat reminds you to change your air filter based on how many hours your heating system has been running (Select one option)	○	○	○	○	○	○
*(e) AutoSchedule: Nest thermostat remembers what temperatures keep you comfortable and creates a custom schedule for your home (Select one option)	○	○	○	○	○	○
*(f) Energy History: see exactly when your system was on and see a summary of your entire month's energy use (Select one option)	○	○	○	○	○	○
*(g) Nest Leaf: the Nest Leaf appears when you turn the Nest thermostat to a temperature that will save energy (Select one option)	○	○	○	○	○	○

page 8

*** Q6. How often do you adjust settings or use features of the Nest thermostat?** (Select one option)

- ○ Every day
- ○ A few times per week
- ○ Several times a month
- ○ Less than once per month
- ○ I have not adjusted settings or used the features of my Nest thermostat
- ○ Don't Know

Q7. What is your favorite aspect of the Nest thermostat?

_____
_____

*** Q8. What additional functions, if any, would you like to see on your Nest thermostat?** (Select one option)

- ○ There are no additional functions I would like to see on the Nest thermostat
- ○ I would like to see the following functions on the Nest thermostat:
- ○ Don't Know

Please list additional functions you would like to see on the Nest thermostat. [Answer this question only if answer to Q#17 is I would like to see the following functions on the Nest thermostat:]

_____
_____

page 9

*** Q9. For the following features of the Nest thermostat, please rank how valuable each feature is to you (where 1 is most valuable, 4 is least valuable):**
[Please rank all option(s).]

To be able to control the Nest thermostat remotely, either online or from your smart phone	
The Nest thermostat can learn your schedule so it does not need to be programmed	
The appearance and style of the Nest thermostat	
Energy savings	

*** Q10 a). After using the Nest thermostat for a half a year, knowing what you know now, do you believe the retail price of $250 makes sense for this thermostat?** (Select one option)

- ○ Definitely Yes – it is worth every penny
- ○ Yes – though expensive, it is still a valuable product
- ○ No – I like it but it is too expensive (would not have purchased if not for Energy Trust program)
- ○ Definitely not - I wouldn't pay a dime for this thing
- ○ Don't Know

*** Q10 b). In addition to saving energy, the Nest thermostat offers other features, including remote access (control of thermostat via online or smartphone), automation (the thermostat learns your schedule so it does need programming), and a modern hi-tech style. If the Nest thermostat provided zero energy savings (knowing it cost $250), do you still feel these other non-energy savings features are worth it?** (Select one option) [Answer this question only if answer to Q#20 is Definitely Yes – it is worth every penny OR Yes – though expensive, it is still a valuable product]

- ○ Yes
- ○ No
- ○ Don't Know

*** Q11. How easy is it for you to operate the Nest thermostat to set the temperature of your home?** (Select one option)

- ○ Very Easy
- ○ Somewhat Easy
- ○ Somewhat Difficult
- ○ Very Difficult
- ○ Don't Know

page 10

*** Q12. Is the temperature in your home more or less comfortable now than before you installed the Nest thermostat?** (Select one option)

- ○ Much more comfortable now
- ○ Somewhat more comfortable now
- ○ Equally comfortable now
- ○ Somewhat less comfortable now
- ○ Much less comfortable now
- ○ Don’t Know

*** Q13 a). On a scale from 1 to 5, where 1 is completely unsatisfied and 5 is completely satisfied, how satisfied are you overall with your Nest thermostat?** (Select one option)

- ○ 1 - Completely Unsatisfied
- ○ 2

- ○ 3
- ○ 4
- ○ 5 - Completely Satisfied
- ○ Don't Know

Q13 b). Why are you unsatisfied with your Nest thermostat? [Answer this question only if answer to Q#24 is 1 - Completely Unsatisfied OR 2]

_____
_____

*** Q14 a). On a scale from 1 to 5, where 1 is completely unsatisfied and 5 is completely satisfied, how satisfied are you overall with the Nest Thermostat Study?** (Select one option)

- ○ 1 - Completely Unsatisfied
- ○ 2
- ○ 3
- ○ 4
- ○ 5 - Completely Satisfied
- ○ Don't Know

Q14 b). Why are you unsatisfied with the Nest Thermostat Study? [Answer this question only if answer to Q#26 is 1 - Completely Unsatisfied OR 2]

_____
_____

*** Q15. Based on your experience to date with the Nest thermostat, how likely are you to recommend this technology to a friend or family member?** (Select one option)

- ○ Completely Unlikely
- ○ Somewhat Unlikely
- ○ Somewhat Likely
- ○ Very Likely
- ○ Don't Know

*** Q16. Which of the following statements best represents your expectations for energy savings as a result of the Nest thermostat?** (Select one option)

- ○ I have high expectations (I expect to save lots of energy)
- ○ I have reasonable expectations (I expect there will be some savings, but not huge)
- ○ I have low expectations (I do not expect there will be any noticeable savings)
- ○ Don't Know

page 11

There are just a few final questions for statistical purposes.

Q17. Did the number of people living in your household change during the winter season (over the last six months)? (Select one option)

- ○ One or more people moved in
- ○ One or more people moved out
- ○ No, nothing has changed

Q18. Did you renovate your home or install any new major appliances during the winter season? (Select one option)

- ○ Yes
- ○ No
- ○ Refused

What did you install? [Answer this question only if answer to Q#31 is Yes]

_____
_____

page 12

Q19. Are there any other items or issues you would like Energy Trust to be aware of so they can work to improve their program offerings in the future?

_____
_____

D. CLEAResult Implementation Report

As stated in the Nest Implementation Plan, the goal of the Nest thermostat study was to determine if the Nest thermostat can be an effective method to reduce household energy by controlling the use of backup strip heat in electrically-backed heat pump homes. This study sought to recruit 200 volunteers who had participated in Energy Trust offerings in the past to receive a free Nest thermostat installation. Installations began in August and were completed mid-December with a total of 177 thermostats installed. The evaluation period of the study will continue for the duration of the 2013-2014 heating season which is defined for this study as November 1, 2013 to May 31, 2014.

D.1 Methodology

D.1.1 Selection

Recruitment for the Nest study began by selecting a list of potential candidate homes from previous Energy Trust participants. The selection criteria for this list included a past Home Energy Review or the free mobile home service, a heat pump as the primary heat source, no activity for the last 12 months and a location along the I-5 corridor. This selection process produced several thousand candidate homes, from which approximately 1600 were selected to make up the treatment group. The remaining homes make up the comparison group. Homes in the comparison group will not be contacted by CLEAResult or Energy Trust; these homes' energy usage will be compared to the treatment group to help determine the savings associated with the Nest installation.

D.1.2 Recruitment

Initially recruitment was conducted via randomized outbound phone calls to homes in the treatment group. CLEAResult developed a list of qualifying questions to ensure eligibility as well as a standard voicemail message when calls went unanswered. As installations began and additional issues were identified, the list of qualifying questions was updated to better screen potential candidates.

After approximately six weeks of outbound calling, CLEAResult developed and mailed a recruitment letter to all remaining candidates in the treatment group who had not spoken with a representative on the phone. The letter was mailed to approximately 1400 homes and, similar to the talking points, explained the benefits of the study. Prominent on the letter was the value of the installation and contact information to call and schedule an appointment.

Together the outbound calling and the recruitment letter resulted in approximately 80% of necessary installations. To complete the remaining 20% of installations, in consultation with Energy Trust, CLEAResult reached beyond the initial treatment group to include homes that completed an online Home Energy Profile (HEP). Although the data collected by the HEP are slightly different than that collected in FastTrack, the datasets were similar enough to allow the same selection criteria to be applied. The resulting group of HEP candidates then received recruitment letters for installations beginning December 2.

D.1.3 Installation Procedure

To maintain consistency and ensure that any disqualifying factors were identified before thermostats were installed, CLEAResult installers followed a standard set of procedures during each visit.

Nest On-Site Checklist

- Homeowner reviews and sign agreement
- Verify and gather site information
- Verify heat pump operation
- Power off heating equipment at breaker panel
- Remove old thermostat, put in Ziploc bag and leave with homeowner
- Install Nest thermostat
- Power on heating equipment at breaker panel
- Affix electrical permit sticker to breaker panel
- Connect to the internet (Router name and Wi-Fi password needed)
- Verify equipment type, wiring, location, and temperature sensor accuracy
- Set heat pump balance to Max Savings
- Gather Technical information
- Homeowner creates Nest account
- Link thermostat to Nest account
- Educate homeowner on controlling Nest
- Leave Nest packaging and information about Nest Support with homeowner

D.2 Data/Results

Table 2: Nest Recruitment, Installation and Site Visits

Data Table:											
	Aug - Sep 6	Sep 7-27	Sep 28- Oct 4	Oct 5-11	Oct 12-18	Oct 19-26	Oct 26-31	Nov.	Dec 2-6	Dec 7-13	Totals
CALLS											
Outbound - First Call	453	320	130	10	148	45	32				1138
Outbound - Second Call	1	21	11	10	60	58	41				202
Inbound Calls		84	123	32	33	72	15	no data	no data	no data	359
LETTERS											
Outbound Letters	-	1410	-	-	690	-	-	337	-	-	2437

Nests Originally Installed	**44**	**24**	**24**	**21**	**25**	**19**	**14**	**0**	**10**	**4**	**185**
Uninstalls		1	1					6			8
On-site DNQ	5	3	8	1	4	7	2	0	5	2	37
Re-visits					1		8	12		1	22
Final Count of Installed Nests:											**177**
Total Site Visits:											**252**

Figure 1 shows that of the 185 Nest installations, the total pilot sample yielded 177 maintained installations. The program made 252 site visits, demonstrating the volume of sites that did not qualify and the volume of call backs from customers to return for technical support.

Figure 2: Inbound Call and Letter Timing

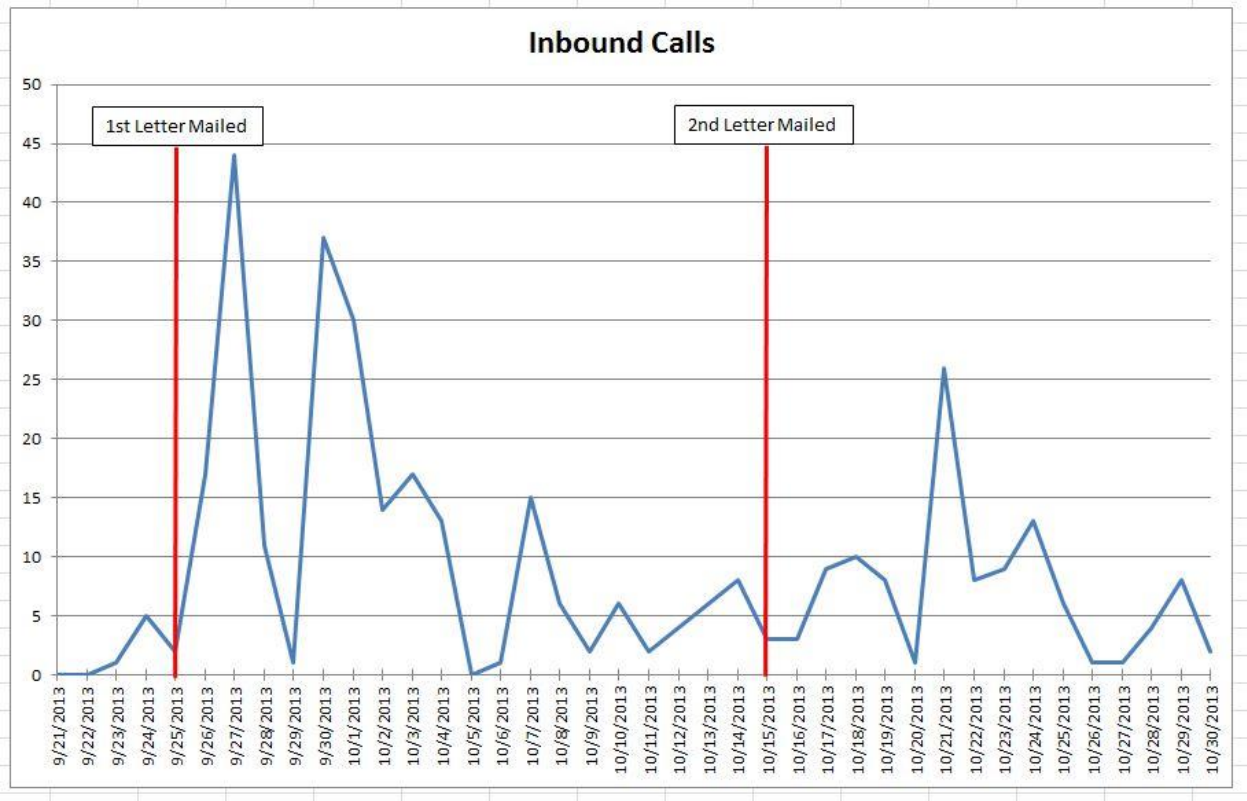

Figure 2 indicates the timing of responses as measured by the inbound calls to the New Initiatives phone line. Recruitment letter sent dates are indicated by the vertical red lines.

Figure 3: Recruitment Letter Response Rates

Letter Response rates:

First Letter	1410
Call-ins 9/25-10/11	218
Response rate	15.40%
Second Letter	690
Call-ins 10/15-10/25	109
Response rate	15.70%
Overall response rate	15.6%

Figure 3 looks at the response rates for the first two recruiting letters that were sent. The note here is that the first letter was sent to all candidates on the recruitment list without a live answer, and the second letter was sent to the remaining subset of the first list that still had not answered or returned our calls.

D.2.1 Data Availability

Customer and pilot data collected via the data forms has been shared with Energy Trust Planning via SharePoint.

D.3 Discussion

D.3.1 On-Site Disqualifications

Equipment Compatibility

CLEAResult installers encountered difficulty with several sites that had older thermostats due to wiring issues. In these sites, the thermostat's wire terminal designators were outdated and did not conform to modern standards. In addition, some older thermostats were left on newer equipment making it difficult to determine the proper connections. Finally, different manufactures utilize different reversing valve switching. These factors led to difficulties in homes that required high level technical assistance within the program to complete these installations.

In addition to issues with older thermostats, the program also encountered problems with newer 3 and 4-wire "communicating thermostats" like the Honeywell Pro8000IAQ. These types of thermostats would have required rewiring at the air handler to allow the Nest to control the system. In one case where the required 5-6 wires were already installed, the installer did complete the rewire and install the Nest, but in all other cases rewiring was deemed outside the scope of the pilot.

Some heat pumps come with additional functionality and integrated controls that make them not compatible with Nest.

The two most common of such systems are the Carrier Infinity and Bryant Evolution series heat pumps. These systems both use 3 or 4 wire connections between the thermostat and the air handler. Both of

these heat pumps feature modulating compressors which, even if the wiring could be adapted to work with Nest, some functionality would be lost during the conversion.
Both the Honeywell Pro8000IAQ and the Infinity/ Evolution have a 3 or 4 wire connection between the thermostat and the air handling equipment would require changing connections at the air handler. This would have resulting in increased appoint time to make the connections and therefore were not a recommended model. Infinity and Evolution models in some cases result in losing some operational functionality.

Equipment Eligibility

Even though every participant was asked if their home was heated by a heat pump, there were some issues early on of non-qualifying systems. The most common confusion was between homes heated by heat pumps and electric furnaces with A/C. Several sites also had multiple heat pumps providing heat to multiple zones in the home and one home visited was heated by a ground-sourced heat pump. After consultation with CLEAResult technical staff, it was determined that multiple systems and ground-sourced heat pumps introduced too many variables into the study. The screening questions were updated to emphasize that only homes heated with a single, ducted air-sourced heat pump would qualify for this study.

Wi-Fi and Routers

The Nest requires wireless internet connectivity to receive local weather information, to allow for remote access (programming from your computer), and to log data. Because of this, CLEAResult installers connected the Nest to Wi-Fi during each installation. One of the early problems encountered by the installers was that the homeowners were unsure of their wireless network passwords. When the installers reported this issue, CLEAResult staff amended the talking points to emphasize the need to have the Wi-Fi password available at the time of the appointment, effectively eliminating this issue.
Another internet connectivity issue was the prevalence of ineligible wireless routers. After installations began and the installers reported that the Nest could not be connected to the routers in some homes, Nest Labs confirmed that some routers are not compatible with Nest and provided CLEAResult with the list of incompatible models. These incompatible routers, many of them older models, do not support a low-power mode that the Nest requires to be able to charge its battery, so if the Nest detected an incompatible model it would not connect. Several homes originally disqualified for this reason replaced their router and then rescheduled their installation.
The third issue identified was the prevalence of mobile Wi-Fi hotspots as the main source of internet access in homes. These devices, typically available from phone companies, are small portable devices that create a Wi-Fi network wherever they are located. While the Nest can connect to and work with these mobile hotspots, their portability introduces the potential for the Nest to periodically lose internet connection when the hotspot was removed from the home. Because the Nest relies on a continuous internet connection for weather information, CLEAResult decided that homes with mobile hotspots as the only source of internet access would not qualify for this study as allowing these homes would introduce more unknowns into the study.

The fourth internet connectivity issue was routers not compatible with Nest. From conversations with Nest technical support CLEAResult learned the thermostat requires that the router it connects with to allow devices to go into a power saving mode while remaining connected. The thermostat needs to enter this power save mode to allow it to stay online while trickle charging its battery. Unfortunately some of the most popular older routers do not support this power save mode and thus the Nest will not connect to them. In some cases updating router firmware can solve these issues, but in most cases the only way to install a Nest in these homes was for the homeowner to replace their router and reschedule the installation.

The final Wi-Fi/router issue was that connecting the thermostats to Wi-Fi was often difficult due to a lack of signal strength at the thermostat location. In some homes, low signal strength caused the installers difficulty in linking thermostats to the customer's Nest accounts in a timely fashion. In some instances, the thermostat would not update to the newest software version until a date and time determine by the Nest's auto-update schedule. When the installer could not connect the Nest account, a return visit was scheduled several days later to finish connecting the account.

D.4 Lessons Learned

D.4.1 Recruitment and Participation

The original recruitment plan for this study was to make outbound calls to the group of identified candidates and schedule installations from these calls. During the first month of recruitment calls were made to 28% of candidates but only resulted in 22% of needed installations. During this time period, it was reported that the two major barriers to recruiting were skepticism of people on the phone making offers and a lack of knowledge of the Nest. When people answered the phone, they were often skeptical that we were trying to sell or scam them, and were hesitant to agree to participate. The vast majority of people also did not know anything about the Nest and had never heard of a "smart thermostat".

In planning future studies, CLEAResult's experience with this pilot suggests that letters followed up by phone calls is a better approach than outbound calling alone because it makes the calls "warm" and allows motivated candidates to sign up on their own. After the letters were mailed, CLEAResult schedulers were able to say they were calling to follow up on the letter and ask if the candidate had thought about participating. Anecdotal accounts from schedulers suggest that the initial suspicion of the study was much lower after the letters were sent. Many candidates were still not interested in participating, but most had opened the letter and were now making an informed decision.

D.4.2 Thermostat Issues

The first set of problems came when a number of participants reported that their Nest thermostat was reporting higher temperatures than the actual ambient temperatures they were experiencing in the homes. This was followed up by a number of revisits which resulted in a number of thermostats being replaced. After a consultation with technical staff at Nest it was discovered that the sub-bases had an issue that was most prevalent in thermostats configured to heat pumps. The problem was with the FETs (field-effect transistor) used as the switches to power the HVAC relays. When these FETs fail, they fail in

a partially-open position which creates the extra heat the thermostat senses. The problem in some cases provided a signal to the compressor relay but not to the indoor fan relay which overheated some compressors, and in one case causing a compressor to fail. Nest provided a number of sub-bases to the program in order to retro fit any thermostats that had an indication of a problem. Any thermostat that had a reported problem had their original sub-base replaced. Upon receiving the sub-bases the program began retro-fitting problem thermostats with the new sub-bases.

The new sub-bases were put into the boxes with the existing stock of thermostats. Upon the beginning of the second install period a new problem was discovered. A number of the new sub-bases were not installing successfully. After a discussion with the same technical person at Nest the program discovered that the thermostat displays needed to be updated to a newer software version to be compatible with the new sub-bases. When a new sub-base was connected to a display with pre-version 3.5 software, the sub-base was "bricked" or rendered permanently inoperable. To prevent this issue, the thermostat displays were allowed to update by installing the original sub-base, connecting the Wi-Fi, waiting for the software auto update to run, then uninstalling and reinstalling the thermostat with the new sub-base before finalizing configuration.

D.4.3 Evaluation considerations

One issue to consider in evaluating this study is the integrity of FastTrack site information. The sites of every home on the candidate list should have been eligible to receive a Nest, however some homes on the list for the treatment group either did not have a heat pump or used a non-qualifying fuel source as their supplementary heat (i.e. wood). Because the comparison group will not be contacted in any way during the study, there is no way to verify that all sites have heat pumps. This introduces the possibility that the comparison group is not identical to the treatment group and may provide a less than perfect comparison.

E. Participant Survey Recruitment Letter

EnergyTrust of Oregon

421 SW Oak St., Suite 300
Portland, OR 97204

1.866.368.7878
503.546.6862 ***fax***
energytrust.org

January 24, 2014
Participant Name
Participant Address
City, «State» Zip Code

Dear Participant Name:

Thank you again for participating in Energy Trust of Oregon's Nest Thermostat Study. Your parti
help us find new products and services to save our customers energy and money. As a valued p
this pilot study, we would like to hear about your experiences with the Nest technology, both duri
installation process and during your first few months of use. To provide us with feedback, we would like you to take a short survey. *As an added incentive, everyone that completes this questionnaire by February 7th will be entered into a drawing for an Apple iPad Air[20]!*
To complete the questionnaire, please go to www.energytrust.org/NestSurvey and enter in the login ID provided below:

Login ID: «SogoProjectID_new»X

The survey link will be active starting January 27th. Again, we thank you for your participation in the Nest Thermostat Study and want to be sure this technology is working for you in a positive manner.
Energy Trust has contracted with Apex Analytics to administer this survey. If you are having trouble with the survey, please call Analyst of Apex Analytics at 303-590-xxxx. If you have any questions about pilot study or this survey, please contact me at the number below.

Sincerely,
Dan Rubado
Energy Trust of Oregon
503-459-xxxx

[20] Odds of winning depend on the number of response, however, there are only 180 participants invited to complete the survey. Apple is not involved with nor do they endorse this study. All Nest Study participants that complete the survey are eligible for the contest. Apex Analytics will randomly select a winner around February 14th. Prize is one Apple iPad Air, 16GB. MSRP of $499. Winner will be contacted via mail, email, and/or phone immediately after the drawing.

F. Regression Output – Best fit Model

```
Mixed-effects ML regression                     Number of obs      =      6845
Group variable: id                              Number of groups   =       324

                                                Obs per group: min =         5
                                                              avg =      21.1
                                                              max =        23

                                                Wald chi2(10)      =   1344.58
Log likelihood = -25109.716                     Prob > chi2        =    0.0000
```

avgdailykwh	Coef.	Std. Err.	z	P>|z|	[90% Conf.	Interval]
circa	-.015305	.0365635	-0.42	0.676	-.0754467	.0448366
sqft	.0088677	.0010603	8.36	0.000	.0071236	.0106117
txgroup						
Treatment	4.335152	1.558175	2.78	0.005	1.772183	6.898121
posttx						
Post-Tx	2.481698	.6956809	3.57	0.000	1.337405	3.625991
txgroup#posttx						
Treatment#Post-Tx	-2.531814	1.177899	-2.15	0.032	-4.469286	-.5943419
avgdailyhdd55	2.348638	.0880049	26.69	0.000	2.203883	2.493393
txgroup# c.avgdailyhdd55						
Treatment	-.1577676	.1480201	-1.07	0.286	-.401239	.0857038
posttx#c.avgdailyhdd55						
Post-Tx	-.1671844	.0689475	-2.42	0.015	-.280593	-.0537758
txgroup#posttx# c.avgdailyhdd55						
Treatment#Post-Tx	.07249	.1161878	0.62	0.533	-.1186219	.2636019
avgdailycdd70	1.60123	.0898524	17.82	0.000	1.453436	1.749024
_cons	43.41984	72.17192	0.60	0.547	-75.2924	162.1321

Random-effects Parameters	Estimate	Std. Err.	[90% Conf.	Interval]
id: Unstructured				
var(av~hdd55)	1.494312	.1250608	1.302136	1.71485
var(_cons)	171.5496	14.17485	149.7491	196.5239
cov(av~hdd55,_cons)	4.041884	1.073534	2.276077	5.807691
var(Residual)	65.13013	1.169886	63.23399	67.08313

LR test vs. linear regression: chi2(3) = 9469.65 Prob > chi2 = 0.0000